Climate ExChange

World
Meteorological
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Weather • Climate • Water

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ISBN 978-0-9568561-3-5

Tudor Rose

Published by Tudor Rose
www.tudor-rose.co.uk

Acknowledgements

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With thanks to all the authors listed in the contents section for their support in making *Climate ExChange* possible.

Acclimatise
Asia-Pacific Economic Cooperation Climate Center
Australian Bureau of Meteorology
Australian Centre for International Agricultural Research (ACIAR)
Bay of Bengal Programme Inter-Governmental Organisation (BOBP-IGO)
Bogor Agricultural University
Caribbean Institute for Meteorology and Hydrology
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Foreword

MICHEL JARRAUD, SECRETARY-GENERAL, WMO

Climate change is accelerating and leading to climate and weather extremes of the greatest socioeconomic and developmental consequences around the world. This is particularly true for those regions, countries and communities that are most climate-vulnerable: the African continent, least developed and land-locked countries and small island developing states.

The 2001–2010 decade was the warmest ever recorded, with an average temperature of 0.21° C above 1991–2000, the warmest decade of the twentieth century, and of 0.46° C above the 1961–1990 annual average of 14° C. The decade witnessed the intensification of climate and weather extremes such as destructive flooding, severe droughts, heat waves, heavy rainfall and severe storms, as well as a dramatic steady reduction of the Arctic sea ice summer cover. The concentration of CO_2 in the atmosphere continued to increase, reaching an average of 389 parts per million, the highest value ever recorded. All these trends were confirmed in 2011 and 2012.

The Rio+20 summit held in June 2012 reaffirmed that climate change is one of the greatest challenges of our time to the attainment of sustainable development and called for reinforced international cooperation to address its impacts. Besides weather and water extremes these include sea level rise, coastal erosion and ocean acidification and make adaptation to climate change an urgent necessity.

As highlighted by the World Meteorological Day celebrated on 23 March 2012, weather, climate and water services are of growing importance for the sustainable socioeconomic development of present and future generations. Advancing knowledge about weather, climate and water is crucial to agriculture and food security, disaster risk reduction, water management, health and many other sectors and will play a crucial role in shaping the global developmental agenda beyond 2015.

The risks of climate variability and change and adaptation to climate change can be better understood and managed only through the development and application of the science and knowledge of climate information and prediction.

The Global Framework for Climate Services (GFCS), initiated at the World Climate Conference-3 (Geneva, Switzerland, 2009), is a major initiative of the United Nations system led by WMO to foster the enhancement and incorporation of climate information and prediction into planning, policy and practice on the global, regional, national and local scales.

The GFCS is conceived to advance global collaboration through multidisciplinary partnerships, improved governance, climate observations, monitoring, research and prediction. Together with capacity-building and exchange of experiences, this will ensure greater availability of, access to, and use of climate services for all countries and in particular enable the most vulnerable in order to limit the impact of, or adapt to, climate change and variability.

In order for the GFCS to achieve its goals, it will have to be user-driven, building on the successes and learning from the challenges of existing initiatives. Most particularly, the National Meteorological and Hydrological Services will have to build on capabilities, facilitating data sharing and thereby demonstrating the benefits of cooperative and multidisciplinary products.

Better climate services through improved quality, accuracy, timeliness, location specificity and user-friendliness of the information will facilitate key societal benefits. These include a reduction in the losses of life and property associated with climate-related natural hazards, enhanced productivity in sectors reliant on climate and a more efficient management of institutions dependent on weather and climate.

After *Elements for Life* (2007) and *Climate Sense* (2009), the World Meteorological Organization and Tudor Rose partner again with *Climate ExChange*. I am confident that this publication will provide a great contribution to illustrate the benefits of, and promote good practices in, climate services.

I wish to thank the over 100 contributing authors who described progresses and challenges in the production and delivery of climate services in priority areas such as water management, agriculture and food security, disaster risk reduction and health. These contributions reflect how people and nations around the world are using or can use climate information to improve their lives and economies in a sustainable way.

Michel Jarraud, Secretary-General, WMO

Preface

DAVID GRIMES, PRESIDENT OF WMO

I am seized by the potential for the Global Framework for Climate Services (GFCS) in reading the Report of the High Level Task-force, where it characterizes a clear and striking appreciation of three key premises: i) everyone is affected by climate, especially by its extremes for their safety and livelihoods; ii) needs-based climate services can be extremely effective in realizing socio-economic benefits by enabling communities, businesses, organizations and governments to adapt through informed choices in managing the associated risks and opportunities; and iii) governments and stakeholder communities at global, regional and national levels can together close the significant gulf between the needs for climate services and the capacity to deliver, especially in places where they need them the most.

The call for bridging this gap came from the Heads of States and Governments, Ministers and Heads of Delegation representing more than 150 countries, 34 United Nations Organizations and 36 Governmental and non-Governmental international organizations who attended the Third World Climate Conference in 2009. They recognized that investment in climate services would be beneficial for their citizens and institutions to adapt to climate variability and change and to build climate resilient communities. They unanimously adopted a Declaration establishing the Global Framework for Climate Services to mainstream value-added information for decision makers through user-driven and science-based activities.

Following from the High Level Task Force's roadmap for the GFCS, the Sixteenth Session of the World Meteorological Congress (Geneva, 16 May to 3 June 2011) endorsed the Report's broad thrusts and initiated the detailed preparations for its implementation to be approved at its First Extraordinary Session of the World Meteorological Congress in Geneva, 29 to 31 October 2012. This has only been made possible through a dedicated team of writers, the WMO secretariat, and the Executive Council Task Team under my leadership.

The outcomes of the GFCS will empower all in society to better adapt to the risks and opportunities from climate variability and change, and especially those who are most exposed to climate related hazards. A framework of coordinated and complementary actions and measures, exercised at global, regional, national and local scales, offers the promise to all of providing meaningful, needs-based climate services for widespread use. The initial priorities are aimed at improving the provision of climate services for decision-making and policy development related to important health, food security and agriculture, water resources and disaster risk reduction outcomes. The success of the GFCS will be in the engagement of providers and users, requiring a global mobilization of effort and an unprecedented collaboration among institutions across political, functional and disciplinary boundaries.

Climate ExChange provides a wealth of information on developments in the provision of climate services by WMO Members. It also highlights initiatives led by others such as the World Bank and the World Food Programme revealing opportunities for partnerships with non-governmental actors. These articles serve to illustrate the solid foundation on which the GFCS can be based. This publication will be a lasting example of how the GFCS can build upon the existing efforts to advance improvements in the provision of needs based climate services.

I am pleased that, once again, WMO has forged a partnership with Tudor Rose in this endeavour.

David Grimes, President of WMO

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How climate services can help people adapt to variability and change

Filipe Domingos Freires Lúcio, Head, Global Framework for Climate Services Office, World Meteorological Organization

Humanity has thrived over the past millennia because of its ability to innovate and adapt. Adapting to new climate conditions, however, has rarely been painless. It has often involved migration and conflict, accompanied by death and suffering. Today, with billions of mouths to feed, a heavy dependence on vulnerable infrastructure, and the risk that climate change will cause rapid and unprecedented impacts, the stakes are as high as ever.

How the natural environment responds to climate variability and change is critically important to human well-being. While people live everywhere on Earth, from the frozen Arctic to the hot and steamy equator, most plant and animal species are too sensitive to climate to inhabit such a broad range. So when the climate that they are used to warms up or cools down, or moisture levels change, many species must either die or migrate. Today the evidence for how climate affects the living world is everywhere.

A recent study reported that Australia's fish populations are moving southward because the waters around Australia are becoming warmer. Food supplies will be affected unless the fishing industry is able to adapt to this and future changes. The record drought that struck the United States in the summer of 2012 had a significant impact on global food supplies and commodity prices. Will the drought return next year? Knowing the probability of good harvests around the world in 2013 would assist planners and markets to ensure global food security.

Even the microscopic viruses and bacteria that can affect human health are climate-sensitive. Dry and dusty conditions in the Sahel region of Africa often precede outbreaks of meningitis; getting climate information to health providers before such conditions progress can ensure more effective vaccination campaigns. In other regions, a particularly wet season can lead to greater incidences of malaria. The flu virus is transmitted more easily in winter, when the atmosphere is colder and drier. These illnesses kill people and harm the economy, so minimizing their impact is important.

The availability of water for agriculture, industry and households also fluctuates with climate. Planners need to know when to restrict water usage before a pending

Image: Japan Meteorological Agency

Japan Meteorological Agency experts monitoring extreme weather phenomena

Image: Deutscher Wetterdienst

Forecasters at Deutscher Wetterdienst study weather maps

drought draws down reservoirs and other supplies. The failure of the monsoon can lead to hardship and hunger. As the climate changes, the distribution of water resources may permanently shift; for example, melt water from glaciers may be released earlier in the spring, affecting fishing, irrigation, energy production and water supplies.

Climate is also the force behind most disasters caused by natural hazards. Many parts of the world are vulnerable to floods, droughts and severe storms. Seasonal climate variation and extreme rain can contribute to landslides and erosion. As greater warmth speeds up the water cycle, and the warmer atmosphere holds more water, more flooding and severe storms can be expected.

By exacerbating climate variability, climate change will increase the need for climate services. The 2007 assessment report of the WMO/UNEP Intergovernmental Panel on Climate Change (IPCC) estimates that the average global temperature (which is now 15° C) will likely increase by 1.8-4.0° C by the end of the century. This would result in an estimated sea-level rise of 28-58 cm – although larger values of up to 1 m by 2100 cannot be ruled out. The IPCC will update these projections in late 2013 based on the most up-to-date research available.

A number of changes in the climate have already been observed. The world's rivers, lakes, wildlife, glaciers, permafrost, coastal zones, disease carriers and many other elements of the natural and physical environment have started responding to the effects of humanity's greenhouse gas emissions. Rising temperatures are accelerating the hydrological cycle, resulting in heavier rains and more evaporation; they are also causing rivers and lakes to freeze later in the autumn and birds to migrate and nest earlier in the spring. Scientists are increasingly confident that, as global warming continues, certain weather events and extremes will become more frequent, widespread or intense.

Scientists are also starting to predict how the climate will change in specific regions. According to the 2007 report, by 2020 between 75 million and 250 million people in Africa may be exposed to increased water stress due to climate change; in some countries yields from rain-fed agriculture could be reduced by up to 50 per cent. By 2050, freshwater availability in Central, South, East and South-East Asia is projected to decrease, particularly in large river basins. Europe's mountain glaciers will retreat, reducing snow cover and winter tourism, and high temperatures and droughts will worsen in southern Europe. Yields of some important crops and of livestock in Latin America are projected to decline. Warming in the western mountains of North America is projected to cause decreased snowpack, resulting in more winter flooding and reduced summer flows.

The science of climate forecasting

To generate actionable information for addressing these and other climate risks and opportunities, the providers of climate services must, of course, be able to forecast the climate. But if forecasters cannot predict next week's weather, how can they predict the longer term climate? A fair question. Of course, meteorologists *can* predict next week's weather, even if the inherent chaos of the atmosphere means they sometimes get it wrong. The weather forecaster's challenge is that small random movements of air and moisture can divert a broader weather pattern, especially at the local level and beyond the timeframe of a week or 10 days.

These small-scale chaotic movements do not affect climate, often defined as the average weather over a 30-year time period. Climate forecasters do not need to predict whether it will rain in Beijing on Tuesday; rather, they aim to predict that the next winter (or


Image: Uzbekistan NMS

Pre-drilling of ablative measuring rods: Uzbekistan Hydro-meteorological Service


Image: George Tarbay, NIU

Students in meteorology at Northern Illinois University, monitor air temperatures and humidity at a weather station in a DeKalb cornfield. The students worked on research showing trends in northeast Illinois dew-point values

the next decade, or the next century) in Beijing will probably be warmer (or colder) than average. They do this by studying large-scale and long-term processes, such as the Earth's orbit, long-term solar radiation cycles, deforestation and other changes in land cover, ocean temperatures and currents, and greenhouse gas emissions. Their main tools are observations of today's climate, studies of past climates, and computer-based modeling of climate processes.

Certain regions of the global atmosphere are strongly affected by sea-surface temperatures and other slow-changing variables. Researchers have demonstrated that interactions among the atmosphere, oceans and land surface can produce fluctuations that are potentially predictable, and that this makes it possible to predict the climate at seasonal and interannual timescales. The most well understood fluctuation is known at the El Niño/Southern Oscillation (ENSO), which is linked to interactions between the atmosphere and the ocean in the tropical Pacific Ocean. Just like the advances in weather prediction, these advances in climate prediction have been made possible by steady improvements in observations and models.

While climate forecasters are demonstrating an ability to predict the average weather of the next season or the next year over a broad area, they cannot fine-tune the weather forecast for Week 6 in a specific locale. Nevertheless, knowing that there is a high probability that the coming monsoon season will have low, average or high rainfall can help farmers and energy and water suppliers, for example, to plan their activities. Similarly, while individual hurricanes, typhoons and other tropical disturbances cannot be predicted beyond a few days in advance, the provision of probabilities for the future tracks, numbers and intensity of such storms would be extremely beneficial to society.

Concern about climate change is also helping to drive research into the climate system and climate forecasting. The evidence available to scientists – from ice cores and other residues of ancient climates to 21st century satellite measurements and sophisticated models run on supercomputers – has grown exponentially. Thanks to these advances, the level of confidence scientists now have in their understanding of the global climate system is 'very high' – defined by the IPCC as being at least a nine in ten chance of being correct.

The scientific method that has made this progress possible is one of humanity's most impressive cultural achievements. By gathering and analyzing evidence, developing hypotheses and designing experiments to test them, scientists have unlocked many of nature's most closely held secrets. The spirited debate amongst competing theories and research teams reflects the vitality of this search for a better understanding of climate variability and climate change.

Climate services

Seasonal to multiyear climate forecasts are increasingly being used to generate actionable information for decision-making on disaster risk reduction, public health, agriculture, fisheries, tourism, transport, and other weather and climate-sensitive sectors. A growing number of governments are building on their experience in weather forecasting to customize climate information and target it to specific users. These climate services make it possible to incorporate science-based climate information and prediction into planning, policy and practice to achieve real benefits for society

Climate services often involve integrating climate information with information from other sectors. This requires close collaboration between agencies and experts from different fields. The resulting information must then be presented to users in formats that they can understand. When presenting information in the form of probabilities, climate service providers must take special care to communicate the concept of probability effectively to people who may be generalists or specialists in other fields. They should also ensure that the information they generate is easily accessible, whether via open websites or dedicated delivery channels.

As described by the articles in this book, governments in all regions of the world are already providing, or preparing to provide, a wide range of climate services. For example:

- Countries as diverse as Guinea-Bissau, India, Indonesia and Mali are providing climate services to support agriculture and food security. They are carrying out programmes to inform farmers about climate impacts while also seeking feedback from these users on how best to design climate information products for agriculture.
- The Ethiopian Meteorological Organization is adopting modern climate forecasting methods and enhancing the quality of the climatology information that it offers. It plans to increase access to climatology and forecast information related to agriculture, aviation, water, health and energy.
- The North American Drought Monitor, prepared jointly by the United States, Canada, and Mexico, illustrates how individual nations can work together at the regional level to provide climate services. The Monitor is a first step in a larger effort to improve the monitoring and assessment of a suite of climate extremes on the continent, including heat waves and cold waves, droughts and floods, and severe storms.
- The German Heat-health Warning System is demonstrating how climate and health services can collaborate on protecting human health in anticipation of an expected increase in the number of heat waves.
- Every month, the Australian Bureau of Meteorology provides a forecast of the likely shifts in temperature and rainfall for the coming three months, giving the 'probability' or 'likelihood' that rainfall or temperature will be above the long-term median. To make this product as user-friendly as possible, the Bureau conducted market research by interviewing internal experts and high-level external users and then conducting an online survey.
- A demonstration project in Armenia aims to reduce the vulnerability of mountain forest ecosystems to climate change. The project is assessing current observation systems and databases, observed and projected climate changes, and climate extremes and climate risks. The goal is to improve seasonal predictions, implement a Climate Watch System for forest fire, and integrate climate change concerns into forest management.
- A number of countries are establishing climate websites to improve access to climate information and services. Finland's site, for example, provides information on climate change science and on practical means for mitigating and adapting to climate. France's site provides regional scenarios for the country and seeks to link the users and providers of this information.

The Global Framework for Climate Services

The Global Framework for Climate Services is an initiative of the United Nations system that seeks to build on and strengthen these national programmes and services. It was launched in 2009 by the World Climate Conference – 3 as a global partnership of governments and organizations that produce and use climate services. The GFCS enables researchers and the producers and users of information to join forces to improve the quality and quantity of climate services worldwide, particularly in developing countries.

The GFCS takes advantage of the continued improvements in climate forecasts and climate change scenarios described earlier to expand access to the best available climate data and information. Policymakers, planners, investors and vulnerable communities need this information in user-friendly formats so that they can prepare for expected trends and changes.

The GFCS is based on eight principles:

- Give a high priority to the needs of climate-vulnerable developing countries
- Put the primary focus on better access to and use of climate information by users
- Address needs at three spatial scales: global, regional and national
- Ensure that climate services are operational and continuously updated
- Recognize that climate information is primarily an international public good and that governments will have a central role in the Framework
- Encourage the global, free and open exchange of climate-relevant data
- Facilitate and strengthen – do not duplicate
- Build climate services through partnerships.

To succeed, the GFCS must, above all else, be driven by the needs of users. Lessons already learned from existing climate services make it clear that engaging the health, water, disaster and agriculture communities requires supporting the existing priorities and work plans of these sectors. Climate service providers also need to respond to the very specific needs of the distinct user groups within each of these broad sectors. National capacity building is also essential to ensuring that people fully understand the climate products and can apply climate information effectively.

The GFCS actively encourages governments to promote a broad exchange of views about how to tailor climate services. It advocates interdisciplinary collaboration between government agencies, private companies and research institutions, and it promotes collaborative problem-solving and 'learning from others'. Building trust with other sectors will encourage data sharing and make it easier to assemble multidisciplinary datasets and products.

While climate services will build on and link together existing capacities and programmes, funding will clearly remain a critical issue. Dependable funding is needed to sustain national monitoring and information infrastructure, from satellites and weather centers to databases and trained personnel. Long-term operating and maintenance costs also need to be secured. The GFCS therefore informs the international donor community about the benefits of climate services and encourages it to support national programmes and services.

The GFCS is clearly an ambitious initiative. Its success will be measured by its ability to establish an effective and sustained global partnership, strengthen national and regional climate services, and empower people around the world to adapt and respond to the impacts of climate variability and climate change.

I
Agriculture

Climate information services for food and agriculture

Ramasamy Selvaraju, Climate, Energy and Tenure Division, Food and Agriculture Organization of the United Nations, Rome

Agriculture constitutes the principal livelihood of 70 per cent of the world's poor and is the primary means of their food security. The rural poor, who depend on agriculture for sustenance and livelihood, are often vulnerable to the direct impacts of adverse climate variations. Improving the ability to provide timely and accurate climate information services for agriculture presents opportunities for managing climate risks and for strategic decision-making relevant to climate-resilient adaptation and food security.

The number of hungry people in the world remains unacceptably high. The United Nations Food and Agricultural Organization (FAO) estimates that a total of 925 million people were undernourished in 2010 – 98 million down from 1.02 million in 2009. The ability of agriculture to reduce the proportion of undernourished population and achieve global food security could be severely affected by increasing climate variability and change.

Smallholder farmers, fishers, livestock herders and forest dwellers, who contribute to food security, are already suffering from climate fluctuations. Enhancing their capacities to respond to a range of current climate risks serves as a basis for reducing vulnerability and adapting to climate change.

Recent advances in climate prediction have raised exciting prospects for managing the risks and reducing vulnerability. Enabling institutions and policies, low-cost information and communication technologies and vibrant local farmer networks could complement the advancement in climate, especially by connecting climate information providers, agriculture support services and end users.

Achieving food security in a changing context

Agriculture, fisheries and livestock are always at the centre of deliberations about food security. Changes in climatic conditions, frequent damage and loss due to extreme weather and climate events, increasingly scarce water resources, expansion of food production systems into marginal areas and loss of biodiversity are some of the major challenges faced by the agriculture sector. The challenges are becoming prominent and thus agriculture need to orient itself to increase food production by 60 per cent compared to 2009 levels to meet the demand of a projected world population of 9.1 billion in 2050. Achieving food security in a changing context warrants a renewed, systemic and integrated approach, taking into account ecological, economic and social perspectives. Beyond doubt, climate information services will be one of the tools to meet the challenges of the future.

Managing food systems and resources

The provision of needs-based climate information to farmers can support the management of agriculture resources (land, water and genetic resources). Better understanding of the climate in a location provides opportunities to design various measures to reduce its impacts on natural resources.

Climate information services are needed for land-use planning, agro-ecological zoning, sustainable land management and forest management. Recent improvements in the provision of advance climate information allow the earliest identification of land areas likely to be affected by a specific climate risk. For instance, monitoring of land degradation, early warning on areas of concern, and current and future risk hotspots need specific climate information products for timely decisions.

Demand for water is increasing and putting pressure on already scarce water resources. Currently, about a third of the world's population lives under water scarcity. Agriculture accounts for about 70 per cent of all water use worldwide and up to 95 per cent in many developing countries. The area under irrigation has increased from 139 million hectares in 1961 to just over 300 million hectares now.

Given the dominant role of agriculture in water use, practices that increase water productivity can greatly enhance the sustainability of agriculture. Climate data and information should be tailored to benefit water resources in river basins, including the release of water depending on seasonal climate outlooks and on-farm water management to reduce water loss and enhance water use efficiency. At farm level, decisions such as area under crops, types and duration of crops, irrigation quantity and timing rely on climate information.

Agricultural biodiversity plays key functions in food and livelihood security. The understanding of abiotic and biotic interactions in the context of climate variability assists in developing strategies for conserving plant and animal genetic resources. To understand the effects of climatic instability on agriculture and the possibilities of reducing inputs, assessment of crop yield stability across environments is critical. Climate information should be considered when selecting suitable locations for in situ conservation of genetic resources.


Image: FAO

Women's group in Mid-hills of Nepal participating in a farmer field school on climate risks

Managing pests and diseases

Changes in incidence, distribution and intensity of pests and diseases due to climate change are likely to cause additional crises in local agricultural production. Climate change is likely to affect vector-borne diseases and may also result in new transmission pathways and different host species.

Changing climate may affect the patterns of disease and pests through altered host distribution and phenology, alter the plant-associated microflora and trigger new plant diseases and pest outbreaks. Early detection of diseases and pest outbreaks based on weather and climate forecasts can assist proactive control measures and thus avoid higher management costs. By monitoring pest thresholds, climate information systems can assist in the development of integrated pest management technologies needed to counter new pests.

Operational monitoring of pests and diseases, and weather-based early warning systems, have long been recognized as an essential part of integrated pest and disease management. Pest and disease forecast models, coupled with weather forecasts generated from climate simulations, can be a basis for pest and disease early warning systems.

Enhancing resilience of coastal communities

Coastal zones constitute extensive areas of the most vulnerable ecosystems, and are strongly exposed to natural hazards such as hurricanes, storms, floods, erosion and salt-water intrusion. Fisheries-dependent communities are particularly vulnerable to rising sea levels, changes in ocean salinity, hurricanes, and a decrease in fish stocks and availability due to increasing water temperature.

Most of the large global marine fisheries are affected by climate variability associated with the El Niño Southern Oscillation (ENSO). Assessment of vulnerability and risks, and development of community level risk reduction plans incorporating climate information, could effectively reduce vulnerability and risk. Customized climate information services for fishers need to serve better information about the impending weather and climate risks to support decision-making on fishing time, area, saving livelihood assets, and matching the actions outlined in the community level

Farmer groups in Highlands of Peru discussing climate risk management options

risk management plans if exists. Strengthening of fishers' cooperatives, community networks on interpretation of climate information and decision-making are the priority.

Reaching the most vulnerable

Mountain regions cover about one fifth of the Earth's continental areas, and are characterized as sensitive ecosystems. Remoteness, marginal environment, heavy dependence on agriculture and livestock, land degradation, frequent occurrence of extreme climate events and non-availability of proper agricultural support services make them highly vulnerable to climate variations. There is a need for locally relevant early warning systems which are often felt to reduce vulnerability and protect lives and livelihood assets.

FAO's work in many countries promotes locally relevant communication protocols, and community networks to facilitate sharing of climate information between farmers and herders, enabling them to better manage climate risks and reduce their dependence on external assistance. For example, in the Bolivian Andes, technical assistance was provided to improve weather stations, prepare vulnerability and risk maps, and set up an automated early warning system protocol linking the national meteorological and hydrological services (SENAHMI), risk management centres and community risk management teams in Potosi Department, which is more than 4,000 metres above mean sea level.

Similarly, herders in arid and semi-arid areas are vulnerable because of highly variable and scarce rainfall. Over-exploitation and degradation of natural resources, remoteness, poor livelihood assets and fewer opportunities for diversification make them more vulnerable. Timely and accurate climate information can be of great help to reduce their vulnerability.

Food security information systems

Climate information can be combined to livelihood analysis and market information systems, to improve early action planning to overcome food stress situations. As large and widely dispersed populations depend on rain-fed agriculture and pastorals, climate monitoring through automatic weather stations and forecasting are important inputs to food security analysis and humanitarian responses.

Satellite rainfall estimates, remote sensing techniques, ensemble forecasting and crop yield forecasting offer significant opportunities for protecting agricultural livelihoods and better responding to food-related emergencies.

Timely and effective humanitarian aid will provide households with opportunities to engage in productive and sustainable livelihood strategies. FAO's Global Information and Early Warning Systems (GIEWS) is mandated to keep the world food supply and demand situation under continuous review. It issues reports on the world food situation and provides early warnings of impending food crises in individual countries. Improved understanding of climate variability including ENSO effects, the implications of weather variables for food security and the vulnerability of rural communities, have become integral to the food security information systems.

Multi-tier and action-oriented climate services

Action-oriented climate advice integrates information on different time scales (intra-seasonal, seasonal and long-term) for risk/opportunity management. Intra-seasonal to inter-annual climate variability impacts the agricultural sector and, therefore, many agricultural decisions can benefit from multi-tier, action-oriented climate services. Information about the passage of the Madden-Julian Oscillation and propagation characteristics of the Monsoon Intra-Seasonal Oscillation provide capabilities for explaining intra-seasonal variability relevant to agricultural applications.

Seasonal climate predictions are of immense use to agriculture ministries, non-governmental organizations and private companies for policy and the seasonal planning process, in addition to seasonal crop and livestock management decisions by farmers and herders. Approaches to applying seasonal to inter-annual climate predictions, including use of ENSO-related climate information products, are well developed and widely demonstrated.

Index-based insurance

In 2005, FAO estimated that the total annual agricultural and forestry insurance premiums worldwide in 2001 amounted to some US$6.5 billion. According to the World Bank (2009), the direct premiums for agricultural insurance have grown rapidly in recent years to reach US18.5 billion in 2008. Even though Index-based insurance products for agriculture represent an attractive alternative, the current insurance mechanisms are not adequately covering the smallholder farmers.

Climate information services could play a major role in providing high-resolution climate data to farmers and insurance managers so as to encourage them to make use of the insurance mechanisms. Strengthening of weather observation networks, monitoring of extreme climate events, standardization of indices, data sharing, early warning systems and capacity building are pre-requisites.

Localized farm advisories

The analysis of real-time weather, crop information, weather and climate forecasts, costs of inputs and prices of farm produce are needed to prepare needs-based and location-specific farm advisories. Major elements in implementing localized farm advisories are:

- Collection of climate, crop and socioeconomic data
- Data analysis and prediction
- Development of impact outlooks and management practices
- Preparation of farmer agro-advisors.

The approach aims to provide a full range of advice regarding crops to be planted, time and quantity of inputs that might be used, and management practices to be followed to prevent or reduce risks, so users will be ready to execute management decisions at short notice based on the anticipated weather and climate.

The local advisories will contain information on input availability with agricultural support services, input suppliers, local cooperatives and farmer's or community-based organizations to make practical and locally relevant decisions.

Climate data, analysis tools and methods

Building a database of climate, soil, agronomic and crop phonological information is important to effectively make use of climate information. Historical daily, weekly and monthly data on precipitation, temperature, solar radiation, relative humidity and evaporation etc, are the essential variables of the database. Planning of adaptation and mitigation practices requires climate change scenarios for the future.

Close cooperation between agencies and organizations dealing with agriculture and climate services is needed to establish a user interface platform (UIP) to promote unrestricted exchange of information between providers and users. The UIP mechanisms are catalysts for strengthening climate monitoring, building climate databases, advocating climate policies at national and regional levels, capacity building, education and training, and developing user-friendly climate information products. FAO promotes such interface mechanisms between NMHSs and agricultural support services at national and sub-national levels, and provides services on data, tools and methods to help reduce the impacts of climate variability (www.fao.org/nr/climpag).

Capacity development

The capacity to identify, collect and share data, use information and relevant methods for data analyses and build knowledge relevant for climate and weather information and food security is critical. A transfer of recent knowledge from climate science, as well as the strengthening of the capacity for agrometeorological observation, the development of customized forecasting products, the management of data and modelling for climate impact assessment and application of climate information at the farm level are of the highest priority. Agriculture extension services need to be strengthened in order to address climate risks and plan for adaptation and mitigation if these are to provide an efficient interface between policymakers and the farming community.

Enabling policies and plans

There are several challenges to be addressed for the continued provision of climate information for decision-making in agriculture at global, national and local levels. The key challenges are financial constraints, restricted institutional mandates and disabling policies. Communication and feedback mechanisms between information providers and users can be sustained by setting up multi-disciplinary institutional mechanisms at national and sub-national levels, with specific roles and responsibilities pertaining to generation, translation, communication and use of climate information for decision-making in agriculture.

Government agencies and institutions seeking climate information for food and agriculture can be advised to prioritize the need for climate services in their development plans, strategies and programmes. Such a prioritization can provide opportunities to leverage funds and technical support for continuous availability of climate information at different levels for decision-making in agriculture and food security.

Reaching farming communities in India through Farmer Awareness Programmes

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Farmer Awareness Programmes have been helping to increase the interaction between local farming communities, regional meteorological centres/meteorological centres (RMCs/MCs), agrometeorological field units (AMFUs) and Krishi Vigyan Kendras (KVKs) in India, and educating farmers about weather and climate information and its applications in operational farm management. The programmes are organized jointly by the India Meteorological Department (IMD), state agricultural universities, Institutes of the Indian Council of Agricultural Research (ICAR) and Indian Institute of Technology, working with local non-governmental organizations (NGOs) and other stakeholders in different parts of the country

As well as helping to make farmers more self-reliant in dealing with weather and climate issues that affect agricultural production, the programmes were also needed to help RMCs/MCs, AMFUs and KVKs understand farmers' requirements for using weather forecast and agrometeorological advisories. To assist the farmers and further develop their adaptive capacity with improved planning and better management decisions, a participatory, cross-disciplinary approach is being taken to delivering climate and weather information and enhancing the awareness of information user groups.

Ground surveys indicate that Farmer Awareness Programmes address a long-standing demand from India's farming community. Typically, each programme lasts for one day and brings together farmers from a group of villages to a centralized location in any given region. Participants can share ideas about crop cultivation with respect to the weather, and farmers can get answers to their questions about weather-sensitive farm operations and strategies as well as climate change. The Farmer Awareness Programme was successfully completed during the years 2009-2010 and 2010-2011 at many AMFUs, which invited farmers from nearby villages to take part. Ninety-four AMFUs located in agricultural universities and ICAR institutes have organized Farmer Awareness Programmes and approximately 10,000 farmers have attended them.

Brochures and posters from the Farmer Awareness Programme

Source: India Meteorological Department

By getting involved in the observation of weather data, farmers can help to produce location-specific agromet advisories

Image: India Meteorological Department

Farmers are provided with rain gauges by the programme

Processes and mechanisms

During the one-day programme, the first half of the day consists of lectures given by atmospheric scientists, meteorologists, agrometeorologists and experts in different disciplines of agriculture (such as entomologists, pathologists, soil scientists, agronomists) in the local language to promote a good dialogue with farmers. The programmes also aim to assess how the Agrometeorological Advisory Service (AAS) can be made more relevant to the local needs of the farming community. The second half of the day includes discussions about farmers' existing knowledge of the use of weather and climate in agriculture and risk management, needs for weather and climate information and ways to improve the communication of this information to farmers. As a number of farmers in rural villages are not fully aware of AAS and do not know about the possible connection between weather and the farming system, they are first appraised on these subjects so they can understand the merits and limitations of the service in relation to various weather-related practical problems they face in agriculture. Primary emphasis is given to a free and frank exchange of ideas and information. This part of the programme is designed to engage all the participants in discussions and obtain full information about their needs for weather and climate information, and how to improve future communication of this information to enable an effective operational decision-making process. Important discussions between resource providers and the user community focus on the use of weather data and weather forecasting in AAS, climate change and climate variability, extreme events, dissemination, animal husbandry and so on. All the resource providers are given proper training on operational agrometeorology by IMD, which also organizes seminars on this subject for in-depth discussions with the people assigned to conduct the Farmer Awareness Programme.

Farmers receive informative brochures; pamphlets outlining weather-based farming guidelines; information on packages and crop practices in the district; leaflets containing information about pests and diseases, severe weather conditions, crops grown under stress conditions and inbuilt contingency plans; and the District Agromet Bulletin – all in local languages. There are also demonstrations on how to install and use rain gauges to record information. At present these rainfall data are being communicated to the AMFUs and used to prepare agromet advisories.

Rain gauges for farmers

It has been observed that in most villages there is at least one farmer who is relatively knowledgeable and educated, and other local farmers are obliged to this person for his or her meaningful advice on crop cultivation. Thus, this individual is indirectly identified as a progressive farmer whose advice is beneficial in farm management.

In order to improve the linkages with the AAS system and develop a local (village) level rain measuring network, five rain gauges made of plastic are distributed to a group of progressive farmers selected by AMFU during the meeting. These farmers are then trained to record and report the rainfall observation to the relevant AMFUs, which in turn communicate it to IMD.

The farmers are familiarized with the measurement of rainfall by ordinary rain gauges and told about IMD's proposed plan for development of a village-level rain measuring network in the country. The purpose of distributing the rain gauges is to involve farmers in the observation of weather data and in the preparation of agromet advisories so they can share their observations with all the relevant AMFUs and help to produce location-specific advisories. At present there are 264 agromet observatories where observations are taken, including morning rainfall measurements. The quality of the farmers' rainfall data is regularly monitored by AMFU and IMD.

Demonstrations for the public

As a part of the programme, some AMFUs have organized exhibitions and demonstrations highlighting various

Farming communities are shown a variety of weather and climate measuring tools to familiarize them with agrometeorological advisory services

production systems including agriculture, horticulture and animal husbandry. An exhibition for schoolchildren was also arranged to raise their awareness about the future impact of weather and climate on agriculture and daily life. Various weather instruments were displayed, such as rain gauges, weathervanes, sunshine recorders and maximum and minimum air temperature thermometers. The exhibitions also include posters containing important information about weather forecast application and reliability and the impact of climate change. Charts are displayed showing agrometeorological research activities in the station, climatic characterization of the region, the onset date of monsoon rainfall in the region, the start of the agromet advisory service unit, medium-range weather forecasts, the preparation of the agromet advisory bulletin and a selection of suitable crops based on the time of monsoon rainfall onset and the impact of climate change. Farmers have visited the agricultural meteorological observatory to get acquainted with the weather instruments, and to be shown the automatic weather station.

Capacities

In each AMFU a Nodal Officer (NO) and a Technical Officer (TO), who have significant experience in agrometeorology, work on AAS. They are given special training in IMD at the time of setting up the AMFUs, and IMD organizes a 21-day AMFU training course covering all agrometeorological information.

The Farmer Awareness Programme includes extensive discussions on how farmers can blend and use traditional knowledge and indigenous skills for weather forecasting with modern forecasting methods in different aspects of agricultural operations to increase the crop yield. A regular survey made for targeted and non-targeted farmers shows that they are more aware and that they trust these services, ultimately producing more agricultural output by using the information provided in the programme.

Farmers' views

One progressive farmer shared his experience about how he had benefited from the agromet advisory issued by the AAS of AMFU Sonitpur, Assam. He described how he was able to save a mature potato crop worth Rs300,000 from damage due to heavy rainfall after receiving a forecast of heavy rainfall well in advance. Another said that he regularly followed the advisory issued by AMFU Pune, Maharashtra and his crop yield had increased by 10-15 per cent compared to other farmers who did not follow the advisory.

Farmers are able to ask questions about the forecasts, services and the effects of climate change, which the NO and TO answer in their regional language. Experts from different fields also answer farmers' queries, and some important messages have been communicated to the farmers through this programme:

- Farmers should take advantage of such awareness programmes to minimize crop loss due to unexpected climatic hazards and to help increase agricultural production
- Farmers are told how to pre-plan farm operations and cropping by getting weather information in advance
- Farmers are requested to keep in touch with KVK regarding their problems, to opt for newer technologies which can sustain productivity levels without affecting climate, and to visit the KVK farm to see how weather data such as temperature, rainfall and relative humidity is recorded by the automatic weather station
- Farmers are asked to keep in touch with the university through the Agriculture Fair, Farmers' Club meetings and the Farmers' Gathering so they can maximize their knowledge about new research outcomes and apply this knowledge on their fields
- Farmers should adopt poultry farming and fisheries as well as dairy and fruit production with agricultural crops to generate extra income; they are encouraged to work through self-help groups and take advantages

of government schemes for different agricultural inputs such as advanced irrigation systems and seeds of different crops.

During the programme, farmers have mentioned their specific requirements from AAS, including:

- Local-level forecasts for the season and month to be given in advance for planning their crops/cropping patterns, and midseason corrections in the event of dry and wet spells
- All four types of periodical weather information (long-term, medium-term, short-term and nowcast) supplied from a single window with agromet advisories
- The agromet advisories should reach farmers well in advance (two to three days) and a full advisory covering all the crops and agricultural tasks to be done should be communicated through the mass media and different government agencies, as well as being available through Kisan Call Centres which provide online services to the farmers
- The AAS bulletin should include information on organic farming, especially pest control measures and mixed farming including vegetables
- Information on threats such as pest, disease and frost should be given at least three days in advance
- The agro-advisory bulletin should be displayed in public areas like the Block Office, Village Office, Panchayat Office, local market and other popular places.

The main difficulty for farmers in rural villages is that they do not have access to the information at the right time. The basic challenges of the meteorological community would be to prepare crop- and location-specific agromet advisories – particularly concerning climate variability, climate change and severe weather conditions – and to communicate these to the farmers through personalized services, online and at the right time. There is a need to increase interaction between meteorologists and the user community, and linkages should be developed between these two groups to protect the crops at appropriate times.

Future goals

As IMD is upgrading the services from district to block level with dissemination at village level, there is a need to sensitize farmers about weather services in more rural areas. Thus the frequency of the programme will be increased. It will be funded by the Ministry of Earth Sciences (MoES), Government of India as and when required.

Based on the requirements, strategies will be framed to implement a farmer-oriented AAS, including:

- Efforts to develop precise and accurate weather forecasts at block level in addition to extended-range weather forecasts at fortnightly, monthly and seasonal scale for application in agriculture (at present, weather forecast and agromet advisories are developed at district level)
- Initiation of agromet advisories for new categories like horticultural crops, livestock, wasteland, forest fires and post-harvest
- Emphasis on developing a mechanism by which a farmer can contact agricultural scientists through the Internet, telephone or video conferencing to get agrometeorological advice on a specific problem
- Tie-up with the existing crop growers' associations for high-value crops like tea, coffee, apple, mango, sugarcane and cotton, to develop suitable crop-specific advisories and build up a mechanism to disseminate the information to targeted growers
- Dissemination of advisories using multichannel systems like the Common Service Centre of the Department of Information Technology, Virtual Academy/Virtual Universities/NGOs, Kisan Call Centres/Kisan Melas/KVK/ICAR and other related institutes, agricultural universities and the extension network of the State Agriculture Department
- Provision of appropriate training to the farmers through capsule courses, with extensive training through the State Agricultural University and State Department of Agriculture with active support from IMD.

Expansion and knowledge transfer

The participation of different stakeholders and the dissemination of knowledge about weather-based agromet services and their use in farming are central issues for the success of the Farmer Awareness Programme. In India, the programme will continue to be organized at regular intervals to make the system sustainable. Key to the success of this endeavour is the development of accurate district-level forecasts and agromet advisories that are useful to the farmers, and the dissemination of advisories through SMS.

India has been divided into 127 agroclimatic zones based on soil characteristics, rainfall distribution, irrigation patterns, cropping patterns and other ecological and social characteristics for the management of agriculture in a systematic and meaningful way. At present the Farmer Awareness Programme is being carried out at AMFUs located in the agroclimatic zones. In the next five-year plan, the programme will be conducted at the 620 KVKs which are located at district level. A special programme will also be conducted for practical demonstrations and the issuance of advisories under different weather and climate conditions.

Other countries, particularly in the South Asian Association for Regional Cooperation (SAARC), can conduct similar programmes which will help to raise the farming community's awareness of current advances in the provision of weather and climate information for facilitating operational decisions on farms. The World Meteorological Organization and SAARC Agriculture Centre have a great role to play in sharing information about India's experience of the Farmer Awareness Programme, particularly in RAII countries. In this regard, a consultation meeting on Operational Agrometeorological Services in SAARC and other countries in RAII regions was organized in Pune from 20-21 April 2012. At that meeting, the initiative was taken to share the mechanism of AAS development in India with the other countries and an in-depth discussion took place on strategies for streamlining the activities of AAS, including the Farmer Awareness Programme, in SAARC and non-SAARC countries.

Under the Global Framework of Climate Services (GFCS), IMD/MoES is already collaborating with different organizations to implement dedicated operational agromet advisory services, to help farmers minimize crop loss against the adverse impact of bad weather and increase crop productivity by taking advantage of favourable weather. These agromet services conform to the basic principles of the GFCS in that they are operational services carried out in collaboration mode for district, regional and national levels. Of the different components of the services, the Farmer Awareness Programme has proved to be highly useful.

Mainstreaming climate information for agricultural activities in Kenya

Peter Ambenje, Samwel Marigi, Samuel Mwangi, Ayub Shaka and William Githungo, Kenya Meteorological Department

The fourth Assessment Report of the Intergovernmental Panel on Climate Change has explicitly demonstrated that climate change is indisputable. In many parts of the world, the impacts associated with climate change are being observed with increased frequency and severity. This is so even in Kenya, where climate-sensitive activities in many socioeconomic sectors such as agriculture and food security, water resources, energy, health, transport and infrastructure are being affected by changes in the climate patterns. This is imposing a strain on the vulnerable communities' livelihoods, especially agricultural and livestock production. Fluctuations in the seasonal rainfall patterns lead to instability in agricultural production and economic hardships. The importance of adaptation to create resilience of the vulnerable communities to climate variability and climate change is, therefore, gaining ground. Effective adaptation to climate variability and climate change is highly dependent on access to climate information for the coming seasons and years to support decisions and choices.

Kenya suffers from food insecurity, mainly due to intra-seasonal and inter-annual variability in rainfall. The relatively high vulnerability of the country to climate-induced crises is due to its high reliance on rainfed agriculture and predominance of agro-ecologies (arid and semi-arid) that are marginal for crop production. Climate variability directly or indirectly influences at least 75 per cent of any agricultural output in the country. In the arid and semi-arid areas, which constitute nearly 80 per cent of the land area, rainfall during a crop season can vary from about a third to two-and-a-half times the normal amounts, making agriculture a risky enterprise.

Image: KMD

Farmers consult with experts from technical institutions to plan ahead

Effective measures to manage the impacts of climate variability have the potential to serve as crucial steps in helping farmers cope better with the variability in climate. In a situation where important farming decisions, whose outcome is highly sensitive to the amount and distribution of rainfall during the season, are to be made well before knowing the seasonal conditions, advance information about the rainfall during the coming season can help farmers make more tactical decisions about investments and adopt management practices that make best use of the season. Seasonal climate forecasts in the range of two to three months in advance, which also include crucial information such as the potential onset and cessation times of rainfall, are vital for farm-level decision-making.

However, weather forecast information is still not as widely used as it should be by end users (farmers) due to:

- Limited clarity on what forecast formats are best suited to user needs, though it is known that the optimal format may vary between applications
- Complexities in the use of information, which may lead to further difficulties if inappropriately used
- Fragmented production and delivery systems which sometimes make it difficult for forecasts to reach the end users who may have a particular need for them
- End users' perceived need for temporal and spatial detail (such as exact rainfall amounts, onset and cessation dates) in the prediction that currently cannot be achieved
- Lack of awareness of the significance of factoring weather/climate information into planning.

Currently, weather forecast information does not guide location-specific decision-making by users. This is, however, information that can be sourced from the national meteorological and hydrological services on request. Additionally, the current major means of disseminating forecast information (print media and internet) do not adequately convey the messages to end users. In some other instances, users get the message when it is too late to apply it in decision-making.

Given the above challenges, the following measures are proposed to ensure effective exploitation of valuable weather and climate information:

- Create links between meteorologists and end users of forecast information to develop use-oriented products
- Communicate the information in the users' local languages
- Develop techniques for raising the awareness of user communities on the benefits of using climate information in decision-making
- Demonstrate the economic value of applying climate information and prediction products in socioeconomic development
- Improve the modes of communication.

Various collaborative efforts — most of them in the marginal areas of Kenya — are involving a range of institutions to support farmers in coping with climate variability. These initiatives include:

Sustainable Agricultural Livelihoods Initiative

The Sustainable Agricultural Livelihoods Initiative project is being implemented by Christian Aid, the Christian Community Services of Mount Kenya East, the Anglican Church of Kenya Diocese of Mbeere and Traidcraft East Africa. The agriculture project located in Mbeere, Embu County, focuses on innovations in agriculture and has a strong component on use of climate science information.

The forecasts are repackaged into user-friendly weather information products and developed into related advisories for crop farmers and pastoralists. The information is regularly disseminated through various channels such as:

- Workshops, mainly at the beginning of seasons to give seasonal climate outlooks
- Field days
- SMS-based messages
- Church gatherings
- Other forms of media (print, radio, TV, internet and telephone).

Based on the forecasts, farmers make guided decisions about the kinds of farming technologies to employ for increased food production and food security.

In all these sites the involvement of technical extension services from the Ministries of Agriculture, Livestock and Health and research institutions like the Kenya Agricultural Research Institute (KARI) are used to advise of agronomic and other management practices that would ensure the farmers reap maximum benefits. The common theme of these projects is the use of climate and weather information to enable farmers to cope with climate variability and change.

Image: KMD

A field visit by experts and farmers

Preliminary evaluation of the impacts produced by these climate and weather services indicates that there is benefit in terms of increased crop production, mainly accruing from increased use of weather and climate information. The supporting technical information from the agricultural and livestock sector further amplifies these benefits as farmers apply better farm management practices based on climate and weather information.

Weather-based advisory service

The predictability of the "Short Rains" (October-November-December) seasonal forecast over much of the south-eastern lowlands and eastern parts of Kenya takes a lot of skill due to the high influence of El Niño Southern Oscillation phenomena on the local climate. The weather-based agro-advisory service was piloted during the 2006-2010 crop season in Machakos, Makueni and Kitui counties. The advisories were aimed at bridging the gap between information availability and usability. The weather-based agro-advisory is a succinct summary of the agricultural activities that team of agricultural experts from the Ministry of Agriculture and KARI and climate experts from the Kenya Meteorological Department

Farmer assessment of usefulness of advisories in planning farm operations

Location	Total farmers (No)	Usefulness (%)			Willingness to pay
		Extremely useful	Somewhat useful	Not very useful	
Kitui	27	59%	33%	0%	81%
Mwingi	39	77%	29%	3%	85%
Mutomo	26	69%	22%	3%	96%

Source: KMD

(KMD) have agreed as the most appropriate or feasible for adapting to the upcoming seasonal climate/rainfall patterns derived from the seasonal forecast. The information is disseminated in meetings that bring together the team of experts and the farmers. In all the locations, farmers showed keen interest in receiving and using the advisory on a regular basis. The experts also undertake field visits during the rainfall season to assess the performance of crops and provide any additional advice to the farmers.

During the pilot period, farmers were able to tailor crop management to expected seasonal climate conditions. Farm level investments could be restricted during predicted bad years, and expanded when good rainfall — and thus good returns to crop investments — is forecast. In practice, it was observed that a broad indication (season likely to be good, average, poor) is sufficient for making good decisions, especially in smallholder agriculture.

A survey conducted to evaluate the usefulness of the advisories showed that most farmers considered the advisories as extremely useful in planning their farm operations, an observation well supported by a willingness of 87 per cent of the farmers interviewed to pay for the service if required.

The pilot research with weather-based agro-advisories has established that farmers can derive significant benefits from the use of climate information, if it is interpreted for location-specific needs and presented in a format they can easily understand. The challenge is to develop location-specific advisories quickly, efficiently and cost-effectively; and deploy them in time without any delay so farmers and their support agents can make the best use of them to mitigate or take advantage of variable climate ahead of the season.

Image: KMD

The March-April-May 2012 forecast briefing at Merti

Image: KMD

The March-April-May 2012 forecast briefing in Gafarsa, Garbatula

Isiolo County: community activities in response to drought

- Scouting by groups to collect information
- Preparation of pasture areas and rehabilitation of shallow wells
- Security surveillance
- Preparations of machines (water pumps, generators)
- Estimation of pasture quantity and quality
- Planning for water management
- Negotiations with elders in other communities for pasture
- Resource mobilization — financial
- Intensive planning for migration (beasts of burden, stopovers, women and children, mapping the route)
- Migration to pasture areas within and outside the county (Laikipia, Samburu, Meru, Wajir, Marsabit, Garissa, Mandera).

Mainstreaming climate information – Isiolo County

The Ministry of State for Development of Northern Kenya and other Arid Lands and the Ministry of State for Planning, National Development and Vision 2030, with support from the International Institute for Environment and Development (IIED) and other partners in Kenya, designed approaches that strengthen institutional capacity for climate adaptation in Kenya's arid lands that can be taken to a larger scale in a subsequent phase. These approaches are being tested through an action research project in Isiolo County, which will maximize opportunities for the pastoral community.

IIED is a policy research institute based in the UK. It is globally recognized for both its work on dry lands and climate change research, capacity-building and policy advocacy, and its participatory approaches.

KMD was brought on board in the project after the first workshop in May 2010 where, the pastoral communities in Isiolo identified climate change as the main problem affecting their activities.

It emerged that when all these activities are planned well in advance, the impacts of droughts on the community are minimized compared to when they are caught unawares. It became important that KMD should be incorporated in the project to directly provide climate forecasts to these pastoralists and support other government departments to plan well. The project is still in its formulation stage, but as its implementers meet the community, one member of KMD personnel is always there to sensitize them to the benefits of climate information and seasonal weather forecast and advise on expected rainfall patterns and potential impacts. Three such sessions have so far been held.

Weather briefing sessions

In July 2011, the first advisory was delivered to pastoralists based on the June-July-August 2011 seasonal forecast. By this time the Ewaso Nyiro River had dried up in Isiolo and retracted to the upper catchment areas. The forecast indicated that in August there would be good rains in the Aberdares Hills, source of the Ewaso Nyiro River, but not in Isiolo. These rains would revive the river, causing some flooding at Isiolo. At the time, herders had moved far from the river looking for pasture and water. This information was immediately interpreted by the pastoralists to mean flooding would rejuvenate green grass and water and give their animals strength to go through the remaining dry spell (September-October 2011). Indeed, good rainfall was realized in Aberdares Hills in August and the Ewaso Nyiro River flooded a large area in Isiolo. A lot of pasture was regenerated, which saw animals through the dry spell. Consequently, the community did not lose animals.

On 3 October 2011, when a meeting was called to give the October-November-December 2011 (OND 2011) rain season forecast to the pastoralists, there was very good feedback for the June-July-August 2011 advisory. Participants were very appreciative of the timely and good quality early warning information and advisory. The OND 2011 rain season forecast again favoured Isiolo with normal to slightly enhanced rainfall. This time, the advisory was for the herders to leave the flood plains by 10 October, since in the Aberdares Hills, the rains were expected to start by the second week of October and the Ewaso Nyiro River would flood. The rains in Isiolo would start in the third week of October and make the situation even worse, marooning herders in the flood plains. Indeed, by 8 October, the river water level had increased. When the seasonal rains started in Isiolo County, in the third week of October, the river experienced serious flooding. Luckily the Provincial Administration (chiefs, district officers and district commissioners) had mobilized herders to leave the flood plains in good time. Again, this information increased the pastoralists' confidence in the forecast and they saved their animals.

During another meeting on 7 March 2012 at Merti, Isiolo County, the pastoralists were given the March-April-May 2012 seasonal forecast with rains expected to be in the below normal levels. Despite these expectations, the pastoralists were not worried because there was still a lot of dry pasture in the county. However, they were cautioned to be on the lookout of bush fires which could burn all the pasture. This time they were convinced the weather forecasts were reliable. They said they would use the information to plan their grazing patterns to see themselves through the dry spell.

Image: KMD

After hearing the seasonal forecast for good rains in October-December 2011, Noor Jelle, a farmer from Nanighi village in Garissa County, planted more improved maize seed supplied by the Kenya Ministry of Agriculture — resulting in this bumper maize harvest

Participatory scenario planning

The Adaptation Learning Programme implemented by CARE International in Africa is supporting communities and local governments in Garissa County to use seasonal climate forecasts and uncertainty for decision-making as part of its community-based adaptation approach in collaboration with KMD.

Participatory scenario planning (PSP) is regarded as a mechanism for collective sharing and interpretation of climate forecasts. PSP is conducted as soon as a seasonal climate forecast is available from meteorological services — that is, as many times in the year as there are rainy seasons in that particular area. A workshop that brings together meteorologists, community members, local government departments and local non-governmental organizations to share their knowledge on climate forecasts is held over one or two days. The workshop creates space for sharing climate information from both local and scientific knowledge, discussing and appreciating the value of the two sources, and finding ways to interpret the information into a form that is locally relevant and useable. This is achieved by participants considering climatic probabilities (which are an expression of the uncertainty in the climate forecast), assessing their likely hazards, risks, opportunities and impacts, and developing scenarios based on the assessment. Discussion of the potential implications of these scenarios on livelihoods leads to agreement on plans and contingencies that respond to the levels of risk and uncertainty.

Climate scenarios equip communities and local governments with information for use in decision-making on diversification of livelihood options, risk management and preparedness to deal with disasters. This is so even when the scenario is for a poor season. Timely access to and communication of seasonal climate advisories from PSP empowers communities to take advantage of the opportunities that climate presents, which is a key part of adapting to climate change. This is achieved through developing plans that make the best use of resources to improve livelihoods while managing risks. In Garissa, Kenya, for example, the expected enhanced rainfall in October-December 2011 was a chance to improve agricultural production by making plans to harvest water and store it for use during dry periods, expanding the area of land under cultivation as more water is available for growing crops and the flooding brings in deposits of fertile soils.

Helping the world's poorest farmers adapt to a changing climate

Warren Page, Manager, Communications, Australian Centre for International Agricultural Research

Agriculture has a significant role to play in managing a changing climate. Farmers have a history of managing and adapting to seasonal variation. In Australia, agriculture produces enough food to feed some 60 million people worldwide, making the nation a net food exporter. This is achieved on the driest inhabited continent.

Australia's strong research and scientific base has led the way in delivering innovations that have helped our farmers adapt to and mitigate the extremes of climate. The majority of Australian farming is undertaken at the broad-acre level, yet the lessons learned can be delivered to different farming situations.

Developing countries are more likely to be affected by climate change because they rely more on agriculture for employment and to contribute to their economies. In many developing countries, agriculture employs and provides livelihoods for 40-70 per cent of the population. Half the world's poor, some 500 million people, rely on farming.

Many of these farmers are smallholders, farming small parcels of land in the hope of producing enough food to feed their families and grow a small surplus. The poorest farmers – who are often located on the more marginal land and production areas – could be expected to bear the brunt of climate change impacts first. They are also the first to feel the effects of seasonal climate variability.

Recent failures of monsoons in South Asia have demonstrated how tenuous life can become for poor farmers. Seasonal forecasts have not been able to predict the failures of the monsoons, so farmers have planted seed expecting rain to fall. In the worst case scenarios many of these farmers can lose half of their annual income and end up with significant or increased debts. Where these debts can only be repaid by selling land, farmers can end up with their only asset and hope for future income disappearing.

The story is similar in many countries, from Indonesia to China to Africa, where poor smallholders living on marginal lands lack the ability to adapt to, and mitigate, climate risk.

The Australian aid programme is working to address these issues, with engagement in agriculture led by the Australian Centre for International Agricultural Research (ACIAR). Agricultural research plays a central role in helping farmers, farmer communities and policymakers develop strategies focused on both adapting to climate change and lessening its effects. ACIAR funds projects that address seasonal variability, the reduction of carbon emissions and the ability of smallholders to adapt to climate change.

Seasonal forecasting

Many Australian and Asia-Pacific farmers grow their crops and raise their livestock in a climate of uncertainty, marked in particular by large variations in rainfall. Over the past 20 years scientists have gained a clearer understanding of the mechanism driving these seasonal swings. It is an ocean-atmosphere interaction in the tropics that gives rise to the El Niño Southern Oscillation (ENSO), a seesaw of climatic conditions near the equator in the Pacific Ocean. It leads to the El Niño effect, where every two to seven years the Pacific air pressure patterns reverse. During this phase, a high-pressure system predominates over Australia and a low-pressure system occurs in the eastern Pacific. This leads to droughts and bushfires in Australia, Indonesia and other South-East Asian countries.

Scientists have gained much from studying the El Niño phenomenon from both actual and historical perspectives, and they now have models on which to base predictions of changing weather and rainfall patterns associated with ENSO.

With global warming, the concern is that El Niño events could become more frequent and more intense. Thus the study of these seasonal fluctuations is important in the overall context of learning more about climate trends and developing practical tools for farmers.

A project in the late 1990s involving Australia, Indonesia, Zimbabwe and India adapted the RAINMAN software package (designed to help Australian farmers construct their individual seasonal forecasts) to produce an international version. This made the tools for seasonal forecasting available to help agriculture in developing countries. The challenge was to convince farmers of their worth.

ACIAR-funded work extended the use of seasonal forecasts to the Philippines, partnering with the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA) to develop and implement strategies to better match forecasts with decision makers' needs. The project involved a series of farm-level and policy-level case studies to determine how the farmers integrate forecasts into their risk management strategies. The team found International RAINMAN a valuable tool to convey the times of the year and locations to expect a strong ENSO signal, and when to use climatology as the most appropriate guide to the approaching season.

PAGASA benefited from the collaboration, lifting its capacity to deliver seasonal climate forecasts (SCFs) for the regions in the case studies. PAGASA in turn part-


Image: Tesfaye Legesse

Women from the Liganwa farmers' group in Siaya, Western Kenya, celebrating their maize harvest

nered with the Philippine Institute for Development Studies and Visayas State University, to identify ways to better link the climate science with the community.

A typical case study in the Philippines involved corn farmers in the Visayas region. Team members compiled a brief description of dominant cropping patterns and corn production practices in the study area, then reviewed and presented a valuation framework for estimating the economic benefits of SCF information under various assumptions of risks and uncertainty. Their task was then to quantify the potential economic value of SCFs to corn farmers in Leyte. These data, along with the findings of another study of corn farmers in Isabela, helped them to draw up policy implications on the usefulness of SCFs to corn farmers throughout the Philippines.

Surveys showed that farmers had a high degree of concern about climate risk and were well aware of El Niño, but they only made moderate use of the information in decision-making. As part of the project, the team refined an Excel-based game that allows participants to work out the best decisions for their situations, based on forecasts that are more than guesswork, but fall short of perfect information.

Water harvesting

In India, research has helped communities to harvest water and use this harvest to produce better returns. Farmers working land on the East India Plateau are among the poorest in India. Traditional farming practices are based around the annual monsoon, with rice crops planted to coincide with those rains. The rice is harvested from farms less than 1 hectare in size on low-lying land.

Most families are faced with not growing enough food, and it is common practice for men to emigrate in search of seasonal work to supplement meagre incomes. Women are left to undertake the roles done by men, but they lack support and resources, especially labour and access to technical know-how.

One place where technical know-how exists is the rural development organization, Professional Assistance for Development Action (PRADAN), which had trialled water-harvesting technology to capture run-off and tap shallow underground water sources. Such technology can be very effective in areas with high seasonal rainfall, such as those that experience the monsoon season.

The difficulty for farmers of the East India Plateau is that enough rain falls for two rice crops, but almost all that rain falls in one concentrated period. Water-harvesting technologies present an opportunity to extend the benefits of that rainfall across a much longer period of the year.

ACIAR developed a project linking scientists from the University of Western Sydney and the Australian National University with the Indian Council for Agricultural Research's Research Complex for Eastern Region and PRADAN.

The aim of the project was to test the PRADAN water-harvesting technology – a network of storage pits in the uplands with channels to funnel water to those pits, allowing increased infiltration of monsoonal rain that could be accessed later using seepage tanks in low-lying areas near villages. PRADAN also worked with villagers to ensure local participation, using participatory methods to ask farmers, particularly women, to identify research questions and carry out field trials.

In the village of Pogro a village core committee (VCC), comprising self-help group representatives, was established to improve project implementation and build social capacity, shifting ownership, responsibility and control to the villagers. The model helped women in the village lead changes, such as managing weeds through planting techniques, to support the water-harvesting network. The VCC oversaw (with project support) the initial implementation of the watershed development plan, along with the introduction of improved rice varieties that mature faster, allowing a second crop, such as mustard or wheat, to be planted in rice paddies.

The results have included dietary improvements and additional income. This has allowed some Pogro villagers to own houses and livestock for the first time and to spend money on educational materials and books for their children. Perhaps the most important change is the strengthening of family units, as the ability to generate income in the village is helping prevent the seasonal exodus of men in search of work.

Farmers and project team inspecting a newly dug seepage pit in a Pogro village watershed, West Bengal

Adapting to change

In Eastern Africa the impacts of climate change are threatening smallholder farmers, many of whom farm on marginal land with large variations in rainfall patterns. Maize and beans are staple crops in these areas, as is the case across most of Africa. People depend on these crops for their daily food and for cash income, but many farmers are facing low yields because of declining soil fertility, erosion and drought.

Helping these farmers adapt to reduced rainfall and drought involves introducing a new system for growing staple crops. The 'Sustainable Intensification of Maize-Legume cropping systems for food security in Eastern and Southern Africa' programme, funded by ACIAR and led by the International Maize and Wheat Improvement Center, is helping farmers test a system change encompassing conservation agriculture, and intercropping improved varieties of maize and legumes.

Crops are sown without ploughing and straw is kept in the field to retain soil moisture and build soil fertility. Increasing the yields of maize and legumes provides more food and gives farmers cash for family needs.

The Liganwa Women's Group in Western Kenya has been testing the new approach to maize and bean farming for three seasons. They have more than tripled their yield using the improved techniques. Rather than ploughing their land, they have been spraying herbicide and planting seeds directly into their fields. They maintain the stover (remnants of harvested crops) on the ground as mulch to improve the soil. The farmers no longer hand plough or weed their crops.

In mid-2011, the farmers celebrated the success of their maize and legume crop. They were keen to share their experiences with other farmers at a field day attended by hundreds of people who came to hear how they are growing more and saving time.

Jane Jahenda Nyonje said the maize grew very well, that she didn't have any problems with pests and disease, and that the yields increased. "The benefits of conservation agriculture are that we don't spend time and money on ploughing and it's very effective on the weeds such as striga," she said.

John Achieng of the Kenya Agricultural Research Institute, who has been assisting the farmers with the on-farm trials, said that while farmers in the areas usually get a yield of two to three bags of maize (90 kilograms) per acre, with conservation agriculture they have found farmers can get up to 20 bags of maize grain. "In the case of beans, farmers are boosting their yields from about 50 kilograms of grain per acre to up to 160 kilograms of grain per acre," he said.

In a season where drought has affected many parts of Kenya and the region, boosting yields this much is making a huge difference to these women, providing food for their families. Grain prices have rocketed up, so they could also make handsome profits if they chose to sell their grain.

Food security remains a challenge for many of the world's poorest farmers. The ability to adapt to climate change is a vital component in their hopes for a better future. ACIAR's research is helping to scale the successes of Australian agriculture to allow smallholder farmers to adapt new ideas, systems and crops, in the face of climate change.

Reducing crop loss through Climate Field School – the Indonesian experience

A.E. Sakya, S.W.B. Harijono, W. Sulistya, Nurhayati, N. Florida, Marjuki Indonesia Agency for Meteorology, Climatology and Geophysics (BMKG)

Agriculture is one of the most highly sensitive development sectors, prone to climate variability and extremes, such as droughts and floods. In the past, good seeds, fertilizer and proper land preparation, irrigation and cultivation processes were sufficient for farmers to maximize their crop production. Nowadays, these conditions are no longer enough. Farmers need to know how to deal with climate variability in order to reduce crop loss through poor productivity.

Human activity has induced carbon dioxide concentration in the air, resulting in higher earth surface temperature. The Intergovernmental Panel on Climate Change has concluded that global warming has shifted climate parameters, variability and characteristics locally, regionally and globally.[1] Locally, changes to rainfall amounts and patterns pose a direct threat in the form of soil erosion rates and changes to soil moisture on which crop productivity depends. The scientific community predicts that such trends will continue.

Warmer climates may provide better conditions for food production; however, the uncontrollable increase in temperatures induces droughts, floods and heat waves, and creates disastrous threats for farmers. In addition, the affected water supply and soil moisture could make it less feasible to continue crop production in certain regions.

There have been many anticipatory efforts to reduce the impacts of extreme climate phenomena. These efforts, however, are mainly responsive, concentrating on how to fix the damage. They are far from being preventive actions.

One of many adaptive efforts to tackle the threat of climate change is the implementation of Climate Field School (CFS). CFS is aimed at connecting farmers to enable the understanding of climate information, particularly on site, through a training process.

The Indonesian Agency for Meteorology, Climatology and Geophysics (BMKG) is a Government agency solely assigned to the dissemination of climate information resulting from the processing of acquired climate parameters from observation stations and depicted both in quantitative and qualitative forms. The amount of rainfall, precipitation and temperatures – among other factors – are plotted numerically for a certain region. Their patterns are mapped or described graphically either locally or regionally to show spatial gradation.

This product has regularly been published for public consumption. BMKG periodically disseminates rainfall prediction, as well as wet and dry season onset prediction, to district and provincial levels of government as well as the Ministry of Agriculture (MoA). It is expected that local government should serve as an intermediary body or interface institution to farmers in the field.

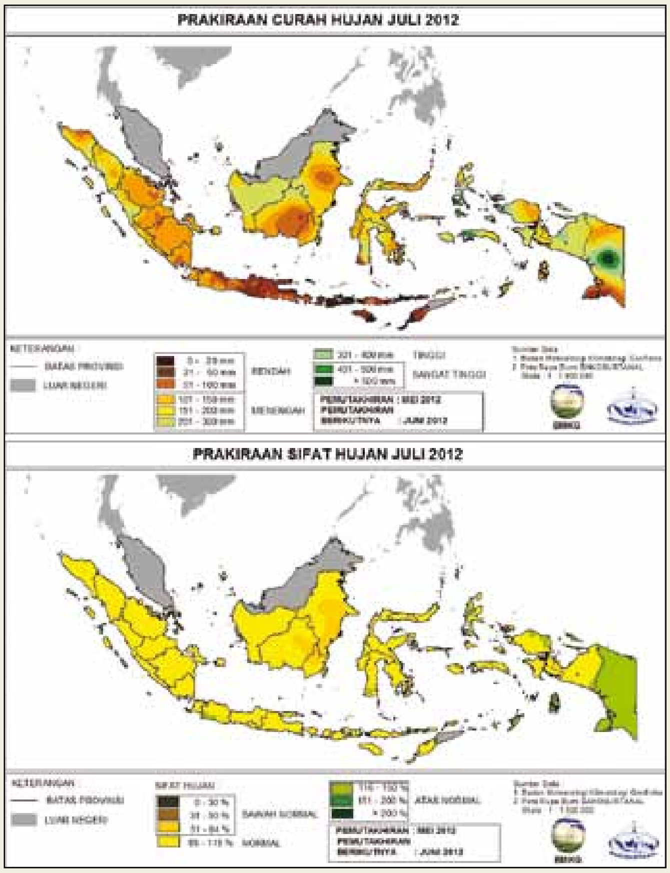
However, this type of information still seems to be difficult for farmers to apply directly for purposes such as planting, cultivating or plowing. In this regard, particularly for agricultural sectors, a closer collaboration with extension workers is necessary. It is in this context that CFS is seen as contributing its strategic role. This report summarizes how Indonesia — particularly BMKG — has extended its service through CFS in helping farmers reduce the potential loss of crops.

Stages of CFS

Target: Agricultural officers (regency level)	→	Target: Extension workers Local government – extension workers	→	Target: Farmers
Function: • Translating climate infomation • Designing dissemination format • Providing simple technology to simulate and observe climate variability		Function: • Implementing climate information for agriculture techniques • Adjusting planting onset based on climate information • Motivating farmers to be aware of climate information		Function: • Communicating CFS knowledge to farmers' household • Transferring CFS knowledge to other farmers

Source: BMKG Indonesia

BMKG's Monthly rainfall prediction



Source: BMKG Indonesia

A considerable task

Indonesia is flanked by two oceans and two continents. As a tropical archipelago, it is also crossed by the mountainous 'ring of fire' and is prone to extreme weather and climates. The long distance between the furthest eastern and western regions provides no easy alternatives to cope with climate and weather problems. There are 342 climate zones based on different climate patterns, and 73 are areas where the wet and dry seasonal onset cannot be accurately identified.

CFS activity encompasses three purposes as follows:

- Improving farmers' climate knowledge and their ability to anticipate extreme climate events in their farming activities
- Assisting farmers in observing climatic parameters and using applications in their farming activities and strategy
- Helping farmers to translate and understand the climate (forecast) information for supporting farming activities, especially for planting decisions and cropping strategy.

CFS as a facilitative programme was launched in 2003. However, its effective implementation has been more widely accepted since 2007. As a programme which promotes the importance of climate information in supporting the agricultural sector and enhancing the capability of farmers to make proper adjustments and adaptations to climate variability and change in Indonesia, CFS is focused more on the regions that are most potentially vulnerable and on areas known as food production centres.

BMKG runs the CFS programme through a close collaboration with extension workers belonging to MoA as well as a group of farmers in the region. The role of BMKG is as the information provider, whereas the extension workers serve facilitating farmers in helping to interpret and translate the climate information in the field.

The syllabus covers a wide range of subjects, including the impact of climate change on plants and livestock and on agriculture; adaptation and mitigation strategies; understanding weather and climate characteristics; and simple measurement practices and water balance approximation for soil moisture. It also addresses the use of seasonal forecasts for the planting strategy and calendar; the economic value of seasonal forecasts; and anticipation of crop diseases and pests.

The main objective of CFS is to transform technical climate information into the practical language of farmers. BMKG as a provider needs facilitators through whom the farmers can easily understand and capture climate information. The extension workers serve this role.

CFS proceeds in three stages, as follows:

First stage — providing 'training for trainers'. Representatives of local government and the regional office of MoA are assisted to comprehend climate information provided by BMKG. The main objectives at this stage are to comprehend climate information, design the dissemination format and introduce simple techniques to observe and simulate climate variables.

Second stage — preparing those who will work with farmers. The trainers trained in the first stage will play a pivotal role in the second stage, in which almost all participants are those who are expected to deal directly with farmers. This stage covers introducing methods to implement climate information for agriculture purposes; designing planting schemes and plans based on the climate information; and motivating farmers to be aware of climate factors.

Third stage — working with farmers. In the final stage, the knowledge obtained in the second stage is implemented directly to farmers in the field. The purpose of

Image: BMKG Indonesia

Training of extension workers takes place in the first and second stages the final stage is to transform and transfer capacity and capability obtained in the second stage directly to farmer households.

The execution of CFS needs strong collaboration between partners and in our experience, the extension workers from MoA serve as ideal facilitators to interpret BMKG's climate information. The role of universities such as Bogor Agriculture Institute is also very important, especially to formulate the concept of the CFS. Funding support from our Government and other sources, such as Ausaid and the United Nations Development Programme, is needed to ensure the continuation of the activities.

Technical aid programme

Support for a CFS project has been provided by AusAID of the Australian Government through a technical aid programme. The programme was conducted in two districts: West Lombok regency in West Nusa Tenggara (NTB) and Kupang regency in East NusaTenggara Timur (NTT).

In the first stage, there were 20 participants, up to six of whom were selected to give training to 20 extension workers in the second stage, when BMKG was also directly involved in facilitating the transformation process. In the third stage, a similar number of extension workers from stage two were selected to become facilitators, with whom farmers could directly communicate in their own language. At all stages, BMKG staff were also involved as trainers and cooperated closely with the extension workers.

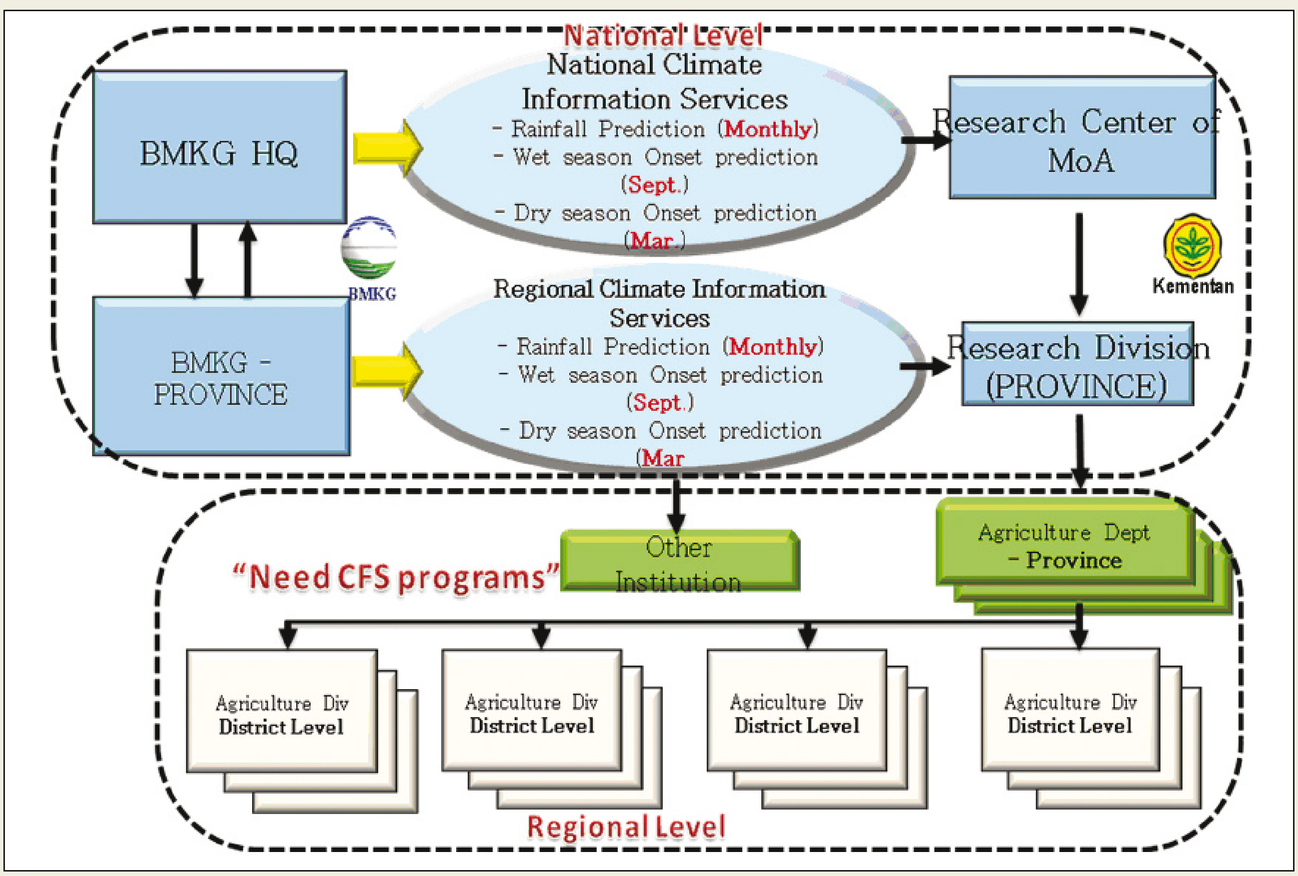
The crucial aspect of the CFS process lies in the third stage, during which information provided by extension workers is delivered to the farmers. While the duration of phases one and two is four days, in phase three it is four months — one planting season. The CFS in NTB and NTT mainly served as an example of how the extension workers could proactively induce and affect the decisions taken in the planting phase by referring to climate information. In the latter case, it was expected that one extension worker would help and involve 15 to 20 farmer group leaders.

Lessons learned

Developing an effective method for communicating climate forecast information to end users such as farmers is really very important. The involvement of intermediaries such as agricultural field officers/extension workers in the process may significantly change the perception of farmers regarding climate information for their support. The 'learning by doing' process serves as an effective process for transferring climate knowledge or climate information to farmers.

Farmers need to be introduced to climate issues through experimental examples with simple explanation and tools, active discussion and opinion sharing, finally

Climate information flow chart



Source: BMKG Indonesia

coming up with the action steps as to gain new perspectives on how to use the climate information on their farming activities and to disseminate this knowledge to other farmers as a continuous process.

One simple lesson conducted in CFS showed farmers how to measure the amount of rainfall using an easy and simple technology. By using a cheap and easily obtained milk can as a rain gauge, they learned to measure the volume of rainfall by converting the captured water in the can into millimetre units.

Participants also learned from real experience in the field that weather and climate conditions do not only affect plant growth, but also influence the development of pests and plant diseases. As part of climate information application modules, an increase was seen in participants' understanding marked by the number of production plants during the process of CFS.

In general, CFS activities were successfully carried out in in Lombok, NTB and Kupang NTT. The participants followed the full series of lectures diligently and actively. At the beginning and end of the CFS classes in phases one and two, the participants took part in pre- and post-testing, through which the achievement of the programme was evaluated. Results indicated that the understanding of CFS participants on average increased by up to 75 per cent, indicating that the objective of CFS had been accomplished. The participating extension workers were expected to share their knowledge with others. Furthermore, the farmers who participated in the third phase of CFS were able to take advantage of climate information services and apply the information in their farming activities.

The improvement in knowledge of climate information and its relation to agricultural activities is indicated by the fact that farmers in Kupang reported up to fourfold crop increases.In the third phase we also calculated how many tons farmers could achieve if we converted their plantations to one hectare of land. According to this method of calculation, production in Kupang was 19 tons per hectare of maize, whereas in Lombok (NTB) the production reached 21 tons per hectare.

Activities during CFS

Throughout this CFS event in Eastern Indonesia we were able to reach many farmers in the field. As an illustration, CFS level two in Lombok produced 10 farmer group leaders, since if one group has 25 members, CFS can reach 250 farmers. Extension workers from ten districts were also involved at this level, so if one district consists of at least of ten farmer groups (for example, the Narmada regency, which

Image: BMKG Indonesia

Improved climate knowledge has led to better crop management

consists of 16 groups) and they actively disseminate what they have learned from CFS to the group, the series of CFS from level one to level three can reach more than 2,500 farmers in West Nusa Tenggara Province.

Tackling challenges with new knowledge

Although CFS has proven that it can directly and significantly improve farmers' ability to adapt to climate variability, extending the activity may pose a challenge. Several issues that may become a hindrance for CFS are:

- Lack of coordination between Government agencies at the regional level due to changes in Government systems such as decentralization
- Difficulties in finding an effective method to scale up the projects as part of national policy to address climate change

The challenges can be dealt with by finding ways of combining the traditional way of farming based on local wisdom with new knowledge based on application of climate information services. In addition, extension of the activities beyond the agricultural sectors to fisheries, health and other climate-sensitive development sectors is likely to yield positive results. Through these means, CFS has the potential to achieve many further successes in future projects.

Examples of training materials

Source: BMKG Indonesia

Delivering advisory services by mobile phone

L.S. Rathore, India Meteorological Department, New Delhi, N. Chattopadhyay, Agricultural Meteorology Division, India Meteorological Department, Pune and K.K. Singh, India Meteorological Department, New Delhi

The challenges facing agriculture in India are ever increasing. First, agriculture is highly dependent on weather and subject to its variability. Second, the possible impacts of climate change pose major challenges. Finally, the sustainability of intensive agriculture using current technologies is being questioned within the context of the global climate change debate. Long-term changes and the increasing frequency of extreme weather events are likely to have adverse impacts on the agricultural sector. Changes in hydrological regimes will directly impact both agricultural production and its methods, while reductions in crop yield and quality as the result of decreasing water availability and precipitation variability could result in loss of rural income. Therefore, the problem must be addressed collectively by scientists, administrators, planners and society.

As a small step towards managing agriculture in the face of challenges from weather and climate variability and to provide 'weatherproofing' for farm production, the India Meteorological Department (IMD), under the Ministry of Earth Sciences, is operating an Integrated Agro-Meteorological Advisory Service (IAAS) at district level in India. Under the Agromet Advisory Services (AAS), the needs of farming communities were established through feedback from end-user groups. This showed that the primary need of the farmer is a location-specific and quantified weather forecast, which led to the creation of the IAAS project, implemented through a five-tier structure:

- Apex Policy Planning Body in Delhi
- National Agromet Service HQ Execution in Pune
- State Agromet Centres – coordination/monitoring
- Agromet Zone Level
- District Level Extension and Training Input Management advisory service.

IAAS includes meteorological, agricultural, extension (two-way communication with user) and information dissemination agencies. IMD has been issuing a quantitative regional level five-day weather forecast across 612 districts since June 2008. The service comprises quantitative forecast products for seven weather parameters, including visibility, rainfall, maximum and minimum temperatures, wind speed and direction, relative humidity and cloudiness, along with weekly cumulative rainfall. These products are generated by IMD New Delhi using the multi-model ensemble technique, which is based on forecast products from several models in India and internationally. These are communicated twice weekly to Agromet Field Units (AMFUs) in state agriculture universities, affiliates of the Indian Council of Agriculture Research (ICAR) and other institutions. A system was then developed for integrating weather, climatic and agrometeorological information for district level advice to communicate the actions farm management can take for harnessing favourable weather and mitigating the impacts of adverse weather.

To help achieve these outcomes, a typical AAS bulletin includes district-specific, quantified, five-day weather forecasts for rainfall, cloud, maximum and minimum temperatures, wind speed and direction, relative humidity and warnings of hazardous weather events, along with crop protection advice. Weather forecasts are provided based on soil moisture levels and guidelines for irrigating, fertilizing, and using herbicides. There is advice on the best dates for farmers to carry out day-to-day intercultural tasks such as pre-sowing, sowing, planting and post-harvest activities.

Forecasts warn of major pests and diseases for principal crops and advice on plant protection. Propagation techniques for microclimate manipulation are shared, including the use of shading, mulching, shelter belts and frost protection, to protect crops from stress.

Bulletins help farmers minimize the impact of agriculture on global warming and environment degradation through judicious management of land, water and farm inputs, in particular pesticides, herbicides and fertilizers. Advice is also given on livestock health, shelter and nutrition.

AAS bulletins are issued at district, state and national levels. District bulletins are communicated by AMFUs and include specific advice for both field and horticultural crops and livestock. Currently these cover 585 districts of the country, while the state bulletin is a composite of district bulletins used by the fertilizer and pesticide industries, the irrigation department, seed corporations, transport and other organizations with agricultural input. National Agromet Advisory Bulletins have been prepared by National Agromet Advisory Service Centre, Division of Agriculture Meteorology, IMD in Pune, using inputs from various states. The Ministry of Agriculture is a major user of these bulletins, which help with decision-making at national Crop Weather Watch Group meetings.

Banana trees damaged by heavy rain and uprooted by high winds in Tamilnadu and Kerala

Coconut palms are vulnerable to the effects of heavy rain and lightning

The following crop losses were recorded in the southern states of India in 2011 due to adverse weather conditions:

- Banana plantations and coconut trees were damaged by heavy rain and lightning in the Tiruppur district of Tamilnadu in April
- Crops such as turmeric, tomato and ladyfinger were damaged by heavy rain in the Cauvery Delta Zone in September, while banana trees were uprooted by high winds in the Coimbatore district of Tamilnadu during October
- Rubber and banana trees were uprooted by high winds and damaged by heavy rain, which also affected other vegetable crops in the Thiruvanathpuram district in Kerala, with similar crops affected in other parts of Kerala, including areca nut, cocoa and coconut
- Banana and ginger crops were damaged by heavy rain in the Wayanad district of Kerala in November.

Agromet advice is disseminated in a range of different ways.

Conventional

Communicating advice to agricultural users should be a quick process. Conventional methods, including bulletins, pamphlets, posters, postal letters, newspapers, radio, TV, mobile phones, local announcements, village meetings, local time-bound markets and personal communication, are most commonly used, with advice delivered to farmers through a multichannel system.

Mobile technology

Under the IAAS scheme, efforts are being made to extend the reach of advice in relation to the needs of farmers. In addition to the multichannel system, the Integrated Agromet Advisory Service (IAAS) project is disseminating advice to the Indian farming community through SMS messaging and Interactive Voice Response Technology (IVR).

In a public-private partnership (PPP) arrangement, AMFUs are preparing and sending district AAS bulletins twice weekly to private companies, including Reuter Market Light, Nokia and Handygo, comprising weather forecasts along with crop, pest, disease, seed and fertilizer information. These enterprises send the bulletins on to farmers as SMS messages of up to 160 characters in the local language. Although content is also sent in English, the real advantage is that the language of the local people is used to communicate with them.

An Indian language-compatible handset enables messages in local languages to be received and assures farmers that SMS text messages originate from IMD by identifying this organization as the sender. In parallel, private companies call farmers to receive feedback on the advice given and any queries they may have. The companies are also teaching farmers across the country how to subscribe and use the SMS service for advice on farm management.

Sixteen states (Delhi, Uttar Pradesh, Punjab, Haryana, Rajasthan, Madhya Pradesh, Orissa, West Bengal, Gujarat, Karnataka, Kerala, Tamilnadu, Andhra Pradesh, Bihar, Maharashtra and Himachal Pradesh) have been covered by this service, with around 3 million farmers receiving SMS messages.

Private companies and their partners participate in direct farmer contact meetings to raise awareness of the SMS system, facilitate its use and explain how this service benefits them. Additional education includes farmers' awareness programmes and fairs.

Lessons learned about users and their needs

To date, the PPP is working well. Private companies have been asked to verify the district-level bulletin and advice for improvement in the AAS system. They have also been asked to collect feedback from farmers so that IMD, in collaboration with AMFUs, will be able to provide a better service. A two-way communication channel has been developed for the free flow of information between scientists and farmers.

A number of IKSL and Reuters subscribers reported that they had successfully averted potential losses by reacting quickly to weather and disease information, while others have reported improved yields by adopting new seed varieties and cultivation practices, according to questionnaires and direct contact with farmers. Those acting on cultivation information state that they gained by replacing traditional 'commonsense' practices with modern cultivation techniques. Weather information has helped to prevent seed and crop loss too, with farmers in Maharashtra using the forecasts to adjust irrigation levels.

Ways in which farmers have saved money as a result of AAS include the following:

- Vikas, a farmer in Nizampur village near Delhi, communicated that he was about to sow carrot seeds, but upon receiving an SMS that heavy rains were coming, he postponed the sowing. Had he not received the message and gone ahead with sowing, he would have lost 25,000 rupees and his efforts would have gone to waste.
- In Palla village, also near Delhi, farmer Surendra had decided to irrigate his paddy crop, but on receiving an SMS that it would rain in the next couple of days, he postponed irrigating, saving on costs, including electricity.
- A farmer in Nekpur village in Bulandshah in the state of Uttar Pradesh was planning to spray fertilizer during September. An SMS text that there would be rains within the next two days convinced him the time was not right. If he had ignored the message, rain would have washed away all the fertilizer.

Expanding the SMS service

Dissemination of the advice will be extensively undertaken using multichannel systems like All India Radio, Doordarshan, private television, radio channels, mobile phone (SMS/IVR), newspapers, the Internet, Common Service Centre of the Department of Information Technology, virtual academies and universities.

Other channels include non-governmental organizations, Kisan call centres, Kisan Melas, Krishi Vigyan Kendra, ICAR and other related institutes, agricultural universities, extension network of the State and the Central Agriculture Department.

The number of private agencies and companies delivering Agromet advice will be increased so that the SMS service reaches more farmers. SMS advice will be extended to other sectors, including fisheries, horticulture, livestock and high-value crops. A voice web service will be launched for farmers so they can ask questions and receive answers to their queries related to agriculture and weather.

The ultimate aim of this initiative is to communicate advice to the nation's 600 million farmers on a real-time basis.

Weather forecast	Advice given	Economic benefits
Light to moderate rainfall – nursery sowing time	Irrigate the nursery during evening hours, keeping standing water during night time to avoid displacement of germinating seeds	Rs. 2,500
Continuous rain for five days – vegetative stage	Postpone nitrogenous fertilizer application to rice	Rs. 750
Light rainfall for the next two days – maturity stage of rice	Postpone paddy harvest	Rs. 2,500 per hectare
Cloud cover, low temperature and higher relative humidity	Infestation of false smut fungus is expected, requiring prophylactic spraying of fungicides probiconozole or 0.1 per cent carbendazim	Rs. 3,000 per hectare
Rainfall	Delay the potato sowing	Rs. 10,000
Continuous rain and relative humidity	Prophylactic sprays for blister blight control in tea	Rs. 1,000

The table above shows how the farmers are benefiting from the advice given by experts in the Agromet Field Unit at Coimbatore, Tamilnadu state

Source: Tamil Nadu Agricultural University, Coimbatore Tamil Nadu, India

Expansion and knowledge transfer

Agromet advice delivered by mobile phone technology is possible in many countries, provided they have a strong AAS system. In order to demonstrate the development of AAS services in the South Asian Association for Regional Cooperation (SAARC) countries (Bangladesh, Sri Lanka, Maldives, Pakistan, Nepal, Bhutan and India) a consultation meeting was organized in Pune in April 2012. In addition to deciding to show how AAS has developed in India and other participating countries, strategies and ways of streamlining the activities of the AAS were also discussed, alongside expanding the AAS through mobile technology across SAARC and non-SAARC countries in the Regional Association II area.

Application of climate services principles

The basic principles of the United Nations Global Framework for Climates Services (GFCS) are included within the IAAS project, alongside a participatory component in which governments' direct involvement has proved highly valuable in implementing the service efficiently and effectively. The seven UNGFCS principles under AAS in India include:

- Ensuring greater availability of, access to, and use of climate services
- Addressing three geographic domains: district, regional and national
- Ensuring operational climate services are the core element of the activities
- Ensuring climate information is primarily provided by governments, which have a central role in its management through the GFCS
- Promoting the free and open exchange of climate-relevant observational data while respecting national and international data policies
- Establishing the role of the AAS activities so that they facilitate and strengthen, rather than duplicating
- Building AAS activities through user-provider partnerships that include all stakeholders.

Accuracy in weather forecasting, the whole-hearted cooperation of agricultural universities, PPP, research and development in different universities and support from the Ministry of Earth Sciences and the Government of India are key to expanding these services in the rural villages of the country. This project's experience could be leveraged to create a scalable model which can then expand across India, utilizing the information developed for all 620 districts nationwide. Farmers in the country have described this as the significant advantage of mobile-enabled information services and efforts would be made to spread information and advice to a large section of the nation's farming community.

SMS Agromet advice coverage delivered by PPP

Source: India Meteorological Department (IMD)

Climate science and services to support decision-making

Seok Joon Cho, Administrator, Korea Meteorological Administration

As increasingly frequent abnormal weather events due to climate change have larger socioeconomic impact, climate change and environmental issues have become one of the most critical global issues for both developed and developing countries. Climate issues require a new approach to solutions in various areas directly linked to our lives including food, health, energy and water resources. Climate science is expected to assume more responsibility for better services through advanced prediction technology and more practical climate science and services.

The Korea Meteorological Administration (KMA) has strived to actively respond to climate change and to come up with practical and effective climate policy while contributing to achieving the Government's major national vision of 'Low carbon, Green growth'. Internationally, KMA has been committed to producing and supplying scientific information to reduce the impact of climate change and variability on developing countries around the world.

Detailed climate change scenarios for adaptation

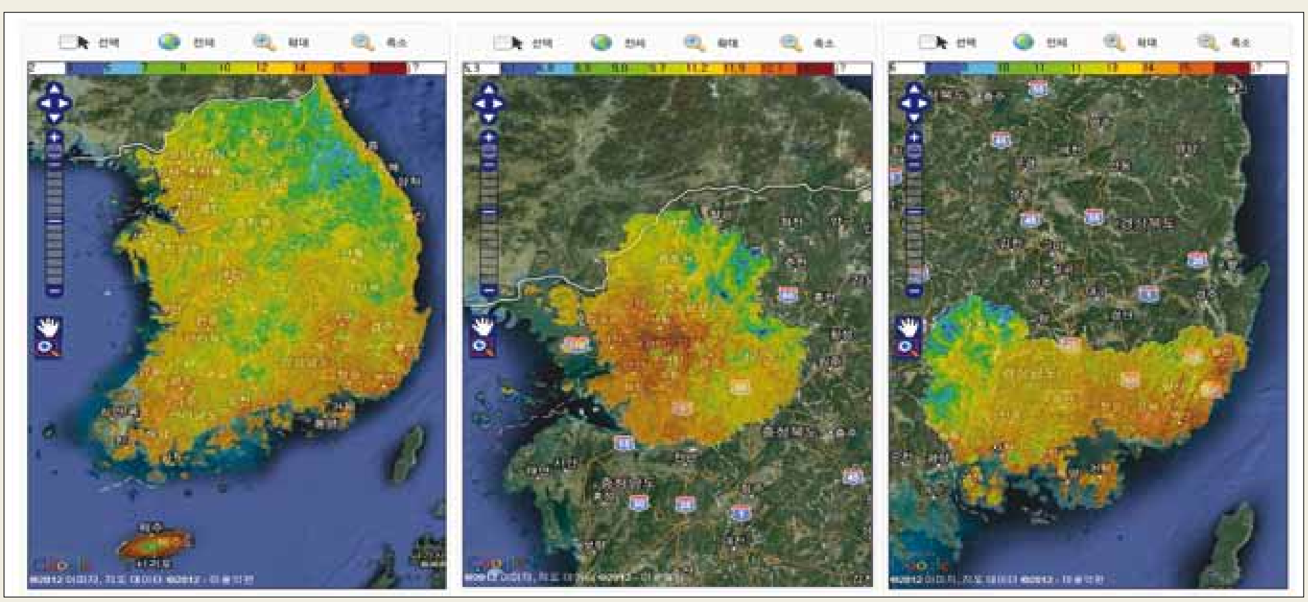
KMA has succeeded in developing global climate change scenarios based on representative concentration pathways (RCPs) with a view to enhancing prediction capability. In December 2011, a detailed climate change scenario (1 km) of South Korea was developed based on RCP 8.5 with consideration of specific topographic and climate characteristics for climate adaptation policy. This scenario was constructed by applying the PRISM based Downscaling Estimation statistical model to climate scenarios for the Korean Peninsula, produced through regional climate models.

The data, including global climate change scenarios (400 km) and scenarios for the Korean Peninsula (27 km) and Climate Extremes Index, are available on the Climate Change Information Center website.[1]

Raising awareness

To promote the use of climate change scenarios in climate adaptation, KMA is running a panel for climate change scenario users where producers and users of scenarios gather together for better communication. This group focuses on policy support for the Government's adaptation policy with public servants from 16 local governments as well as nine ministries, including the

Climate change scenarios for South Korea (1 km)



Source: www.climate.go.kr

Image: KMA

Participants at the TT-GSCU task force meetings in Busan, Republic of Korea, June 2012

Ministry of Education, Science and Technology, the Ministry for Food, Agriculture, Forestry and Fisheries, the Ministry of Health and Welfare, the Ministry of Land, Transport and Maritime Affairs, and the Ministry of Environment. The panel holds meetings twice a year.

KMA hosts workshops on national climate change scenarios to raise public awareness on climate change, to broaden understanding of climate change scenarios in adaptation fields such as energy, agriculture and health, and to promote the use of climate scenarios. KMA has also published and distributed various materials such as *Tips for Easy Use of Climate Change Scenarios and a Casebook on Understanding and Utilization of Climate Change Scenarios* and used such publications for staff training as well as education tours.

Customized climate information

As climate change has different impacts on different regions, KMA launched the Regional Climate Services in 2011, recognizing that a specific strategy tailored to a certain region is required.

The regional services led by KMA enable local governments and businesses to make use of climate science information for industries including agriculture, fisheries, manufacturing and tourism. The services produce and provide customized climate science information suited to industries in different regions.

In 2011, 15 areas such as specialized crops, the south-west tidal flats, alpine agriculture and tangerine farming were selected for pilot projects, and climate science information was collected and provided for these areas. After a project verification process, specific information for each industry will be supplied for the wider application of climate science information.

Long-range forecasting

The World Meteorological Organization (WMO) Lead Centre for Long-Range Forecast Multi Model Ensemble (LC LRFMME) is responsible for collecting and standardizing long-range forecast data produced by 12 GPCs worldwide and providing the data to WMO member countries. The centre also produces multi model ensemble (MME) prediction data, standardizes global climate prediction data and develops cutting-edge prediction technology through the accumulation of MME prediction technology. In addition, it provides developing countries with education and training opportunities on advanced climate prediction technology. For example, KMA along with the US National Oceanic and Atmospheric Administration sponsored a training workshop for developing countries (the Fourth International Training Workshop on Climate Variability and Prediction) held in San José, Costa Rica on August 7-17 2012. KMA made a contribution to the workshop by sending Korean experts in the areas of climate prediction and monitoring who gave lectures and practical exercises on MME theories, the utilization of WMO-LC LRFMME data and climate information services. KMA will continue such training programmes to help develop the capacity of developing nations in adaptation and reducing vulnerability to climate change.

In 2010, at the CBS expert meeting of the WMO Commission for Climatology in Switzerland, it was decided that data from the LC LRFMME would be used as basic prediction data for global seasonal climate updates (GSCU), so the centre provided data for the pilot publication of GSCU in September 2011 and February 2012. In June 2012, a GSCU task force meeting was held in Busan, Korea to discuss ways to practically foster GSCU.

Collecting and distributing global weather data

WMO approved Seoul to become the world's sixth host of a Global Information System Centre (GISC-Seoul), a hub for collecting and distributing global weather data. GISC-Seoul, run by KMA within the WMO Information System, can be described as a massive, web-based global electronic library of weather information.

Image: KMA

Fourth session of the Joint WMO-IOC Technical Commission for Oceanograph and Marine Meteorology (JCOMM) (Yeosu, Republic of Korea, 23-31 May 2012)

GISC-Seoul will make it possible to supply real-time information that is essential to responses against climate change, and to obtain worldwide weather and climate data for weather forecasts and climate change research in real time. As a result, it will contribute to producing future weather and climate information. KMA is planning to establish a standard operation system for the stable exchange of weather data, to step up support for data collecting and producing centres at home and abroad, and to implement more advanced operation of the centre.

Use of Climate Science Information

Should we be able to make accurate predictions on abnormal climate phenomena that will happen in the future in terms of spatial and temporal distribution and intensity, those predictions would greatly contribute to disaster prevention as well as reducing social and economic losses. Using climate science information is the right way to make it happen.

Taking advantage of climate science information, farmers are choosing the appropriate crops and seeding period suitable for the new climate environment while fishermen are preparing for the proper fishing instruments fit for the newly-emerging fish. With the help of climate science information, companies are making efforts to reduce cost and improve added value in the whole process from production to marketing that includes supply and demand of raw materials, production, stock management, promotion and distribution of products, and the development of new products.

Long-range forecast information provided by KMA are usually used for predicting fruit quality, crop yields and biological seasons such as time of blossoming and harvest, and expecting blight occurrence. In case of abnormal low temperature in spring, fruits' blossoming period would be delayed. And the delay would make the fruits grow belatedly. However, weather conditions during the growing period can somewhat compensate the delayed growth driven by the prolonged blossoming period since fruits have long growing period. Therefore, long-range forecast information in three or five months is being utilized to predict the condition of crop.

Technology and information sharing for a better future

Climate services refer to providing essential climate data and information to users in the public and private sectors who are responsible for decision-making in a range of climate-related areas including economic, social and cultural fields.

KMA has set up the climate service system and provided customized information suited to different regions by producing climate change scenarios, operating the WMO LC LRFMME, and hosting GISC-Seoul. In addition, KMA carries out education and training programmes to help users make full use of climate science and services, and manages a system for better communication among producers and users of climate information.

In particular, given that the general public without special knowledge on weather and climate may have difficulties in understanding the characteristics and uncertainty of climate and harnessing such services, a policy is promoted to allow weather and climate experts to work at power exchanges or local organizations as meteorological advisors. In this role, they would play not only offer relevant information produced by KMA, but also explain the implications and give consultations to officials in order to help them predict energy demand in advance.

KMA will develop and upgrade the climate services in relation to the newly proposed WMO Global Framework for Climate Services. This work will be based on KMA's current infrastructure and capacity as described above. Such efforts will enhance the climate change response capabilities of countries around the world including Korea, thereby protecting life and property, reducing financial losses and fostering opportunities to generate profit.

Climate services for agricultural production in Guinea Bissau

Francisco Gomes, National Institute of Meteorology, Guinea Bissau

Guinea Bissau is a relatively small territory in West Africa. Its population of 1.5 million inhabits an archipelago totalling some 36,125 square kilometres in an area of low altitude. These characteristics mean that the country is highly susceptible to the effects of climate variability with an associated increased risk of flooding from rain and salt water in arable areas, impacting agricultural production.

Guinea Bissau's main economic activities revolve around agriculture and livestock, both of which are impacted by variable rainfall. According to the Department of Agricultural Statistics, 30 per cent of the area is equivalent to 1.41 million hectares of arable land, of which 200,000 hectares are low land and more than 1 million hectares are mangrove ecology areas.[1] The agricultural sector is threatened by the effects of various conditions such as drought, flood, high water, salinization and coastal erosion. The high rainfall variability from one season to another, coupled with unprecedented drought in the Sahel during the 1970s and 1980s, led the scientific community to seek ways to enable seasonal predictability in the Sahel, resulting in operational applications for seasonal forecasting such as PRESAO in West Africa. On the other hand, there is a strong demand in sub-Saharan Africa for climate information that relates to local needs and seasons, such as the beginning and end of the rainy season. All these elements must be able to respond to customer needs and serve as working tools of climate services.

The need for a climatological service for agriculture in Guinea Bissau is justified by the fact that this industry is the basis of the country's largest economy, employing 82 per cent of rural manpower and contributing with 50 per cent of gross domestic product and 93 per cent of exports, according to data from the World Bank. The sector is highly dependent on climatic factors such as rainfall, due to the low level of mechanization of agricultural production systems. Due to a lack of rainwater management systems, a small amount of rainfall actually benefits agriculture while the rest is lost through seepage and surface drainage into rivers.[2] It is therefore imperative that the climatological service seeks to regulate the needs of the agricultural sector and improve the products available to minimize the effects of climate variability on yield losses in agricultural production.

Addressing the climate challenge

Climate risks in agriculture in Guinea Bissau are enormous, and agro-climatic modern knowledge is very limited. The area is managed mainly by empirical knowledge that enables subsistence agriculture, despite the economic importance of the sector. This considerably increases the gap between climate services offered and the needs of users, and makes it difficult to trade between service users. On the other hand, the responsiveness of climate services is too slow to meet the challenges of climate variability in the sector.

Climate service responsibilities are divided between the National Institute of Meteorology (INM), which manages the synoptic and agro-climatic networks, and the National Water Resources which operates the hydroclimatic service and data relating to it. Relatively limited operational capabilities have been weakened by the political and military conflict from 1998 to 1999, during which the observation network and the weather media were ransacked. In addition, there are damages and shortages of human resources in sufficient quality and quantity to enable a means of operation.

Despite this status, the climate service leads many activities to meet the needs of users, and particularly the area of agriculture. The provision of a climate service for agriculture began in a systematic way in 1987, with the Meteorological and Hydrological Services building project funded by the United Nations Development Fund (UNDP) and executed by the World Meteorological Organization (WMO).[3] Through this project, observation networks including seven synoptic stations, 19 agro-climatic stations and 40 rainfall stations were equipped.

The service provided is based on the use of historical control data, agro-climatic information and current data. Thus, field activities are performed annually during the rainy season to monitor crops and help peasants to better integrate data and agro-climatic information. This is monitored by the Multidisciplinary Group Work (GTP) coordinated by INM through the Department of Climatology and Agrometeorology. Activities such as seminars and workshops, training materials mainly relating to climate change at the request of institutions, projects and associations are also part of this service.

Despite the current difficulties, characterized by the lack of critical operating resources, the Department of Climatology develops products and provides the following benefits:

- Special ballot application
- Agro-hydrometeorological decadal and monthly newsletters (65 copies are distributed to different institutions)

Agricultural production 2011/12

Crop	2011/2012	2010/2011	Average 2006-2010	Difference %	
				2011/2010	2011/average (2006-2010)
Rice (upland)	57,074	51,327	49,662	11.2	32.9
Rice (lowland)	102,880	90,134	59,211	14.1	151.7
Rice (mangrove)	69,696	63,779	44,078	9.3	150.4
Rice SAB*	3,800	4,000	3,800	-5.0	-5.0
Total rice	**233,449**	**209,240**	**156,751**	**11.6**	**101.9**
Maize	6,639	5,819	15,541	14.1	-75.8
Sorghum	23,058	20,223	18,172	14.0	27.3
Mil	16,221	15,004	25,175	8.1	-54.2
Fonio	553	524	740	5.6	-59.2
Dry cereal SAB	1,300	1,500	1,514	-13.3	-14.1
Total dry cereal	**47,772**	**43,070**	**61,757**	**10.9**	**-43.0**
Grand total	**281,221**	**252,310**	**218,508**	**11.5**	**41.0**
Cassava	19,922	17,852	Na	11.6	Na
Sweet potato	11,986	10,318	Na	16.2	Na
Peanut	42,759	36,177	Na	18.2	Na
Cowpea	554	515	Na	7.5	Na

*Sector Autonomo de Bissau. Na = Data not available

Source: NIM

- Monitoring of agro-meteorological crops each month during the rainy season (from May to November), with reports provided to various institutions such as the Ministry of Agriculture, Food and Agriculture Organization (FAO), World Food Programme (WFP), UNDP and so on
- Data and climate information to users
- Agro-meteorological services.

These products and services are the basis for the management of socioeconomic issues for users such as the agrarian sector, where they power the early warning system for food security. The are provided at zero cost to major users such as:

- Policymakers and ministers
- Agricultural products (GTP/Agrhymet)
- Development partner organizations
- Various private users
- Environment (special services).

Certain conditions, such as the need for databases and software, and for appropriate quality data observed from stations outside regular inspections, make it difficult to provide these services and may affect the quality of the products developed, significantly reducing the contribution of this service to development, disaster risk reduction and adaptation to climate change in agriculture.

Delivering climate services to users

The effect of climate on agriculture has always been based on empirical knowledge. That knowledge continues to dominate certain cultural practices, especially in a country like Guinea Bissau where the enrolment rate for climate services and the rate of intervention in agricultural rural areas is relatively low. It is a challenge to filter scientific information into this environment, and the first task is to offer practical demonstrations of the benefits of this information in relation to empirical knowledge. This will help farmers to abandon their customary practices, and facilitate acceptance of scientific tools for climate change adaptation and the dissemination of climate information to the most vulnerable group of users.

Dissemination of climate information services for the rural areas is provided by various partners involved in areas such as rural agricultural projects, non-governmental organizations, the GTP – which manages crop monitoring activities – and also by the press. Another way is to disseminate information through the Minister of Agriculture and Rural Development, which does not start a crop without the results of the consensus seasonal forecast from PRESAO, coordinated by the African Centre for Meteorological Applications for Development. In this ceremony the Minister informs farmers on seasonal rain forecasting for the season and the necessary measures to take. All information generated by this service is given in the form of meteorology bulletins for different users or a printed report. In some cases, such as seasonal forecasting, a feedback session is organized and several partners are invited. Weak financial and material resources are limiting factors in the process of information dissemination.

INM, which is part of the climatological service, currently operates both the investment and the operation of the national budget of the state through its Ministry Affiliation: Department of Social Equipment. Given the current economic challenges facing the country, which have been exacerbated by the crisis caused by the politico-military conflict of 1998-1999,

Personnel need and actual: Central

Category	Requirement	Actual	Difference
Class I	9	6	3
Class II	12	4	8
Class III	16	8	8
Administrative	3	0	3
Financial	1	0	1
Support	11	20	-9
Total	**52**	**38**	**14**

Source: NIM

Personnel need and actual: Network

Category	Requirement	Actual	Difference
Class III	7	5	2
Class IV	66	29	37
Support	26	8	18
Total	**99**	**32**	**57**

Source: NIM

the National Weather Service has only very limited means of operating and investment. The budget essentially provides the salaries of workers and other employees.

As an indicator to measure the services provided to the agricultural sector, assessment based essentially on agro-climatic conditions is done in October every year by Agrhymet, FAO, WFP and the Government, to predict the performance of each crop. A field evaluation is also made by the GTP at the end of each campaign.

Difficulties

In the context of users, the difficulties lie in interpreting weather and climate information for their integration in appropriate agricultural activities. These difficulties are at any level, such as policymakers, agronomists and other users.

Rainfall variability and its temporal distribution cause enormous difficulties for farmers as they tend to plant varieties of crops suited to a year of low rainfall. Despite the existence of seasonal forecasts and adaptable varieties for different rainfall conditions, their applications are still a big challenge and continue to cause considerable losses to agricultural yields, according to the GTP's assessment reports on land.

Outlook

Given the tasks expected of the National Weather Service and the quality requirements of some users such as agriculture, maritime and civil protection, the INM has been established as an autonomous institute since October 2011. This autonomy should enable the meteorological service to use the flexible management to improve the development of various products and provide high quality services. However, it should be noted that even in the case of the institute, there has been no change in the average investment and operation of the national budget.

In addition, for better management of the agricultural sector's vulnerability to climate risks, climate services are essential. Improved access to climate information is needed to guide the development of risk management and natural resources, agriculture and infrastructure.

Improved forecasts and early warning systems are essential. Observations, historical data, modelling studies for floods, rainfall and humidity of the soil are crucial to reducing disaster risk. An operational and improved observation network, with the appropriate databases to store historical data, and digitization of current and archive information, are also necessary. The current database is being recovered and scanned using Excel software for the damage caused by the political and military conflict of 1998-1999.

On the field of infrastructure it is imperative that all synoptic stations have at least one building to house meteorological facilities, and that the institute's headquarters are rehabilitated.

"It is envisaged to establish an integrated system for the provision of climate services, and their application to decision-making at all levels of society. This implementation calls an unprecedented collaboration between institutions, ignoring political boundaries, functional and disciplinary and requires mobilization efforts at the global level." In this context we believe that this study does not attempt to give examples of references to a climate service from an operational point of view, but shows aspects that illustrate the gap between the most and least advanced climate services and resources, drawing attention to the need to take into consideration these differences.

Station list and status

Location	Type	Built	Identification	Lat. (N)	Long. (W)	Alt. (m)	Status
Bolama	Synop	1905	61769	11°36'	15°29'	20	RC
Bissau/Aero	Synop	1941	61766	11°52'	15°56'	29	Station OK
Bafatá	Synop	1950	61781	12°10'	14°40'	43	RC
Bissorã	Synop	1950	61777	12°14'	15°27'	10	to rehabilitate
Farim	Synop	1950	61775	12°29'	15°30'	03	to rehabilitate
Cufar	Synop	1950	61778	11°19'	15°23'	19	to rehabilitate
Gabu	Synop	1941	61790	12°17'	14°14'	83	RC
M.Boé/Beli	Agro	1950	190030	11°45'	14°13'	75	to rehabilitate
Quinhamel	Agro	1985	190020	11°53'	15°52'		to rehabilitate
Cabuxanque	Agro	1992	190054	11°17'	15°07'		to rehabilitate
Contuboel	Agro	1989	190041	12°22'	14°35'	08	to rehabilitate
Bissau/Granja	Agro	1992	-	11°51'	15°36'		to rehabilitate
Bula	Agro	1950	190007	12°03'	15°44'	30	to rehabilitate
Bubaque	Agro	1940	190026	11°04'	16°02'	30	to rehabilitate
Bissau/Obs	Cli	1916	190021	11°51'	15°36'	20	to rehabilitate
Buba	Cli	1940	190024	11°36'	15°05'	10	to rehabilitate
Gabu	Cli	1941	190013	12°17'	14°14'	83	RC
Catio	Cli	1946	190027	11°17'	15°16'	18	to rehabilitate
Caió de Fora	Cli	1950	190018	11°50'	16°19'	39,5	to rehabilitate
Varela	Cli	1950	190004	12°17'	16°36'	13	to rehabilitate
Cacine	Cli	1950	190028	11°08'	15°01'	06	to rehabilitate
Pirada	Cli	1950	190011	12°40'	14°10'	55	to rehabilitate
Sonaco	Cli	1950	190012	12°24'	14°29'	25	to rehabilitate
Orango	Cli	1995	190048	11°04'	16°09'		to rehabilitate
Formosa	Cli	1995	190050	11°33'	15°50'		to rehabilitate
Quêbo Coli	Cli	1996	190057	11°32'	14°47		to rehabilitate
Tche-Tche	Rainfall	1956	190055	12°17'	14°12'	-	OK
Mansaba	Rainfall	1950	190010	12°18'	15°10'	43	OK
Canchungo	Rainfall	1950	190006	12°04'	14°02'	15	OK
Cacheu	Rainfall	1950	190005	12°06'	16°10'	14	OK
Fulacunda	Rainfall	1950	190023	11°47'	15°11'	34	to rehabilitate
Potugole	Rainfall	1950	190019	11°58'	15°08'	10	to rehabilitate
Bruntuma	Rainfall	1950	190016	12°28'	13°40'	100	to rehabilitate
Xitole	Rainfall	1950	190031	11°44'	14°49'	30	OK
Empada	Rainfall	1968	190025	11°33'	15°14'	-	OK
Tite	Rainfall	1980	190022	11°47'	15°24'	-	to rehabilitate
Galomaro	Rainfall	1985	190029	11°56'	14°37'	-	to rehabilitate
Bambadinca	Rainfall	1978	190015	12°02'	14°52'	-	to rehabilitate
Pitche	Rainfall	1985	190017	12°19'	13°58'	-	OK
S. Domingos	Rainfall	1958	190032	12°24'	16°12'	22	OK
Calequisse	Rainfall	1985	190033	12°04'	16°14'	50	OK
Bigene	Rainfall	1985	190034	12°25'	15°33'	50	OK
Ingoré	Rainfall	1985	190035	12°24'	15°48'	30	OK
Djolmete	Rainfall	1985	190036	12°13'	15°52'	30	to rehabilitate
Mansoa	Rainfall	1950	190010	12°04'	15°19'	08	OK
Cuntima	Rainfall	1985	190038	12°39'	15°02'	-	to rehabilitate
Sare Bacar	Rainfall	1985	190039	12°51'	14°27'	-	to rehabilitate
Fajonquito	Rainfall	1995	190040	12°32'	15°14'	-	to rehabilitate
Ganadu	Rainfall	1985	190042	12°16'	14°43'	-	to rehabilitate
Canquelifa	Rainfall	1985	190043	12°35'	13°52'	-	OK
Cade	Rainfall	1985	190044	12°14'	13°54'	50	to rehabilitate
Picixe	Rainfall	1950	190045	11°50'	16°08'	-	to rehabilitate
Caravela	Rainfall	1962	190046	11°33'	16°20'	15	to rehabilitate
Uno	Rainfall	1995	190047	11°13'	16°10'	-	to rehabilitate
Bissassema	Rainfall	1987	190049	11°45'	15°28'	-	to rehabilitate
Bedanda	Rainfall	1955	190051	11°27'	15°06'	14	OK
Nhacra	Rainfall	1985	190062	11°27'	16°28'	-	OK
Binar	Rainfall	1985	190060	12°07'	16°24'	-	to rehabilitate
Bachil	Rainfall	1985	190063	12°13'	16°64'	-	to rehabilitate
Nhala	Rainfall	1987	-	11°53'	15°28'	-	to rehabilitate
Foia	Rainfall	1987	-	11°48'	16°36'	-	to rehabilitate
Guiledje	Rainfall	1987	-	11°20'	15°07'	-	to rehabilitate
I. Galinha	Rainfall	1993	-	11°28'	16°18'	-	to rehabilitate
Fa	Rainfall	-	190014	12°06'	14°49'	-	to rehabilitate
Quebo	Rainfall	1950	190057	11°33'	14°49'	-	to rehabilitate
Saltinho	Rainfall	1950	-	11°38'	14°40'	-	to rehabilitate

Synop=Synoptical; Agro=Agrometeorological; Cli=Climatological; RC=Ongoing rehabilitation. Source: NIM

Supporting decision-making in the sugar industry with integrated seasonal climate forecasting

Roger C. Stone, Neil Cliffe, Shahbaz Mushtaq, University of Southern Queensland; and Yvette Everingham, James Cook University, Australia

An integrated approach has been developed linking seasonal climate forecasting models to sugar yield, production and sugar content models in order to improve predictability of the size of the Queensland sugar crop in any year.

Queensland produces 90 per cent of the Australian sugar crop, most of it destined for export. In this respect, approximately 32 million tons of cane and 5 million tons of raw sugar is produced in a 'normal climate year'. To produce this amount of sugar there are approximately 4,000 cane farms, 24 sugar mills and six bulk storage ports, making export agency Queensland Sugar Limited (QSL) the third-largest sugar supplier in the world. Climate extremes, especially excessive rain during the harvesting period (June to November) can result in massive losses for the entire industry – from the farm production component through to the milling and especially the marketing and export components. For example, in 2010, one component alone of the sugar industry suffered a loss of Au$500m following excessive rain through the entire harvest period, due to the development and continuation of the major La Niña event. This resulted in yield downgrading and inability to harvest many crops due to wet weather and flooding. Appropriate climate forecasting systems, especially those that have the capability to be integrated into sugar yield models and core decision systems, are urgently required to be developed and included at various stages of the management cycle in the sugar industry.

QSL requires precise forecasts of total yield, the likelihood of 'standover cane' (cane that cannot be harvested) and other likely disruptions due to weather and climate, especially excessive rain and lack of potential for dry spells. Other industry sectors are also closely involved, particularly all the sugar mill owners and operators in Queensland but also the cane growers themselves and their farming organizations such as the Queensland Cane Growers' Council. Direct knowledge of seasonal climate forecasting opportunities will allow farmers to make better decisions for the coming seasons about:

- Planting and harvesting
- Farm equipment purchases, which need to be more aligned to the season ahead – such as the purchase of irrigation equipment in potentially excessively dry seasons compared with purchase of tractors with wide tyres in potentially excessively wet seasons
- Scheduling of harvesting operations in potentially wet seasons to harvest the wet blocks first.

For farming and mill production, the following types of climate information are used:

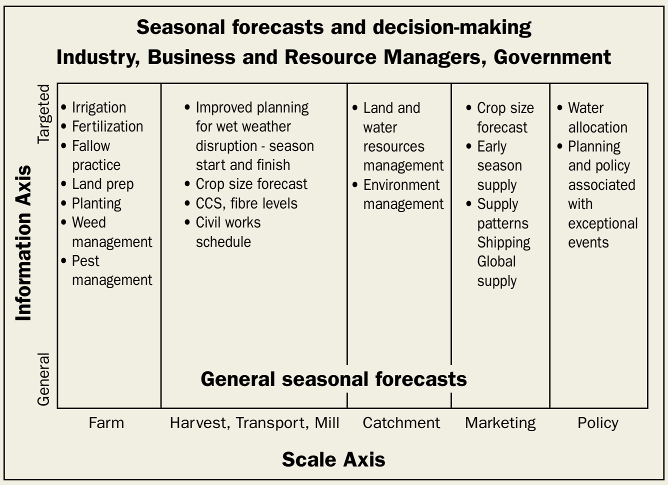
- Southern Oscillation Index (SOI)-derived seasonal forecasting (SOI phases)[1] for regional-scale forecasts updated each month on a rolling three-month basis
- Outputs from the new generation of seasonal forecast outputs locally and internationally, such as Bureau of Meteorology general statements of likely El Niño Southern Oscillation (ENSO) conditions, amd US Climate Prediction Center outputs on potential for El Niño and La Niña events
- Specific web-based services of the University of Southern Queensland (USQ), Bureau of Meteorology and other bodies
- Regular production of targeted climate forecast newsletters that provide reviews of the various climate forecast products currently available, specifically written for local regions and incorporating 'farmer jargon' where possible.

Export and marketing agencies use a fully integrated yield production model incorporating crop simulation model input (such as the Agricultural Production Systems Simulator (APSIM) and Canegrow) integrated with statistical climate forecast systems (SOI phases etc.), but also likely soon to incorporate aspects of the model code associated with Global Climate Model seasonal forecast systems such as Bureau of Meteorology POAMA/ACCESS; UK Met Office and European Centre for Medium-Range Weather Forecasts (ECMWF) seasonal forecast output downscaled to local regions. This type of output is in research mode only at this stage. Once deemed suitable for operational use, a direct operational system may be developed emanating directly from the climate agency itself.

The climate forecast information issued for growers and millers is tailored to the extent that the timing of issue of key aspects of the forecast is closely aligned with the major decisions being made across the state both 'on-farm' and at the mill production level:

- Close attention is paid to the output of probabilistic forecasts of likely extreme conditions, especially the potential for excessive rainfall according to the user's pre-defined criteria, but also in terms of aspects such as forecasts of numbers of frosts through the growing season and the need for extra irrigation activity

The relationships between scale, information, content and decision makers in defining a systems-based approach to applying seasonal forecasts in agriculture – a key example from the sugar industry



Source: After Hammer, 2000; Everingham et al., 2002; Stone and Meinke, 2005

An example of climate forecasting-yield forecasting output from a past year, using both targeted seasonal climate forecasting and crop modelling for each of the terminal mill regions in Queensland

Terminal Region	Forecast (t/ha)	Standard error (t/ha)	Historical Mean (t/ha)	Simulated Yield Component	Comment
Bundaberg	11.4	0.937	11.0	Biomass	Sugar yield forecast is unchanged from last month
Mackay	11.7	1.141	10.8	Biomass	Sugar yield forecast is slightly down (0.2 t/ha) from last month
Townsville	17.0	0.915	17.1	Biomass	Sugar yield forecast is unchanged from last month
Lucinda	10.9	1.109	10.6	Biomass	Sugar yield forecast is slightly down (0.2 t/ha) from last month
Cairns/ Mourilyan	10.3	0.860	10.5	Biomass	Sugar yield forecast is slightly down (0.1 t/ha) from last month

Source: Y. Everingham and QSL, 2012

- The more targeted forecasts are provided by USQ's climate scientists and agronomists using peer reviewed and verified climate forecast systems, mostly developed in-house
- Aspects associated with gathering the exact needs of growers and millers are derived from exhaustive workshops held in every growing region of the state. These workshops are highly effective and facilitated by a well-recognized extension specialist, who is also versed in climate forecasting systems and their output.

Stakeholder involvement

Stakeholders were identified following extensive meetings and workshops with the leading marketing and export agency and the leading grower representative body in the Queensland sugar industry. The following stakeholders were consulted within a focused meeting and workshop environment:

- QSL
- The Queensland Cane Growers' Council and each of its local branch offices
- Each of the eight sugar mill managers and key staff
- Some individual growers known to the project managers though previous research project activity.

The focused meeting and workshop process distilled the key issues, although this took a number of months to achieve.

Key agencies including the UK Met Office (Hadley Centre), the Centre for Australian Weather and Climate Research, James Cook University (JCU) and USQ were among the agencies consulted on the research and 'product' output process, with USQ leading the project.

Climate forecast information and associated research is provided by climate scientists at USQ in collaboration with the Bureau of Meteorology (Australia) and the UK Met Office. Aspects related to ECMWF involvement are negotiated through the UK Met Office.

Targeted output for the sugar industry is provided by USQ's Australian Centre for Sustainable Catchments through the auspices of QSL specialist management staff and local branch offices of the Queensland Cane Growers' Council and the Queensland Department of Agriculture, Forestry and Fisheries. More specific output will be provided through focused workshops conducted directly with various agencies involved with the sugar industry.

USQ (previously through the Queensland government) has established its own published and verified targeted seasonal climate forecasting system and this forms the mainstay of the required detailed seasonal climate forecasting outputs for the sugar industry. Importantly, this system can be seamlessly integrated into (sugar) crop simulation models such as APSIM and other yield forecasting models.[2]

With regard to the 'new generation' of climate model outputs (GCM) to be incorporated in a research framework for long-lead decision-making, agreements have

Example of forecasting probability values of excessive rainfall – Macknade Sugar Mill, North Queensland (values shaded in green are statistically significant)

on	lead (mths)	response	SOI period	32032 Macknade Neg	Pos	Fal	Ris	Neu
on	0	rainfall	aug/sep	0.05	0.47	0.10	0.23	0.22
on	1	rainfall	jul/aug	0.00	0.46	0.30	0.32	0.21
on	2	rainfall	jun/jul	0.00	0.56	0.13	0.26	0.16
on	3	rainfall	may/jun	0.00	0.41	0.25	0.43	0.10
on	4	rainfall	apr/may	0.06	0.32	0.21	0.39	0.19
on	5	rainfall	mar/apr	0.13	0.29	0.06	0.38	0.30
on	6	rainfall	feb/mar	0.23	0.29	0.13	0.25	0.30

Source: USQ/JCU

been made or are being made with the UK Met Office and Bureau of Meteorology for the development of suitably designed, more targeted output systems.

Funding

The above programme for the Queensland sugar industry is directly funded as a research and development project by QSL ($A2.7m plus all data and travel costs). Thus, following earlier funding by a research and development corporation through levies made on the value of crops harvested in any year, the funding is now being provided directly from the private sector. This process was necessary because climate science and developments in seasonal climate forecasting could provide obvious benefits to all sectors of the Queensland sugar industry, which was suffering massive losses, especially in La Niña years.

The project has a five-year timescale with plans to provide continuous funding beyond that if the research and development and ongoing output is deemed to be successful in aiding decision-making across the industry, especially in the exporting and marketing sectors.

Making it happen

There are four key institutions involved in climate forecast and crop modelling provision:

- USQ — climate science, engineering, remote sensing, aspects of downscaling, farmer education, and project leadership
- JCU — key aspects of crop simulation modelling
- UK Met Office (through a research agreement) — research involving the capability of a new generation of climate models (UK Met Office and ECMWF) for the sugar industry in Queensland; provision of data feeds from current GCM outputs
- Bureau of Meteorology — provision of outputs from POAMA/ACCESS model into an integrated overall modelling system; provision of generalized output involving the Madden Julian Oscillation, including information provided by the Tropical Climate Bulletin.

The current project development involves QSL, Queensland Cane Growers' Council (head office and all branch offices) and the Queensland Department of Agriculture, Forestry and Fisheries (both head office and the Mackay regional office).

It should be noted that the above activity is currently within a research and development framework. If deemed successful by all sectors of the sugar industry, especially the marketing and export sections of the overall value chain, then an operational system involving regular provision of output will be provided by a combined team comprising the UK Met Office and the Australian Bureau of Meteorology, the current operational statistical seasonal climate forecast system in use in Queensland and also used by the Queensland Government, and crop model output runs developed by USQ and JCU.

Evaluation

A full feedback process conducted through intensive workshops is an integral part of the project. The research project will be evaluated against agreed milestones in October 2012. Each workshop is evaluated through use of a carefully designed questionnaire provided to each participant. The project and project funding (and follow-up services) will be adjusted in light of the evaluation received, especially by the donors. Aspects related to climate change are not directly included in the project.

Capacities

At present, mostly existing personnel have been engaged in the research project and development stages of this work. These include two climate scientists (one at PhD level), one mathematics/statistics specialist (at PhD level) one sugar cane crop simulation modelling specialist (PhD level), one specialist extension office (at MSc level) and computer programming project support staff.

It is probably a mistake to regard the separation of capabilities according to whether individuals are 'users' or 'developers'. In this project there are two climate scientists with very extensive research publication and operational capabilities, located at USQ. They interact with key climate scientists at the UK Met Office and the Bureau of Meteorology, and they also have the capacity to liaise directly with agronomists and crop modellers engaged at JCU. Key user agencies such as QSL or Queensland Cane Growers' Council do not have climate scientists on their staff; rather, they employ chemical engineers or environmental scientists.

Some capacities are lacking. It can be difficult to locate climate scientists within national organizations who have the required breadth of understanding of the computerized interfacing needs in linking a climate model to a crop simulation model, for example. Rather complex software development is needed that can integrate all modelling and output systems involving a wide range of expertise. Additional challenges involve the sheer effort required in developing legal agreements between agencies and associated activity.

A massive amount of innovation is needed if one is serious about linking climate science with real decision-making, especially if the output required is much more than normal climate variables, such as 'tons of sugar per hectare' or similar. The key innovation is in development of engineering and software systems that can provide the integration necessary for complex outputs — which is often where the decisions exist.

What next?

The project's goals are to ensure continued improvement to the provision of yield and other outputs which involve climate forecast systems as opposed to mere 'outputs'. This means there is a need for awareness of breakthroughs and developments in seasonal forecast systems (especially coupled models) and that these must be created in such a way as to allow integration into decision systems.

The research programme and operational outputs described here could easily be scaled up for application in any region where sugar, or other crops, is grown.

The project's main challenges are:

- The need for continued funding — it is easy to lose ongoing funding with the result that the same industry unnecessarily suffers from the same impacts for a number of years
- The need for closer interaction with key industry sectors (not necessarily the ones first thought of such as farmers, but to address issues across the entire value chain in production)
- Keeping all relevant agencies 'on side' as it may not necessarily be the local agency that has the best research capacity in integrated climate systems research and development.

This project satisfies the principles of the Global Framework for Climate Services. All countries could easily benefit from the approach and the model outlined here can be applied for all countries, although aspects related to the value of climate systems to marketing and trade would need further evaluation for certain countries. The programme addresses all three geographic domains identified in the principles: local farmers and mills, regional production issues, and global trading and marketing issues. Operational climate services are the core element of the project — but there is a need to recognize the importance of the capability of the underlying system to be integrated into other systems such as agricultural models.

A climate forecasting fact sheet provided to QSL for the use of millers, farmers and other general users of the information that will be provided both during the course of the research and development stage and when the process becomes operational


QSL
Developing Improved Climate and Yield Forecasting Systems for the Sugar Industry

Source: QSL, USQ, JCU

A real-world farmer example

Sugar farmer Darren describes his decision-making in his own words, in early winter 2009, after attending a 'Managing for Climate' workshop in Mackay, Queensland, Australia:

"Climate pattern in transitional stage so I keep a watchful eye on the climate updates."

"I take special interest in the sea surface temperatures (SST) particularly in the Niño 3 region."

"There is currently some indication of warming in the Niño 3 region which hints at a possible El Niño pattern developing."

"Replant would be kept to a minimum."

"Harvest drier areas earlier, even if commercial cane sugar may be affected."

"We don't run the farm based solely on climate information and forecasts, it's just another tool to consider when making decisions."

Darren's decision-making concerns use of seasonal climate forecasting information in sugar cane harvesting and replanting. Note the detail of understanding and ownership of climate information and forecasting this farmer has gained through involvement in participatory research and focused workshop activity.

Source: USQ/JCU

Seasonal climate prediction in Chile: the Agroclimate Outlook

Juan Quintana, Benito Piuzzi and Jorge F. Carrasco, Dirección Meteorológica de Chile – Dirección General Aeronáutica Civil; and Liliana Villanueva, Ministerio de Agricultura, Unidad de Emergencia Agrícola

The Agroclimate Outlook is a monthly bulletin produced by the Dirección Meteorológica de Chile (DMC) and freely available in the organization's website. It contains information about the predicted seasonal climate conditions that are most likely to prevail during the next three months. The total precipitation accumulation and the average minimum and maximum air temperatures for the three-month period are predicted variables, which are considered for analysing and predicting the implications in the agriculture sector. The seasonal forecast is based on the correlation between the El Niño Southern Oscillation (ENSO) and the predicted variables in Chile.

Agricultural meteorology deals with the relationship between weather and climate and crop, livestock and soil management. Agricultural activity carries implicit risks of diverse origins, among which, are atmospheric factors. Generally speaking, these factors can be weather- or climate-related, according to the duration of the meteorological event. Thus, phenomena that develop and have a lifetime from a few hours to a week are considered weather-related and their forecasts are produced at least on a daily basis. On the other hand, there are other phenomena whose genesis and duration involve longer periods of time, from few weeks to months or even years. These are considered climate-related and their forecasts are produced and disseminated on a monthly basis. Weather or climate forecasts, regardless of their characteristics, do not refer to or indicate the degree of risk given by the prediction; they rather express and inform users on the degree of likelihood that a meteorological event can occur in a given time and place. Atmospheric factors can have implications on agriculture and related activities, and knowing in advance how they will develop (forecasts) and affect a region can help farmers and decision-makers to take actions for mitigating or benefiting from the predicted atmospheric conditions. For example, they can receive information for better agriculture water management, for planning periods of planting and harvesting, for improving livestock management or for altering grazing and rotation pastures.

The most frequent weather and climate risks in Chile

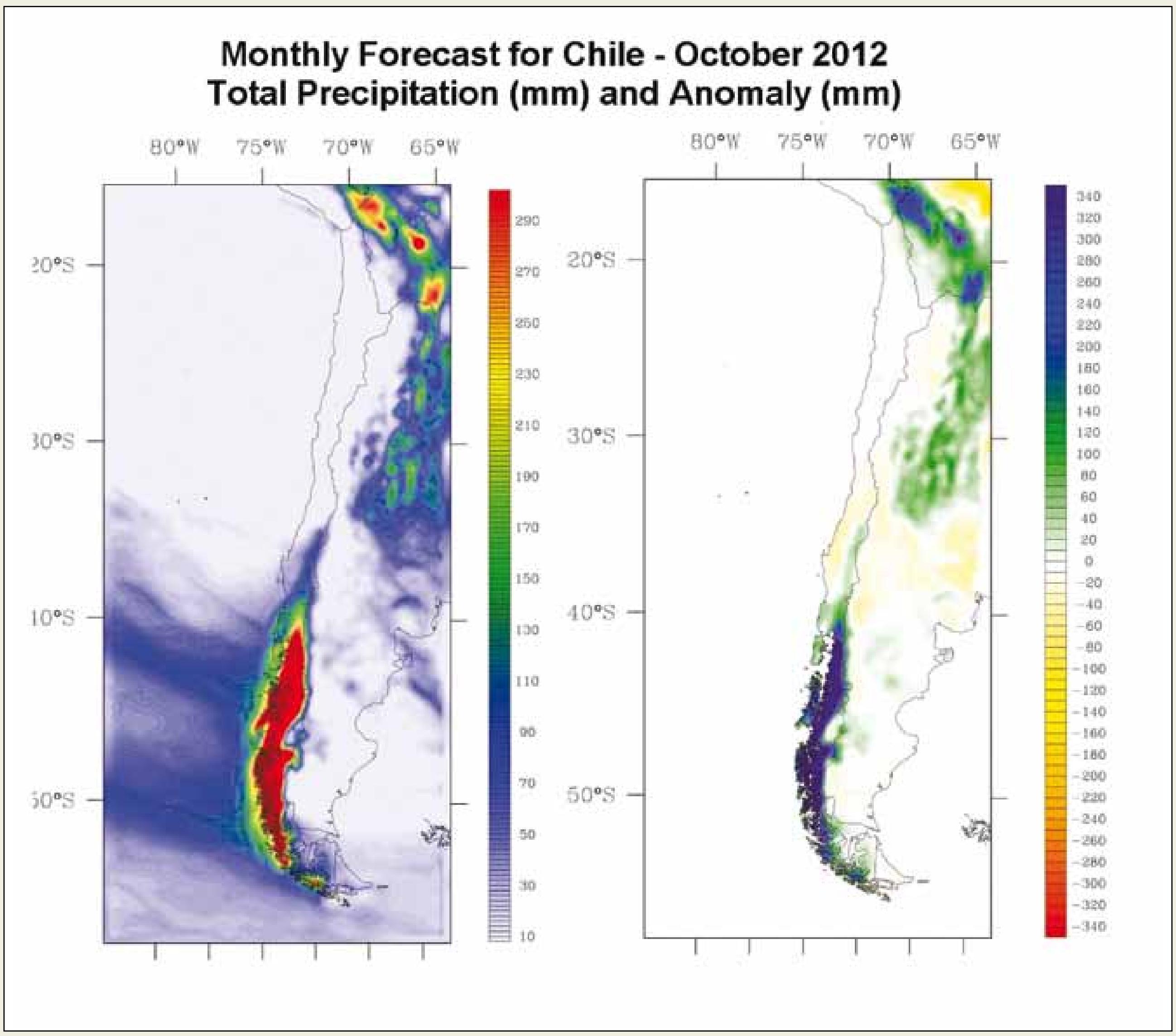
Source: DMC

The natural climate variability in Chile often results in extreme meteorological events, such as droughts, floods, cold waves (including frost), heat waves and sometimes severe thunderstorms and hailstorms. These extreme phenomena occur on different temporal and spatial scales — thunderstorms and floods can last a few hours, while frosts and droughts might last for days or even months; and while some events might affect a small area, others will be of synoptic scale, affecting a large region. This variability is the result of natural processes that, alone or combined with others, can develop an atmospheric condition triggering and supporting the occurrence of a meteorological event. For instance, frost days are mostly caused by very cold air masses moving behind a frontal band. Periods with little or no precipitation during the winter, or a rainy period (three to four weeks) in central Chile (30-40° south) can be associated with atmospheric alterations caused by the Madden-Julian Oscillation,[1] which is an intra-seasonal climate variability that takes place in the equatorial band of the Indic and western Pacific ocean region with a recurrence period of 30-60 days. On the other hand, under or above annual normal precipitation in Chile is most likely associated with the inter-annual variability caused by ENSO, which is an oceanic-atmospheric mechanism that, in part, controls the seasonal climate variability, mostly in central Chile (28-40°). Increasing the sea surface temperature (SST) above normal (El Niño) or decreasing below normal (La Niña) in the central-equatorial Pacific ocean, can originate changes in atmospheric circulation in the Southern Hemisphere that can favour or inhibit precipitation events in the central, as well as in the northern and southern regions of Chile.[2]

Thus, seasonal climate prediction in Chile is mainly based on changes in the SST that take place in the central equatorial Pacific Ocean (known as El Niño 3.4), and its prediction is produced using global numerical climate models. The variability of the atmospheric conditions affecting the country, at different spatial and time scales has a significant impact on agriculture in the central region, where the main activity is located.[3] Knowing the precipitation and air temperature behaviour that will most likely prevail for the next three months will enable farmers and decision-makers to take adequate actions in advance for mitigating the possible impacts of meteorological conditions in their different management areas, or for adapting measurements to benefit from them.

DMC began to make seasonal predictions (three months) for precipitation and extreme air temperatures for Chile in 2000. Initially, it used conventional statistical technique such as simple linear regression, considering the SST, the accumulated precipitation and average minimum and maximum air temperatures for Chilean stations as predicting variables. Later in 2003, the Climate Predictability Tool (CPT) developed by the International Research Institute for Climate and Society (IRI) at the University of Columbia was incorporated.

A climate forecast for precipitation accumulation corresponding to October 2012, using the Climate Mesoscale Model - version 5



Source: DMC

The CPT uses multivariable techniques, such as canonical correlation and principal components analysis, to construct a statistical model for predicting the accumulated seasonal precipitation and average extreme temperatures.

Of relevant importance for developing seasonal climate predictions in Chile, and for their application in the agriculture sector, has been the participation of the DMC in the Regional Climate Forums organized by the International Centre on El Niño Research (CIIFEN) and World Meteorological Organization since the beginning of 2000. Thus, for example, a specific application of climate information to meet the needs of local farmers and to help them in reducing the socioeconomic impact of climate in farming activity was developed,[4] through a CIIFEN-led project called 'Applied Climate Information for agriculture risk management in the Andes countries'. The project also presented the opportunity of implementing the Mesoscale Climate Model — version 5 for the first time in Chile, and to run monthly numerical simulation with a resolution of 10, 30 and 90 kilometres. Now, new computer facilities implemented in the Weather Service during the first quarter of 2012 will permit the initiation of a new development in seasonal prediction, with the agriculture sector being one of the main beneficiaries of the improved spatial resolution of climate model outputs.

In this way, DMC has developed a seasonal climate forecast called Agroclimate Outlook, in addition to providing daily weather services including those for the agriculture activities. This is elaborated during the first half of each month and it predicts the precipitation accumulation and average extreme air temperatures (minimum and maximum) for the next three-month period with implications for the agriculture sector. This seasonal forecast is based on the ENSO prediction. The statistical predicted values obtained by the CPT model are compared with the observations obtained for the 1980-2010 period. For that, percentile 33 and 66 values were determined for precipitation and air temperature, to define below-normal, normal and above-normal levels. Thus for precipitation, the predicted values can fall in the drought (below-normal), normal or rainy (above-normal) season. For temperature, the predicted values can forecast a cold (below-normal), normal or warm (above-normal) season. This information has become an important input for farmers and other agriculture-related users who can use it to plan and make decisions at least 30 days in advance. In this context, the DMC disseminates the seasonal climate outlook to users through its website[5] and meetings coordinated with agriculture organizations.

The bulletin includes information that contributes to making decisions according to the current hydrological scenario (excess or deficit). This enables users to take advantage of their advance knowledge of the likely amount of precipitation expected for the next three-month period, so they can optimize their storage and distribution, or take actions to mitigate the negative impact of excess precipitation or water shortages. The bulletin also contributes to evaluating forage availability, estimating agriculture water demands according to plant phenology, assessing risk for drought prone areas and so on. On the other hand, estimation of the thermal factor is important for various agriculture activities — for example, the implication of the air temperature on pollination and fruit growth; evaluating and correlating plant growth and freezing periods, estimating the state of the environmental for farm animal birth periods, and freezing hour accumulation for olive plantation and harvest planning. In summer, the maximum air temperature forecast is important not only for the possible occurrence of heat waves, but also for the dangerous development and propagation of fires that can destroy forests and agriculture areas, plagues and other plant diseases. In other seasons, the information can be used for planning activities such as ground preparedness, crops, pasture management, preparation of silos, use of agro-chemicals, transportation, rotating pasture and so on.

The Agroclimate Outlook is published monthly on the website of the Ministry of Agriculture (MINAGRI),[6] particularly in the agrometeorological portal.[7] Thus, the bulletin is widely disseminated in the country and freely available to all users. In addition, MINAGRI sends a remainder to all registered users by email when the latest bulletin is available on the website. Monthly information available on the MINAGRI website includes:

- A National Executive Summary presenting the seasonal Agroclimate Outlook (including meteorological parameters and the El Niño — La Niña situation) and a summary of regional recommendations for agriculture activity.
- The Agroclimatic Risk Analysis bulletin, produced by the National Institute of Agriculture Research for the main fruit trees and crops. It analyses the risk for agriculture production in relation to the meteorological situation and seasonal prediction.
- Reports from the Fruit Development Foundation about the analysis of possible agroclimatic risks to tree fruit species. This is similar to the Agroclimatic Risk Analysis bulletin but it centres the analysis on the tree fruit species in each region.
- The Regional Agroclimatic Bulletin, which analyses the agroclimatic situation based on data provide by the agroclimate network[8] and the seasonal prediction produced by DMC.

In general, these bulletins use the meteorological seasonal prediction produced by DMC to evaluate the probable implications on different agriculture activities within the forecast period, making recommendations to the farmer for mitigating possible negative consequences or taking advantage of favourable climate conditions for their production.

Preliminary evaluation of the Agroclimate Outlook indicates its high value for users due to the quality and quantitative information that it includes — information that is used by farmers, specialized users and policymakers for taking informed decisions. Interaction with and feedback from end users has been important in the development and improvement of this bulletin, as it has emphasized the aspects that are of real interest and that constitute a contribution to agriculture activity. The Ministry of Agriculture has played an important role in participating and contributing to making the bulleting available to agriculture users. Today the bulletin is distributed monthly through emails and personal presentations, not only to the farmers, but also to authorities, policymakers, associations and general users.

Climate services and agriculture in the Caribbean

Adrian R. Trotman, Caribbean Institute for Meteorology and Hydrology

Food security is a critical concern for national governments in the Caribbean. This is particularly the case given increasing food prices globally coupled with the global recession and declining food production in the region. In recent decades, in most of the Caribbean Community (CARICOM) states, the tourism and services sectors have been dominant forces in their economies while agriculture has declined in relative importance, both in terms of its contribution to gross domestic product (GDP) and its share of the labour force. Among the problems facing the agriculture sector are losses in preferential markets (for example for sugar and bananas in Europe), inefficient production, slow traditional farming methods, soil erosion, slow technological advances, pests and diseases, shortage of inputs and lack of appropriate and timely dissemination of weather and climate information to promote sustainable agriculture. All of these increase the risk of losses and disasters in the sector. Nevertheless, a significant proportion of the economically active population is still involved in agriculture and agricultural employment is especially important for the livelihoods of the poor. Agricultural production contributes directly to food security, but it also supports poverty reduction and acts as an engine of overall economic growth in the region.

Weather, climate and agriculture in the Caribbean

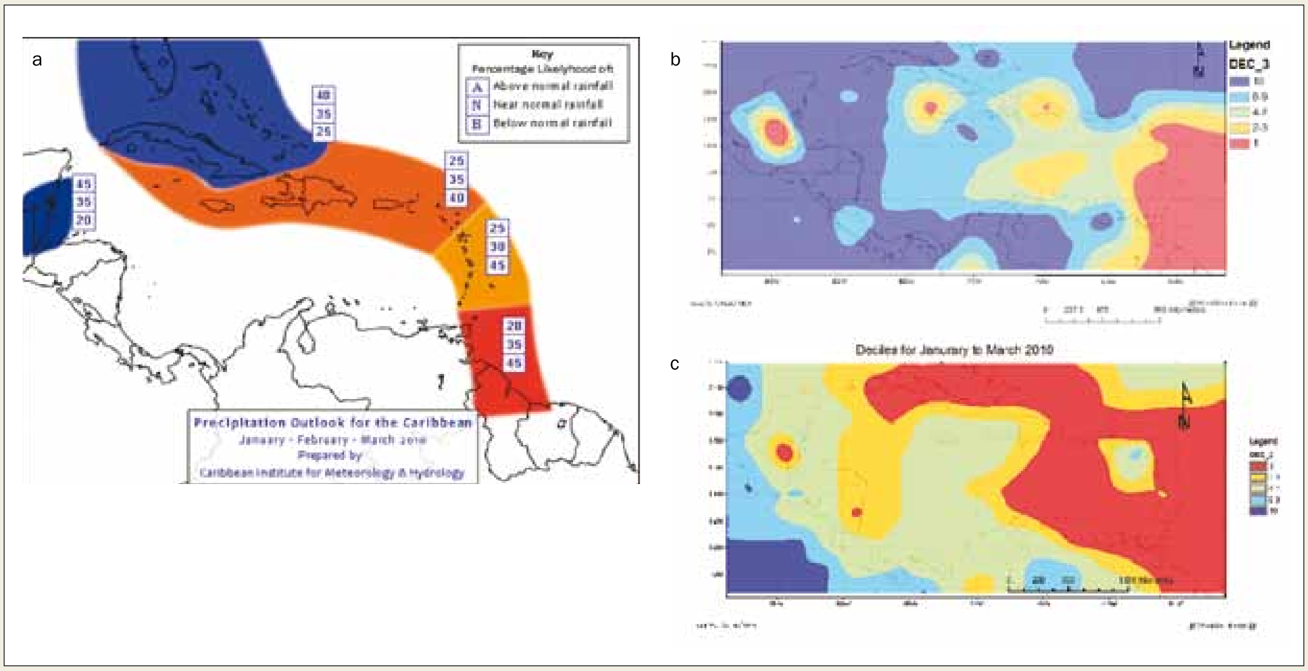
The Caribbean region is vulnerable to a wide range of natural hazards, ranging from catastrophic events such as floods, droughts, and tropical cyclones to pests and diseases in plants, animals and humans. These disasters cause much suffering, infrastructure and environmental damage, aggravate food insecurity and slow down or even reverse development gains. The impacts are noticeably more significant in poor rural communities.

Land degradation is a threat to natural resources with direct negative impacts on food security, poverty, and environmental and political stability. Climate variability, climate change and land degradation are intimately linked and generate unexpected effects such as an increased occurrence of extreme weather conditions in the region with greater consequences due to more vulnerable landscapes. Estimates suggest that the total annual impacts of potential climate change on all CARICOM member states and associated members by 2080 will be US$11.2 billion (referenced to 2007 US$), representing about 11.3 per cent of the total annual GDP of all 20 CARICOM states in 2007.[1] Climate change is likely to exacerbate the impacts of natural variability and its extremes. The Intergovernmental Panel on Climate Change has suggested that in future the Caribbean will experience reduced rainfall and more frequent droughts, accompanied by more frequent episodes of high intensity rainfall which can lead to flooding.[2] Recent research has also suggested that the annual number of category 4 and 5 hurricanes occurring in the North Atlantic will increase.

Weather and climate significantly affect agricultural production in the Caribbean. The rainy season coincides with the disastrous hurricane season and these hurricanes cause much damage. For example, in 2004 Grenada's agricultural sector suffered almost US$40 million in losses with damage to the nutmeg industry, affecting the approximately 30,720 people it directly and indirectly employed (about 30 per cent of its population).[3] Rainfall variability results in droughts and floods with significant impacts on agricultural production. In a region where rainfed agriculture, rather than the use of irrigation, still dominates, any reduction in rainfall below what is normal has negative consequences for agriculture. The drought in 2009 to 2010 was the most severe in decades causing crop and livestock losses, increases in food prices, reduction in export of some commodities like bananas, and increased pumping of water for irrigation (for example, it cost the Government of Guyana US$16,000 per day to operate pumps and conduct other works essential for the delivery of water in one of its regions).[4] On the other hand, flooding also results in major and frequent losses: for example, in Guyana in 2005, flooding resulted in 59.5 per cent GDP in total losses with US$55 million from agriculture alone,[5] which was followed by another flood event the next year.[6] Hence, it is important to raise the awareness of the farming community in the region to such climate-related impacts and to climate products and services that could reduce their vulnerability and associated climate risks.

CAMI: a Caribbean approach

Weather and climate information is of critical importance to the decision-making process for agriculture, water resources management and environmental conservation in the Caribbean. Through the African, Caribbean and Pacific Group of Countries' Science and Technology programme that is funded by the European Union, the Caribbean launched the Caribbean Agrometeorological Initiative (CAMI) in February 2010.[7] The lead agency, the Caribbean Institute for Meteorology and Hydrology (CIMH), partnered with



A tercile forecast produced at the beginning of January 2010 (A), indicating likely drier than normal conditions in most of the Caribbean;
(B) three-month deciles showing the rainfall status in the Caribbean with a clear indication of severely dry conditions by December 2009 (Decile 1 — red area);
and (C) a three-month decile showing severely dry conditions for January-March 2010 — as suggested by the forecast

Source: CIMH

the Caribbean Agricultural Research and Development Institute (CARDI), the World Meteorological Organization (WMO) and 10 National Meteorological Services of CARICOM states to implement the initiative. The overarching objective of CAMI is to increase and sustain agricultural productivity at the farm level through improved applications of weather and climate information, using an integrated and coordinated approach. This is specifically done by providing information on seasonal rainfall prediction, which in turn supports improved irrigation management, development of pest and disease forecasting systems for improved on-farm management decisions, and crop simulation modelling. This is achieved through the preparation and wide distribution of user-friendly weather and climate information newsletters and bulletins and the organization of regular forums with the farming community and agricultural extension agencies, to promote a better understanding of the applications of weather and climate information and to obtain feedback to provide better products from the meteorological services for use by the farming community.

Given the small size of the Caribbean countries, there is a lack of trained manpower to provide agro-meteorological services and applications on an individual country basis. But through a concerted regional approach, such services could be made available to the farming community. Hence this action emphasizes the promotion of an integrated approach to sustainable development in the Caribbean through coordination and networking of the limited meteorological services available in the region. CAMI, now in its final year, has established closer contacts with the WMO Agrometeorology Division, with Global Producing Centres of Long-range Forecasts, in particular the International Research Institute for Climate and Society and Météo-France, by collaborating with other initiatives, such as the Caribbean Climate Outlook Forum (CariCOF),[8] that work closely with them. CIMH coordinates these networking efforts on behalf of the Caribbean countries. CAMI emphasizes training of meteorological and agricultural services personnel in relevant aspects of agro-meteorology. Capacity has also been built in the regional research institutes (CIMH, CARDI), through working with international scientists and attachments at leading international institutes. The regional research institutions have, and will continue to expand the experience and knowledge gained, as they train people across the region.

Capacity building

CAMI sought to build the capacity of national meteorological services (NMSs), CIMH, CARDI, and agricultural extension services and farmers (as users) in the Caribbean through a series of training workshops, international attachments and farmers' forums. The NMSs, and CIMH and CARDI as product developers, researchers and trainers were the main targets of the training workshops and international attachments, whereas training was provided in interpretation of products and agro-meteorological needs of the region mainly through farmers' forums. Capacity was also, and continues to be, built through the provision of tools such as those which estimate evapotranspiration and water use needs, evaluate the

Image: CIMH

The banner used in the CAMI regional monthly bulletin

efficiency of irrigation systems, provide risk levels of pests and diseases, simulate the growth and development of some important regional crops (mainly used to estimate climate change impacts), and facilitate statistical analyses of climatic data. More needs to be done, but CAMI has gone a long way in facilitating regional capacity needs in weather and climate information for agriculture in the Caribbean, and breaking the collaborative and dialogue barriers between meteorologist, agriculture extension and farmer.

Climate observations and monitoring

CIMH has, in recent years, intensified climate observation and monitoring. Through many initiatives that enhance the network of instruments (including the Caribbean Water Initiative, the CARICOM/Brazil/Food and Agriculture Organization Cooperation on Disaster Risk Reduction, Enhancing Resilience to Reduce Vulnerability in the Caribbean, Caribbean Disaster Management) and through the Caribbean Drought and Precipitation Monitoring Network (CDPMN), CIMH acts as a regional mechanism for observing, monitoring, and to some extent predicting rainfall and its extremes. It also assists governments of its member states in establishing their own observation and monitoring systems through training workshops and programmes, and providing tools. Some of these tools include software for calculating rainfall indices such as the Standardised Precipitation Index (SPI) and Deciles.[9] The focus now is the regional observation and monitoring of temperature, which also is very important in the development and severity of droughts. Farmers and extension services officers have been exposed to the use and interpretation of these and other products through the CAMI farmers' forums. Agricultural and hydrological drought monitoring are emerging aspects of the programme, using instruments provided through a cooperative agreement between CARICOM and the Government of Brazil for three of the countries as pilots. CIMH has also developed an online web portal for reporting signs of drought and water stress, which is about to become active, and would allow communities including those actively involved in farming to become a part of the monitoring network. These aspects are being presented in the 2012 version of the forums.

Research, modelling and predictions

CIMH, in collaboration with regional and international partners of CariCOF, produces a regional seasonal rainfall outlook that projects three to six months into the future. This process, which has existed for more than a decade, had been solely performed by CIMH but is now greatly enhanced through the collaborative forum established in February 2012. It uses regional data to provide probabilistic tercile rainfall forecasts using the Climate Predictability Tool.[10] These forecasts are compared with output from global climate centres. Outlooks on temperatures, both ambient and sea surface, are also provided for three to six months using outputs from the global centres. CAMI has collaborated on two major CariCOF workshops, one in 2010 and the other in 2012, and has been utilizing this product to provide information to the farming and the wider agricultural community in the Caribbean. The use and interpretation of this product have been introduced at the project's farmers' forums, where the outlooks were introduced in conjunction with the indices from the CDPMN to show how they were used together during the 2009-2010 Caribbean drought to inform and advise government. The farmers and extension officers were then shown how the same products were used during the following year when there was excessive rainfall.

In collaboration with other research institutions in the region, in particular the University of the West Indies and the Institute for Meteorology of Cuba, climate variability and change research is ongoing and expanding. The regional human resource, though relatively small, is extremely dedicated and has been producing some cutting-edge research in this area, which will enhance predictability in the region. The Caribbean Community Climate Change Centre (CCCCC) coordinates and seeks funding for much of the research into climate change adaptation and mainstreaming in Caribbean agriculture. It works with CIMH and other relevant regional and national agencies for this cause and is one of the stakeholders of CAMI.

CAMI has also, through its activities on pests and diseases and crop simulation modelling, made an important step towards forecasting pest and disease outbreaks and the projection of potential yields due to climate change. Much more work needs to be done on this, as many gaps in biological and soil data in particular, have been identified. Stronger agronomic, crop protection and soil research programmes in the region are necessities.

Climate services information system

CAMI recognized that developing information must be followed by dissemination. In collaboration with its national partners, it produces a regional bulletin for farmers, with the information and interpretations highlighted earlier at a regional level. However, CIMH has been working with the NMSs and agricultural extension services, from Antigua and Barbuda for example, to develop their own national bulletins.[11] Some countries have already launched their bulletins while others are in the process of launching theirs. Through feedback from users, and in particular the formation of tripartite committees in the pilot states, the aim is to make this product more relevant by focusing on particular needs, and making the language more farmer-friendly. In collaboration with the Technical Centre for Agriculture and Rural Cooperation, CAMI has been investigating the potential use of other media for dissemination of information, particularly using more modern technology such as mobile phones. Some consideration is also being given to using smartphone applications. Through the bulletins, tripartite committees and regional forums, CAMI has caught the attention of agricultural decision-makers in the region. In some countries, there have been requests for similar agro-meteorological training for agriculture extension services.

User interface system

After a recommendation from its mid-term evaluation, CAMI has been forming tripartite (NMS, extension services and farmers groups as core) committees to expand and sustain the activity of the project once it is finished. This is essentially a stakeholder committee and has the capacity to act as an interface between the product developers and users. CAMI also established an online forum to enhance discussion and feedback, and to ensure they are continuous. There is now the need to link these separate entities into one comprehensive user interface system. Further, some countries have been including the CAMI initiatives, outputs and recommendations in disaster risk reduction strategies for agriculture. Jamaica, for example, is committed to a recommendation to its cabinet that its CAMI tripartite committee be a part of a disaster risk reduction committee recommended for agriculture.

Outputs and outcomes

Certainly, the region has to go well beyond what the three-year CAMI project provides in order to make the comprehensive impact in agriculture that the meteorological services and research institutions seek. The project itself reveals many gaps that need addressing in the follow-up from CAMI, including:

- Higher resolution and timely climate information and forecasts, requiring a denser network of meteorological instruments and greater allocation of resources to cover the many agro-climatic zones
- A communication strategy for dissemination of weather and climate information for agriculture (the development process has begun, but needs to be continued
- NMS staff dedicated to agro-climatology, rather than having this as part of their day-to-day duties
- Further training of agriculture extension services staff in agro-meteorology
- Enhancement of biological and general agricultural data collection and recording (this has limited the impact of pests and diseases and crop simulation activity)
- National disaster risk reduction committees in agriculture (the tripartite committees formed through CAMI or an enhanced version of these) ratified by government and reporting to government.

Certainly, the list is not exhaustive, but it identifies needs that often arise or are strongly recommended. The fact that there is an activity that identified such gaps, heightened the awareness of weather, climate and climate change issues in agriculture, began the provision of information specifically for the industry and has influenced agricultural policy-making in the region suggests that CAMI was well worth it, but needs to move even further. The region looks forward to the continued collaboration of all stakeholders in an industry that has served the region for centuries.

Image: © www.istockphoto.com/stevenallan

Agriculture in the Caribbean

Climate outlooks for food security in Central America

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In the Central American countries, the Climate Forum (FCAC) and the Forum on Applications of Climate Outlooks to Food and Nutrition Security (FAPC) processes have enabled the provision of weather services and the reduction of obstacles such as limited human resources and data infrastructure. Regular publication of seasonal climate outlooks has made national meteorological and hydrological services (NMHSs) visible and shown the benefits of climate information in reducing vulnerability to climate variability. The focus on food security as a priority for the states in the region has created synergies among regional technical organizations, which are contributing to transform climate information into climate risk scenarios. This is the ultimate goal of benefiting Central American communities that are exposed to food insecurity associated with climate variability.

Central America is characterized by significant climate variability, manifested in high vulnerability to disasters. According to the Long-Term Climate Risk Index (Germanwatch, 2011), some countries in the region such as Honduras and Nicaragua were among the 10 most affected by climate-related events between 1991 and 2010. Extreme weather events increase the risk of food insecurity in many communities of the region, some already in precarious nutrition situations. Reducing this risk is a high priority on the agenda of Central American governments.

Since 2000, NMHSs have jointly developed a process for regular issuance and dissemination of climate outlooks. This weather service is intended to support decision-making among the sectoral entities responsible for food security programmes in the seven countries of Central America, with special emphasis on key sectors for food and nutrition security and areas seasonally or chronically affected by food production or access problems.

In order to provide this service, it has been necessary to strengthen regional capacities and to:

- Analyse global, regional and local weather information and place it in a relevant context and scale
- Enable the highlighting of different climate areas in each of the countries
- Promote synergies with institutions and organizations linked to food and nutrition security (FNS)
- Add value to climate forecasting through situational analyses that translate seasonal climate outlooks into climate risk scenarios.

To address the first need, the NMHS used the coordination mechanism provided by the Regional Committee on Hydraulic Resources, Executive Secretariat of the Central American Integration System (SICA), responsible for coordinating meteorological and hydrological activities in the region and consolidating the FCAC. This forum reunites human resources skilled in climatology, hydrology and atmospheric sciences throughout the region. Currently, the FCAC working group uses weather information from the NMHSs, model results and the forecasts of the international weather centres of the World Meteorological Organization (WMO) network, as well as statistical tools in order to issue seasonal climate outlooks on a scale relevant to national and sub-national levels in the seven countries.

Image: SICA

Women from Tacana, Guatemala, carrying water to their households; through the PRESANCA and PRESISAN initiatives, beneficiaries in the vulnerable communities become FCAC and FAPC end users


Image: PRESANCA II-SICA

Beneficiaries of the Presanca programme at San Jose Cusmapa preparing a seedbed guided by facilitators; climate risk scenarios are used to manage climate risk in the communities

On the other hand, the component for reaching the users of the Central America Climate Outlook (CA-CO) has been based on a clear and concrete report structure, supported by broad electronic dissemination and the use of graphic resources to share the information, including a probability map according to precipitation scenarios – higher than normal, normal or lower than normal – and a table of the regions in all countries, according to those scenarios. This has enabled it to focus the attention of users, whose number and interest have increased with each new report delivered and shared with the community.

Since 2000, the FCAC has issued 38 seasonal outlooks, quite an accomplishment by the Central America Regional Committee on Hydraulic Resources (CRRH) member countries, through their NMHSs which contribute specialized human resources, data analysis work and development of services and products to benefit the region. All of this is facilitated by the logistics management and coordination of the CRRH Executive Secretariat and supported by the Central American Integration System (SICA). FCAC technical meetings have received funding from various donors including the European Union, the Government of Taiwan, the Government of Mexico, the Fiduciary Fund of Spain in the WMO and the National Oceanic and Atmospheric Administration, among others.

Supporting the FCAC and FAPC

The 'Strategic Framework to face the situation of food and nutrition insecurity associated to conditions of drought and climate change' approved by the Central American Presidents in December 2002, placed the mandate to support actions on food security, including the management of climate risk by all the regional institutions involved. This strategy adopted the CA-CO as its technical reference for mitigating and preventing the impacts of climate variability and change. It also recognizes the CA-CO as a dependable source of information for the governments in the region regarding decision-making related to reducing vulnerability to climate. In subsequent decisions, the Central American Presidents have stressed the need to manage climate risk as one of the priorities for all of these countries, as expressed in the Extraordinary Summit of Heads of State and Government of the SICA Member Countries in October 2011; 37th Ordinary Meeting of Heads of State and Government of the SICA Member Countries in December 2011.

Based on such framework, SICA's regional technical secretariats of fisheries, agriculture, risk management, health, water and sanitation and food security participate in the process of interpreting the results of the CA-CO for FNS, placing special emphasis on the areas seasonally or chronically affected by food production or access problems. After 13 years, the CA-CO reaches hundreds of users directly and keeps increasing its seasonal demand, as all those users employ it as a reference resource every three months for decision-making on diverse activities to assure food security.

FAPC

Starting in 2006, CRRH and the Regional Program for Food and Nutrition Security (PREFNSCA), funded by the European Union, promoted the FAPC for the purpose of reinterpreting climate outlooks in terms of climate hazards relevant to the sectors involved in FNS, and thus became the first users of the FCAC output. In the FAPC, experts from all those sectors work with FCAC experts, analysing and taking ownership of the forecast in order to jointly generate climate risk scenarios specific to the sectors. Based on these scenarios, they identify measures for managing the risk.

The output of the FAPC, a quarterly seasonal outlook, is disseminated using SICA mechanisms through its sectoral regional secretariats. These technical secretariats use their networks of government organizations and ministries, secretariats and cabinets responsible for food security management, each under their own mandate, to spread the results of the FCAC and FAPC for technical and political decision-making regarding food insecurity.

The PRESANCA II Programme, working with highly vulnerable communities of Central America, provides support in several ways, including technical advice. All PRESANCA activities are intended to solve pre-existing food insecurity as well as to prevent it. The FAPC serves as a starting point for discussion at national level, in the fora currently promoted by PRESISAN-PRESANCA II, where emphasis is placed on actions intended to avoid losses on harvesting and basic goods, so the vulnerable communities can reduce the impact of climate variability on their livelihoods.

These fora prioritize seasonal analysis of the implications and conditions associated with climate variability and its impacts on the various sectors and on FNS, depending on the season of the year, with the participation of private officials and stakeholders who give a new context to the information.

New resources to support the FCAC and FAPC process

To support these processes the NMHSs, coordinated by CRRH, have constructed a Central America Climate Database through the Regional Fund for Public Assets of the Inter-American Development Bank. This has enabled the quality-controlled collection, ordering and classification of historical records from over 150 weather stations in the seven countries and, with the support of the PREVDA programme, the Central American Meteorological and Hydrological Integration Center – an information-sharing platform that will improve virtual technical coordination between the meteorological and hydrological services.

Challenges

The main challenges facing the FCAC and FAPC are the introduction of more information contributed by users' sectors for the development of situational analyses and their involvement in financial sustainability to ensure continuity of this process.

FCAC and FAPC have responded to an unsatisfied need, filling the seasonal climate information gap that existed previously. The results of this initiative include facilitating the exchange of information between countries, sectors and institutional and individual, public and private users. In addition, FCAC and FAPC are promoting better knowledge of the potential of weather outlooks and increased expectations for more products and services in response to situations associated with particular behaviours of climate variability.

FCAC and FAPC are used as technical reference for the national fora coordinated by PREFNSCA, where inter-sectoral institutions discuss seasonal issues associated with FNS in each country. However, there is currently no way to measure its impact in improving FNS conditions. It should be noted that food insecurity problems are of a structural nature and climate variability, although a relevant part, represents only one of the factors that influence it. However, recognizing that it will have an impact, a contingent evaluation instrument is expected to be developed by FAPC for reducing food insecurity associated to climate risk.

The working model described is based on acceptance that the national weather services have limited conditions and resources, but their capacities to generate products and services are enhanced by regional technical cooperation, integrated into working groups. This sectoral model at Central American scale has been possible thanks to the existence of a regional institutionality represented by SICA and supported by a political mandate at the highest level, which has prioritized risk reduction and promoted joint work by the regional sectoral institutions on all issues related to that risk and to FNS. This makes the Central American experience an example that can be replicated in other regions that share the same limitations, and which can contribute to sectoral institutional integration at regional and national level.

Applying the climate outlook to the fisheries sector, December 2011-January 2012

Above normal rainfall scenario	Possible effects	Suggested measures
Sea and fisheries	Intense rainfall events; and high river flows likely to impact aquaculture of shrimp and tilapia Severe weather conditions very likely to affect fishing activities and damage public roads and infrastructure High risk of red tide because of sudden increased of plankton organisms	Strengthen communication with National Weather Services and promote effective communication channels for dissemination of alerts
Aquaculture	Impacts on shrimp and tilapia ponds because of overflowing or dam breaks, loss of animals, larvae and risk of viral diseases	For fisheries authorities: Be prepared with maps and contacts of producers for easy alert distribution and help. Strengthen bulwarks Help producers to develop their contingency plans Be prepared with extra empty ponds to move displaced animals from impacted areas
Artisan fisheries	Loss of days at sea Loss of fishing gear	For social system authorities: Contingency/emergency help for families depending on daily catches Contingency funds to help small fisheries replace fishing gear Strengthen controls and/or help small fisheries with communications and security equipment

Source: Jorge Lopez-OSPESCA

MOSAICC: an interdisciplinary system of models to evaluate the impact of climate change on agriculture

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The Food and Agriculture Organization of the United Nations (FAO), in partnership with European research institutes, has developed an integrated suite of models for assessing the impact of climate change on agriculture at a national level. The Modelling System for Agricultural Impacts of Climate Change (MOSAICC) is based on a generic methodology defined to assess the impact of climate change on agriculture, covering climate data downscaling, crop yield projections, water resource estimations and an economic model. The economic model is a computable general equilibrium (CGE) model designed to assess the impacts of changing in yields on the economy at national level. All models are connected through common spatial database architecture and interconnected in terms of input and output. All models and databases are platform independent and can be hosted on a central server. Multiple users can access the MOSAICC toolbox simultaneously through a common web interface, making data exchange easier, transparent and more efficient for users.

MOSAICC is unique and innovative as it combines a web-based interactive and integrated modelling environment with tools and materials for capacity building and technology transfer to (government) institutions

Image: courtesy of Roberto Sandoval

Training on the MOSAICC system in the Philippines and scientists. The specific design allows interdisciplinary working groups to stimulate cooperation and foster knowledge exchange. Currently, the MOSAICC toolbox is under validation in Morocco, after which it will be implemented in other countries. The model development is funded by the European Union programme, Improved Global Governance for Hunger Reduction.

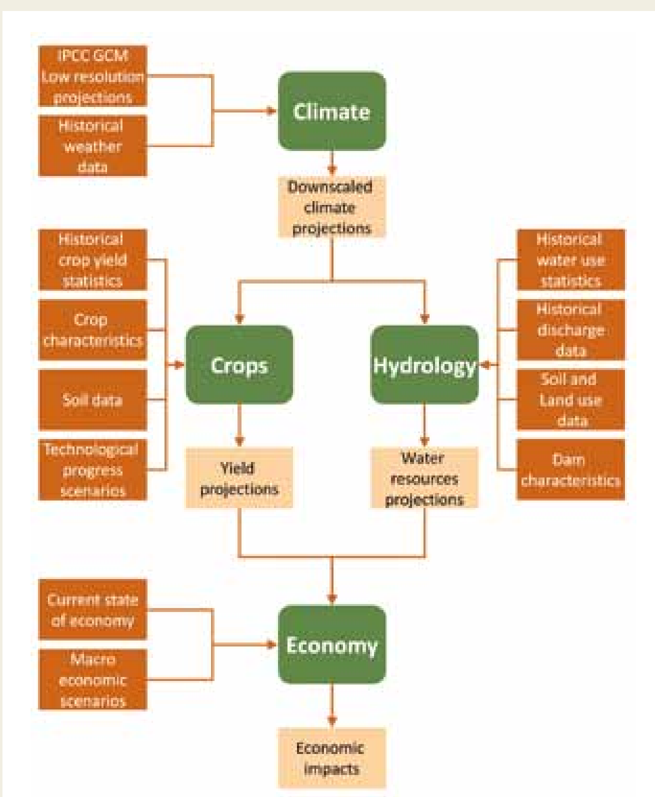
The system

The assemblage of the MOSAICC toolbox is based on a generic methodology defined to assess the impact of climate change on agriculture, including statistical downscaling of climate data, crop yield projections, water resources estimations and economic modelling. Low-resolution (typically 250 km) climate data serve as primary input for the whole model structure. These datasets feed the hydrological and crop models, which need information on elevation, land cover and soil. The outputs of these models subsequently serve as input for the economic impact assessment.

Statistical downscaling portal for climate data

The climate scenario predictions are produced using observed weather time series combined with global climate models (GCM). The coarse resolution of the GCM needs to be downscaled to make it applicable for the regional or country scale. A statistical downscaling tool based on the Data Access and Downscaling tool is used.[1] This tool allows for downscaling large-scale predictors of data on precipitation and minimum and maximum temperature to a set of weather stations, provided enough observations are available.

A methodological flow-chart of MOSAICC



Source: FAO

Crop growth simulation

Two different models were selected to estimate the crop yield. The first model is called WABAL, and was designed to simulate the soil water balance at crop level. Basically, it is a vertical soil profile, with no explicit spatial extent. It is usually used at the level of agrometeorological stations, pixels or cultivated areas. The model requires a minimum number of inputs on precipitation, evapotranspiration, soil water holding capacity and crop parameters. Variables like the water requirement satisfaction index, water surplus or deficit and actual evapotranspiration are the outputs of WABAL. The second model, also developed by FAO, is AQUACROP.[2] This model simulates the crop response to water in a more sophisticated way. AQUACROP requires crop parameters (data on crop physiology, cultivars, management) that are much more sophisticated and more difficult to acquire than the ones needed for WABAL. A distinction is made between crop transpiration and soil evaporation; furthermore the root development and canopy cover can be simulated. Crop water stress, biomass production and yield estimates are part of the outputs. In addition, CO_2 concentration in the atmosphere can be taken into account. The selection between WABAL and AQUACROP depends on the availability and detail of climate information at country level.

Hydrological modelling

The Spatial Tools for River basins and Environment and Analysis of Management options (STREAM)[3] is a grid-based spatially-explicit distributed water balance model that describes the hydrological cycle as a series of storage compartments and flows. It was originally designed for river basin studies with an emphasis on water management aspects. The original version has been successfully applied at spatial scales ranging from small sub-basins[4] through medium to large basins such as Krishna,[5] Zambezi[6] and Meuse,[7] up to the (sub-) continental and global scale. STREAM calculates the water balance per time-step (user-defined, typically 10-30 days) for a spatially distributed gridded landscape. The model requires information on precipitation, temperature, land cover, soil type, depth and elevation. From temperature data the actual and potential evapotranspiration are calculated using the Thornthwaite equations.[8] MOSAICC uses the open source version of STREAM; this version presents the advantages of handling direct data on evaporation and the ability to integrate dams using an automatic calibration procedure. Furthermore, a new procedure for flow accumulation has been implemented in this version of STREAM.

Economic modelling

The economic modelling comprises a dynamic CGE model that simulates the evolution of the economy based on variations in crop yield projection.[9] The model allows the user to define multiple activities producing one commodity. To allow a spatial variation, commodities can be produced by different activities. The CGE is based on activities, commodities and regions. Data from other models are aggregated before being entered into to the CGE. The model accounts for different crops as well as differentiated crop yields across the country. The effect of crop yield variations is simulated using a shift parameter in the activity production functions. The model provides estimations for all the endogenous variables (such as commodity prices, imports, taxes, household income and savings). A set of inputs (benchmark) including values of all these variables at a given time is used to calibrate the model. Then when shocks are simulated using the exogenous variables (changing crop yields for example), these variables get new values (output). The effects of changing yields can be assessed by comparing benchmark and 'shocked' situations. Climate change can affect agricultural production. First, yield changes predicted by one of the crop models (WABAL or AQUACROP) are passed on to the economic model through exogenous shocks to a technical shift parameter in the production function. Changes in the availability of irrigation water predicted by the STREAM model are passed to the economic model through an exogenous decrease of the water endowment.

Results

The MOSAICC toolbox is still in development stage, and no in-depth testing has yet been carried out. The alpha version of the interface is divided into five different sections: Home, Functions, Data, Tools and Documents. In the Functions section, all models can be accessed. All models are displayed as separate models, for which the input data and parameters can be specified by browsing through different pages. Climate scenarios can be downscaled and upscaled through space and time and calibrated with in situ data. After specifying all input data, the selected model can be run. The input and output data are stored on the server; they can be explored in the Data section and subsequently be used as input for downstream models. All data are attached to a personal user profile and can be shared among different users. The Tools section contains information on all the past model runs. Furthermore, a document section is available, which contains information on all the models.

Lessons learned

The MOSAICC toolbox is a complex project, because it assimilates different methodological approaches in a comprehensive manner. The inherent complexities originate from the social, physical and technical interactions which all have their own sources of uncertainty. A model's performance depends on many variables such as quality of input data, model structure, calibration, and validation. The MOSAICC toolbox is not flawless from a scientific technical perspective. However, the goals of the project reach much further than simple technical model integration. The MOSAICC toolbox is actually a very novel and innovative approach to developing, comparing and evaluating the impact of climate change in an interactive way, where state-of-the-art technologies are used in a bottom-up management strategy.

MOSAICC is a tool used to develop institutions' technical capacities to produce information on climate change and agriculture; in agreement with the Principles of the Global Framework for Climate Services. Furthermore, partnerships are designed in a way to transfer the ownership of the MOSAICC system to the institutions and eventually to involve the partners in the development, the testing and dissemination of the system.

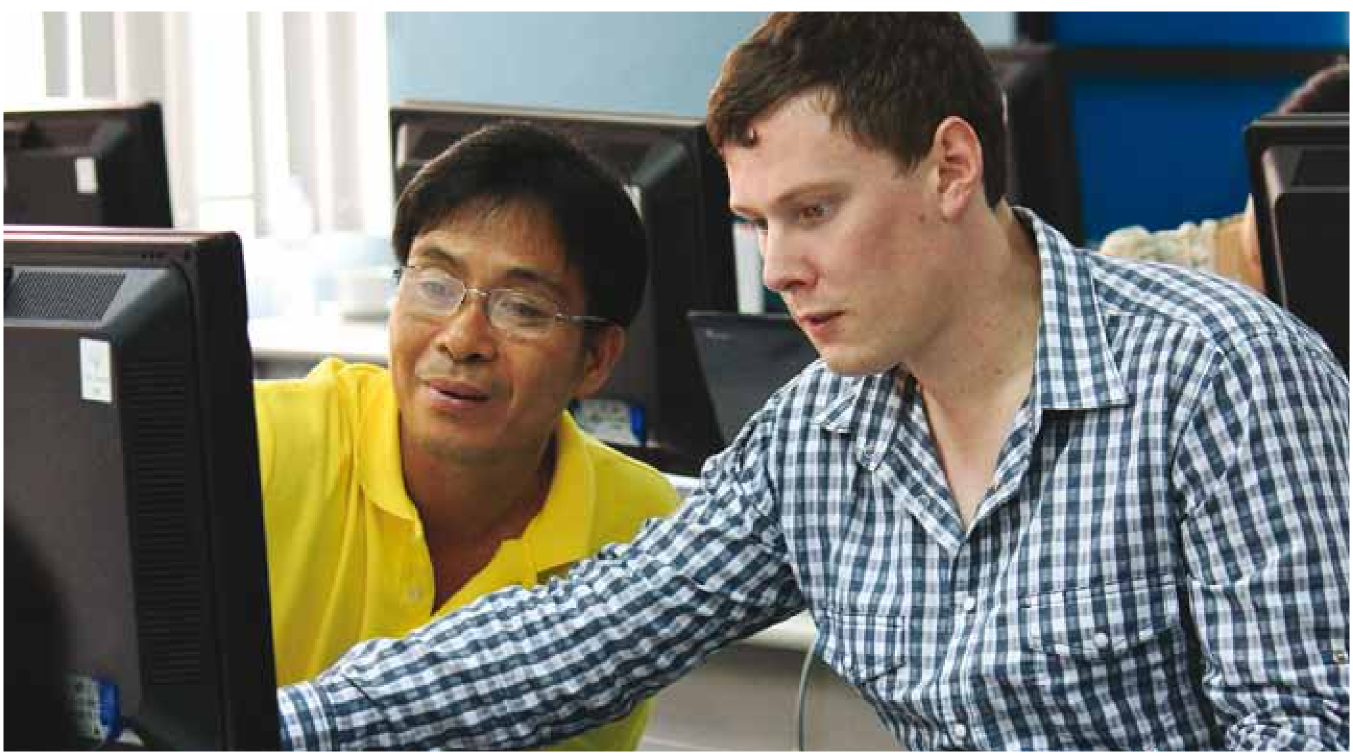


Image: courtesy of Roberto Sandoval

MOSAICC system training

Climate information services for herder families in Mongolia

National Weather and Hydrological Service, Mongolia

The people of Mongolia live under extremely harsh weather and climate conditions. Their daily behaviour is directly dependent on weather, therefore weather and climate information are very important and hold significant benefits for them.

Today, these people are facing many challenging issues due to climate changes and the increase of greenhouse gases in the atmosphere, a phenomenon caused by human activity. In the last 70 years, the annual mean air temperature of Mongolia has increased by 2.1^0C and annual precipitation has decreased by nearly ten per cent between 1940 and 2011. This condition is causing dryness and intensifying the severity and harshness of weather and climate compared with previous years. One fact which exemplifies this change is that the frequency of almost all types of atmospheric extreme events has doubled in the last decade compared to the previous decade.

Under the influence of this climate change, the Mongolian climate is becoming more severe and harsh with the risk of significant impacts for the country's citizens, especially rural communities and herder families.

Image: National Weather and Hydrological Service, Mongolia

Typical herders wintering, Tsogt-ovoo soum of Umnugobi aimag, 2008

Currently in Mongolia, the agriculture sector produces 20 per cent of the country's gross domestic product. Among them, the livestock sector accounts for nearly 80 per cent of total agriculture production. The livestock sector is based on a traditional nomadic pasture system and a herder family's livelihood is much dependent and influenced by weather and climate.

Every year in summer and autumn, herder families need to prepare for the oncoming winter and spring, to prevent the loss of their livestock. To prepare for winter, the conditions of the past summer in terms of biomass and vegetation growth, and the coming winter weather and climate outlook are essential information for decision-makers at *soum* (small administrative unit), *aimag* (province) and country level as they plan the migration of herder families, prepare hay and arrange other measures.

According to government resolution No. 190, which considers measures to protect livestock from drought and harsh winter (*zud*), an assessment of pasture capacity must be carried out over Mongolia in August every year. Using this information, the winter weather and climate outlook is prepared and disseminated by Mongolia's National Weather and Hydrological Service.

This climate information is fundamentally important for planning the following activities:

- Organizing the wintering-springing of livestock
- Balancing the use of pasture in an effective way
- Warning herder communities as early as possible about warm harsh winters
- Assessing the main human factors influencing pasture and grazing.

Long-term pasture monitoring in Mongolia has been carried out every year since 2001, at 1,550 points across the country using 'line point intercept' methodology. Simultaneously, the number and type of livestock, area of pasture in hectares and the number of days the pasture is expected to be used is gathered from the monitoring points in order to assess pasture capacity.

For instance, in the winter-spring of 2011-2012 the summer condition was normal over 70 per cent of the country, with semi-drought in 25 per cent and drought in 5 per cent. Generally, summer conditions were quiet good and the carrying pasture capacity was enough for livestock wintering. An exact assessment showed that

Pasture capacity and number of livestock losses in Mongolia during the past decade

Year of pasture capacity for winter-spring	Area of semi-drought and drought (%)	Area of territory (%)				Number of livestock losses, (million head of sheep)
		Pasture resource (0-50%)	Enough pasture (51-100%)	Pasture exceeds 1-3 times (101-300%)	Pasture exceeds many times (>301%)	
2001-2002	80	30.8	21.9	21.5	25.8	2.743
2002-2003	70	30.0	15.0	35.0	20.0	1.218
2002-2003	15	61.5	20.7	17.7	-	0.227
2004-2005	60	46.0	25.5	24.5	4.0	0.601
2005-2006	50	39.8	24.4	30.0	5.6	0.413
2006-2007	40	40.8	25.5	22.3	11.4	0.222
2007-2008	70	30.4	14.2	26.4	29.0	1.531
2008-2009	40	30	20	20	30	1.598
2009-2010	60	35	10	20	35	10.319
2010-2011	50	45	20	20	15	0.506
2011-2012	30	70	10	10	10	-

Source: National Weather and Hydrological Service, Mongolia

Image: National Weather and Hydrological Service, Mongolia

A livestock pasture in Mongolia

70 per cent of the total territory had pasture resource, 10 per cent had enough pasture, a further 10 per cent was by one to three times overgrazed, 5 per cent was three to five times overgrazed, and 5 per cent was more than five times overgrazed by livestock.

Pasture capacity is directly controlled by summer conditions. If drought has persisted in the summer season in a certain region, its carrying capacity will probably be exceeded many times. This condition is combined with extreme weather, with the result that the livestock wintering situation becomes serious with mass livestock losses.

The National Weather and Hydrological Service in Mongolia officially releases climate information based on harmonizing pasture carrying capacity and the winter climate outlook, and organizes seminars among stakeholders every autumn. Official climate information is disseminated to the Government, public and private sectors, and to herder communities through the mass media.

Providing end users with such climate information is especially beneficial for herders' families, helping them to adapt to the changing environment and climate and to reduce their vulnerability to the risks and impacts associated with climate change.

Climate change adaptation methodologies in the Bay of Bengal fishing communities

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The Bay of Bengal Large Marine Ecosystem (BOBLME) comprising the Bay of Bengal, the Andaman Sea and the Straits of Malacca is a large but relatively shallow embayment of the north-eastern Indian Ocean. Eight countries border the BOBLME: the Maldives, Sri Lanka, India (east coast), Bangladesh, Myanmar, Thailand, Indonesia and Malaysia. Located in the tropics, the climate of the BOBLME is dominated by the two monsoons, the South-west and the North-east monsoon. However, the monsoonal rainfall is not continuous, rather discrete with periods of heavy rainfall events. The region is also highly prone to cyclones and storm surges and about seven per cent of the global cyclonic events occur in this region.

The waters of the BOBLME are highly productive and rich in biodiversity. Until the 1970s, marine fishery in the Bay was limited to coastal waters using traditional craft and gear. However, since the 1980s, rapid motorization and mechanization in the region has led to considerable expansion of the fishery into offshore waters. The total marine capture fisheries production from the BOBLME has increased from 1,451,905 tonnes in 1979 to 4,170,138 tonnes in 2006, with an annual average growth rate of seven per cent[1].

The socio-economic scenario in the BOBLME

The countries surrounding the BOBLME are largely lower to middle income economies, characterized by high population and below average level of human development (see table). This macroeconomic scenario is mirrored in the coastal region in general and fisheries in particular. Some studies have estimated that during 1990 about 400 million people were living in the LME's catchment area and many of them were subsisting at or below poverty level[2].

Being a traditional activity in the region, marine capture fishing has not only been practiced from time immemorial, but is usually associated with the same social or ethnic groups. However, this composition is changing rapidly as people from other primary activities are migrating to fisheries and constituting a growing part-time work force in the sector. Although a small portion, relatively well-off people from traditional fishing communities are also migrating to other sectors.

Marine fisheries, being de facto open access regime in the region, are characterized by a large number of fishers and fishing vessels (see table), and growing. For example, the total number of fishing vessels in Bangladesh, India, Maldives and Sri Lanka has increased from 0.17 million to 0.92 million between 1998 and 2010. This race to fish can to an extent be attributed to improving integration of coastal economies with national and international economies.

To sum up, despite being an important economic activity in the region, the fisheries sector is passing through a difficult stage. The sector is yet to stabilize and sustainability of the observed growth is questionable. The situation is further aggravated by a general lack of information on the state of fisheries resources as well as socio-economic attributes of fishers in the region.

Human development in the BOBLME region

Country	Population (2010)[a]	Population Density (people per sq. km, 2010)[a]	Human Development Index – 2011 (Level)[b]	Population living on less than $1.25 a day at 2005 international prices[c]
Bangladesh	148,692,000	1032.6	0.500 (low)	43.3 (2010)
India	1,224,614,000	372.5	0.547 (medium)	32.7 (2010)
Indonesia	239,871,000	125.9	0.617 (medium)	18.1 (2010)
Malaysia	28,401,000	86.1	0.761 (high)	0.2 (2009, $2)
Maldives	316,000	1060	0.661 (medium)	-
Myanmar	47,963,000	70.9	0.483 (low)	NA
Sri Lanka	20,860,000	317.9	0.691 (medium)	7.0 (2007)
Thailand	69,122,000	134.7	0.682 (medium)	0.4 (2009)

Source: a. FAO: FAO Statistical Yearbook 2012; b. UNDP: Human Development Report, 2011; c. World Bank: World Development Indicator

Fisher population and total fishing fleet in the BOBLME region

Country	Fisher folk population (2010)	Total fishing fleet (2010)	Exclusive economic zone (sq km)[c]	Marine capture fisheries production, 2010 (in tonnes)
Bangladesh[a]	902,961	50,555	78,538	607,492
India[a]	4, 054,802	194,490	2,290,268	3,226,213
Indonesia[b]	5,971,725	570,827	3,617,349	5,039,416
Malaysia[b]	155,913	49,756	447,276	1,428,881
Maldives[a]	14,241	979	916,189	94,953
Myanmar[b]	3,160,070	32,824	520,262	2,048,590
Sri Lanka[a]	825,200	46,138	530,684	385, 058
Thailand[b]	-	-	306,365	1,617,399

Source: a. Anon (2012) Annual report of the Bay of Bengal Programme Inter-Governmental Organisation. BOBP-IGO, 2012; b. Anon (2010) Fishery Statistics Bulletin of Southeast Asia. SEAFDEC, 2010; c. Sea Around Us Project, 2012 (May differ with EEZ presented by national governments)

Given the scenario, it is difficult to predict the impact of a shock or stimulus such as changing climate. While gauging the impacts of the changing climate is a priority area in research and policy discussions, different scenarios have emerged from such discourses, which are at best conjectures. As a result, dealing with climate change requires flexibility and constant monitoring for timely action.

Possible impact of changing climate on the fisheries sector in the BOBLME region

A global study, Vulnerability of National Economies to the Impacts of Climate Change on Fisheries,[3] has estimated the sensitivity, adaptive capacity and vulnerability of the national economies to changing climate and shows that the region has low adaptive capacity and is moderately vulnerable, except Bangladesh, which is highly vulnerable.

Analyzing the data on sea surface temperature (SST) and other parameters from a variety of global sources, Vivekanandan et al. (2009) found warming of the sea surface along the entire Indian coast. The SST increased by 0.2ºC along the northwest, southwest and northeast coasts and by 0.3ºC along the southeast coast during the 45-year period from 1961 to 2005. The study has predicted that the annual average SST in the Indian seas would increase by 2.0ºC to 3.5ºC by 2099. The study has also predicted several scenarios, which include regional extinction of some tropical fish stocks and some other stocks moving towards higher latitudes. Other studies carried out by the Indian Council of Agricultural Research in this regard show that different Indian marine species will respond to

Image: S Jayaraj

Interaction with Sembasipalli fishers on the impact of climate change on fisheries

Image: S Jayaraj

Awareness programme for fishers in Cox's Bazaar, Bangladesh

Image: S Jayaraj

Changes in the distribution of fish species in the Bay of Bengal region is also necessitating alterations in the fishing gear and harvesting practices

Image: S Jayaraj

Climate change has greater implications on the small-scale and artisanal fisheries in the Bay of Bengal region

climate change differently and the overall change may remain unpredictable.

For example, the oil sardine *Sardinella longiceps* and the Indian mackerel *Rastrelliger kanagurta* accounted for 21 per cent of the marine fish catch in 2006. These small pelagics, especially the oil sardines, have been known for restricted distribution — between latitude 8ºN and 14ºN and longitude 75ºE and 77ºE (Malabar upwelling zone along the southwest coast of India) where the annual average SST ranges from 27 to 29ºC. Until 1985, almost the entire catch was from the Malabar upwelling zone and there was little or no catch from latitudes north of 14ºN. However, during the last two decades, with the warming of waters in latitudes north of 14ºN (by 0.04ºC per decade), the oil sardine is moving to northern latitudes. It has also been found that catches from the Malabar upwelling zone have not gone down. This infers that the oil sardine fishery is extending northward, not shifting northward.

In a similar way, the study also shows that the Indian mackerel is found to be extending northwards. However, besides exploring northern waters, the Indian mackerel has been descending deeper as well during the last two decades. The species normally occupies surface and sub-surface waters. During 1985-89, only two per cent of the mackerel catch was from bottom trawlers, the remainder was caught by pelagic gear. However, during 2003-2007 an estimated 15 per cent of the mackerel has been caught by bottom trawlers, indicating that mackerel has been extending deeper and downward as well.

Hilsa, the national fish of Bangladesh, accounts for 13-14 per cent of the total fish production of the country. During the last two decades, hilsa production from inland waters has declined by about 20 per cent, whereas a threefold increase is seen in the yield from the marine waters. Scientists are attributing this shift to climatic aberrations occurring during the last decade or so.

However, one of the biggest challenges will be dealing with rising sea level and coastal erosion. Erosion due to sea level rise in the region is estimated to be 7,125m^3 per year, implying an erosion rate of 0.3x106m^4 per year. Using the extreme conditions of wave height and sea level rise, erosion is expected to increase by 15.3 percent by the year 2100. Presently, most of the fishers in the region are living within the high tide line. Due to expanding urbanization and industrialization, cities are also rapidly inching towards the buffer zone. In India between 2001 and 2011, coastal population has increased from 163 million to 184 million (13%) putting more pressure on the already densely populated coastal regions of the country.

Apart from such impacts, climate change will have implications for health, availability of food and physical infrastructure. Fishers living very close to the sea are ill-prepared to face such changes and in the final analysis these general socio-environmental impacts may further accentuate the sector specific risks from changing climate, thereby increasing the vulnerability of fishers.

Improving fisheries management

By now most countries in the BOBLME region have developed adaptation plans for climate change. However, these plans being economy-wide have little specific measures for the fisheries sector and action on them has also been tardy. The primary reason for the slow development is lack of resources and lack of an effective implementation programme that could make best use of available limited resources. From the present state of affairs, it is also seen that for adapting to climate change it is necessary to first strengthen the existing management measures and their successful implementation.

The fisheries sector is facing the familiar problems of overfishing, pollution and habitat degradation. Reducing fishing mortality in the majority of fisheries, which are currently fully exploited or overexploited, is one of the principal means of reducing the impacts of climate change. Reduction of fishing effort will (i) maximize sustainable yields, (ii) help adaptation of fish stocks and marine ecosystems to climate impacts, and (iii) reduce greenhouse gas emission by fishing boats. In this regards, it is also necessary to seriously consider adapting the FAO's Code of Conduct for Responsible Fisheries.

Monitoring, Control and Surveillance (MCS) mechanisms need to be improved to observe and manage the fish stocks and fishing efforts. MCS should also include collection of climatic and oceanographic data. Long-term environmental and ecological monitoring programmes are important, since data cannot be collected retrospectively. In India, spatial marine fish catch and effort data are available for the last four decades but a synergy between climatic and oceanographic data and fisheries data is lacking. Projections on climate change impact on fish populations need to be developed as the first step for future analytical and empirical models, and for planning better management adaptations. In most of the other countries in the region, the data collections mechanisms also need to be further strengthened to draw conclusions on the impact of climate change on fisheries.

Towards a methodology for adapting to climate change in the BOBLME region[4]

Taking preventive measures — Coastal planning should take into account the impacts of climate change, especially sea level rise, SST, prolonged droughts, severe rainfall, cyclones and storm surges. Integrated coastal zone management is essential for coastal zone planning, management, monitoring and evaluation. It requires close coordination with government agencies and communities. Coastal communities should be prepared to combat climate change through disaster preparedness activities.

Increased awareness on the impacts of climate change — Countries should prepare specific policy documents on the implications of climate change for fisheries sector. These documents should take into account all relevant social, economic and environmental policies and actions including education, training and public awareness related to climate change. Effort is also required to raise awareness of the impact, vulnerability, adaptation and mitigation related to climate change among all stakeholders so that they can become watchful and perceptive.

Research requirements — All these procedures should be guided by a cooperative research programme. That is a programme not just specifically for climate change but more on how to move from the present state to a state of readiness. This should also involve a two-way interaction with the fishers to keep them informed of the developments at all times.

Presently, options for adaptation to climate change in the BOBLME region are limited but do exist. In the present context, the primary challenge before the fisheries sector is to ensure food and nutritional security, improve livelihood and economic output, and ensure ecosystem integrity. These objectives call for identifying and addressing the concerns arising out of climate change; evolving adaptive mechanisms and implementing action across all stakeholders at national, regional and international levels.

Image: S Jayaraj

Increased landings of low value species such as oil sardines require interventions in post-harvest methodologies, especially for fisher women in the region

Case study: Sembasipalli village, Pulicat, Tamil Nadu

Sembasipalli village is located 50km to the north of Chennai city and lies on margin of Pulicat Lake, one of the largest brackish water lakes in India. The village has 250 households, with a total population of 920.

Sembasipalli has 262 active fishers and a fleet of 86 motorized boats. Fishing and fishing-related activities and rearing of livestock form the major economic activity in the village. Most fishing is carried out with set bag nets in the estuarine waters during monsoon and gill nets and purse-seines throughout the year in the lake and the adjacent sea. The major species harvested include: Indian mackerel, oil and lesser sardines, prawns and crabs.

Mullets and Lactarius spp. formed the dominant fishery in the late eighties, but have gradually declined and are now rarely found in the lake fishery. This is due primarily to: reduced rainfall, siltation of the lake mouth and consequent decreased inflows and less water exchange, increase in temperature and reduction in water level due to heavy intake of water by the neighbouring thermal power plant at Ennore. The villagers feel that besides the impacts of the thermal power plant, the repeated delay in the onset of monsoon in the area is affecting the spawning of fish and thereby reduction in fish abundance.

Due to the decline in fish catches from the lake and coastal waters, the fishers are venturing into the deeper waters. Ten years ago the fishers were fishing in depths of 12-15 fathoms, but now they are fishing in 25-35 fathoms, an increased distance of 5-8km from the traditional fishing grounds. As compared to previous years, the Indian mackerels and oil sardine are now dominating the landings.

The fishers of Sembasipalli seem to be more aware of the phenomenon of changing climate. From the general observations, the villagers have reported occurrences of erratic winds after the December 2004 Asian Tsunami, increased SST and sea level. The villagers feel that their day-to-day life is affected by the changing climate and they would like to learn more about the science behind the climate change phenomenon and adaptation of climate change through awareness programmes.

Improved livelihoods and building resilience in the semi-arid tropics: science-led, knowledge-based watershed management

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Rainfed agriculture (1.25 billion hectares out of 1.55 billion hectares arable area) plays an important role globally in improving livelihoods and food security as it covers 63 per cent of total agriculture in Asia and 97 per cent in Africa. These areas are not only the hotspots of poverty but are also food insecure, hotspots of malnutrition, water scarcity, prone to severe land degradation and more vulnerable to the impacts of climate change.[1] With increasing demand for food production to meet the needs of the growing population (9 billion by 2050), growing incomes and changing food habits, water scarcity will also intensify. The per-capita availability of water has declined considerably; for example, in India water availability was 1,820 cubic metres per person in 2001 compared to 5,177 cubic metres in 1951, and it is expected to decrease further to 1,341 cubic metres by 2025 and 1140 cubic metres by 2050.

Water is a finite natural resource and agriculture is a major user, with 70 per cent of water withdrawal globally for food production. Green water (such as rainwater stored in the soil profile) is a valuable resource and often neglected when considering water management for food production, which constitutes 85 per cent of total freshwater use in crop plants and 98 per cent in grassland across the world.[2] With competing demand from other sectors like domestic, industry and ecosystem management, the pressure for efficient water use by agriculture will grow. Water is the primary limiting factor in dryland the water scarcity scenario in developing countries. Rainfed agriculture has a vast untapped potential, as the current farmers' yields are lower by two to five times that of achievable crop yields in Asia and Africa.[3]

Now, however, there is a new paradigm to unlock the potential of rainfed agriculture and build resilience against the impacts of climate change through knowledge-based interventions at watershed scale.

Impacts of climate change

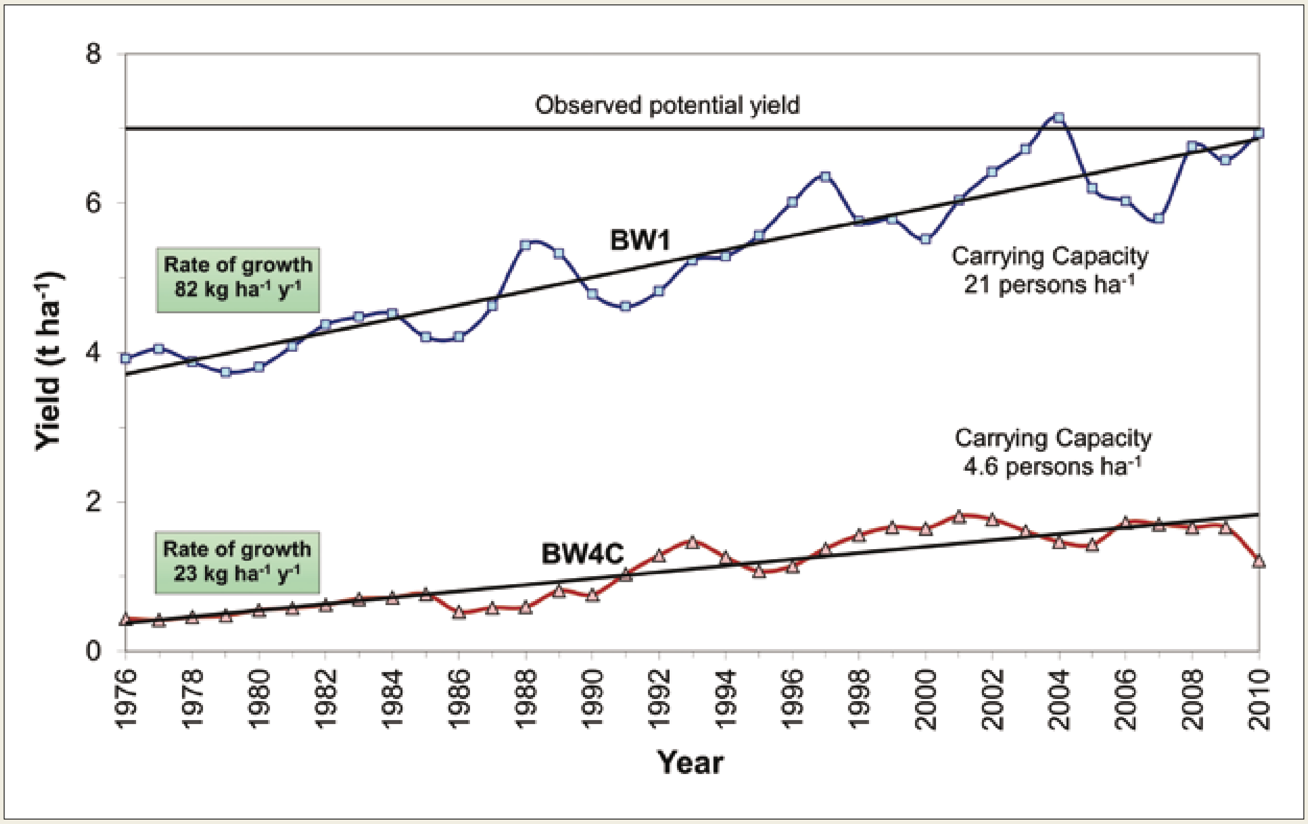
With the growing evidence of global warming and its associated impacts on climate change, the existing water scarcity scenario is getting further exacerbated by the increased variability of rainfall events during the season. Although impacts of climate change at macro level are established, a large knowledge gap exists at local level about the impacts of climate change. Further, millions of smallholders and development workers in Asia and Africa are not aware of the local impacts of climate change in their regions. For example, analysis at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has revealed that at Patancheru in India, a paradox of decreasing evapotranspiration under increasing temperature regime has been observed over the last 35 years, with a reduction of 200 mm y^{-1} in potential evapotranspiration from 1,850 mm to 1,650 mm largely due to decreasing wind speed.[4] Similarly, at Nemmikal watershed in the Nalgonda district of Andhra Pradesh, India, the length of the growing period (LGP) has decreased by about 15 days since 1978 and the climate has shifted to more aridity from semi-arid. The shift in LGP, if not understood by the farmers, generally results in more crop failures due to late season drought.

Another study using long-term gridded weather data sets in India revealed that 5.1 million hectares have become drier and 5.6 million hectares have become wetter during the periods 1971-1990 and 1991-2004. For example, Rajasthan (1.5 million hectares) and Gujarat (0.99 million hectares) became drier as some of the semi-arid tropic areas were converted into arid areas, with the largest shift in Madhya Pradesh where an additional 3.82 million hectares became semi-arid.

New paradigm

Considering the existing yield gaps and lack of knowledge for small and marginal farmers, ICRISAT and its partners have developed farmer-centric knowledge intensive soil, water, nutrient and crop management options at watershed scale through community participation.[5] Based on the participatory assessment of the constraints and potential as well as yield gap analysis using crop simulation models in consultation with community members, the potential interventions for rainwater harvesting, soil moisture conservation, soil fertility management, use of drought tolerant high-yielding cultivars, land and water management practices and integrated pest management options were introduced in partnership with the community.

Vast untapped potential of rainfed agriculture, (long term experiment at ICRISAT)



Source: ICRISAT

To provide the necessary knowledge to the farmers, an ICRISAT-led consortium comprising of national agricultural research systems, development agencies like government line departments and non-governmental organizations provided technical backstopping to the community. Soil health assessment, stress-tolerant high-yielding cultivars, water analysis and so on were used as an entry point for building rapport with the community. Improved rain-water management and harvesting resulted in ensuring increased green water use efficiency as well as augmenting water resources (ground and surface water) through low-cost water harvesting structures. Through watershed management, groundwater availability increased in benchmark watersheds in different states of India, Thailand, Vietnam and China.[6] The diagnostic participatory soil health assessment in the watershed revealed widespread deficiencies of zinc, boron and sulphur in farmers' fields which were holding back the potential of rainfed agriculture in the regions.[7]

Soil-test based plant nutrient management, along with seeds of improved cultivars, seed treatment and other soil and nutrient management practices, showed up to four-fold increases in crop yields at different benchmark watershed locations in India, Thailand, Vietnam and China. In addition, participatory watershed management reduced soil loss (by two to four times), increased groundwater recharge (2-3 m rise in the water table), reduced run-off (30-60 per cent), increased greenery cover and improved economic gains for the farmers. Social capital — in terms of collective action, institution building and self-help groups — provided add-on benefits from the integrated watershed management. These interventions at watershed scale have shown a win-win situation for upstream rainfed farmers with a positive trade-off in terms of a 30 per cent increase in incomes, with reduced run-off to the Osman sagar providing drinking water to Hyderabad, India with an additional cost of US$4 million.

These interventions improved green water use efficiency by 64-72 per cent, run-off reduced from 19 per cent to 8 per cent and enhanced groundwater recharge from 8 per cent to 20 per cent at the basin level. They also built resilience during the drought year, as evident from the data at Kothapally benchmark watershed. Here, in the 2002 drought year there was no change in the share of agricultural income to total family income in the watershed, whereas non-watershed villages saw a drastic reduction of agricultural income from 44 per cent to 12 per cent of family income. Families in non-watershed villages had to migrate for their livelihoods, whereas in Kothapally, farmers could manage their livelihoods.

ICRISAT and the Government of Karnataka have taken a knowledge-based, bridging yield gaps mission-mode initiative by forming a consortium and a network of stakeholders for sharing their knowledge about the weather as well as soil health and improved management practices covering all the 30 districts in the state. During the 2011 rainy season, the soil-test based nutrient management interventions along with improved seeds, seed treat-

Image: ICRISAT

Low-cost rainwater harvesting structures

ments and use of bio-fertilizers resulted in 21-66 per cent increases in crop yields covering three million hectares in 30 districts.

An innovative extension system was used as well as an institutional arrangement to empower the farmers through the Rytha Samparka Kendra (the state's extension service centre), farm facilitators and innovative supply chains. The missionary approach has shown its benefit for 3.3 million farmer families since 2009 through increases in productivity of 21-66 per cent over the farmers' practices. For the Government of Karnataka, this translated to an annual agricultural growth rate of 5.9 per cent during 2009-10, and 11.6 per cent growth during 2010-11. During 2011, three million hectares were covered in the rainy season and the economic returns were to the tune of US$ 130 million.

ICRISAT-led consortiums under the Andhra Pradesh Rural Livelihood Project of the Government of Andhra Pradesh and the Department for International Development have developed knowledge-sharing systems by developing a hub-and-spoke model at Addakal, one of the most drought-prone regions in Andhra Pradesh. The information and communication technology (ICT) based rural knowledge centre is operated by the women's self-help groups and is maintained not only as a knowledge-sharing system within the community, but also as a provider of financial services through cooperative banking and running a highway restaurant as to generate income. This ICT-based knowledge hub is under the Virtual Academy for the Semi-Arid Tropics and has been used further for providing ICT-enabled systems to enable early warnings for disaster management with a combination of top-down and bottom-up approaches and community mobilization.[8]

This pilot experiment revealed that the functional literacy of women was sufficient to handle ICT information hubs at watershed/village level and it enabled improved management of natural resources as well as improving their livelihoods by acting as a service provider to the community. The community actively participated in this initiative and has shown its potential for developing drought vulnerability assessments using ICT as a development tool with the help of intermediaries. The village knowledge centre is owned and operated by the community. Currently, the India Meteorological Department provides integrated advisory services for use by the farming community at district level. This network shares the information through email advisories, TV, mobile telephones and the radio network, and farmers are assisted with weather-based agro advisory through Krishi Vignan Kendras, enabling them to take advantage of prognosticated weather conditions and thereby form a response strategy.

There is an urgent need to develop a climate change network for Indian agriculture as well as for other countries in Asia and Africa by adopting a hybrid model of using ICT where it is feasible along with traditional communication channels like community radios, TV, mobile telephones and trained human resources at community and village level. This will go a long way in building the resilience of the community to cope with the impacts of climate change, particularly in rainfed areas of developing Asia and Africa. Such a knowledge network would enable the farmers to harness the untapped potential of rainfed agriculture for improving their livelihoods and achieving food security through sustainable intensification of rainfed agriculture.

Climate change impact on Indonesian fisheries

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Indonesia is one the largest archipelago countries in the world with total coastline exceeding 81,000 km and 5.8 million square metres of ocean. Indonesia is also the third-largest producer of captured fish in the world.[1] Therefore, fishery activities are economically and socially important in Indonesia. However, these activities start to decrease as a result of climate changes (weather uncertainty, extreme weather, increase of sea surface temperature (SST), decrease in oceanic primary productivity, changes in speed and direction of winds) and increasing fuel oil prices. Climate changes will also affect the distribution and abundance of fish in the sea, while the increase of fuel oil prices makes fishermen more reluctant to go sailing for fish. These factors cause fishing activities and productivity to slow down.

The global warming that occurred in the last three decades was caused by an increased concentration of greenhouse gases (GHGs) in the atmosphere such as CO_2, NO_2, and CH_4.[2] Compared with the SST annual average for 1951-1980, the annual average global SST has increased significantly, from about 0.1° C in 1981 to about 0.5° C in 2009.[3] This rise was concomitant with the increase of GHG concentration in the atmosphere, especially in the last three decades.[4] If there is no significant reduction of greenhouse gas emissions, some models have predicted a rise in global surface temperature in 2100 of 2.1-4.6° C, compared to the global surface temperature in 1990.[5] Based on the measurements of CO_2 at Mauna Loa, Hawaii and the South Pole, CO_2 concentrations continue to increase, from about 315 parts per million by volume (ppmv) in 1959 to about 385 ppmv in 2008.[6] This indicates an increase in the concentration of CO_2 in the atmosphere of about 1.4 ppmv every year over the last 50 years. The increasing trend of CO_2 concentration in Mauna Loa and the South Pole was also obtained in near-linear fashion.[7]

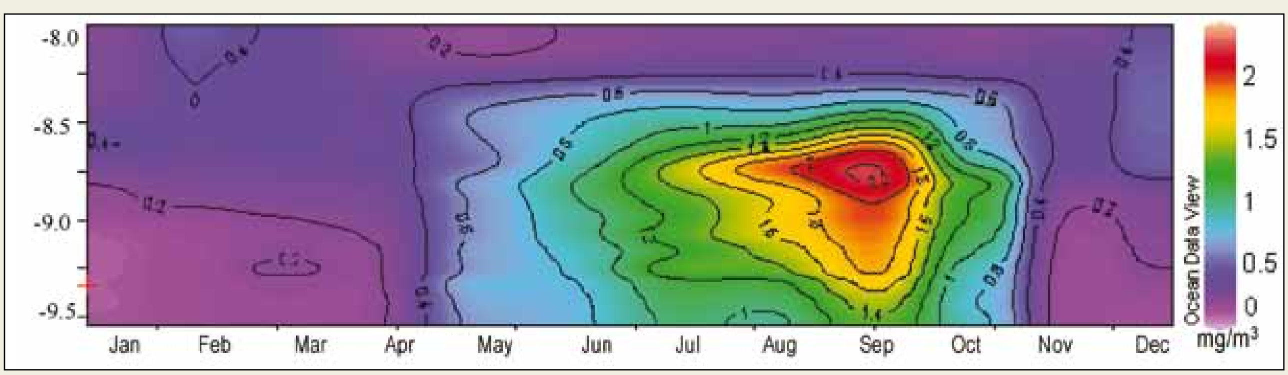
Global warming as a causal factor of climate change has a strong impact on marine living resources and environments. Many studies indicate that climate variability and change have influenced marine fisheries.[8]

The descending trend of fisheries productivity due to global warming forces us to take urgent adaptation measures in response to opportunities and threats for food and livelihood provision. These include data and information on ocean conditions and fish resources in order to ensure sustainable fisheries management and food safety assurance.

SST and chl-a concentration

Data for SST and chlorophyll-a (chl-a) concentrations in Indonesian waters in the last two decades were analysed to study their variability and trends. Monthly average

A time-latitude plot of chl-a concentration in the Bali Strait (January-December)



Source: Department of Marine Science and Technology, Bogor Agricultural University

SST data from January 1982 to December 2009 and chl-a concentration from January1998 to December 2011 were obtained from the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration websites.[9]

In general, SST values in Indonesian waters varied from 25.0° C to 31.0° C. Relatively high SST values were encountered during the May-July period (summer), while the November-January period (winter) showed relatively low values. The SST pattern was heavily influenced by seasonal wind conditions such as the monsoon winds.[10] During the northwest monsoon (November-February), relatively cold winds and high moisture from the South China Sea will lead to high rainfall and lower SST in the Indonesian region. In contrast, during the southeast monsoon (May-August), the flow of wind from mainland Australia carries little moisture and leads to a relatively high SST with little rainfall (dry season).[11] The El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole Mode (IODM) also influenced the inter-annual variability of SST in Indonesian waters.[12]

Some specific waters such as the Java Sea and Makassar Strait had slightly different SST patterns. Relatively high SST values were commonly found in October-December and March-May, while relatively low values were seen in July-September and in January-February. The Bali Strait and Arafura seas had different SST patterns from other locations, with a maximum SST in November-March and minimum SST in May-October. These patterns demonstrated that the SST fluctuations in the Bali Strait, Arafura Sea, Java Sea and Makassar Strait were influenced by monsoon winds and by the ocean circulation in this area.[13]

In general, the SST trend at various locations in Indonesian waters over the last two decades has tended to increase. Over the same period, it has tended to decrease in the Indian Ocean south of Java, the Bali Strait and Arafura Sea. This may be due to an intensified upwelling phenomenon in these regions.

In contrast to SST, the pattern of chl-a concentration tended to decrease in general, except in the Indian Ocean south of Java, the Bali Strait and Arafura Seas where intensified upwelling was evident. Climate warming has reduced vertical mixing since the water column is stabilized by thermal stratification, decreasing nutrients the in upper layer.[14]

Variability of oceanographic parameters and fisheries production

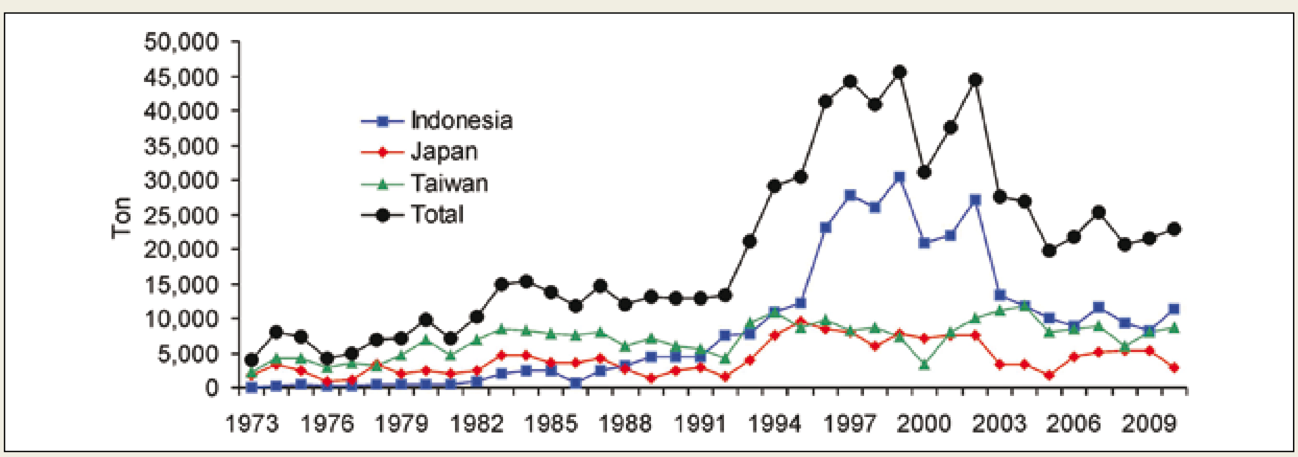
The oceanographic parameters of Indonesian waters were affected by monsoon wind, ENSO, and IODM.[15] During southeast monsoon between May and August, the wind blows from the southeast towards the northwest along the southern coast of Java-Bali-Nusa Tenggara (eastern Indian Ocean or EIO), causing water masses along the coast to be pushed away from the coast, and producing seasonal upwelling within the regions. The upwelling process brings deep-water mass with nutrient-rich cold water to the surface, and that affects thermocline layer shallowing and increases the fertility of waters. Time series data from the SeaWiFS in the Bali Strait upwelling region clearly indicated the increase in chl-a concentration due to the upwelling process, which begins in May and peaks in September in this area.

Bigeye tuna (Thunnus obesus) was mostly caught in the layer of 10-15° C isotherm, because this layer is suitable for the species.[16] Time series data for the catch rate (hook rate or HR) of bigeye tuna over 15 years showed that during the upwelling period, the bigeye tuna HR generally increased.

Generally, the long line hook used to catch bigeye tuna varied in depth from 100-250 metres. At the time of upwelling, the 10-15° C isotherm was about 50 metres shallower than normal, resulting in a growing number of hooks reaching the bigeye tuna fishing layer — hence the increased hook rate. At the time of upwelling, phytoplankton abundance also increased, resulting in an abundance of small pelagic fish as a food source for bigeye tuna.

The climate change impacts of ENSO and IODM are seemingly anomalous from SST and chl-a concentrations in 1994, 1997-1998 and 2006-2007. During ENSO and IODM positive periods, more intense upwelling occurs, the thermocline layer becomes shallower and chl-a concentrations increase significantly in the EIO.

Bigeye tuna production rates for Indonesia, Taiwan, and Japan in EIO, 1973-2010



Source: IOTC, 2012 http://www.iotc.org

Therefore, the hook rate of bigeye tuna and production rate of Sardinella lemuru (Sardine) increased significantly in the EIO.[17]

Climate impact on fisheries

The impacts of climate change on marine fisheries in Indonesian waters are not well understood. Modelling and analysis of the potential impact of climate change on global fisheries has shown that the potential fish catch in Indonesian waters will decrease by 15-30 per cent due to global warming.

Based on data published by the Indian Ocean Tuna Commission (IOTC), the three major bigeye tuna producers — Indonesia, Taiwan, and Japan — saw a significant decrease in bigeye tuna production in the EIO region from 1997 to 2010. Satellite data from theis period also shows a downward trend in the abundance of phytoplankton, and this decrease is thought to be one of the factors causing the decline of the region's bigeye tuna potential.

Fisheries production data for the past 15 years in two different fish landing sites (the west Sumatra waters representing a non-upwelling region and the Bali Strait representing an upwelling region) showed a different trend. The dominant fish species caught in west Sumatra waters were yellowfin tuna (Thunnus albacares), bigeye tuna and Skipjack (Katsuwanus pelamis). Fisheries production in the west Sumatra waters for 1994-2008 showed a decreasing trend concomitant with a decreasing trend of chl-a concentration. Some researchers explained that the declining trend of phytoplankton abundance in tropical waters was related to the declining trend of nutrient supply from the deep to the surface due to the global warming.[19]

In contrast to the west Sumatra waters, Sardine production in upwelling region of the Bali Strait was likely to increase over the past 15 years. Modelling results on the impact of climate change on global fisheries also showed that in areas of upwelling regions such as the south coast of Java including the Bali Strait, the potential fisheries productivity was also expected to increase.[20] Satellite data also showed an increasing trend in phytoplankton abundance in the Bali Strait. Global warming may have intensified the alongshore wind stress on the ocean surface, leading to accelerations of coastal upwelling in this region.[21]

Sardine is a plankton feeder, and 52 per cent of the Sardine fish density was affected by phytoplankton abundance in the Bali Strait.[22] The sardine spawning season in the Bali occurs around May-July (the upwelling season). During the larval stage, sardines consume plankton, and synchrony between the peak in plankton abundance and the sardines' larval stage is a crucial factor in determining the survival of larva.[23]

Managing production

Physical and biological oceanographic parameters influence the distribution and abundance of fish in Indonesian waters. For example, the highest sardine production correlated significantly with the abundance of phytoplankton with the fourth month of the time lag.[24]

In Indonesia, the sardine plays an important role in the economics of fishermen around the territorial waters of the Bali Strait, representing 90 per cent of fishery product in the area. Generally, sardine production in the Bali Strait increases from October until January, gradually decreasing in February. But in 1997-8 and in 2006-7 the sardine catch increased from October to July. This was due to phytoplankton blooming in those years, and this positive anomaly of phytoplankton was related to intense upwelling during IODM. Otherwise, the fish production has declined sharply when the concentration of phytoplankton is lowest. Thus, the abundance of phytoplankton sustained the stock of sardines in the Bali Strait.[25]

Sardine production increased by 200-300 per cent in 1997-8 and 2006-7, and this actually produced a negative impact on the fishermen due to a sharp drop in fish prices. The increase/decrease in fish production due to climate variability and changes should be managed by providing information on oceanographic conditions that affect the abundance of fish. For example, an increase in the abundance of sardines in the Bali Strait can be predicted from the trend in chl-a concentrations four months earlier. If the anomaly is positive, the next four months is expected to see an abundance of sardines. Therefore, appropriate management is needed such as adjusting the number of vessels to catch fish so that fish production will not be excessive, keeping some excess production for further fish processing, or distributing the excess fish to other areas. In contrast, during a negative anomaly of chl-a concentration, fish production can be expected to decline so that it is necessary to arrange a supply from other regions.

Another interesting example is the change in the abundance of tuna in the Indian Ocean during the blooming of phytoplankton due to climate variability during IODM. Information about oceanographic parameter variability can be used as an indicator to predict the abundance of fish in the sea, to assist fishermen in fisheries management and ensure the availability and security of fish.

In Indonesia, system information to predict potential fishing grounds has been developed by the Ministry of Maritime Affairs and Fisheries. This information is a service to the fishermen, to improve the efficiency and effectiveness of fishing efforts. The resulting map is made using data analysis of oceanography parameters from satellite imagery and multi-sensor climatological data from the Indonesian Agency of Meteorology and Climatology. This information system needs to be improved, specifically in terms of its accuracy in forecasting the long-term potential of fish resources, in particular to anticipate the effects of climate variability and change.

Climate variations and changes seem to affect the fisheries productivity, and this is likely to bring a range of opportunities and challenges to the fisheries sector in Indonesia. In general, global warming causes a decline in fish production in Indonesia. However, in upwelling regions, global warming seems to increase fish production due to an intensified upwelling process.

Variations in oceanographic conditions due to climate significantly affect the potential of fishery resources in Indonesia. Therefore the time series data and information of oceanographic parameters such as sea surface temperature, phytoplankton abundance and wind can be used as a basis for better management of the risks associated with climate variability and change as well for adaptation so that Indonesia's fisheries sector can be well managed in terms of availability and food security.

II
Water

Partnerships on water resource management in France

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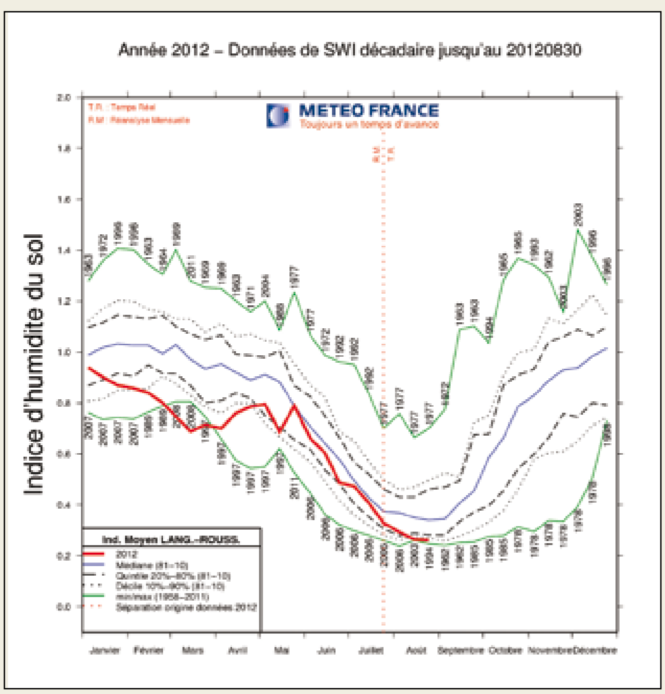
Jean-Philippe Vidal, Institut National de Recherche en Sciences et Techniques pour l'Environnement et l'Agriculture;
Stéphanie Singla, Eric Martin, Météo-France and CNRS, Centre National de Recherches Météorologiques;
Florence Habets, CNRS, UMR Sisyphe UPMC, Mines ParisTech

In order to improve weather forecasts, meteorological models have been gradually sophisticated and most operational suites nowadays include a full representation of surface conditions — oceans, continental surfaces and snow, ice or glaciers — as well as of the coupling with the atmosphere.

Interactive Soil-Vegetation-Atmosphere Transfer (SVAT) models are embedded in numerical weather forecast or climate models. Such systems compute the interplay between the bottom part of the atmosphere and the upper part of the soil: they describe in detail the surface conditions of primary interest for water management. They can be activated in various modes, covering a large spectrum of applications from a long-term reanalysis to daily monitoring of surface conditions, short range to seasonal forecasting or secular climate scenarios. A rich set of products and services can therefore be delivered by meteorological and climatological services to water resource managers, adding to a routine approach the other critical dimensions that enrich dialogue and create the real value of the service — getting useful support in the event of a crisis as well as receiving valuable elements for short-term (daily and weekly), mid-term (monthly and seasonally) or long-term (climate scenarios) planning. The availability of a comprehensive set of products covering all time and space scales relevant to water monitoring is highly appreciated by different users, which receive the tailored information immediately available in their own information systems.



A time sketch showing the evolution of the Soil Wetness Index for a French region (red) in 2012, with climatological references

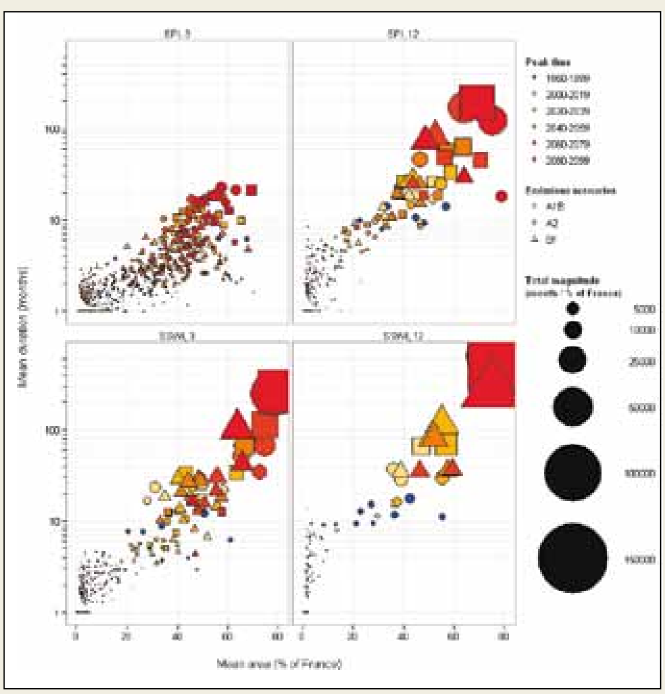
An interactive SVAT hydrology suite called Safran-Isba-Modcou (SIM) has been developed in the research department at Météo-France, in close cooperation with the hydrological research community. It was initially meant for improving weather forecasts but it would obviously serve other objectives. Safran performs an analysis of eight essential atmospheric parameters. Isba is a SVAT model and Modcou a distributed hydrological model over all French catchments. Interestingly the Isba-Modcou pair can be driven by various atmospheric forcings from a reanalysis to short- or mid-term numerical weather forecasts, to seasonal forecasts and climate scenarios — provided a suitable downscaling is applied to the large-scale fields.

SIM is first of all a community model (Météo-France, Mines Paris Tech, Irstea) developed by scientists and benefiting from regular upgrades by research laboratories over the past 20 years.[1] Many studies have been carried out with this suite, giving good confidence in its behaviour under various circumstances. Interestingly, SIM is used daily in the operational suites of the meteorological service, Météo-France.[2] SIM is integrated every day, rerun at day+1 in order to gather a greater number of observations, rerun at the end of each month so that its analysis benefits from the integration of the non-automatic observations made by voluntary observers, and rerun at the end of each year to retain the best homogenous archive for climatological applications.

Project after project, day after day, the numerical suite has been improved to represent increasingly sophisticated details and physical processes. Research is of course still ongoing to improve the models! A transfer of the system to the operational teams was done in the early 2000s. Since then, it is operated routinely, run every day in order to describe the past weather conditions that prevailed over the country. Such an operational product is quite useful for monitoring water resources (soil moisture, river flows) and for assessing the magnitude of extreme events, namely droughts. The SIM system is of course used for climate monitoring and extreme events evaluation (notably for natural disaster assessment).

Thanks to the 1958-to-present reanalysis, a climatology of the SIM variables is available for use. Current situations can therefore be compared to past events or climatological references. This helps users to evaluate the level of magnitude of a given event or situation compared to historical references.

Daily, weekly, monthly and yearly products are used for climate monitoring and support of the French authorities and agencies in charge of water management, from national (SCHAPI, Service Central d'Hydrométéorologie et d'Appui à la Prévision des Inondations) to local levels. The information is tailored to cover the various administrative districts mapping France, as well as the hydrological watersheds and basins. The suite is used not only for monitoring and analysis, but also for prediction. Two types of predictions are run. Mid-range ensemble forecasting (up to 10 days), taking advantage of the ECMWF products, is operational for flood and low-flow forecast for the main French rivers, and products are delivered to the relevant users. Seasonal forecasting is currently under evaluation: although the signal over Western Europe is rather dim both in terms of temperature or precipitation, it has been shown that predictability can be found for water resources, mainly due to snowpacks in the mountain areas, delayed aquifer response and, in very few cases, soil moisture.[3] No doubt in the near future, the set of timescales offered to users will also encompass the seasonal ones.



Climate change scenarios for two precipitation and soil wetness indices (with logarithmic scale)

The information is produced on an 8 km regular grid covering the entire territory. This makes the management of data and the elaboration of products easier. Products can therefore be elaborated for a given region or a department. Administrative divisions can be chosen, and of course river basins. In this way, the drought in the Languedoc-Roussillon administrative region in March 2012 was clearly recorded and a warning with references to past extreme events was issued by the authorities regarding the need for careful usage of water. Rainy conditions during spring brought the Soil Wetness Index (SWI) back closer to normal, permitting a looser watch on the conditions which were manageable until summer when the drought came.

The hydrometeorological and climatical information is delivered to actors by various means. Dedicated websites are the main way for delivering all relevant materials to users, both at the national level (Ministry) and for regional and local entities. Notifications and bulletins are produced on a monthly basis, or in case of a particular need. Météo-France experts also take part in hydrological coordination commissions, where all stakeholders share their views on water use. Results are disseminated through a website.[4] The agencies in charge of water management are also directly connected to Météo-France climatologists hotline, enabling efficient support especially in case of a tricky situation. They also collect products and data for fulfilling their everyday duties as well as for running research and development projects.

Climate change impact on water resources

France is concerned by the impacts of climate change on water resources. Until recent years, attention has been mainly paid to precipitations or river flows, especially for large basin rivers.[5] In 2007, it was decided to conduct a project tackling the effects of climate change on water resource and droughts. The ClimSec project had a twofold objective: to characterize past evolution and to provide scenarios for the future. It was decided to use a physical model, able to describe the atmosphere — vegetation — soil interactions rather than older parametric approaches based on potential evapotranspiration. Quite logically, the SIM was selected, because of its consistency with the other productions.

Image: © Météo-France/Patrick Pichard

Drought in Camargue, South France, August 2007

A near-surface atmospheric reanalysis was first performed, forced by ERA-40 and ERA-Interim.[6] Suitable indices, already used in other countries, have then been derived in order to characterize the various types of droughts than can occur, based on the SIM suite's variables: precipitation, SWI and river flows. A new climatology of droughts was established over France.[7] Such a climatology, combined with the daily updated analysis, improved at the end of each month and revisited at the end of each year, enables characterization of the situation and paves the way to a large number of tailored services. The Norbert Gerbier-Mumm prize, delivered in 2011 by the World Meteorological Organization, recognized the interest of such an approach.

Work was next completed to address the impact of climate change during the twenty-first century on water resources.[8] The forcings used were in that case regional climate scenarios. Various scenarios, climate models and downscaling techniques were used to address some of the uncertainties inherent in high-resolution climate projections. Results show a very strong increase in dry conditions over France. The role of the rising temperatures is prominent, driving a very strong increase in evaporation demand. In most cases, this process is dominant in relation to changes in precipitation. Severe soil drought conditions are expected to prevail from the middle of the century, showing the urgent need for adaptation measures.[9]

This study is a first attempt from the research community and the French meteorological service to address the impact of climate change on water resources. The models, the scenarios, and more generally all features of this study could be refined, revisited and definitely improved. This will of course be done in the near future, with improvements of all components of the study. Although weaknesses can still be found in the tools or the methodology, the result of this work is a major one for our society. The message is clear: France will almost certainly experience severe droughts, and therefore adaptation has to be prepared right now for sustainable and reasonable water use, agreed by all stakeholders.

Perhaps a more complicated part of the work is now to carry this message to citizens and decision-makers, and to imagine suitable forms for delivering it. This is a challenge that will drive climatologists to work with even larger communities, with specialists in information representation, sociologists, historians and more, and to find ways to get the entire society moving!

Building the Seasonal Streamflow Forecasting Service

Claire Hawksworth, Trudy Wilson, Jeff Perkins, Senlin Zhou and Bat Le,
Climate and Water Division, Australian Bureau of Meteorology

Australia is the driest inhabited continent on Earth, with the least amount of water in rivers, the lowest runoff and the smallest area of permanent wetlands of all the continents.[1] One third of the continent produces almost no runoff at all and Australia's rainfall and streamflow are among the most variable in the world. Streamflows are likely to be higher in winter and spring in southern Australia and, conversely, during late summer and autumn in northern Australia due to monsoonal rains.

The Australian Government has given the national weather and climate agency, the Bureau of Meteorology (BoM), responsibility for compiling and disseminating comprehensive water information. Under the Water Act 2007, BoM is working with water managers across Australia to deliver high quality national water information to government, industry and the community. BoM has had longstanding responsibilities for flood forecasting and warning services, but one of its new responsibilities under the Water Act is providing regular water availability forecasts. To address this requirement, in late 2008 the Extended Hydrological Prediction (EHP) section was created within BoM to provide short-term (up to 10 days), seasonal (up to three months) and long-term (decadal and inter-decadal) water availability forecasts.

Streamflow information is relied on by a range of water managers and users, including irrigators, urban and rural water supply authorities, environmental managers and hydroelectricity generators.[2] Predictions of short-term and seasonal streamflows, and long-term water availability forecasts, can potentially allow these water managers and users to better plan, operate and manage water use; to inform water allocation, environmental flow management and water trading decisions; and to assist with development of water policies to ensure security of supply.

An operational Seasonal Streamflow Forecasting Service was publicly launched in December 2010. Each month BoM issues three-month outlooks of total streamflow volumes at a site. These forecasts are freely available online at *www.bom.gov.au/water/ssf* for 36 sites in 16 river basins.

The Seasonal Streamflow Forecasting Service is targeted at water agency managers. BoM continues to work closely with key water agency managers to ensure the service meets their needs. EHP staff members and BoM's Communication and Adoption team are involved in stakeholder engagement and tailoring information to suit users. In addition to the forecast terciles, other products such as historical data and the forecast probability distribution and the forecast exceedance probability for each forecast location are provided on the website.

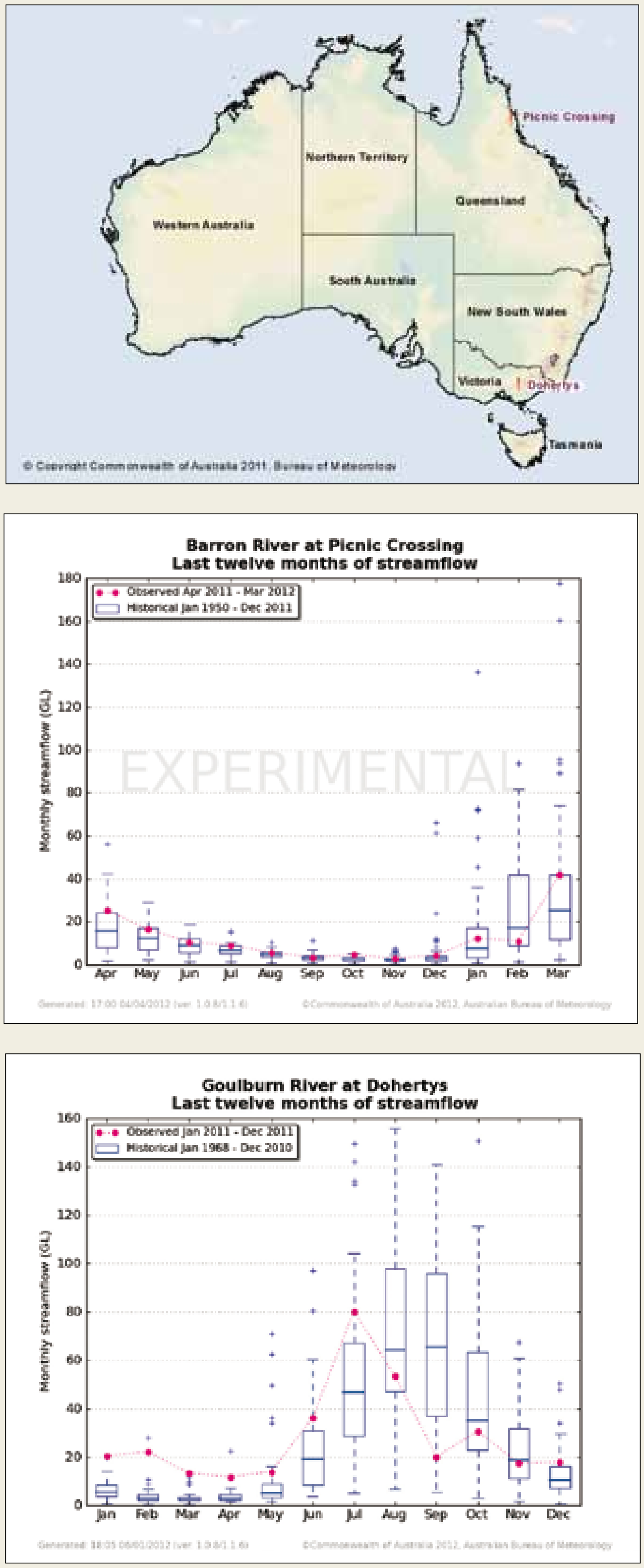
The current service is based on a statistical approach, and a dynamic approach is being developed in parallel.[3] The integration of these approaches in the future will provide better accuracy, reliability and scalability, as well as enabling the possibility of forecasts at different timescales such as monthly or multi-seasonal.

Information incorporated in the service

BoM's seasonal streamflow forecasts rely on streamflow data collected over many years by state agencies and other organizations, as well as climate information from BoM and international organizations such as the US National Oceanic and Atmospheric Administration. Antecedent streamflows, El Niño Southern Oscillation indices and other climate indicators are used as predictors in the forecast generation process. Most of the climate indices used in the forecasts are generated within BoM from raw data using a geo-processing model. To produce the forecasts, most data from external sources is downloaded from public websites and then converted into a suitable format. Some of the monthly streamflow data is provided directly to BoM from water agencies, free of charge, with the forecasts being the return benefit to the agencies.

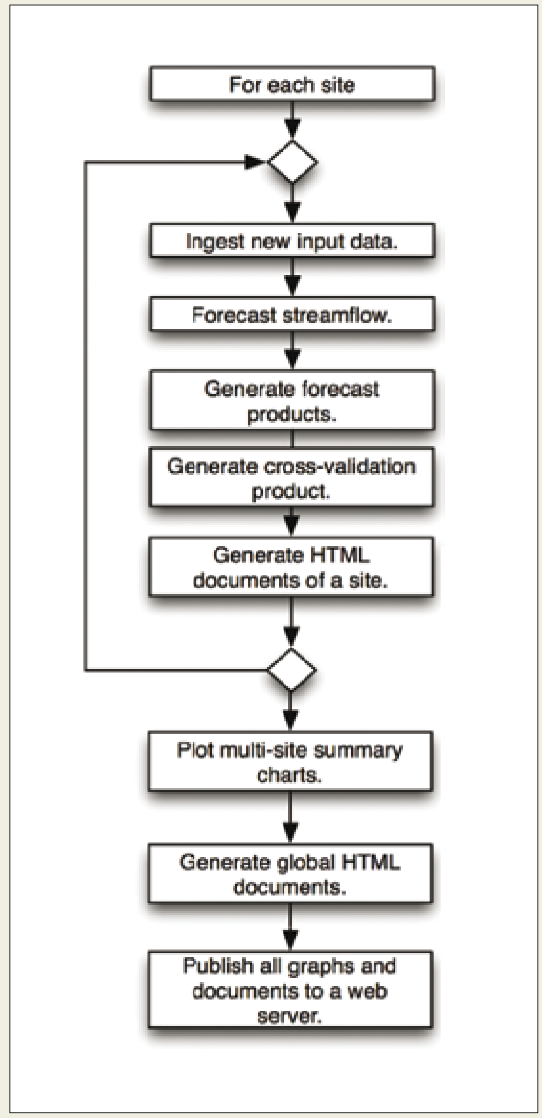
Processes, mechanisms and capacities

The Seasonal Streamflow Forecasting Service builds on more than two decades of BoM involvement in seasonal climate outlooks and quality research provided by BoM's substantial research partnership with the Commonwealth Scientific and Industrial Research Organisation (CSIRO). This research partnership has taken place through the South Eastern Australian Climate Initiative, the Water Information Research and Development Alliance (WIRADA) and the Centre for Australian Weather and Climate Research. BoM's seasonal streamflow forecasts will be used in operational water management systems across Australia. An example of integrated modelling software combining river and catchment modelling to support water planning and river operations is eWater Source, launched in May 2012. eWater Source is an Australia-wide collaboration effort backed by the Australian Government and designed to boost the capability of managers to use robust and defensible science to give advice to policy and decision makers.



The locations of Picnic Crossing and Dohertys (top) and monthly historical streamflow boxplots for the Barron River at Picnic Crossing (middle) and the Goulburn River at Dohertys (bottom), with the monthly observed streamflows for January-December 2011 shown as pink dots

Source: BoM

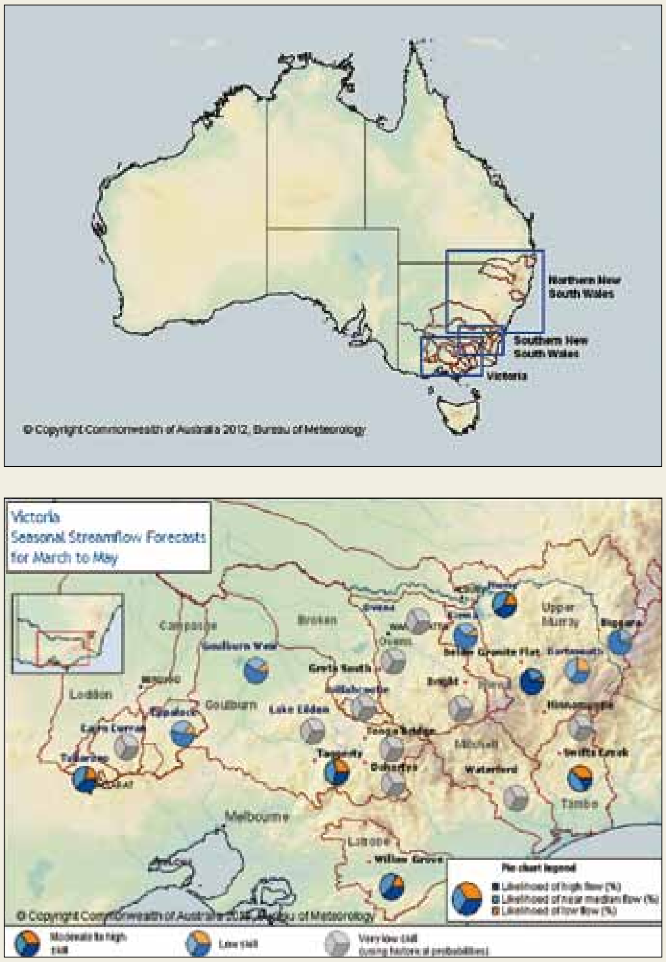


Data flow for the seasonal streamflow forecast update

Source: BoM

The transition from research on seasonal streamflow forecasting to operations was a combined effort from the teams in CSIRO and BoM, beginning in early 2009.[4] The research team has been keenly involved in stakeholder engagement, service planning and adapting research deliverables to meet service development needs. The technology and knowledge transfer between the research and service development teams is excellent and based on good communication, common goals and shared planning.

To understand user needs for seasonal streamflow forecasts, BoM's experience in operating a seasonal climate prediction service was drawn upon, including creating the outlooks and delivering and communicating them. Considerable time and effort was devoted to developing relationships with key stakeholders from the major water agencies around the country. BoM already had strong relationships with many agencies, built over years of



The river basins for which seasonal streamflow forecasts are currently provided (top) and a sample of the forecast terciles for Victoria (above)

Source: BoM

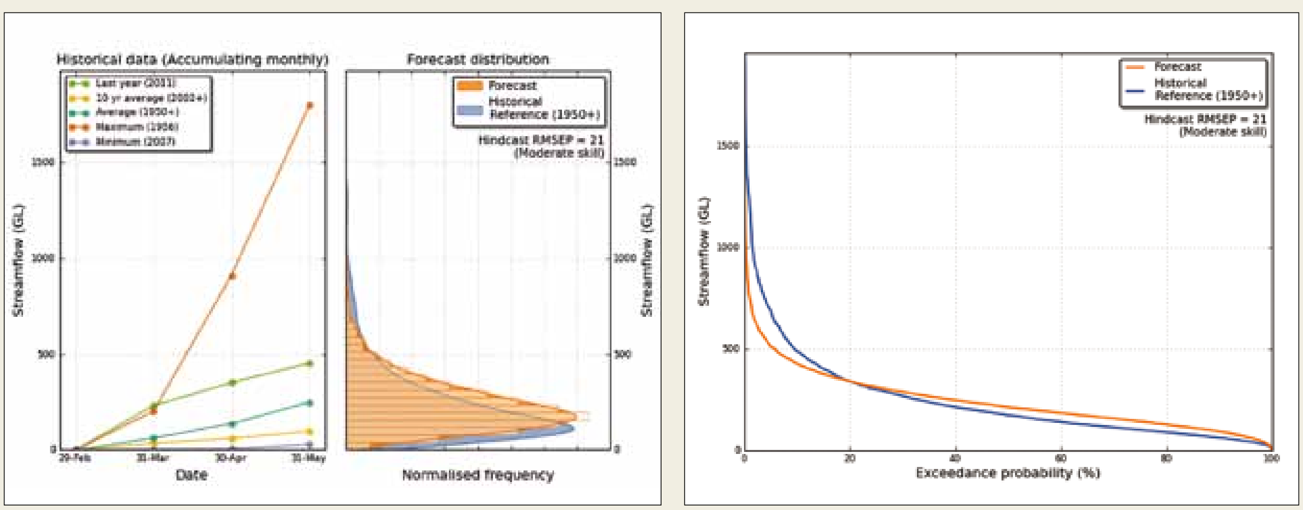
providing flood forecasting services and seasonal climate outlooks. From January 2009, key water forecasting services stakeholders participated in planning meetings and user needs workshops hosted by BoM.

One valuable example of stakeholder collaboration during the development of the service was an iterative process to gain feedback from users about the display of low-skilled forecasts. In order to manage this, an options paper was developed and feedback was requested from key agencies. The responses drove the development of a trial solution using a seasonal streamflow forecasting experimental website. Further feedback was then requested before implementation.

The current forecasting system is based on Bayesian joint probability (BJP) modelling.[5] To ensure timely and reliable delivery of the Seasonal Streamflow Forecasting Service, BoM developed a new modelling system called Water Availability Forecasting for Australian Rivers (WAFARi). Through frequent contact between the BoM service team and external stakeholders, critical user needs for the service were identified. New features satisfying these needs were quickly implemented, providing users with tangible products upon which they could provide more specific feedback. As a result of these efforts, WAFARi evolved into a full operational system equipped with many tools to support the entire workflow for the seasonal streamflow forecasts. These tools range from data management in a central database to web publication. Some of the tools were designed to exploit the parallel computing power of a massive BoM cluster to accelerate the computationally intensive analysis of the BJP model.

The seasonal streamflow forecasts are prepared at the beginning of each month by EHP staff members and uploaded to BoM's website, which is the most common place for stakeholders to access the forecasts and information about them. Following forecast publication, an email

Unregulated inflow to Hume Dam, forecast period: Mar 2012 - May 2012



Historical data and the forecast probability distribution (left), and the forecast exceedance probability (right), for Hume Dam in Victoria

Source: BoM

Image: BoM

The Bureau's Acting Director Dr Rob Vertessy presenting at the NWI Briefings (top); and the Acting Manager of the Flood Forecasting and Warning Section Jeff Perkins, presenting at an NWI workshop (above)

is sent to approximately 700 interested stakeholders, notifying them of the update and providing them with highlights and a summary. These 700 stakeholders, primarily from the water industry, expressed their interest in receiving these emails by subscribing through BoM's website and when attending workshops. Each month, senior staff members from BoM present the National Climate and Water Briefing in the nation's capital, Canberra. This briefing, to senior policy and planning managers from government agencies and other organizations, details the latest climate and water conditions in Australia.

Users of the seasonal streamflow forecasts have a range of climate expertise. To improve stakeholder understanding of progress in water information and the value it brings, in November and December 2011 Climate and Water Division staff delivered a series of eight National Water Information (NWI) Briefings, one in each capital city in Australia. Overall there were 1005 participants, comprising 831 external participants and 174 BoM staff. Similar briefings had been previously undertaken during 2007–8 and 2009. The briefings were a mixture of plenary sessions and technical and interactive workshops. There were three seasonal streamflow forecasting workshops, held in Melbourne, Sydney and Canberra. These workshops were designed primarily to educate participants about the seasonal streamflow forecasts and to build relationships with more stakeholders. One of the outcomes of the briefings was a noticeable increase in access of BoM's water information products.

During the NWI workshops, a number of external stakeholders expressed their interest in being involved in case studies, which will be conducted in 2012 and published on BoM's website. The aim of these case studies will be to show how key stakeholders have achieved a good outcome by using seasonal streamflow forecasts to inform their decision-making processes.

Although there is a feedback form on the seasonal streamflow forecast website, BoM has received little direct feedback from users about the service. To help address this, the EHP team conducted a user survey during the first half of 2012. The objectives of this survey include:

- Determining who is using the products, how they are being used and how often
- Finding out whether users are satisfied with service delivery
- Learning how users feel the current service could be improved.

What next?

The Seasonal Streamflow Forecasting Service will be extended to include 70 sites by December 2012, with investigations of possible new sites currently underway. The service could be further expanded in the future, subject to availability of resources and suitable forecasting sites. Some of the main challenges moving forward are:

- Finding such suitable forecasting sites in as many different hydroclimatic regions as possible
- Trying to satisfy user needs within the constraints of available resources.

As well as user need, in order to be considered for inclusion in the service, forecast locations must satisfy criteria of data availability and forecast skill and accuracy. Progress will be reported in the WIRADA annual report.[6]

Principles of the Global Framework

This case study most obviously relates to the Global Framework for Climate Services Principle 8, which emphasizes the importance of user-provider partnerships. Understanding and responding to user needs has been an essential part of the development of the Seasonal Streamflow Forecasting Service from the very beginning, and has continued throughout the transition to and maintenance of an operational service. Forecasts must ultimately lead to changes in decisions that result in improved outcomes in water resource management – producing skilful predictions is a necessary but insufficient requirement to satisfy customers. One aim of stakeholder engagement is to create ownership of the products and services within potential user segments, but the main advantage of early user involvement is the development of a fundamentally better service satisfying the real needs of users.

Developing the capacity of Central Asian national planning agencies to model climate impact scenarios and develop adaptation strategies

Jaakko Nuottokari, Head of International Consulting, Consulting Services;
Dr Ari Venäläinen Senior Research Scientist, Climate Change;
and Natalia Pimenoff, Research Scientist, Climate Change, Finnish Meteorological Institute

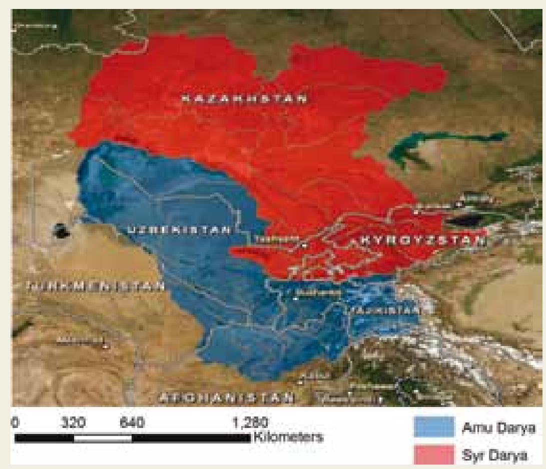
Water resources management in the Central Asia region faces big challenges. The hydrological regimes of the two major rivers in the region, the Syr Darya and the Amu Darya, are complex and vulnerable to climate change. Currently, melt-water from the mountain glaciers supplements the water supply in the rivers. Unfortunately this extra reserve is predicted to vanish in a few decades as the small glaciers disappear totally. Water diversions to agricultural, industrial and domestic users have reduced flows in downstream regions, resulting in severe ecological damage. The administrative-institutional system is fragmented with six independent countries sharing control, often with contradicting objectives.

A recent project developed and introduced measures to adapt to changing hydrological regimes. These measures build climate resilience in target watersheds against anticipated disaster scenarios, reducing potentially adverse climate impact on energy supply, food production and environmental sustainability. The impact of the project is on more efficient national strategies for climate change adaptation, with the outcome of an improved national capacity to model climate scenarios and develop adaptation strategies.

Climate information as basis for decision-making

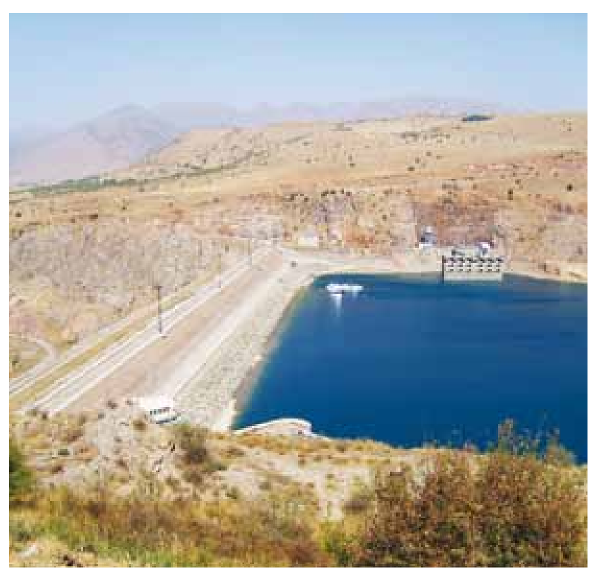
The project developed national capacity in each of the participating countries to use models to prepare climate change impact scenarios and develop adaptation strategies. This resulted in improved national strategies for climate change adaptation. It was implemented in close collaboration with the main regional and national organizations responsible for land and water management.

The project involved the downscaling of Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report climate models for the Central Asia region, and the use of this data for hydrological modelling to determine effects to river flows and resulting water resources available for users. The climate information was produced by the Finnish Meteorological Institute (FMI) and hydrological modelling was done by FutureWater from the Netherlands. The outcomes were shared in stakeholder workshops involving key decision-makers from the national governments of Central Asian countries.



The Amu Darya and Syr Darya river basins: hydrological models for these river basins are used to make simulations including climate change scenarios

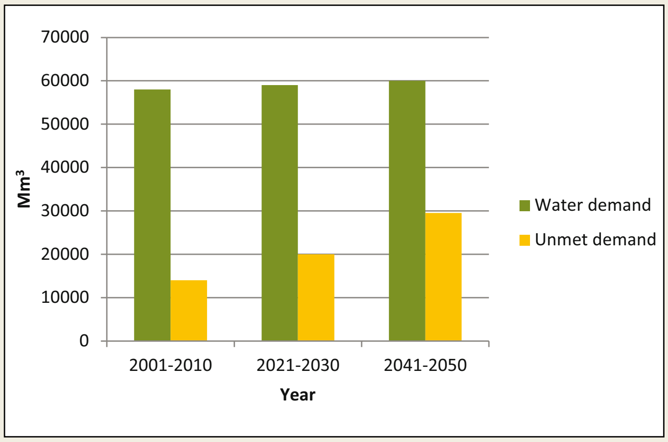
Image: Dr Ari Venäläinen, FMI



The Charvak reservoir and power plant in Uzbekistan

Image: Dr Ari Venäläinen, FMI

Changes in annual demand and unmet demand in water resources for the Amu Darya basin



Source: Punkari, M, P. Droogers, W. Immerzeel, A. Lutz, N. Pimenoff and A. Venäläinen (2012). Water and Adaptation Interventions in Central and West Asia. Final Report. Asian Development Bank Project TA 7532

Implementation

The project was implemented under the leadership of the Finnish Consulting Group and in collaboration with FMI and FutureWater, which developed hydrological models to assess the availability of water resources in the region under climate change. The project focuses on the Aral Sea basin (Pamir and Tien Shan mountains) in the Kyrgyz Republic, Tajikistan, Kazakhstan, Turkmenistan and Uzbekistan. Hydrological models are developed for the Amu Darya and Syr Darya, and simulations made using these models include several climate change scenarios processed by FMI.

Work was carried out in two phases:

- Development of a knowledge base on the likely impacts of climate change on the Amu Darya and Syr Darya river basins
- Development of capacity to use outputs in regional, national and river-basin adaptation planning.

These outputs were applied to risk management strategies at the regional, national, and river basin levels. The work builds on approaches and methods used in similar projects for glacial-fed river systems, such as Indus or Chu and Talas rivers.

The national hydrometeorological services were identified as key national stakeholders in the project by the donor agency, along with ministries and planning agencies tasked with water management. Focus on water management and institutional capacity building draws from the strategies and policies for projects of the Asian Development Bank (ADB), which provided the funding for the activity and is formulated by member countries. The project follows an earlier project by ADB and is thus part of a scale-up of institutional capacity building within ADB countries focusing on adaptation to climate change. As the project results are mainly training material and other guidance information, they can be used by ADB, its member countries or any community that so desires. The work was completed using existing climate and hydrological models with the infrastructure of the project partners, so no infrastructure investments were made.

Results

Climate data to be applied in hydrological modelling included daily mean temperatures and daily precipitation data in a grid covering the Central Asian countries. On one hand the hydrological modelling required present day climate data — for calibration of the model — and on the other hand it needed future climate projections. The gridded data representing present-day daily mean, maximum and minimum temperatures were produced by surface observations of temperature for the years 2001-2010, and kriging interpolation. The present-day daily precipitation data were established using satellite-based precipitation data. Future climate projections for 2011-2050 were processed using simulations of five different global climate models from the IPCC's Coupled Model Intercomparison Project Phase 3 (CMIP3) project. Global model simulations of the future were downscaled to the dense grid using the gridded present-day climate data and delta change method.

The annual mean temperature in the Central Asian main catchment area is projected to rise by about three degrees and the changes to annual precipitation are very small during the coming 40 years. When we look at the seasonal precipitation changes, the already dry south-western parts become even drier, especially during summer. In some places in the mountains precipitation might increase. However, there is variation from model to model. Mean temperatures rise consistently throughout the year, with the warming strongest in the mountains and in the northern parts of the area. This information was used in modelling the changes in hydrological circumstances and assessing societal impacts.

Climate change leads to increased demand for water due to increases in temperature, leading to higher evapotranspiration rates for agricultural crops. The stronger increase in demand is for the Amu Darya basin (4.4 per cent) in comparison with the demand increase for the Syr Darya basin (3.8 per cent). This is due to the slightly stronger projected increase in temperature in the Amu Darya basin compared to the Syr Darya basin. Moreover, since precipitation does not change much in the downstream areas, the large increase in unmet demand is also caused by a decrease in run-off generation in the upstream mountains.

The project had a large training component and all the material and graphs on the current and future climate, along with training, were delivered to stakeholders. As demonstrated by the large unmet demand in water resources, adaptation to climate change is a necessity and all possible activities should be implemented urgently. The project thus recommended adaptation strategies and supports the development of investment plans for future projects in, for example, strategies for water management, reservoirs, hydropower, canals, irrigation, flood protection, disaster/hazard preparedness, modifications in cultivation, soil and forest protection, and hydrometeorological GIS, modelling and observation technology.

Identifying local climate impacts on weather and water

Marina Timofeyeva, Fiona Horsfall and Jenna Meyers, National Oceanic and Atmospheric Administration; Annette Hollingshead, Wyle Information Systems

Understanding and provision of integrated environmental information is one of the top priorities in the new Weather-Ready Nation strategy recently introduced by the National Weather Service (NWS) at the US National Oceanic and Atmospheric Administration (NOAA). The ability to identify and predict local climate impacts on weather and water is critical because most climate-sensitive decisions occur at the local level such as cities, counties and states.

Climate serves as a driving force in the frequency of extreme weather and water events. Public warnings on the occurrence of climate events and their possible impacts, such as fresh water shortages in the Pacific Islands during El Niño events, provide actionable information to help build communities' resilience to weather and water elements. Efficient local service is a key component for the effective dissemination of climate information. The NWS is presently working towards developing a local climate analysis tool (LCAT) to enable office staff and technical users to access, manipulate, and interpret climate data, and characterize climate variability and change linkages to weather and water elements.

To ensure the relevance of the tool to end users, the LCAT Integrated Working Team identifies requirements and sets priorities for development. LCAT's capabilities are being developed to respond to the needs of NOAA staff providing operational climate services, as well as those of external technical users making climate-sensitive decisions. External technical user groups include:

Image: NOAA

A billboard in Pohnpei during the severe El Niño event in 1997-1998

- Natural resource managers (such as hydrologists, planning and operational engineers of water reservoirs and energy turbines using water, nuclear, wind and solar sources of power generation)
- Wildlife managers including fisheries, national parks, and marine sanctuaries
- Researchers working on climate information applications for national security including agriculture, environment, transportation and military matters.

The LCAT Integrated Working Team is using different ways to identify requirements, including literature surveys, reviews of user logs maintained by NWS local offices, and direct engagement with users, such as through the Annual Climate Prediction Application Science Workshop.

The enabling role of LCAT

LCAT is an online interactive tool that will enable local users to conduct regional and local climate studies using state-of-the-art station and reanalysis gridded data and various statistical techniques. LCAT uses the principles of artificial intelligence to respond to queries, in particular, through use of machine technology that responds intelligently to input from users. The user translates customer questions into primary variables and issues, and LCAT pulls the most relevant data and analysis techniques to provide information back to the user, who in turn responds to their customer. Most responses take on the order of 10 seconds, which includes providing statistics, graphical displays of information, translations for users, metadata, and a summary of the user request to LCAT.

The results are used to provide services to guide local decision makers in weather- and climate-sensitive actions and to deliver information to the general public. LCAT augments current climate reference materials with relevant regional and local. Its main emphasis is to enable studies of extreme meteorological and hydrological events such as tornadoes, floods, droughts and severe storms. LCAT will close a very critical gap in NWS local climate services because it provides analysis of climate variables beyond average temperature and total precipitation. NWS external partners and government agencies will benefit by incorporating LCAT's output easily into their own analysis and delivery systems.

Present and near-term capabilities

NWS has identified five existing requirements for local climate information:

- Local impacts of climate change
- Local impacts of climate variability
- Drought severity studies
- Climate studies for water resources
- Attribution of extreme meteorological and hydrological events.

The methodologies for the first four requirements have been included in LCAT phase one implementation.

The local rate of climate change is defined as a slope of the mean trend estimated from the ensemble of three trend techniques: hinge,[2] optimal climate normals (running mean for optimal time periods),[3] and the exponentially-weighted moving average.[4]

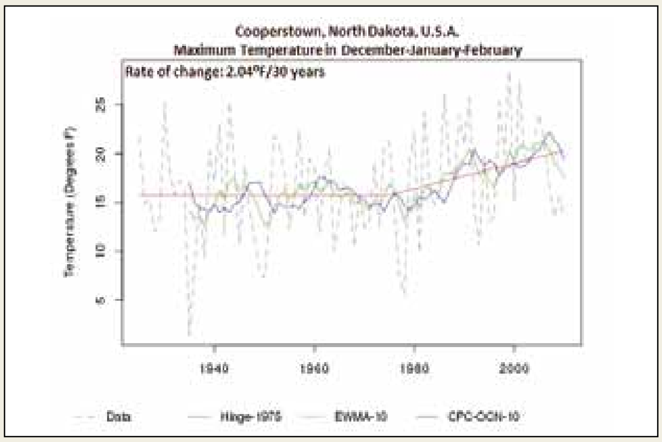
Root mean squared error is used to determine the best trend fit to observations with the least error. Analysis of ensemble information allows assessment of mean climatological data and uncertainty due to the trend fitting techniques.

Studies of the impacts of climate variability on local extremes use compositing techniques applied to various definitions of local variables, from specified percentiles to critical thresholds. Drought studies combine the visual capabilities of Google maps with statistical estimates of drought severity indices. Climate studies for water resources applications include:

- Current and expected maps of water resources
- Site-specific, interactive information on forecast ensemble distribution for water resources and their expected evolution
- Historical analogues of present and expected river flow
- The relationship between water parameters and climate variability indices.

NWS is leveraging internal and external NOAA partnerships to develop methodologies for the requirement on the attribution of extreme meteorological and hydrological events. This section of LCAT will include references to explain the climatological drivers for extreme events such as the 2010 heat wave and drought in Russia, the 2011 Missouri River flood and the unusually warm March in the eastern USA in 2012.

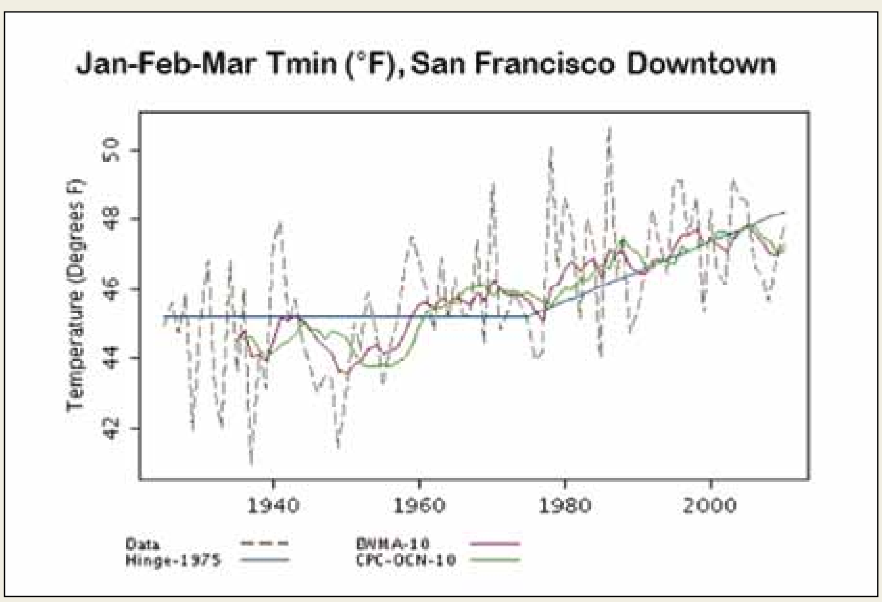
The near-term development plan includes the incorporation of various climate variability indices such as North Atlantic, Arctic, Madden Julian, Pacific Decadal and other



LCAT produces various trend analyses of time series and calculates the rate of change for looking at the impacts of climate change at locations

Source: NOAA

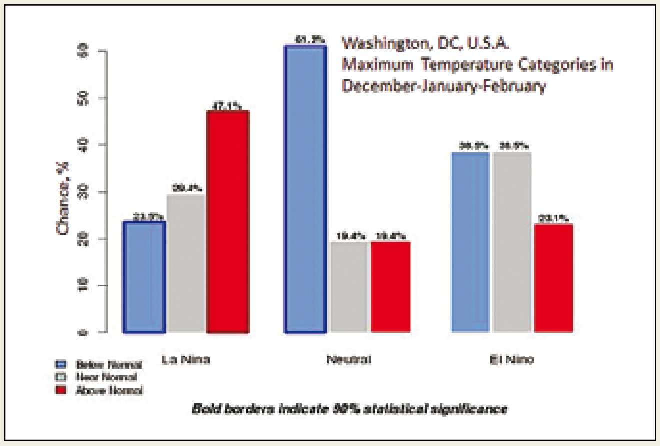
An LCAT local climate rate change analysis for minimum surface temperature in San Francisco, California



Trend Performance	
Root Mean Square Error	
Hinge with anchor at 1975:	1.74
Exponentially Weighted Moving Average (Alpha=10):	1.39
CPC Optimal Climate Normal (10-Year MovingAverage):	1.71
Ensemble Performance	
Ensemble Standard Deviation	0.40
Rate of Change	
Annual Rate of Change	0.047 Degrees F per year
Decadal Rate of Change	0.47 Degrees F per decade
Climatological Rate of Change	1.41 Degrees F per 30-year period

Source: NOAA

oscillations with documented impacts of weather and water parameters. In addition, LCAT will have access to NOAA's severe weather data sets, which will enable climatological and impact studies of frequencies in tornados, floods, snowstorms, heat waves, lightning and other extreme events. For example, a pilot study analysed the relationship between tornados and El Niño Southern Oscillation (ENSO) events, helping to identify areas with significant tornados and an enhanced number of tornado days during La Niña events in the central USA region. The plan also includes developing numerous options for user-defined climate analysis, such as tuning to strong climate events using multiple indices of climate variability and critical percentiles of data distributions. Plans for LCAT include the capability to extend to existing data visualization tools and to add options for three-dimensional and multiple-site graphical capabilities.

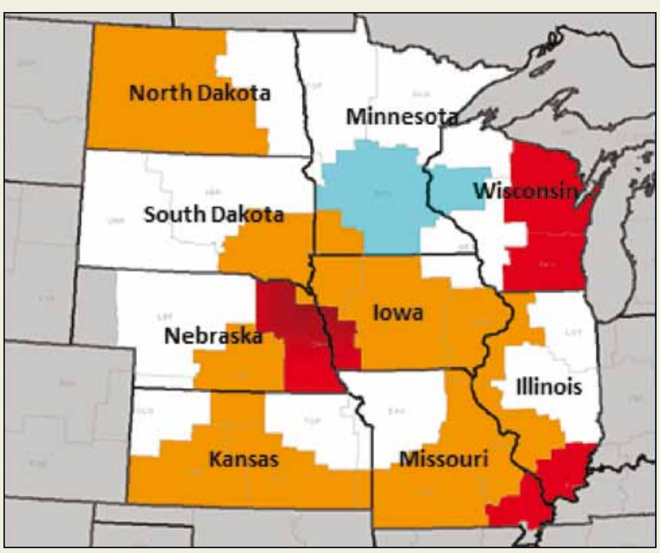


For looking at the impacts of climate variability, LCAT examines the relationship between climate phenomena such as El Niño Southern Oscillation and local climate variables. This example shows a statistically significant chance (bold border) for above normal maximum temperature during La Niña events. The temperature categories are defined using a climatological reference period of 1981-2010.

Source: NOAA

Results of a pilot study that helps to identify areas with significant tornados and enhanced numbers of tornado days during La Niña events in the central USA

Orange: Area with enhanced significant tornados
Cyan: Area with diminished significant tornados
Red: Area with enhanced number of tornados days



Source: NOAA

Future goals and applications

Plans for LCAT include building the capability to extend it to existing data visualization tools and adding options for three-dimensional and multiple-site graphical capabilities. Additionally, LCAT will be developed for climate studies in key environmental and economic sectors. For example, to support marine sanctuaries and coastal systems, LCAT will have access to NOAA global sea level, tidal and coastal surges monitoring data, which will enable climate studies at specific harbours or marsh habitats. To support renewable energy decisions, LCAT will use global surface observation, satellite and reanalysis wind, cloud cover and solar insulation data to allow the analysis of local climatology at different heights of the atmosphere anywhere on Earth. Extension to reanalysis data will enhance LCAT global applications and enable the potential use of data from Global Circulation Models for model inter-comparison on regional scales. The LCAT development plan also includes potential access to demographic and biological data to help with holistic environmental climatological analysis.

User engagement

LCAT was beta tested by approximately 40 NOAA staff, who were eager to start local climate studies. Several training events took place to engage beta testers:

- Live webinars were recorded and provided to users for further reference
- A training workshop was held, that included instructions on using LCAT, information on data and methods used for analy ses, practice sessions, and discussions to collect user feedback
- Fact sheets were developed describing LCAT capabilities.

Feedback from beta testers identified new requirements to be added to the tool prior to operational implementation for internal use by NOAA. LCAT's application for NOAA's external use requires the engagement of users and integration of new requirements. LCAT's development is an iterative process of user engagement that includes identifying user needs, formulating requirements and setting priorities; coordinating with subject matter experts on best practices for use of appropriate data and scientific methods to respond to these needs; building and testing new LCAT capabilities; training and user feedback.

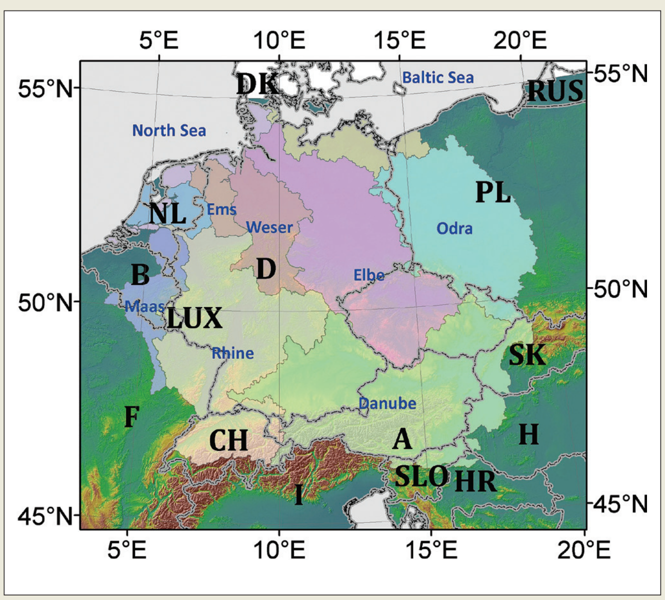
This continuous development will ensure that LCAT provides the analysis tools and capabilities to meet the needs of a wide range of stakeholders, enabling the interpretation and dissemination of climate data to support climate-sensitive decisions.

An integrated climate service for the transboundary river basin and coastal management of Germany

By Professor Dr H Moser, Dr J Cullman, Dr S Kofalk, Dr S Mai and Dr E Nilson, Federal Institute of Hydrology, Germany; and S Rösner, Dr P Becker, Dr A Gratzki and K-J Schreiber, German Meteorological Service

All infrastructure planning in water resources management, waterways engineering, flood protection, and coastal defence requires knowledge of meteorological, hydrological and oceanographic parameters on a climate scale. Since the planning horizon of such infrastructure projects spans from decades to a century and beyond, information about historical and future climate changes is of utmost relevance.

The KLIWAS programme (KLIWAS — Impacts of climate change on waterways and navigation - Searching for options of adaptation) provides an integrated climate information service for trans-boundary river basin and coastal management in Germany. It was initiated as a contribution to the German Strategy for Adaptation to Climate Change[1]. The KLIWAS initiative provides climatological data and assesses climate impacts for the following sectors: water regime, water resources management; coastal and marine protection; biological diversity; fishery; and transport, transport infrastructure. KLIWAS serves as a knowledge base for stakeholders, like the Federal Waterways and Shipping Administration, and for all others concerned with one of these sectors. The activity is coordinated by the German Federal Institute of Hydrology on behalf of the German Ministry of Transport, Building and Urban Development. It is closely linked to services provided by the German Meteorological Service.



The focus areas for KLIWAS work are the basins of the rivers Rhine, Danube and Elbe and the coastal areas of the North Sea

Source: BfG

Identifying the user needs and expectations of the water sector

The outcome of the departmental climate related hydrological and oceanographical service is driven by stakeholders involved in river basin and coastal management. To identify the stakeholders, water authorities from inside and outside Germany are informed, for example through the direct involvement of KLIWAS in international river commissions or through organisation of regular meetings with politicians, water managers and waterway users (such as KLIWAS Status conferences and KLIWAS stakeholder workshops).

We used experiences and a common understanding built by the implementation of the European Water Framework Directive (EU-WFD). The EU-WFD summarizes much of the European experience on pollution, water quality and ecosystem management, and it represents a comprehensive way to ensure that there is enough clean water for different uses, and to avoid disasters like flooding and droughts. Besides there are existing traditional responsibilites and roles within the framework of water management in a federal organized state, with its decision and participation processes which are also used to set up our climate services.

Stakeholders (including the European Commission, the Federal Ministry of Transport, Building and Urban Development and its Waterways and Shipping Administration, several other Federal Government and federal state ministries and their executive agencies, representatives from shipping, ports and industry consulting engineers, water management, environmental protection, nature conservation, and academia, primarily from the field of climate change impact research) are in contact with the KLIWAS consortium to fulfil their needs for climate change related information raised by the latest IPCC asessment report[2]. Existing participation processes

Image: Fritz Kohmann/BfG

Pushed convoy sailing on the Elbe river near Dresden

are used; for example through international river commissions and working groups.

Users of the services on an operational level of management prepare decisions in policy development and economy and define at the end which information or data for which analyses and which decisions have to be designed as service products.

The outcome of reiterated meetings with users led to a set of indicators by which we characterise climate change and impacts e.g. projections for discharges etc.

With respect to the service products, the following general user expectations were identified:

- *A sound scientific approach has to be the basis for the model derived products:* The multi-model approach of KLIWAS is the scientific approach in climate change impact research.
- *A clear concept of the evaluation facilitates the application of the results:* KLIWAS has designed a general evaluation framework for climate impact research. This includes quality criteria for model data, defined spatial and temporal resolutions of data products and specific statistical measures for different user groups.
- *The multi-sectoral interests in water management have to be integrated into the approach:* We reached this by integration of multi-diciplinary model chains (climate, water quantity, -quality, -ecology, engineering, and economic aspects). This means to build up a scale-consistent prognostic model chain and defined clear workflow between partners to reach an operational level in our climate services.
- *The data and information products have to be available and easily applicable:* For this reason we implemented web-based distribution channels via our portals, matching international standards of data-management.
- *Accompanying documents concerning certainty and uncertainty of climate projections have to be provided to support the users.* Uncertainty guidance forms a core element of all KLIWAS documents.

Identifying the institutional framework

The institutional framework of KLIWAS was built upon the competences of the agencies responsible and able to offer services related to relevant management questions. If additional know-how is required, third parties are being involved.

Together the association of the National Meteorological Service of Germany (DWD), the German Maritime and Hydrographic Agency (BSH), the German Federal Institute of Hydrology (BfG) and the German Federal Waterways Engineering and Research Institute (BAW) offered these competences in form of the KLIWAS research programme. The Federal Ministry of Transport, Building and Urban Development financed the programme — comprising 31 projects — with an initial lifetime of five years (starting in 2009) and a budget of four million euros per year. These funds are invested to set up a climate service on a longer perspective; after 2013 the service is intended to continue operationally. The funding of the services is completed and supplemented by other research funds, for example from the Seventh European Framework Programme and the German Federal Ministry of Education and Research.

KLIWAS is based on data, methods and models, generated not only by the four governmental institutes (DWD, BfG, BSH and BAW) but by a network of institutions (such as the hydrological and meteorological services of Germany and the neighbouring countries). This integrated approach is regarded as a key concept to provide information that is based on the state of the art of knowledge. Data products are presented and discussed in national and/or international expert groups before they are offered to stakeholders and for further application. This feedback is essential for the transparency, reliability and thus for the acceptance of the KLIWAS services and products. Use of KLIWAS products outside of the KLIWAS community follows the data policy of the institutes which participate in the KLIWAS research program. Hydrological services are free of cost.

From an organisational point of view the top level of the institutes has a monitoring role and evaluates the results — in close cooperation with the financing ministry — with respect to general strategic questions. Decisions on the operational level are made by the responsible project managers together with the users of our services and scientific partners.

Data and models

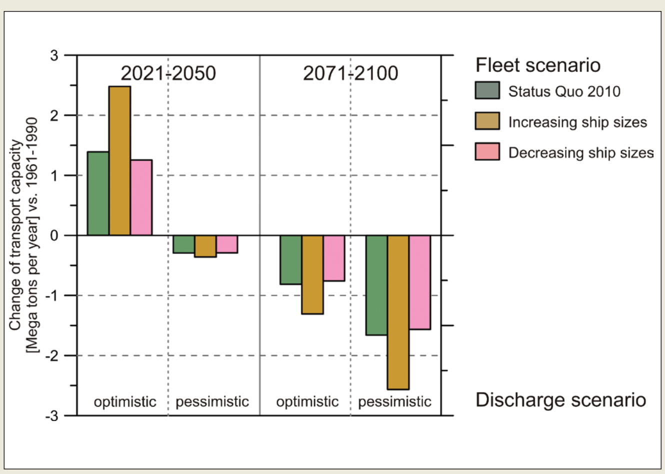
The meteorological and hydrological data and models of KLIWAS are linked in a complex model chain which mimics the complex structure of the system under investigation, namely the major river systems and the coastal areas of Germany and the neighbouring countries. At each link of the chain multiple models are involved to give an idea of the uncertainty associated with each modelling step.

In the framework of KLIWAS DWD acquires climate model output from global and regional climate models from various research groups. The model data are then further processed for the use in KLIWAS impact models. This post-processing includes the verification of control runs, the statistical analysis of the future climate projections, further downscaling of regional climate model output by means of statistical methods and the bias correction of model output. In addition, DWD compiles and generates meteorological reference data sets for the entire international basins of the rivers under investigation, as well as for the North Sea, the Baltic Sea, and the adjacent North Atlantic. The reference data sets support the verification of climate model data and KLIWAS impact models as, for example, hydrological models, and are used for the bias correction of climate model output.

At BfG and BSH the simulated and observed meteorological data are used as input for hydrological and oceanographic models to assess the impact of climate variability on stream flows, sea level etc. The climate model data are bias-corrected to be applicable in the impact models. Also here, multiple correction methods are compared to demonstrate the specific modifications of model results.

Methods and (hydrological) models are set up and/or evaluated in cooperation with water research institutes and water managers working on the same river basins as KLIWAS. All institutions and persons bring in their own hydrological expertise and data. For example, the model used for short term forecasts is used in the same version in Germany and the Netherlands. Thus, the quality of the models and data is double-checked and consistent across the border.

The KLIWAS programme does not end with information on water quantity and hydrodynamics. It also tailors specific information for different user groups. For example, further models are coupled to assess and monetize the effects of climate and hydrological change on inland waterway transport. Specific information on future transport costs and capacities under climate change conditions are offered – including an uncertainty statement. Using this information, the users (for example, the BAW) evaluate adaptation measures such as innovative steering techniques for the vessels travelling on the River Rhine.



This graph on the effect of projected climate change on transport capacity of cargo on the Rhine river is an example of user-specific information generated by KLIWAS

Source: Development Centre for Ship Technology and Transport Systems

Example service: discharge scenarios for policy development

As a consequence of the close stakeholder involvement, information provided by KLIWAS is already in use in policy development. For example, in 2010 KLIWAS and network partners agreed on a general evaluation framework designed to select and process climate model data for the purpose of impact modelling.[3] This procedure resulted in a reduced ensemble (20 out of 26 members) of bias corrected climate simulations, which are regarded as suitable for hydrological modelling. On that basis a set of hydrological indicators was generated, which characterises the potential future hydrological regimes of the River Rhine in the middle and the end of the 21st century. The indicators were chosen to meet the user needs that were identified; i.e. they indicate a bandwidth of results for relevant hydrological statistics given the current modelling uncertainty as sampled by an ensemble of quality checked and bias corrected climate simulations. This work was coordinated, documented and published online by the International Commission for the Hydrology of the Rhine basin (CHR).[4]

The indicators were discussed by the International Commission for the Protection of the Rhine (ICPR), an advisory board that coordinates the work of representatives of the governments of Switzerland, France, Germany, Luxemburg, Netherlands and the European Commission. Guidance on how to read the indicators was given during specific workshops for representatives dealing with floods, ecology, sediments and strategic questions. In 2011, the ICPR members adopted the indicators as scenarios to prepare the development of forward looking, sustainable water management adjustment strategies to floods, ecology and water quality.

The data and the documentation on the ICPR scenarios are now accessible online in four languages (English, French, Dutch, and German) via the ICPR website.[5] This information is increasingly accepted and used. For example, the inland navigation sector as organised in the Central Commission for the Navigation of the Rhine takes the same values as basis for an assessment for adaptation needs.[6]

Example service: WAVOS daily low flow forecast

Within the integrated modelling system of the institutes forming the KLIWAS consortium, not only centennial projections but also daily forecasts are offered. The latter is implemented as an operational online service, named WAVOS.

Currently, the service covers lead times up to four days for selected gauges along several major rivers in Central Europe (Rhine, Elbe, Upper Danube, Oder). One purpose of the daily forecasts is to support the transport and logistics sector along the rivers when vessel operations may be restricted due to extreme flow conditions. But also other users benefit from this service, for example, the flood centres of the German federal states.

The service is based on a comparable model chain as the climate service – starting from meteorological model output, which is optimised to be applicable in hydrological and hydrodynamic models. The forecasting system takes weather forecasts of the German Meteorological Service as input. The initialisation is based on station data retrieved from DWD and the French Meteorological Service (Météo-France).

These data are assimilated into the hydrological and hydrodynamic components which are run at BfG. At the end of the processing chain, stream flow and water level information is offered for relevant gauges on the waterways. The forecasts are updated daily. They are accessible free of charge via the internet and videotext. Up to 4,000 clicks per day on the website indicate the high level of acceptance of the service.

Lessons learned

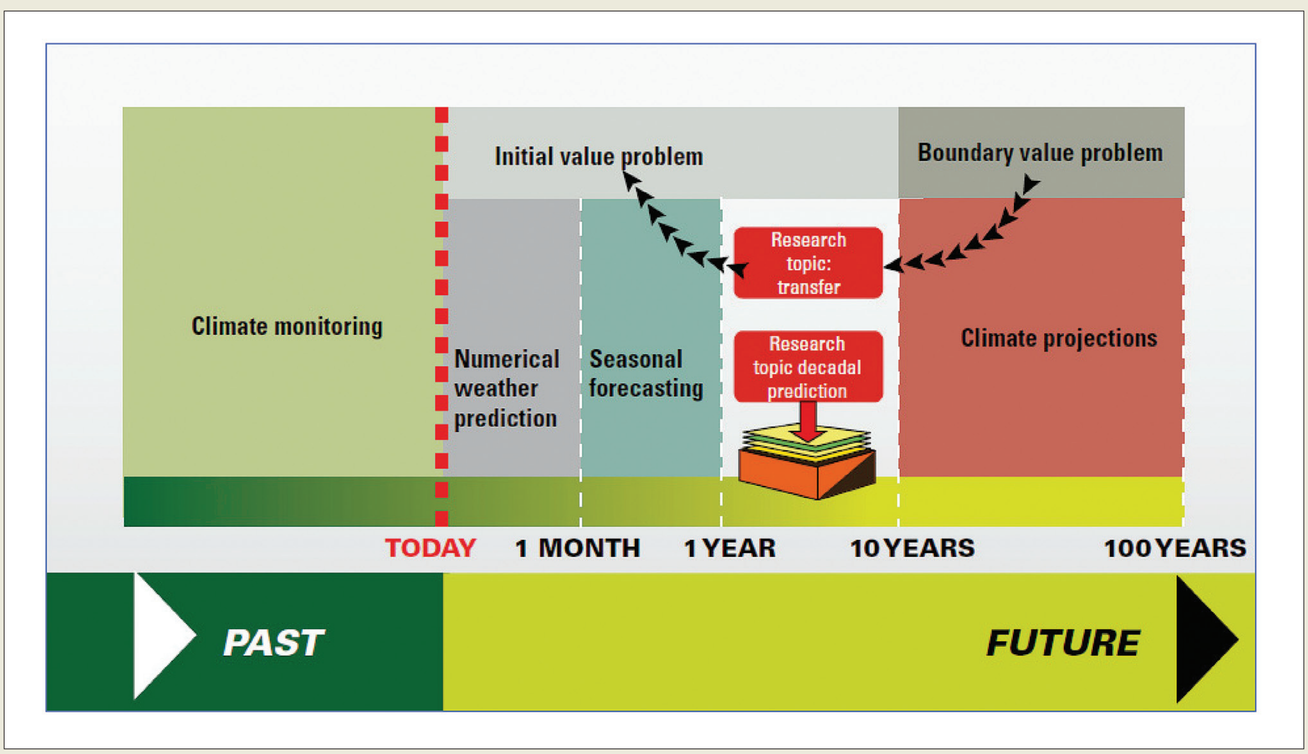
The processing framework and scientific network of KLIWAS gives information on climate change and climate impacts that is quantitative, is tailored for relevant environmental and economic sectors, includes uncertainty guidance that has proven to be comprehensible for stakeholders and is widely accepted in science and administration due to early coordination with scientific institutions working in the same area and field. However, it is dependent on the current capability of complex model chains to resemble real world phenomena, and on the availability and quality of observed data on all components of the water balance.

KLIWAS continues to work on the improvement of data and models and on the dissemination of results. Currently, an integration of many data and models is regarded as best choice to obtain relevant information on climate change and climate impacts.

With the current human, infrastructural, institutional and procedural capacities, KLIWAS has reached a service level that is acceptable for many users. The evaluation framework is particularly appreciated. For example, the Water director of Germany concludes, that "KLIWAS breaks new methodical ground as a pioneer and pathfinder towards the establishment of a multi-model approach. The representation of the spans of possible projections provides a new quality for climate risk assessment to decision makers."[7]

However, a higher service level is still conceivable and would help to support additional user groups with more specific information. For example, technical improvements like advanced data exchange portals could help to push data faster through the model chain. This could set resources free for additional post processing steps, more in-depth data evaluation, and individual user support. In addition, the coherency of the presentation of the different services could be improved.

A topic already scheduled by KLIWAS is the improvement of the seasonal to decadal prediction capabilities. In addition to the work on the medium range weather forecasts, the hydrological system offers many opportunities here through its slow components (snow and groundwater storage). These will be exploited in the coming years, making the KLIWAS services 'seamless'.



The hydrological system offers many opportunities for improved long term forecasts, enabling KLIWAS to make its services 'seamless'

Source: DWD

Adapting to climate change in the Niemen River basin

Vladimir Korneev, Central Research Institute for Complex Use of Water Resources, Belarus

The project 'Management of the Niemen River basin taking account of adaptation to climate change' is part of the United Nations Economic Commission for Europe (UNECE) programme of pilot projects. Thus, it can use the UNECE platform to enable exchange of practices and experience between this project and other similar initiatives aimed at the development of cooperation for adaptation to climate change in transboundary basins. The project on the Niemen is implemented within the framework of the Environment and Security initiative (ENVSEC) through the United Nations Development Programme.

In the context of climate change adaptation, it is important to improve the integrated management of water resources in the transboundary basin of the Niemen River, which flows through the territory of Belarus, Lithuania and the Russian Federation and into the Baltic Sea. The Niemen River plays an important role in the socioeconomic life of all these countries. Over recent decades, the issue of estimates and the forecasting of water resource formation in the river's transboundary basin, as well as the quality of such water resources based on agreed methodology, have become especially important due to climate change.

There is active water use in the Niemen River basin due to a great number of industrial and agricultural enterprises as well as oil and product pipelines. The project addresses the problems of water use in the river basin, including the socioeconomic problems related to different sectors of the economy, such as drinking water supply, water supply for industry and hydroelectric power stations, recreation, and wastewater cleaning and removal.

Image: Vladimir Korneev, 2012

The Niemen River, approximately 20 km upstream of Grodno city

A new hydroelectric power plant under construction on the Niemen River

Considerable tasks

The project objectives will be met by the implementation of the following activities:

- Assessment of the current state of the river basin's water resources (quantitative aspects) and of the impact of economic activities on these
- Study of the changes in climatic characteristics for the river basin and elaboration of climate change scenarios
- Forecasting the runoff of the river basin in the context of climate change, taking into account different scenarios for water use and socioeconomic development
- Analysis of the hydrometeorological, hydrochemical and hydrobiological monitoring systems in the Niemen River basin and assessment of the need to optimize these systems for climate change monitoring (including emergency cases)
- Estimation and forecast of the future climate change impact on water quality at the highest generalization level
- Development of a common information platform (Internet database), containing data on water resources management and adaptation to climate change for the Niemen River basin countries.

Results achieved

The project is being conducted over a 19-month period between September 2011 and March 2013.

Monthly meteorological and hydrological data were collected from Lithuanian and Belarusian hydrological services and preceded with the calculation of seasonal and annual values (data from 1961 to 2010) for the forecasting of climate change and its impact on water resources in the river basin. Temperature and precipitation data were collected from 23 stations (eight in Belarus and 15 in Lithuania) to ensure the statistical validity of the data. Additional information necessary for hydrological modelling was also collected, including wind speed, humidity and sunshine duration. Runoff data were gathered from 25 stations (12 in Belarus and 13 in Lithuania). Statistical analysis and evaluation of changes of meteorological and hydrological characteristics took place in order to identify changes in these.

Climate forecasting for the whole Niemen River basin was done using CCLM model outputs based on initial and boundary conditions of the Global Circulation Model ECHAM5/MPI-OM. Two greenhouse gas emission scenarios were used: A1B (a relatively high-emission scenario) and B1 (a low-emission scenario). A near-term forecast was made for 2020-2050 and runoff forecasting was carried out using separate Belarusian and Lithuanian regional models based on climate forecasting results. Initial data for this forecasting were produced by the meteorological services of the Niemen countries.

The biggest surprise was found in the vulnerability assessment of the Niemen River basin. A case study of current and forecasted status shows considerable varia-

The Niemen River basin

Source: Central Research Institute for Complex Use of Water Resources

tion of meteorological and hydrological characteristic changes on an annual scale from 1961 to 2010 and for 2020 to 2050. Both periods showed increases and decreases during some months of the year and an increase in annual, winter and summer temperatures as well as an increase of winter precipitation, decreases in maximum spring and summer discharges and increased winter flow. In addition, the peak of the spring flood and the dates of minimum winter flow tend to occur earlier in the whole basin area.

The most important lesson from this assessment was that a common approach to statistical analysis and elaboration of meteorological and hydrological characteristics reveals some trends towards change.

Information regarding socioeconomic factors is not a part of the Niemen River basin countries' hydrometeorological services. Generalized information in this field and other socioeconomic factors in the Niemen countries are presented in the national statistical offices and in the corresponding ministries. This information is not accessible online, but it can be received by special request from the corresponding agencies.

Involving the stakeholders

The main stakeholders involved in the process of climate impact assessment on water resources in the Niemen River basin are the Central Research Institute for Complex Use of Water Resources (Belarus) and Vilnius University (Lithuania) as well as the hydrometeorological services of these countries. The Ministry of Natural Resources and Environmental Protection and the Ministry of Emergency Situations of the Republic of Belarus, as well as other ministries including the Ministry of Housing and communal services and local administrations in the river basin, are the main stakeholders. Similar stakeholders can be identified in Lithuania. The Nevsko-Ladojskoye Basin Administration is the main stakeholder involved in Niemen water resources management in the Kaliningrad Region of the Russian Federation. These stakeholders were identified due to their importance in the decision-making process.

The hydrometeorology services of the Niemen countries are involved in the project activities as the organizations responsible for the meteorological and hydrological networks in the river basin. Some meteorological information (from 2009) and hydrological information (water levels for the last 30 days) are accessible online. These services are preparing reports about meteorological and hydrological situations which can be used by other stakeholders including the Ministry of Emergency Situation and the Ministry of Natural Resources and Environmental Protection, as well as other ministries and stakeholders as necessary. The hydrometeorological services of the various countries are also responsible for cooperation with the World Meteorological Organization.

Managing for the future

The main results of the project will be recommendations for the improvement of water management in the Niemen River basin, taking into account adaptation to climate change. These recommendations can be used by management authorities in the Niemen River basin (such as the Ministry of Environment of all the Niemen countries and their regional branches), other stakeholders, public authorities and citizens. They will be especially useful for the improvement of water supply and wastewater cleaning and removal systems, and for optimizing water quantity and quality monitoring systems and improving assessment and forecasting.

Some of the project's activities are funded by the Environment and Security Initiative, while the routing of meteorological and hydrological monitoring in the Niemen countries' national monitoring systems is supported by the countries' national budgets. This context guarantees the project's financial sustainability.

The project is evaluated through Project Steering Committee meetings with the participation of representatives from UNECE, ENVSEC and the main stakeholders, as well as through project working group meetings.

Installation and successful functioning of the common information platform (internet database), containing data on water resources management and adaptation to climate change for the Niemen River basin countries, is an important focus for the future. This platform should be based on the regular data exchange between the Niemen countries.

An important goal is the development and implementation of recommendations for national programmes and projects on the improvement of water resources management in the river basin, in relation to climate change. A new international project on assessment of the climate change impact on groundwater in the Niemen river basin will also be beneficial.

In keeping with Principles 6 and 8 of the Global Framework for Climate Services, this project promotes the free and open exchange of climate-relevant observational data between the Niemen countries. Recommendations for adaptation to climate change will be developed in the framework of the project, and these will take into account the participation of the main users, with provider partnerships that include the main stakeholders.

The Danube River Basin climate adaptation strategy

International Commission for the Protection of the Danube River

Climate change impacts will pose an increasingly significant threat in the Danube River Basin (DRB) if the reduction of greenhouse gas emissions is not complemented by climate adaptation measures. Due to changes in temperature and precipitation, impacts are expected for different sectors on a transboundary scale because water and its availability is a cross-cutting issue with major relevance for different sectors. Therefore, water is a key focus for adaptation steps on different levels and for integrating different stakeholders and interest groups.

More work still needs to be done to clearly understand the scale and magnitude of pressures and impacts, but it is obvious that there are actions that can and must be taken now, among the priorities for the overall management of the DRB. As a starting point, an international conference on Water and Climate Change in the DRB was held in December 2007, raising awareness and drawing first conclusions on the way forward. This event has opened a dialogue about climate change and adaptation in the DRB and work is ongoing in line with policy developments, specifically at the level of the European Union. The most recent step is the development of a Strategy on Adaptation to Climate Change for the whole Danube basin, based on the findings of the research.

Protecting the Danube River Basin

From its source to the Black Sea, the Danube is approximately 2,800 km long, making it the second-longest European river after the Volga. Its catchment area, the DRB, extends into the territories of 19 countries and comprises more than 800,000 square kilometres or about 10 per cent of continental Europe, encompassing a wide variety of cultures, landscapes and ecosystems.[1]

Historically, human activities such as households, industries and agriculture have put pressure on these ecosystems, contributing to decades of decreasing water quality. Problems built up that could not be addressed by individual countries alone. With the fall of the Iron Curtain in 1989, a new window of opportunity opened for the Danube countries and the need for cooperative water management became more obvious than ever.

The DRB is outlined by natural watersheds. Of the 19 countries that have territories within this basin, 14 cover more than 2,000 square kilometres. On 29 June 1994, these main Danube countries – some of them not situated on the river, but within the basin – signed the Danube River Protection Convention[2] in Sofia, Bulgaria, defining three main areas for action:

- Protection of water and associated ecological resources
- Sustainable use of water in the Danube Basin
- Managing floods and ice hazards.

Today, the Danube River Protection Convention has 15 contracting parties: 14 countries and the European Union. Together, they form the International Commission for the Protection of the Danube River (ICPDR). Its permanent secretariat is based in Vienna and started its work in 1998.

Policies and management plans

In 2000, the European Union (EU) adopted the EU Water Framework Directive (WFD).[3] It mandates water management according to the outlines of natural river basins rather than national or other administrative borders. Alongside the implementation of the EU Floods Directive (EFD) of 2007,[4] the WFD is ICPDR's highest priority as all its contracting parties, including the non-EU countries, agreed to coordinate its implementation. This involved the development of a DRB Management Plan (DRBM Plan) in 2009,[5] based on an analysis of the main pressures, water uses and environmental conditions in the basin. Today, the DRBM Plan and several Flood Action Programmes[6] list hundreds of measures and policies through which ICPDR and its contracting parties work towards healthier river environments, sustainable water use and the protection of citizens.

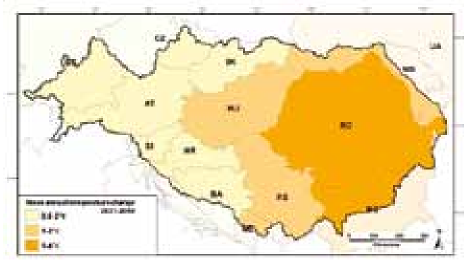
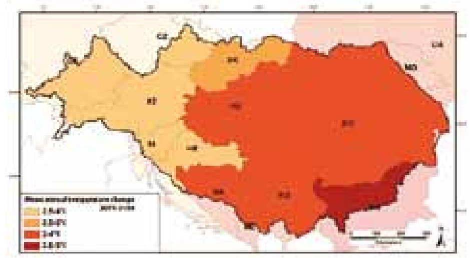
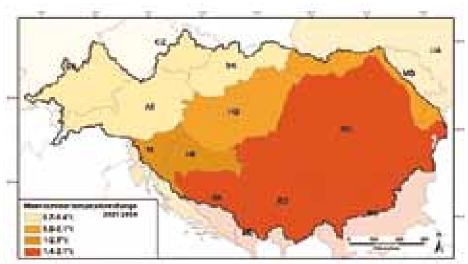
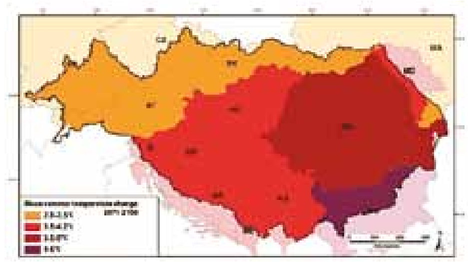
In order to take the required steps on adaptation to climate change, ICPDR was asked in the Danube Declaration from 2010[7] to develop a Climate Adaptation Strategy for the DRB by the end of 2012. Within ICPDR, Germany was nominated as the lead country in this task, which is coordinated by the River Basin Management Expert Group, comprising national experts and representatives from different stakeholders and observer organizations.

The first step, the 'Danube Study – Climate Change Adaptation',[8] was initiated by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and finalized in January 2012. The study was developed by the Department of Geography of the Ludwig-Maximilians University Munich and summarizes all the latest available information on climate change and adaptation relevant for the DRB. It provides a basis for the second step, the 'ICPDR Strategy on Adaptation to Climate Change', which is now being developed to provide guidance on how to address climate adaptation in the DRB.

Climate change scenarios

The Danube study stressed that in order to assess the future development of climate parameters, air temperature and precipitation, most of the projects

Change of mean annual and mean summer temperature in the Danube River Basin for 2021-2050 and 2071-2100 according to A1B scenario of different model results

	2021-2050	2071-2100
Mean annual temperature changes		
Mean summer temperature changes		

Source: LMU

and studies use the Intergovernmental Panel on Climate Change (IPCC) emission scenarios A1B, A2, B1 and B2. However, other emission scenarios are also applied in a few projects and studies.

Different Global and Regional Circulation Models are used as meteorological drivers, so spatial resolution of the simulation results varies. The future development is mainly based on single model runs, only some projects use ensemble model runs. Finally, different dynamical and statistical downscaling methods are applied to model the future development of air temperature and precipitation with a spatial resolution between 1 km and 10 km. As reference periods mainly the periods 1961-1990 and 1971-2000 are used and most of the simulations are projected for the future periods 2021-2050 and 2071-2100.

Air temperature

In total, 59 projects and studies with statements regarding IPCC scenarios or trends were analysed, and all of them assume a temperature increase during this century, both annually and in every season, with a rising gradient from north-west to south-east in the DRB. While there are considerable differences in the investigated areas due to climate influencing factors like altitude, mountainous massifs and seas, the main future trends are similar for all areas. Also the mean temperatures of all seasons are likely to increase, only for winter all models show a relatively high uncertainty.

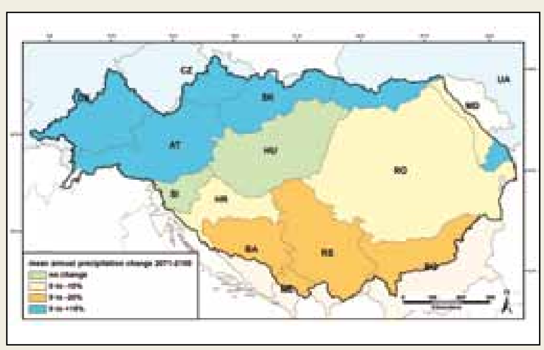
Precipitation

The DRB is located in the transition zone between expected increasing (Northern Europe) and decreasing (Southern Europe) future precipitation. According to the analysed projects, mean annual values in many countries of the DRB will most likely remain almost constant, but seasonally and regionally large changes are projected for the twenty-first century. A decrease in summer

Change of mean annual precipitation in the Danube River Basin for the periods 2021-2050 and 2071-2100 according to A1B scenario of different model results

2021-2050

2071-2100



Source: LMU

More intensive and frequent dry spells are expected to cause negative impacts on different water-related sectors, like inland navigation

precipitation and an increase in winter precipitation in most areas are to be expected. While winter variability increases significantly, there are no clear trends for spring and autumn. In the future, more extreme events such as torrential precipitation events and widespread drying are to be expected, the latter mainly in Southern and Eastern parts of the DRB.

Extreme weather events

The simulations show for the DRB a future increase in intensity and frequency of dry spells, hot days and heat waves as well as increases in heavy rainfall, but the latter is uncertain in spatial and temporal allocation. Due to the warming trend fewer frost days are probable in winter. Whilst for the Upper Basin a general increased risk of storm-related heavy precipitation with high wind speeds is assumed, for the Middle Basin the amount of extreme precipitation days are expected to increase in winter and decrease in summer.

Water-related impacts

The Danube study considers several climate change impacts on water-related issues and possible adaptation measures. This includes impacts on water availability, supply and demand, groundwater, snow cover and runoff as well as impacts on different water uses, which encompasses agriculture, irrigation, forestry, land use, soils, biodiversity and ecosystems, limnology and water-related energy production, navigation, health and tourism.

Basically, the impacts on water-related sectors are triggered by temperature and precipitation changes. The main impacts in connection with water management are the availability of water, extreme hydrological events, the quality of water and impacts which affect the water user sectors. Temperature and precipitation changes may cause reduction in water availability, groundwater recharge and decreases in snow and glacier ice storage and soil water content. Furthermore, changes in seasonal runoff regimes, with a likely decrease in summer and increase in winter, are triggered by changes in rainfall distribution and evapotranspiration, as well as reduced snow storage. Increasing water temperature may also cause greater pressures on water quality. No clear picture can be provided on changes in flood magnitudes and frequencies, but more intense, longer and more frequent droughts, low flow and water scarcity situations are expected.

All these impacts can cause changes in ecosystems and biodiversity with shifts of the aquatic and terrestrial flora and fauna. Regarding water users, climate-related increases in water demand of households, industry and agriculture are expected, causing higher water stress in water-dependent sectors such as agriculture (irrigation), forestry, navigation and water-related energy production. But positive effects on different sectors were also observed, like the reduction of ice days on rivers or longer vegetation periods.

Despite the uncertainties in climate change impacts, which are specifically addressed in the Danube study, possible adaptation measures are introduced for each impact area. In order to avoid regrettable adaptation activities, these measures are focused on win-win and no-regret options, because measures of these categories minimize climate risks but also have other social, environmental or economic benefits.

Image: F. Kovacs

Although no clear picture can be provided at the current stage on expected changes in flood magnitude and frequencies, focusing on integrated flood risk management with the implementation of the EU Floods Directive on Danube Basin-wide scale, is considered as a no-regret measure for adaptation to climate change and the protection of the local population

Possible adaptation measures

The Danube study includes a summary of possible adaptation measures for each investigated impact field, which can be ordered according to different categories (for example, based on the United Nations Economic Commission for Europe Guidance on Water and Adaptation to Climate Change).[9]

Possible adaptation measures can include preparatory measures for adaptation (e.g. intensified monitoring activities to assess climate change impacts or forecasting and warning systems, further research to close knowledge gaps), ecosystem-based measures (e.g. implementation of a green infrastructure to connect biogeographic regions and habitats, protection and restoration of water-retention areas), behavioural/managerial measures (including support for education, capacity-building and knowledge transfer or promotion of water-saving behaviour), technological measures (e.g. improvement of infrastructure such as more efficient irrigation systems in agriculture or the construction and modification of dams and reservoirs for different purposes like drinking water supply), as well as policy approaches (like support of an institutional framework to coordinate activities e.g. on flood risk management).

Developing a climate adaptation strategy

The Danube study was an important step towards adapting the DRB to climate change. By addressing the whole basin, it helps to generate a joint understanding of the issues and identify the required transboundary actions. The ICPDR Strategy on Adaptation to Climate Change is currently being developed, to be finalized by the end of 2012. The strategy should guide the way to fully integrate climate adaptation in the work of ICPDR by making best use of existing structures and instruments, in particular the WFD and EFD.

Image: Alexander Ivanov

Green infrastructure like the extension of natural areas and the (re-) connection of wetlands and floodplains to the main river can provide various benefits for adaptation to climate change, creating win-win solutions like the reduction of flood peaks, increased robustness against low flow situations and drought spells, beside the protection and maintenance of the natural ecosystem

The 2nd DRB and 1st Danube Flood Risk Management Plan, due by 2015 and to be updated according to the six-year planning cycles, will be the key tools for adapting the DRB to climate change. The adaptation strategy will therefore not include a programme of measures since the required adaptation measures will be discussed and enshrined in the forthcoming management plans. ICPDR will focus in this process on the issues that are relevant for the basin-wide scale.

For further information please get in contact with the ICPDR secretariat via www.icpdr.org

III
Health

Informing decision-making in health using seasonal climate outlooks

Yahya Abawi, Jason A. Smith, Amanda Amjadali, David Jones, Diann Woods and Michael J. Coughlan, Australian Bureau of Meteorology; and Lloyd Tahani, Solomon Islands Meteorological Service

The Pacific region experiences substantial climate variability as a result of the El Niño Southern Oscillation (ENSO). Specifically, the seasonal changes in rainfall and temperature can cause droughts, flooding and temperature extremes. Fortunately for the region, many of the associated impacts are predictable using statistical and dynamical climate models, allowing a degree of preparedness and proactive management of the most severe impacts.

The Government of Australia (GoA) has contributed significant resources to supporting Pacific islands' management of and responses to climate variability and change. GoA funds a range of climate-related programmes and projects through the bilateral and regional programmes of the Australian Agency for International Development (AusAID). One such project is the Pacific Islands Climate Prediction Project (PI-CPP), which has been implemented by the Australian Bureau of Meteorology. The goal of PI-CPP was to strengthen the capacity of Pacific Island countries (PICs) in seasonal climate prediction and to provide climate-related information. A key component of the project was to build indigenous capability in preparing and issuing seasonal forecasts, noting the significant skill potential value of forecasts.

Map of the Solomon Islands showing major islands and towns

Source: Australian Bureau of Meteorology

From the outset, it was recognized that merely supporting National Meteorological Services (NMSs) to produce seasonal climate forecasts would not guarantee their effective uptake by climate-sensitive industries and resource managers. A key component of PI-CPP, therefore, has been a pilot project programme to use the seasonal forecasts to support vulnerable sectors such as health, agriculture, water and renewable energy. Integral to each pilot project have been follow-up visits and workshops in the participating PICs to outline the project results and explore the potential for developing operational information and warning systems. The implementation and sustained operation of such systems require close collaboration and coordination between NMSs as the primary providers of climate information and the user/client groups that need to integrate the information into their planning, management and decision-making processes.[1]

ENSO and malaria in the Solomon Islands

One such pilot project on the application of seasonal forecasts has been the development of a prototype malaria early warning system in the Solomon Islands. In order to facilitate the project, the PI-CPP team coordinated with both the Solomon Islands Meteorological Service (SIMS) and the Solomon Islands Medical Training and Research Institute (SIMTRI). A principal objective of the project was to develop malaria outlooks based on the historical relationship between malaria incidence and the effects of the ENSO phenomenon on rainfall and temperature. Determining the precise nature of this correlation was itself a key component of the project and the subject of lengthy investigation. Once the relationships were well understood, it became possible to develop a prototype early warning system in which SIMS could issue bulletins for periods in which upcoming climate conditions were favourable for high malaria incidence, thus allowing medical services and residents to take measures to minimize infection. It is also expected that such forecasts would provide sufficient lead time for healthcare services to efficiently incorporate in their planning the need for additional medical resources during these periods.

Tackling malaria

Malaria is a primary focus of one of the United Nations Development Programme (UNDP) Millennium Development Goals[2] and remains one of the most widespread and devastating infectious diseases in tropical developing countries around the world.

The Solomon Islands is no exception, where malaria is a leading cause of death. World Health Organization data published in April 2011 showed a malarial death rate of approximately eight per cent of total deaths. The age-adjusted death rate of approximately 30 per 100,000 of population ranks the Solomon Islands as 33rd in the world. Malaria continues to have a high cost in both economic and social terms in the Solomon Islands, with low productivity at work and absenteeism in schools.

In the Solomon Islands, *Plasmodium falciparum,* the severe and life-threatening form of malaria parasite, accounts for 60-70 per cent of all confirmed cases. As mosquitoes are the carrier of this disease, worldwide malarial epidemics tend to occur when environmental conditions such as rainfall, temperature and relative humidity create optimal conditions for mosquito breeding.

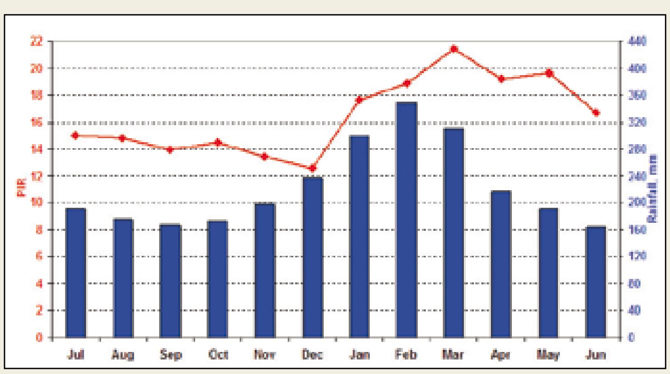
The climate of the Solomon Islands is significantly influenced by the ENSO phenomenon. El Niño conditions are generally associated with below-average rainfall and above-average temperatures, while La Niña conditions are generally associated with above-average rainfall and below-average temperatures. The tendency for an ENSO state to develop and persist once it is initiated makes it possible to forecast seasonal rainfall and other hydroclimatic variables with some accuracy, employing key climate indices such as the Southern Oscillation Index and patterns of Sea Surface Temperature anomalies. Therefore there is potential to forecast the elevated risk of malaria outbreaks in the Solomon Islands with sufficient lead time to reduce the potential incidence of the disease through targeted control strategies.

Lessons from data

In collaboration with SIMTRI, records of both confirmed and suspected (unconfirmed) malaria cases for nine provinces were obtained for the period 1975-2007. Corresponding climate data for this period, including rainfall, maximum and minimum temperature and relative humidity data, were prepared by SIMS.

Records were collected for each of the nine Solomon Island provinces and were collated into five regions for the purpose of this study.

Average monthly PIR and rainfall for the Solomon Islands, 1975-2007



Source: Australian Bureau of Meteorology

Data for the central (including Central, Guadalcanal, Isobel and Honiara provinces) and western (including Western and Choiseul provinces) regions were aggregated, while the provinces of Makir, Temotu and Malaita were treated as separate regions. The grouping of data in this way gave significant consideration to geographical location, orographic effects and the availability of malaria outpatients and climate data. Considerable adjustments were made to population data and the associated records on malaria incidence to reflect the groupings, and the malarial incidence was calculated as a Positive Incidence Ratio (PIR), which is defined as the number of positive films per 1,000 head of population.

The numbers of confirmed malaria cases were identified using data from 1975-2008 during the peak infection period (December to May). Linear and non-linear regression techniques were used to relate PIR to climate (temperature and rainfall) and non-climate (for example, population growth) factors. The analyses show that incidence of malaria peaks during the wet season (December to April). However, it was also evident that, somewhat counter-intuitively, above median rainfall during this peak period tends to suppress the number of malaria cases. The likely cause is a flushing out of mosquito breeding sites by the heavier than normal rainfall. Conversely, below-median rainfall during the wet season tends to increase the incidence of malaria.

Together these results indicate that malaria would tend to be more prevalent during El Niño events and less so during La Niña events. The maximum correlation between rainfall and PIR is subject to a significant lag time, with PIR lagging rainfall by approximately two months. This makes rainfall a useful parameter for forecasting PIR with sufficient lead time to inform planning and management decisions. On the other hand, temperature influence on the number of malaria cases tends to have a shorter lag period, hence lower than normal rainfall from November to January followed by higher than normal temperatures in December and January triggers a high incidence of malaria in the Solomon Islands.

Health data collected from SIMTRI showed that the PIR was relatively high from 1990 through to 1995, at a time when El Niño patterns prevailed from April 1991 to March 1995. Five out of six November-April rainfall totals were below average during this period. Climate factors (rainfall and temperature) explained up to 70 per cent of variability in the number of malaria cases. An early warning system for malaria based on seasonal climate forecasts for the peak infection period was therefore assessed to be viable for the Solomon Islands.

It is also noteworthy that projections of future climate suggest an increasing trend toward higher temperatures and no significant change in the rainfall pattern for the Solomon Islands, which could pose a future increased risk of malaria and therefore an increased urgency for the development of improved management strategies.

Use of climate information

A prime example of the use of climate information to facilitate improvements in malaria management is the Malaria Early Warning System (MEWS) developed in Sub-Saharan Africa over the last decade by the Roll Back Malaria partners under the auspices of the World Meteorological Organization.[3] With the confirmation of a robust relationship between ENSO phenomena and malaria incidence in the Solomon Islands, the development of a similar early warning system for the Solomon Islands is considered feasible.

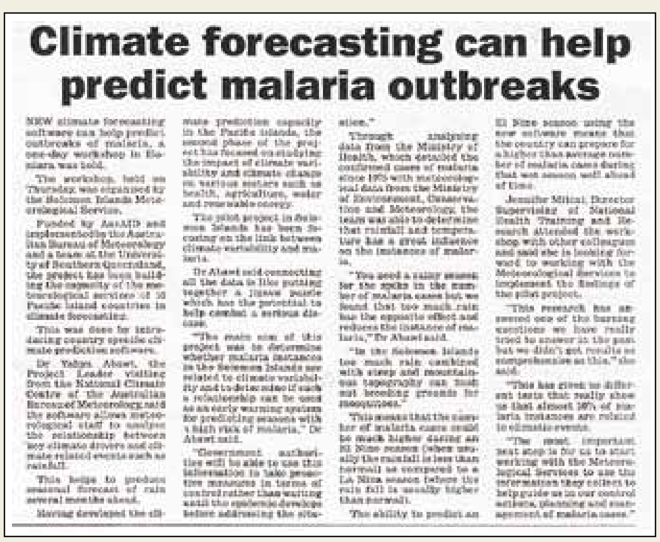
An operational early warning system will require the establishment of a number of protocols and procedures for ensuring the rapid and timely exchange of information between the NMS and relevant health providers, as well as an effective means of informing key Government entities and the wider population. The end results will be improved healthcare outcomes for the residents of the Solomon Islands and a more appropriate provision of health services during periods of high malaria incidence, thus improving the standard of care, the quality of healthcare outcomes, and cost savings due to more efficient use of resources. These improvements will likely lead to benefits in the overall wellbeing of the local population, particularly during periods of high malaria risk and infection potential. They will also bring long-term benefits to work and education output (due to reduction in lost productivity from illness and incapacity), as well as improvements to quality of life, subjective life satisfaction and possibly average life expectancy.

Outreach

This project has been a pioneering case study of the impact of climate variability and possible climate change on the health of a Pacific community. Although the study has focused on the Solomon Islands, the methodology has wider applications in a number of other Pacific Island nations for improving the management of malaria in Papua New Guinea and Vanuatu, dengue fever in Fiji, and waterborne pathogens in Kiribati. Contrary to the common belief that higher rainfall in the tropics is generally conducive to a higher incidence of malaria, this study has concluded that a certain rainfall threshold, if exceeded, can significantly reduce the incidence of malaria. It is not clear whether direct extrapolation of the results of this study to other regions is appropriate, due to substantial differences in the effects of the ENSO cycle on different PICs and to variations in topography and geography across the region, all of which can significantly affect the epidemiology of climate-related illnesses.

The results of this research were presented in a workshop in Honiara and received wide coverage in local media and an interview on the ABC Pacific Channel with Lloyd Tahani of the Solomon Islands NMS. The project has raised the profile of the NMS in the Solomon Islands and has fostered closer collaboration between it and health service organizations in the country.

The PI-CPP Solomon Islands pilot project received wide coverage in the local media



Climate forecasting can help predict malaria outbreaks

Source: *Solomon Star*, 1 August 2009

Towards a sustainable system

Following the Honiara workshop, Dr Jennifer Mitini, Director of National Health Research and Training, said in an interview:

"The research has answered one of the burning questions we have really tried to answer in the past, but we didn't get results as comprehensive as this [study]. The most important next step is for [the health community] to start working with the Meteorological Services to use the information they collect to help guide us in our control actions, planning and management of malaria cases."

An early warning system for malaria has enormous potential, from a public health perspective, to be a very valuable tool in reducing the spread of malaria in the population of the Solomon Islands, and possibly other PICs. It is important that any early warning system be sustainable once external resources are removed. Experience in other developing countries has shown that the implementation of simple and reliable alert systems can be a better use of resources than trying to develop very costly and complex model-based systems.[4] This pilot project has demonstrated that it is possible to produce malaria alerts based on seasonal climate forecasts issued by SIMS and that this information could be provided to the authorities and general public to complement existing control strategies and policies.

The direct link between the outcomes of this study and the Millennium Development Goal of a way of reducing the incidence of malaria poses distinct advantages for the future developments of an alert system in the Solomon Islands and other PICs. With respect to the Solomon Islands, the advantages are threefold. Firstly the commitment to the goal of malaria reduction is already a well-established policy for both the Solomon Islands Government and international donors. The Solomon Islands Government has been heavily engaged in malaria reduction for several decades. Its commitment to reduction strategies has already contributed to a reduction in malaria of more than 60 per cent.[5] International financial commitments to malaria control currently total around US$2 billion worldwide, of which around US$2.5 million has been earmarked specifically for Solomon Islands reduction campaigns.[6] Secondly, there is evidence that the African MEWS, which is also based on climatic forecasts, has helped to reduce the incidence of malaria in that part of the world. Thirdly, a project to develop an operational early warning system would complement current reduction strategies such as the widespread use of insecticide-treated bed nets. A recent survey by the UNDP found that around 70 per cent of the population of the Solomon Islands was using these nets, with the lowest rate of use in the lower socioeconomic groups.[7] Early warning of potential outbreaks would enable authorities or donors to ensure that nets were distributed to economically disadvantaged sectors of the population, in addition to ensuring that anti-malarial medication was available for prompt treatment of any infections that did occur.

These advantages would need to be exploited to ensure the future development and sustainability of an early warning system. Feedback on the project results indicates that SIMS and SIMTRI are keen to develop the prototype system of this study into an operational malarial early warning system, with recognition that further and ongoing engagement of all stakeholders will be essential for ensuring that the system and its associated services are robust and sustainable.

A third and expanded phase of the PI-CPP, called Climate and Ocean Monitoring and Prediction (COMP), commenced in July 2012. COMP sits under the broader Climate and Oceans Support Program for the Pacific (COSPPac), which, like PI-CPP, is funded by AusAID and implemented by the Australian Bureau of Meteorology. One component of COMP will be to support climate-sensitive industries to understand and use seasonal climate information through the implementation of sustainable application projects in COMP partner countries.[8] These projects will build initially on the results of the PI-CPP pilot projects, including the Solomon Islands malaria study and, where appropriate, COSPPac will support the development of fully operational climate risk management and early warning systems. The projects will play a significant role in COSPPac as a means of showing how climate data and predictions can be used to confer real and measurable benefits across a number of industry sectors in the Pacific exposed to significant risk from climate variability and extremes.

Images: Australian Bureau of Meteorology

Climate information helps provide an early warning system for malaria outbreaks in the Solomon Islands, allowing for improved healthcare and a reduction in lost productivity

The Heat Health Warning System as an example of climate services at the Deutscher Wetterdienst

S. Rösner, Dr P. Becker and Dr Christina Koppe, Deutscher Wetterdienst

The German Heat Health Warning System (HHWS) is among the first measures to adapt to a warming climate in Germany. It demonstrates how climate and health services need to collaborate in order to protect human health in the face of an anticipated increase in the number of heat waves.[1]

The German Adaptation Strategy (Deutsche Anpassungs Strategie or DAS)[2] was developed to systematically address the changes ahead, creating a framework for adaptation to the consequences of climate change in Germany at the federal level. It describes the possible consequences of future climate for 15 sectors and areas, including human health. In August 2011 the German Government also adopted an 'Action Plan Adaptation' of the DAS.[3] The HHWS represents an already implemented activity to support adaptation measures in the human health sector.

In summer 2003 an extensive heat wave hit many European countries, causing between 35,000 and 50,000 heat-related extra deaths.[4] Older and sick people, as well as the very young, were most at risk. In Germany the number of additional casualties attributable to the heat wave probably exceeded several thousand. An investigation for Baden-Württemberg showed excess mortality of about 1,100.[5] Some of these casualties could have been avoided if precautionary measures had been taken, and an early warning system would enable the preparation of such measures.

Until 2003 there were only two operational HHWS in Europe: in Lisbon and Rome. Heat load was forecasted and communicated in Germany, but not as a warning. However, the high numbers of heat-related deaths that summer across Europe led to an increase in HHWSs. A survey in spring 2006 by the German weather service Deutscher Wetterdienst (DWD), in the context of the EuroHEAT project, showed that heat warnings were issued in 16 countries and that several countries were planning to implement a HHWS in the near future. By 2009, 28 countries in Europe were issuing heat warnings.

HHWSs use a variety of methods to identify heat episodes. These differ from country to country or even from city to city, mainly because the term 'heat wave' has not yet been defined and there is no consensus in the scientific community on which indicator is most closely linked to adverse health outcomes.

Following the 2003 event the Federal Ministry for Health and Social Safety, on the initiative of DWD, appointed a commission to develop recommendations for a heat warning system in Germany. In 2004 the federal states of Baden-Württemberg and Hesse developed pilot heat warning systems. These were successful, and DWD decided to introduce a regionalized HHWS for all of Germany, developed in close cooperation with public health authorities.[6] At that time DWD already had a long history in providing thermal load forecasts to various user communities, and this enabled the quick implementation of the German HHWS.

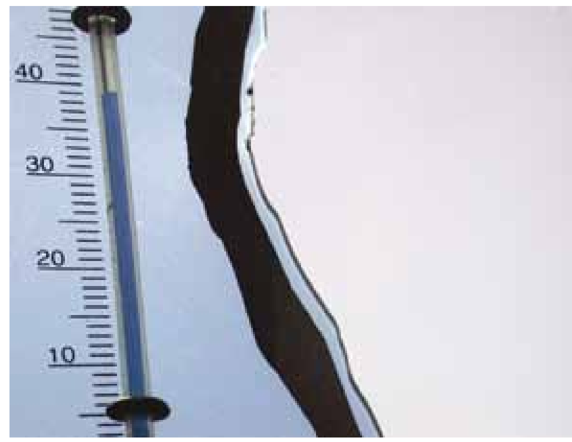


Image: matchka/pixelio.de

Heat waves are an emerging public health problem in many parts of the world

During the development phase there were frequent discussions with health administrations from Hesse and Baden-Württemberg, which are responsible for turning information from the HHWS into concrete actions and advice. It was agreed not to communicate excess casualties — which cannot be reliably estimated and would give the HHWS negative associations – but to produce a heat load index.

The HHWS

HHWSs consist of two parts: a meteorological component (monitoring the weather situation, triggering and issuing warnings) and a public health component (action plans, intervention measures). The meteorological component is based on a heat load indicator.[7] It is important to identify a heat load indicator related to human health impacts, and a threshold to trigger intervention actions.

For Germany's HHWS the meteorological statistics had to be linked with the mortality data, which were available for Baden-Württemberg, for different European cities outside Germany (Budapest, London, Lisbon and Madrid) and for the Netherlands due to DWD's participation in the European cCASHh-project. The goal was to estimate excess mortality as a function of the heat load, and this required mortality statistics to be corrected for changes in population and the annual cycle. For all analysed mortality time series, on days with a strong or higher heat load, mortality was increased by 10 per cent or more. When selecting the threshold value for issuing warnings and triggering interventions, various aspects must be considered: too frequent warnings will lead to warning-fatigue, while if warnings are too rare users might forget what they ought to do. So we used days with a strong (category +3) or extreme (category +4) heat load to trigger heat warnings in Germany. Within the 36 analysed years, 121 days fell within these categories.

Germany's HHWS is based on a combination of DWD's weather forecast output and a health-related assessment of the thermal environment. The latter combines a complete heat budget model with a short-term adaptation approach.[4] Four fundamental meteorological factors are needed to assess the human thermal environments: air temperature, mean radiant temperature, humidity and wind velocity. In addition, physiological parameters like the metabolic rate or weight and clothing worn by a person are needed to assess the thermal load. Since no information is available about an individual's physiological parameters, the assessment is made for a standardized person. DWD uses a complete heat budget model of the human body, which takes into account all relevant mechanisms of heat exchange with the atmospheric environment. Heat exchange is modelled for a standard male, known as 'Klima-Michel', who chooses his clothing to maintain thermal comfort as far as possible. Based on the calculated perceived temperature (PT),[8] nine physiological stress categories from 'extreme cold stress' to 'extreme heat load' have been defined.

Image: Thomas Max Müller/pixelio.de

Warnings call on the public to behave heat-related

Warnings are issued for 'strong heat load' and 'extreme heat load' periods of at least two consecutive days. On each day, when the PT at 12 Universal Time Coordinated exceeds a threshold of around 32° C, a warning is issued by DWD at about 10am covering a two-day period. The warning threshold is not fixed. It takes into account that humans adapt to their thermal environments and can cope better with heat if they are used to it. Therefore the thresholds are a bit higher in Germany's warmer regions and in late summer. An additional requirement for a warning to be issued is that night-time temperatures stay above a certain threshold (15-18° C), as high minimum temperatures prevent people from recovering sufficiently.

While DWD is responsible for the meteorological component of the HHWS, partners are needed to make sure the information reaches those who need it most — elderly and very young people — and to introduce a set of interventions. Due to the federal structure of the German health system, these partners are the respective federal health authorities and DWD had to negotiate and sign contracts with all 16 Federal Laender (federal states) to make sure the warnings get through. In some Laender, interventions vary between a warning for a 'strong' and an 'extreme' heat load. For DWD however, the communication strategy remains the same independent of the level of warning.

Warnings are issued for all counties across Germany during the warm season (typically May to September), for six different altitude categories in line with DWD's general warning strategy. Before a heat warning is issued, the automatically-generated warning guidance is reviewed by a biometeorologist. In addition to the information from the heat stress model, a building simulation model provides information about indoor conditions.

All the HHWS warnings are issued to the general public through the DWD warning platform on the Internet, and are accessible through the multilingual Meteoalarm platform. Newsletter systems are also available for the general public and elderly care and nursing homes. The relevant health and supervisory authorities are directly notified; they are responsible for defining and monitoring the implementation of intervention measures. They also have the option of broadcasting the warning more widely to the public on radio and television.[4]

Administrative challenges

Among DWD's duties is "the provision of meteorological services for the general public or for individual customers and users, especially in the fields of … public health."[9] It also includes regulations on remuneration. In general "The Deutscher Wetterdienst shall charge a remuneration for the provision of its services."[10] The aim was to provide the HHWS service free of charge, so a series of internal discussions was needed to establish that this type of service is an essential product and can be part of DWD's Global Data

Set. DWD will continue to disseminate heat warnings as they fall within the list of its legal duties, and as no other institution is allowed to issue official warnings.

Due to the federal structure of Germany, DWD had to negotiate cooperation agreements with all 16 Laender individually, as they are responsible for issuing guidance to organizations for taking action. A HHWS can only save lives if effective intervention measures are implemented. As public health intervention has to be triggered by the Laender health systems, DWD can only influence the effectiveness of the meteorological component of the HHWS and is not able to influence the public health component.

As part of the negotiations with the Laender, the users who would receive DWD's warnings had to be identified, and technical details on how to communicate clarified. At first, a long list of fax numbers and email addresses had to be maintained by DWD. In some of the Laender the public health authority takes care of distributing the warnings to end users. DWD has now switched direct distribution of the warnings to its newsletter system, with end users responsible for maintaining correct email addresses. A few interfaces in the Laender still receive the warnings by fax.

As the mass media consists of independent organizations, DWD has no influence on using this means of communication to disseminate warnings. Warnings need to be reliable and available on a routine basis, so DWD must provide them on platforms that it controls, such as the website and newsletter.

Outlook

A process has been established for monitoring, evaluating and improving the whole warning system of DWD, of which the HHWS is just one element. Quality management indices have been identified for the meteorological component of the HHWS and the warning mechanism is continually being improved according to performance against these. Feedback is generally positive and the service will be continued.

Issues still to be addressed include direct user contact — for example, how can elderly people, many of whom live alone, be informed and measures initiated? Another issue is how to better address indoor climate, as only a few houses in Germany have air conditioning. As people (and especially the vulnerable population) stay indoors most of the time, the German HHWS is currently extended by the prediction of heat stress in typical rooms, so it is feasible to forecast heat stress using a combination of outdoor and indoor predictions. Another issue results from the special climate in dense urban settlements. DWD is also considering developing applications for mobile devices for personalized services.

In principle, DWD's HHWS can be applied in other countries due its flexible approach to assessing heat load. It has not yet been directly implemented in another country, but several national meteorological and hydrological services (NMHS) have shown a keen interest. Some have been provided with the underlying Klima-Michel model, although it isn't known whether this is being used for heat load warnings.

Since 2005, DWD's HHSW has demonstrated its usefulness during several heat waves and the warnings are widely accepted by public health authorities. In future, with a warming climate, more of these warnings can be expected. As an indicator for heat load affecting human health, the number of hot days for Germany as a whole is routinely presented in the German Climate Atlas in terms of historical, present and future climate conditions. In addition, the future number of hot days has been calculated for a several cities in Germany using various regional climate models.[11]

DWD's experience and knowledge in climate impact modelling and assessment of derived information about future climate in different sectors might also be applicable to other countries. However, this would entail adapting DWD's tools and procedures to specific circumstances in other countries. DWD will be happy to support the development and provision of national climate services in other countries with its experience and knowledge.

Image: Cisco Ripac/pixelio.de

Closed blinds protect indoor conditions against the heat outdoors

Climate implications of atmospheric warming due to aerosol black carbon over the Indian region

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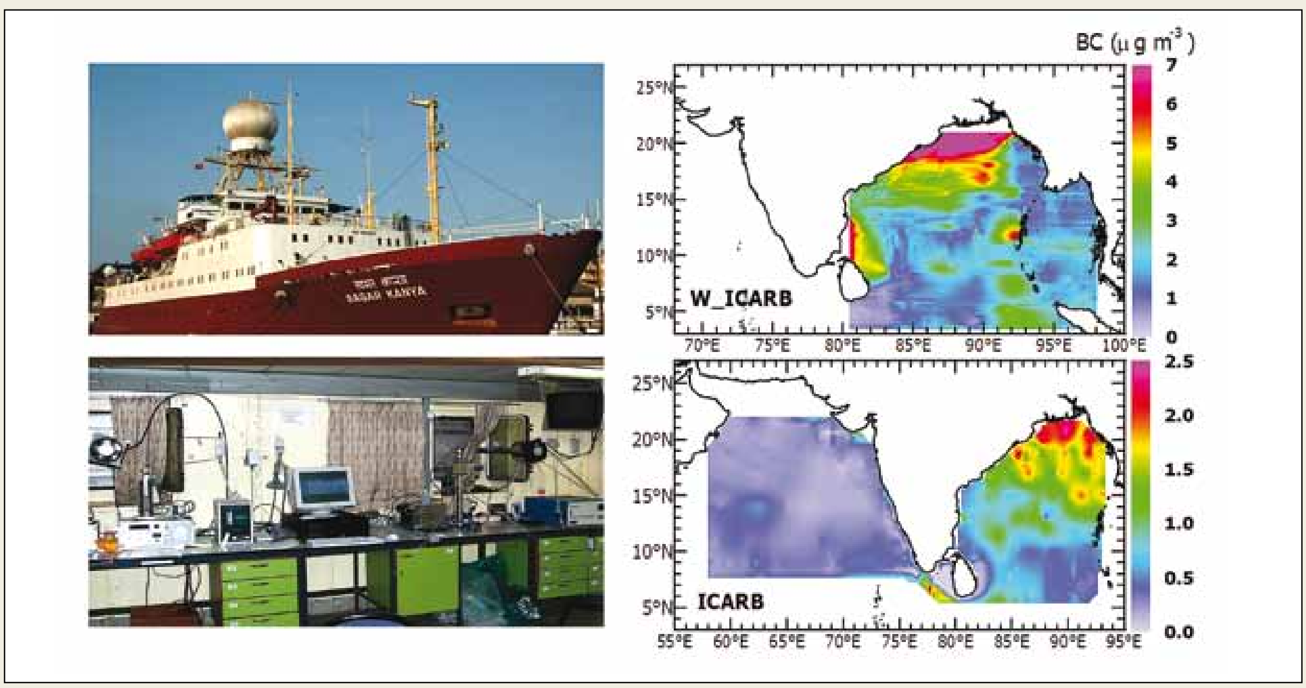
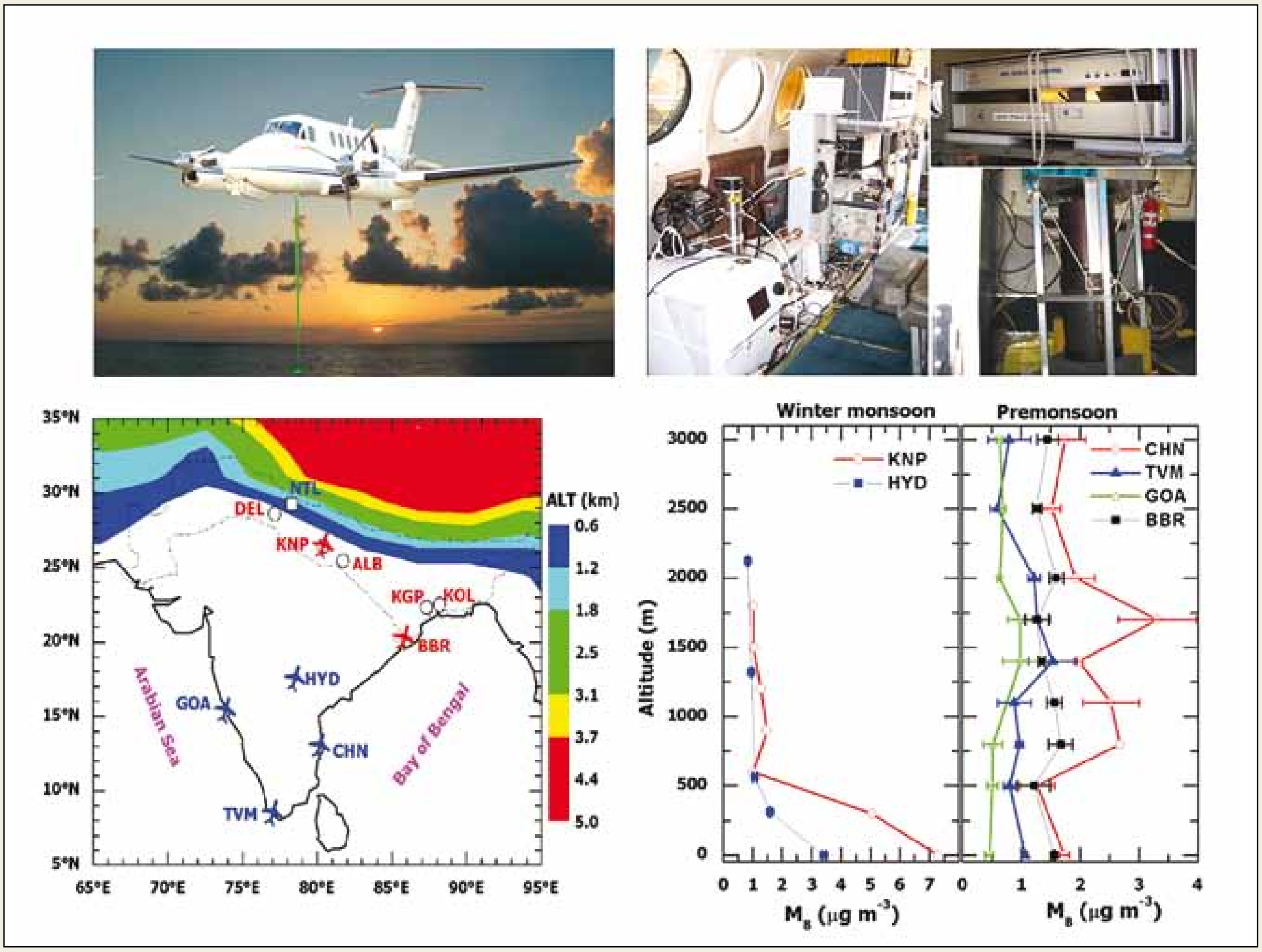
The importance of black carbon (BC) aerosols, a by-product of all low-temperature combustion processes, in significantly altering the radiation balance of the Earth-Atmosphere system through strong, wide-spectral absorption and impacting the regional and global climate has been well recognized in the recent years.

Extensive measurements as part of national and international field campaigns as well as network observatories and global/regional climate model simulations are being carried out to characterize BC, its abundance, vertical distribution, contribution to atmospheric warming, albedo change, glacier/snow melting and to assess its implications for climate and the environment. In India these studies have been spearheaded by the Indian Space Research Organization (ISRO), under the Aerosol Radiative Forcing over India (ARFI) project of its Geosphere Biosphere Program (ISRO-GBP) with active participation from a large number of research and academic institutions. An appraisal of BC aerosol research in India suggests that while this topic witnessed significant advancement during the past decade, a number of important climate-relevant issues are still at large.



The ORV Sagar Kanya (top left) with its specialist aerosol laboratory (bottom left). The right-hand panels show the spatial distribution of BC over oceanic regions around India during W_ICARB and ICARB

Source: ARFI



Top panels: The instrumented aircraft used to measure BC profiles (left) and the inside view of the aircraft with instruments. Bottom Panels: Locations of aircraft measurements of BC with aircraft symbol (left). The altitude distribution of BC over Indian region during winter and pre-monsoon seasons (right panels).

Source: ARFI

Atmospheric aerosols, particulate suspension in the atmosphere, affects radiation balance by scattering and absorbing the radiation (direct effects), modifying the microphysical and radiative properties of clouds (indirect effects), and degrading air quality with adverse effects on health. Among the various aerosol types, there has been increased interest in BC aerosols due to their high absorption characteristics over a wide wavelength range from ultraviolet to infrared. In addition to exerting its own radiative impacts, BC can substantially alter the radiative properties of the entire aerosol system and their ability to act as cloud condensation nuclei. The overall effect of aerosols when viewed from space is a brightening of the planet and net climatic cooling at the surface. However, BC contributes significantly to dimming as well as to the warming of the lower atmosphere, producing an effect analogous to greenhouse warming, which is amplified if the BC aerosol layer occurs over highly reflective landmass (snow/ice /glaciers) or highly scattered clouds.[1] On the other hand, BC within the cloud can lead to 'cloud burn-off' and a reduction of cloud cover.[2] In addition to these climate implications, BC is a health hazard and is believed to be carcinogenic.

In recent years there have been several studies of the climate impact of BC aerosols. While some of these have argued that BC intensifies droughts and floods in Asian countries,[3] others have suggested that BC leads to the advancement and intensification of monsoons.[4] There have been reports that BC blocks sunlight from reaching the Earth's surface and leads to reduced crop yields.[5] As most of these are based on model outputs, which use transport model simulations as input for the global/regional distribution of BC, they are not adequately validated. Limited validation exercises have shown that the transport models underperform, at least in simulating BC, over India.[6] All these point to the need for and importance of accurate measurements of BC from ground and airborne platforms.

Evolution of BC studies

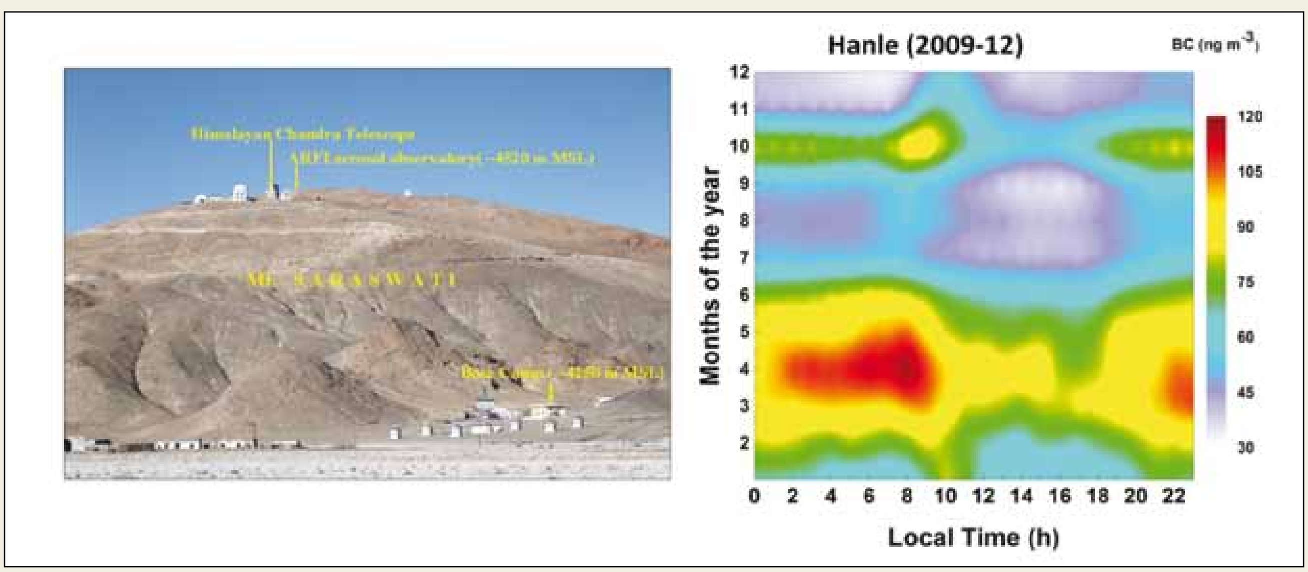
Systematic and long-term measurements of BC over the Indian region was initiated in 2000, under the ISRO-GBP Aerosol Climatology and Effects project, in response to recommendations made in an interim assessment of the aerosol characteristics over the region in 1998. The first long-term measurement was initiated in 2000 from Trivandrum, a coastal station at the southern tip of the Indian Peninsula[7] using a dual-channel aethalometer. Synthesizing aerosol absorption with other optical and physical properties of aerosols, from collocated and concurrent measurements, a quantification of the effect of BC on aerosol forcing was done over an urban site for the first time in India,[8] which showed that large BC absorption led to a change in the sign of the forcing at the top of the atmosphere. This was perhaps the first regional effort in this direction.

Taking a cue from this, and realizing the highly heterogeneous sources of carbonaceous aerosols over this region arising from varying living habits, long-term measurements of BC using similar and inter-compared instruments following well-laid protocols have been established under ISRO-GBP, in a phased manner, involving a large number of universities and research institutions. These were also supported by thematic field campaigns (fixed stations and mobile platforms) over the mainland, shipboard measurements over oceans, and aircraft and balloon experiments.

Spatio-temporal changes in BC concentrations over the landmass arise due to changes in the synoptic and regional meteorology as well as changes in human activities (agricultural waste burning, forest fires etc). While these are quite significant, it is difficult to characterize them because of the large inter-annual variations in these processes. A land campaign (LC-I) was conducted in February-March 2004, to understand the spatial distribution of aerosol including BC over central and peninsular India, using identical instruments over spatially separated locations, covering an area of more than 1 million square kilometres.[9] This was followed up with Land Campaign II (LC-II) in December 2004,[10] during which BC and composite aerosol measurements were made with atmospheric boundary layer parameters along a chain of stations in the Indo-Gangectic plain (IGP).

The ARFINET network of BC observatories was established under the ARFI project of ISRO-GBP. It has data from 32 observatories, including the two island stations to study long-range transport and spatial gradients. This forms the only long-term and exhaustive source of primary data over the region. Spatial distribution measurements show consistently high BC concentrations prevailing over the IGP and the north-eastern regions of India, compared to the southern and western parts. In addition, BC concentrations show temporal variations on both diurnal and seasonal scales. While the diurnal variations are pronounced over the plains, and are mostly associated with atmospheric boundary layer (ABL) dynamics, the seasonal variations (winter high and summer low) are influenced by synoptic monsoon circulation modulated by the seasonal changes in the convective mixing and the resulting enhanced vertical dispersal of BC in the ABL during summer. Additional contributions arise from the heterogeneous spatial distribution of the sources. The higher organic carbon (OC) to BC ratio (typically >5 except in cities) seen over Indian regions indicates the significant contribution of biomass burning and also that total carbon over India is more scattering (less absorbing) in nature.[11]

Unlike over the landmass, variations over the oceans are more controlled by transport and driven by meteorology. Extensive measurement of BC and its fraction of total aerosol mass made over the Arabian Sea during the Arabian Sea Monsoon Experiment (ARMEX) have shown a seven-fold decrease in BC concentration (~700 ng m^{-3} to ~100 ng m^{-3}), associated with changes in synoptic winds between continental and marine environments.[12] Radiative transfer calculations show that such large decrease in BC leads to significant decrease in atmospheric forcing (heating) efficiency (from 70 W $m^{-2}\,\tau^{-1}$ to 15 W $m^{-2}\,\tau^{-1}$). Based on the most exhaustive shipboard measurements under the Integrated Campaign for Aerosols, gases and Radiation Budget (ICARB) and Winter_ICARB (W_ICARB), the spatial distribution of BC has been shown with associated atmospheric warming over the oceanic regions around India and a strong seasonality associated with synoptic meteorology and forest fires.[13] The concentration of BC



The Himalayan aerosol observatory at Hanle (left); the mean picture of diurnal and monthly temporal evolution of BC over the area (right)

Source: ARFI

over the Bay of Bengal is around three to four times higher in winter compared to that during pre-monsoon, and in the given season it is about three to four times higher than that over Arabian Sea.

Altitude profiles of BC

The climate impact of BC depends on its altitude distribution in the atmosphere. The higher the altitude of a BC particle, the higher its direct radiative forcing, which will be highest when it is placed over cloud layers. Despite being produced primarily near the surface, significant amounts of BC occur at higher altitudes, being lofted by turbulent motions, thermal convections and general circulation. Being located in the tropics and with significantly strong sources of BC on the ground, the altitude profile over the Indian region assumes great significance from a climate perspective.

The first in-situ measurement of the altitude profile of BC over India was made using an instrumented aircraft in 2004. This showed a rapid decrease in its concentration in the ABL, while above the ABL the BC concentration decreases much more slowly so a significant amount of BC (as large as 1 μg m^{-3}) is present within and above low-level clouds.[14] Subsequently, several airborne measurements have been made for the altitude distribution of BC over India during the pre-monsoon season of 2006 and winter 2009 under the air segment of ICARB and W_ICARB. Measurements during ICARB have shown that during summer and pre-monsoon seasons, India is characterized by the presence of elevated layers of enhanced BC above the boundary layer, in the region of 2-4 km over different locations.[15] Such layers of enhanced aerosol absorption during the summer and pre-monsoon seasons, when the region receives high solar insolation and experience increased cloudiness, lead to significant atmospheric warming which could reach peak values of 3-5 K during local noon.[16] A synthesis of the ship-borne, ground-based network and aircraft data along with a radiative transfer simulation has led to the discovery of a strong meridional gradient in aerosol-induced atmospheric warming: from about a degree at ~2 km over the ocean, gradually increasing to about 5 K at around 4 km over central India.[17] This aerosol layer persists over the entire Indian region during the summer season, as revealed by the ARFI network observations and by the examination of CALIPSO data, which showed the layer rising to ~5 km at the Himalayan region.

In view of the importance of the above finding, the Regional Aerosol Warming Experiment (RAWEX) was formulated to quantify the atmospheric effects of elevated BC layers. Under RAWEX extensive measurements of BC altitude distribution were made concurrently with the atmospheric thermodynamics, onboard a high-altitude balloon from the central part of India. During the pre-monsoon season, when convection is also strong over the region, the altitude distribution of BC showed multiple peaks; two surprisingly large ones at ~ 4.5 km and another above 8 km. Associated with these, a rapid decrease in the environmental lapse rate and a sharp increase in atmosphere stability were observed, probably caused by the atmospheric warming of the BC layers. The change in environmental lapse rate and increase in atmospheric stability lead to the further trapping of BC aerosols at higher altitudes, raising the question of whether BC layers build 'their own homes' up in the atmostphere.[18]

BC over the Himalayas

The Himalayan region assumes enormous significance both in the climate change scenario and in societal implications. The Himalayan glaciers are believed to be the largest source of fresh water outside the Polar region and play a very important role in the hydrological cycle over south Asia. Millions of its population are directly or indirectly dependent on the water flowing through the rivers fed by these glaciers. Even though there are several geological and glaciological reasons for glacier retreat or advance, BC deposition on Himalayan glaciers is increasingly projected as a major factor contributing to faster retreat,[19] and several caveats have been put forward. Model simulations have predicted increases in Himalayan glacier retreat due to BC-induced snow surface darkening. The long-term measurements of BC being made over a high altitude location, Hanle (32.5°N, 78.5°E and 4520 m msl) in the western trans-Himalayas, have shown significantly higher concentrations during spring and low ones during summer.[20] These also showed that the BC concentrations over Hanle are, in general, significantly lower than those observed over other eastern Himalayan regions such as Nepal. It would be premature to draw strong conclusions on the impact of BC on snow/glaciers and more efforts are needed.

Outstanding issues

Extensive measurements of BC and assessment of its impact on air quality and regional climate are being made through the ARFINET network of 35 observatories established as a part of ISRO- GBP. In addition campaigns are conducted to address to specific questions on BC and its effects. These efforts brought out the large spatio-temporal heterogeneity as a result of changes in local BC emissions, meteorology and long-range transport. The most important outcomes include a first-cut spatial map of BC showing high concentrations over the IGP and north-east India, and spatial as well as seasonal distinctiveness over the oceans. Significant impacts of long-range transport are noted from the east on the Bay of Bengal and from the west over the Arabian Sea. Altitude profiles of BC aerosols using aircraft and high altitude balloons have led to discovery of the presence of elevated aerosol layers (with substantial BC fractions) and a strong meridional gradient in BC-induced atmospheric warming. On examination of our current knowledge on BC-climate impact, it appears that a number of outstanding issues remain.

More information is needed on the vertical distribution of BC over the entire Indian region, while information on the state of mixing of BC with other species is virtually unavailable over the region, and this needs to be addressed. In addition, while addressing the indirect effect of BC, it is important to consider the Twomy effect versus 'cloud burning' by BC. Simultaneous measurements of BC and cloud microphysical properties are essential.

There is a tendency to project the mitigation of BC as a rapid solution to slow down global warming. It is very important to consider the large values of OC/BC ratios reported over India before attempting such strategies, especially because in most cases the sources of OC and BC are the same. The construction of regional maps of OC/BC ratios should be a target in future field campaigns. Accurate assessment of any such strategies is required before implementation, as they could play a significant role in shaping international policy.

The Chilean Ultraviolet Radiation Network: monitoring and forecasting the UV index for health protection

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Dirección Meteorológica de Chile – Dirección General de Aeronáutica Civil

The Dirección Meteorológica de Chile (DMC) operates an ultraviolet radiation network (URN) consisting of 20 stations, most of them deployed in a meridional transect from around 17º S to 56º S, including one station at Easter Island and another on the northern tip of the Antarctic Peninsula (~62º S). The stations measure solar ultraviolet radiation within the wavelength range 280-320 nm (UV-B). The data are expressed in terms of erythemic irradiance as a risk index (UVI), according with the World Meteorological Organization (WMO) and the World Health Organization (WHO). Daily 24-hour maxima of UVI are predicted for cities where the stations are located.

The continental Chilean territory spreads in a north-south direction for about 4,500 km along the western coast of South America (17° S to 56° S) including the Andes Range with several peaks exceeding 6,000 m. It hosts a large variety of climates, from north to south and from the coast to the mountains. Apart of the annual cycle, the near-surface air temperature decreases southward and eastward due to altitude, while precipitation varies from north to south with a maximum in extratropical latitudes where weather systems travel eastward. In the northern part is the driest desert of the world, while in the southern part (50° S) the rainy region (more than 6,000 mm per year) is found, along with the largest continental ice caps in the world outside the Polar regions (the Northern and Southern Patagonian Ice Fields). In spring, the southern Chilean territory is also exposed to a thinner stratospheric ozone layer that fluctuates between 260 and 300 Dobson Units (DU), well below what is considered a normal value (350 DU). This means that incoming ultraviolet radiation (UV) reaching the ground is a hazard, mainly during solar noon hours with values that can exceed the limit considered a risk for human health. During cloudless sky conditions, the total amount of UV-B received on the surface varies with latitude, terrain altitude and the time of year; therefore, UV-B is higher towards the Equator than towards the poles, increases with altitude, and presents a maximum near the summer solstice.


Image: Sociedad Dermatológica de Chile

Sunburn caused by excessive exposure to UV radiation

The Chilean URN measures UV-B irradiance, which is used to calculate the erythemic irradiance and finally expressed in term of the UVI risk index to transmit a simple warning message to the public. The UVI is a measure of the UV-B intensity on the earth surface at the solar noon, is given on a scale that runs from zero to more than 11, according with WMO and WHO. The index represents the risk level for skin damage due to sun exposure.

At present, 20 stations are deployed at different cities from Arica in northern Chile (~ 18°, 70°W, 23 metres above sea level (masl)) to Eduardo Frei Montalva (~ 62°S, 53°W, 10 masl) located on the northern tip of the Antarctic Peninsula. The distribution of the URN includes stations in coastal and inland cities, as well as, three stations located at higher elevations such as San Pedro de Atacama (~ 18°S, 70°W, 2450 masl), El Tololo (~ 30°S, 70°W, 2030 masl) and Central Andes (~ 33°S, 71°W, 2746 masl). There is also a station at Easter Island (~ 27°S, 109°W, 47 masl). All the stations are equipped with a pyranometer instrument with a sensor that measures UV-B radiation within the spectral band 280-320 nm. The unit used is the miliwatt/metre^2 (mW/m^2). The DMC also has a standard pyranometer which is calibrated in the World Radiation Centre of the Physikalish-Meteorologisches Observatorium DavosInstitute, Switzerland. This instrument is used as a reference for calibration, which is done by comparing the data recorded by the standard pyranometer simultaneously with those under.

The worldwide increase in skin cancer, people exposing themselves to direct solar radiation, the global depletion of the stratospheric ozone, and the fact the Chilean territory can directly be affected by the ozone hole were all motivations for DMC to implement the URN for measuring UV-B. The objective of this initiative was to create through time a database that would permit the study of the impact of ozone depletion in Chile. Thus, the data analysis would be used to improve our knowledge of spatial and temporal distribution. At the same time, all this new information would help to develop prevention programmes to overcome the adverse effects of the eventual UV-B increase. The first station was installed in the capital city of Santiago (~ 33°S, 70°W, 520 masl) in 1992, where almost half the nation's population is located. A second station was deployed in the Antarctic Chilean Base Eduardo Frei Montalva, a place affected by the spring ozone depletion associated with the ozone hole. Annual and daily cycles of UVI were characterized at different locations in Chile, using data collected for the corresponding stations. Five years of almost continuous monitoring in most of the stations has allowed the analysis of UV-B behaviour and how it is influenced by factors such as elevation, latitude, surface reflectivity and cloud cover and type.

The monthly average UVI behaviour in Chilean territory shows an annual cycle with a maximum in January and a minimum in June, as well as the southward decrease with higher values in the northern part, reflecting the astronomical and latitudinal factors. The daily seasonal average cycle reveals that the maximum

UVI descriptions and associated recommendations

UVI	Description	Media Graphic Colour	Recommended Protection
0-2 Low	No danger to the average person	Green	Wear sunglasses on bright days; use sunscreen if there is snow on the ground, which reflects UV radiation, or if you have particularly fair skin.
3-5 Moderate	Little risk of harm from unprotected sun exposure	Yellow	Wear sunglasses on bright days; use sunscreen if there is snow on the Wear sunglasses and use sunscreen, cover the body with clothing and a hat, and seek shade around midday when the sun is most intense., which reflects UV radiation, or if you have particularly fair skin.
6-7 High	High risk of harm from unprotected sun exposure	Orange	Wear sunglasses and use sunscreen having SPF 15 or higher, cover the body with sun protective clothing and a wide-brim hat, and reduce time in the sun from two hours before to three hours after solar noon (roughly 11:00 to 16:00 LT during summer).
8-10 Very high	Very high risk of harm from unprotected sun exposure	Red	Wear sunscreen, a shirt, sunglasses, and a hat. Do not stay out in the sun for too long.
11+ Extreme	Extreme risk of harm from unprotected sun exposure	Violet	Take all precautions, including: wear sunglasses and use sunscreen, cover the body with a long-sleeve shirt and trousers, wear a very broad hat, and avoid the sun from two hours before to three hours after solar noon.

Source: DMC

is recorded around 13:00 local time (LT) year-round in the whole country. In northern and central Chile, the period of high-risk exposure (levels above 6) goes from 10:00 to 17:00 LT in summer, while in the most southern city (Punta Arenas, ~ 53°, 70°W, 39 masl), on average, the UVI is under level 6 risk year-round; that is, the index only reaches moderate values which are equivalent to small risk of damage from unprotected sun exposure. However, during spring, Punta Arenas and the surrounding areas can experience episodes of significant UVI increase.

Analysis of the data recorded by stations deployed at different elevations indicates an increment of UV – and therefore of the UVI – with altitude. This is due to two factors: first, at higher altitudes more UV can get to the surface because the atmosphere is thinner. And second, due to a clearer atmosphere, lower values of aerosol optical depth are found near the surface atmosphere as compared with values at lower altitudes.[1] In northern Chile, comparison between data recorded by the stations located at Antofagasta (~ 23°S, 70°W, 115 masl) and San Pedro de Atacama during cloudless days in summer reveals differences in UVI of five to seven levels, which correspond to an altitudinal increase of two to three units per kilometre. However, on average, results from the Chilean stations concur with the overall altitudinal increment of 10-12 per cent of the UV levels per kilometre. This altitudinal factor on UV radiation is not constant throughout the year; significant seasonal variation is mainly found in winter when the vertical differences at midday hours are higher due to a greater solar zenith angle.

The incoming UV irradiance is attenuated by clouds, which depend on both thickness and cloudiness (type and amount). Thin or scattered cloud can have little effect or even enhance the UV compared with cloudless skies. On the other hand, cloudy days can decrease UV irradiance reaching the ground by absorption and scattering through the water vapour and the aerosols. A good correlation between UV and cloudiness was found at stations located in northern and central Chile (r = 0.88 for Santiago), but the correlation is poor in the southern regions, most probably due to the presence of cumuliform clouds as revealed the study done at Valdivia.[2] However, days with a concentration below 250 DU can correlate with episodes of increased UVI under cloudless sky conditions in summer. The impact of this on human health is documented by a medical study[3] that found a relation between stratospheric ozone concentration below 260 DU and cases of sunburn in children due to exposure during January. With regard to the ozone hole that develops in the southern Polar regions during the spring season, regions with minimum concentration eventually reach the Antarctic Peninsula and the southern tip of South America. Large increases in UV-B associated with the Antarctic ozone hole have been measured, with increases up to 38 times those of similar days with normal ozone.[4] Significant decreases of stratospheric ozone along with increments of UV-B occurred during the mid and late austral spring of 1999. These events caused a significant increase of patients with sunburn in Punta Arenas.[5]

Image: Sociedad Dermatológica de Chile

Skin cancer caused by excessive exposure to UV radiaton

The stratospheric ozone layer is a natural protective filter for the harmful UV radiation provided by the atmosphere. Depletion of this layer has negative effects on flora and fauna, including human health, due to exposure to higher UV levels. This fact motivated some senators and the Chilean Government to produce a law regarding the protection of the stratospheric ozone layer. The Ozone Law, as it is called, was published in 2006. Its main objectives are to establish control mechanisms for substances that deplete the stratospheric ozone, and to ensure the appropriate implementation of the Montreal Protocol and the protection of human health and ecosystems affected by UV. The law gives responsibility to the DMC as the official source of information and public dissemination of the UVI and risk for human beings. Today, the daily maximum UVI and the prediction for the next day can be found on the institutional webpage www.meteochile.gob.cl. The law was later complemented by a Supreme Decree that was published in 2011, with the purpose of establishing regulations for health protection and preventions to be applied at workplaces. This is a pioneer legislation in Latin America which establishes a precedent in the prevention of occupational health risk in the country.

In this context permanent monitoring, the addition of new stations to the URN, climate UV studies and the daily forecast have become essential information not only with regard to physical and biological effects over the territory, but also with regard to supporting decision-makers within the framework of protecting public and occupational health.

Climate information in support of the health sector

Nirivololona Raholijao, Madagascar Directorate General of Meteorology, Alain Rakotoarisoa, Madagascar Directorate of Public Health and Epidemiological Surveillance/MSANP and Haleh Kootval, World Meteorological Organization[1]

Madagascar is an island in the Indian Ocean with 19.6 million inhabitants and an area of 587,000 km². Classified as a low-income country with an economy based primarily on agriculture, Madagascar has a poverty ratio estimated at 66.4 per cent, with disparities between urban and rural areas.

Situated between latitudes 12° and 25° S, Madagascar has an essentially tropical climate with two distinct seasons: the winter dry season from May to October and the summer rainy season from October to April. During the tropical cyclone season from November to April, several tropical disturbances usually cause severe damage. Rainfall and temperatures differ widely across the island due to variations in altitude.

Impact of climate-sensitive diseases on public health

Communicable diseases are a burden for public health in Madagascar. Many vector-borne diseases, zoonoses (transmitted from animals to humans) and waterborne diseases are dependent on climatic factors. Climate-sensitive diseases are responsible for 39.1 per cent of the causes of morbidity registered at health centres in Madagascar and contribute to 57 per cent of the alerts received by the Direction de la Veille Sanitaire et de la Surveillance Epidémiologique in Madagascar. This does not include alerts that go directly to individual health programmes fighting diseases such as malaria and plague. In 2011, the plague fatality rate was 18.30 per cent, while malaria mortality rates in 2010 were 8.63 per cent for children under five years old and 2.84 per cent for those over five.

Climate services for the health sector

The National Meteorological and Hydrometeorological Service (NMHS) in Madagascar started providing climate information and data to the health sector

Image: Madagascar Met Services

People waiting for the physician at the Centre de Santé de Base Niveau II (CSBII) of Ambositra, a health sentinel site in 2003 when the malaria unit of the Ministry of Health met NMHS representatives following an outbreak. The aim was to establish a close collaboration between the unit and the Applied Research Service of the NMHS for malaria monitoring, prevention and response. This collaboration was strengthened by participation of malaria unit staff in the United States International Research Institute for Climate and Society (IRI) summer institute and of Applied Research Service staff in the Southern African Development Community (SADC) Climate Expert Meeting and the Southern African Regional Outlook Forum (SARCOF) in 2005. The Epidemiological Surveillance Service, the Institut Pasteur de Madagascar and international organizations working in the health sector such as UNICEF and the President's Malaria Initiative/United States Agency for International Development were also included.

This existing cooperation was one of the criteria used by the World Meteorological Organization (WMO) in the selection of Madagascar as the first country for the implementation in 2008 of a Learning Through Doing pilot project focusing on the use of climate information in support of the health sector. The project objectives were:

- To help Madagascar's National Weather Service to meet the specific needs of the health sector in terms of climate data and information
- To adopt new working methods in the health sector with regard to the effective and efficient use of climate data and information for the prevention of epidemics.

The key outcomes expected from the project were:

- Improved service delivery
- Enhanced capacity in the NMHS
- Better use of weather and climate services in the health sector.

Within the framework of the project, three diseases were considered: malaria, plague and Rift Valley fever (RVF). However, the outcomes could be extended to all climate-sensitive diseases.

Malaria
Malaria remains the primary public health problem in Madagascar. In sub-arid regions like the southern part of the country, malaria is influenced by climate, as rainfall is very important to development of mosquito breeding sites. Malaria prevails mainly during the wet season in all districts of the island. The Central Highlands area has a marked seasonality with an almost total absence of malaria during the winter period. Fever surveillance has taken place since 2007 in thirteen sites across Madagascar and climate variability information will be helpful for understanding the distribution of malaria cases.

Plague
From 1957 to 2001, 20,900 suspected cases of plague were notified in Madagascar, including 4,473 confirmed or probable bacteriological (21.4 per cent). There have been two important increases in plague incidence: between 1985 and 1990, partly due to the socioeconomic difficulties of the country, and from 1994 to 1997, following improvements to the epidemiological monitoring system and the reappearance of the plague in the port of Mahajanga. Endemic plague is prevalent from September to March (hot and wet season) and July to November (dry season) respectively in the highlands and Mahajanga. This confirms the importance of the climate component in plague surveillance.

Image: Madagascar Met Services

From right, the project coordinator and co-chair of the CHWG, the focal point for the Rift Valley Fever, with staff and patient

Rift Valley fever
Rift Valley fever is a viral anthropozoonosis transmitted by mosquitoes. Not much is known about the virus reservoir and the impact on it of climate or environmental changes. The presence of the RVF virus in Madagascar was demonstrated in 1979 by isolations from mosquitoes captured in the Moramanga district rain forest 130 km east of Antananarivo. Since then, epidemics of RFV have been linked to climate changes and ecological perturbations caused by humans, favouring the population dynamic of the mosquito vectors and the transmission of the virus. Its impact is socially and economically important because it affects both cattle and human populations.

A workshop to launch the pilot project in October 2008 resulted in the signature of a memorandum of understanding (MOU) for partnership in climate and health by ministers and the appointment of two project coordinators: one specialist and an expert in climate. It also led to the establishment of the Madagascar Climate and Health Working Group (CHWG) and the definition of the terms of reference and formal appointment of the members (Ministry of Health, Ministry in Charge of the NMHS, Institut Pasteur de Madagascar, World Health Organization, Roll Back Malaria, USAID, and Institut National de Santé Publique et Communautaire).

The CHWG aims to identify the information and service needs of the health sector, including gaps in current data, information and service delivery, and to provide recommendations for filling these gaps. Strategies include institutional data sharing and targeting of research, education and training needs across the sectors. Access to climate and weather tools for

The climate trainer inspects a climate station with health trainees

the health sector is key, as is the use of early warning systems for climate-sensitive diseases.

Capacity-building for national, local and community-based organizations will widen and strengthen services in this area. The CHWG will organize and present to decision makers scientific evidence on the impact of climate variability and climate change on health and run an annual workshop on weather/climate and health issues, collaborating with similar entities throughout the region to share experiences and build on one another's skills. Finally it will mobilize resources to ensure the sustainability of this venture.

The creation of the CHWG has allowed for a focus on climate health issues by bringing together all the stakeholders in a common group to improve project management and to identify a focal point for each disease. The group comprises eight health experts (one each for malaria, plague, RVF and health and environmental issues, and four for epidemiological surveillance), five climate experts (climatology, weather forecasting, climate forecasting, research, hydrology), and five NMHS climate specialists and one researcher from the Institut Pasteur de Madagascar.

The CHWG identified priority activities such as staff training to allow health and climate experts to reach a joint definition of needs in climate services. Two workshop training sessions were organized with local and IRI facilitators. The training improved knowledge of climate data and information at national and international levels as well as methods for accessing and manipulating existing databases to analyse and interpret epidemiological and climate data. This has enabled the development of products that meet the specific needs of health sector users.

Identified climate services needs for the health sector in Madagascar include climate data from the health sentinel sites, information on intraseasonal and seasonal climate outlooks and risks (especially regarding floods in association with tropical cyclones or long wet spells), and weather and/or climate data from locations reporting disease outbreaks. Climate information and data are provided free of charge to assist in epidemiological surveillance, prevention and response, but also for the purpose of climate health research activities.

Resources

Seasonal and Intraseasonal Climate Outlook

This publication is supplied to the health sector at the end of the dry season, giving information on the coming rainy season in terms of global trends, rainfall, temperature, tropical cyclone activity, climate risks and benefits. The publication is disseminated by the NMHS through e-mail to all climate and health stakeholders at the central level and is used by the Ministry of Health to produce its Climate and Health monthly bulletin.

Climate data from the NMHS

This is provided free of charge upon request for research or post-disease outbreak analysis. This product is aimed at addressing longstanding difficulties with obtaining historical epidemiological data.

Climate data from the health sentinel sites

There are about 40 sentinel sites for fever and/or Syndrome de Deficit Respiratoire Aigu. The pilot project funded the installation of six manual climate stations and the Institut Pasteur de Madagascar provided two automated stations. The Ministry of Health and the NMHS signed a MOU defining the roles of each sector in the implementation of climate observation on the sites.

Local health staff members were trained in the measurement of daily rainfall, maximum and minimum temperatures, humidity and evaporation, as well as cloud cover and wind observations. Climate experts also provided on-site training on simple weather- and climate-related issues and the use of the African Centre of Meteorological Applications for Development's Climat Sante (CLIMS) code for the weekly transmission of the data. On-site training was given on the use of the climate data for local epidemiological monitoring and surveillance. Climate data were collected daily and transmitted to the central health centres including the Institut Pasteur de Madagascar and the NMHS and, once verified, shared with all stakeholders.

As a result of the project, meteorological data can be analysed together with epidemiological data (historical, real time and forecast) to facilitate early detection of fresh disease outbreaks and/or probable epidemics. Data transformed into information can be forwarded to decision makers and managers at all levels for early response or preventative actions.

Health sector benefits from climate data and information

The use of climate parameters (temperature, rainfall, humidity) as predictive indicators of the resurgence of priority diseases improves the surveillance of diseases dependent on weather and climate variability. For example, early detection of malaria resurgence in Ifanadiana (Vatovavy Fitovinany) took place in February 2012 after tropical cyclone Irina caused raised temperatures and heavy rainfall.

Malaria in Madagascar is favoured by monthly temperatures between 18° C and 32° C, monthly rainfall above 80mm and humidity above 60 per cent. Plague needs temperatures between 19° C and 25° C during the rainy season from October to April and a soil humidity of 85-95 per cent. RVF is favored by a temperature between 21° C and 24° C after heavy rainfall (176mm-255mm) in the wet areas.

Quick decision-making supports early detection of possible epidemic outbreaks in order to adapt the strategy for prevention and response. The Climate Outlook and the Climate and Health Bulletin are very helpful in that sense. Climate observation stations at the sentinel sites add value in improving the local management of an epidemic by enabling direct use of the meteorological data collected for analysis and action.

Building capacity, ensuring support

WMO provided the funding for the implementation of the pilot project, covering workshop training, international training and exchanges, strengthening of the climate observation network through the installation of climate stations at six health sentinel sites, on-site training of local health experts in climate observation and station maintenance, and follow-up visits to the sentinel site stations. The development and delivery of climate products are supported by the NMHS budget.

The service involves two main institutions: the Ministry of Public Health and the Ministry of Meteorology. The Institut Pasteur de Madagascar as a private institution is involved in the financial management of the health sentinel sites and in the research component of the activities of the CHWG. IRI was the facilitator for the two training workshop series. MOUs for data access and exchange and research collaboration were signed between the NMHS and IRI and the Ministry of Public Health and IRI.

A process for the evaluation of the impact of the services on health in Madagascar remains to be established. The CHWG believes that the assessment could not be performed until four or five years after the end of the pilot project. WMO and WHO are invited to provide some guidance in the project/service evaluation methodologies. However, the health actors already recognize the benefits gained from the use of climate data and information and the existing climate stations on the sentinel sites.

At Madagascar NMHS, the Applied Research Service has been in charge of the development and dissemination of climate information since 1997. Capacity-building of human resources occurred through the participation in the SARCOF climate experts' meeting and training through the SADC community and the visiting scientist process at the National Oceanic and Atmospheric Administration/National Weather Service/Climate Prediction Center in the USA.

During the training workshops and the on-site installation of the climate stations, NMHS experts provided courses for user organizations on weather and climate and on how to interpret climate information. Health staff at the central level learned from IRI facilitators how to use the climate data for health issue purposes. Most of the health trainees at the central level hold postgraduate degrees in public health.

The future

The main challenges facing all the stakeholders are sustainability of the activities and maintenance of the current dynamism and enthusiasm. For the NMHS, the main goal is the improvement of the quality of services provided in terms of tailoring, accuracy and timeliness in dissemination. For the health sector, the main goal is optimal, efficient use of climate data and information to reduce the burden from climate-dependent diseases. Keeping the local health staff motivated in the observation tasks is another challenge for the health sector.

Four key factors will be crucial to the long-term success of the health and climate working groups:

- Interest in working together
- Awareness of health professionals of the need for climate information and services
- Presence of an external agent (such as WMO) acting as a catalyst to bring the groups together
- Availability of seed funding mechanisms for pilot projects.

It is likely to require approximately three to five years of experience (and hence of sustained seed funding) before the first results are seen.

Scaling up of this kind of programme is an important long-term goal, which depends mainly on the availability of budget from the institutions involved in the process and the willingness of the decision makers to support the programme, both financially and institutionally. The lessons learned can be transferred to other sectors and locations.

Seasonal forecasting for Africa: water, health management and capacity building

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Seasonal forecasting takes advantage of the close and energetic interaction between the ocean and the atmosphere. The ocean — which forms most of the Earth's surface – is a slowly varying-changing component of the Earth system, providing a signal that can be exploited for prediction at seasonal timescales. The tropical ocean belt is the primary source of predictive skill at timescales ranging from weeks to months, with a direct impact in the tropics. This enables high predictive skill for seasonal forecasting in many regions of the world, albeit with very different behaviours.

In Africa, many actors take advantage of seasonal climate information, with applications ranging from operational decision processes to research, education and awareness of climate variability, change and impacts. A few valuable examples highlight the principles of the Global Framework for Climate Services (GFCS). Some of them bring obvious benefit which can be estimated, or exhibit virtues required by the framework. Others teach us lessons and shed light on the essential conditions for achieving success in establishing a valuable seasonal forecasting service — or on a larger scale, a climate service:

- Find the parameters, areas and time-lags where skill exists — they can be far from the basic information routinely handled by national meteorological and hydrological services (NMHS)
- Bring together a need, users, scientists covering the domains to be analysed and climatologists
- Share and correlate a few decades of data from both the application sector and the forecasting system — needless to say, success comes from sharing and tenacity.

Image: © IRD

Traditional cultures along the Senegal River, Kayes, Mali

Of course it isn't as simple as that. The first task is to estimate what information can be forecast. Actors come from various domains and cultures, and communication is a long-term endeavour. Data are sparse, missing, and unavailable or often considered as assets that cannot be released. The approach is probabilistic and results are not guaranteed at each trial, so a long-term view is needed to appreciate the benefits; but understanding and accepting the principle of a decision-making process with uncertainties is not that straightforward. And last but not least, the road is long between geophysical or impact forecasts, and decisions or results involve many other factors, quite often having to deal with policy, culture, economy or opportunity. The devil hides in the details, and the value of the forecast must be assessed in the real and complex chain of decision-making — for example, can seasonal forecasting provide manageable information for health when major decisions are taken years in advance? Many difficulties lie ahead when climatologists and users start to consider taking advantage of seasonal climate forecasting, but the potential for applications and success is important and worth the effort.

For climatologists dealing with past and future climates, seasonal forecasting is the application of climate sciences and modelling that permits very quick feedback, and hence continuous progress and development of skills and services. Seasonal forecasting takes full advantage of the entire climatologist's toolbox (numerical climate models, downscaling, observations, statistics, etc). It also implies a deeper knowledge of climate dynamics and geophysics, considers the atmosphere, ocean, continental surfaces, their interactions and climate dynamics. Atmosphericians, oceanographers, agronomists and other impact sectors' specialists have to interact closely. For climatologists, who get involved in forecasting and can be exposed to users' feedback — as well as meteorologists, who can extend the range of their capabilities from weekly or monthly to seasonal timescales — the benefit of elaborating seasonal forecast is tremendous, because of the exchanges and feedbacks. This also explains why capacity building is a key aspect of seasonal forecasting, which definitely must be perceived as a major climate service to develop knowledge and know-how for meteorological services and their users. Seasonal forecasting is a complicated activity and using it requires a real partnership involving mutual education and confidence as well as long-term commitment.

Water management in Western Africa

A flagship application of seasonal forecasting is the yearly forecast for the Organisation pour la mise en valeur du fleuve Sénégal (OMVS), which was created in 1972 to manage the Senegal River basin. The Senegal River is of vital importance for the bordering countries: Senegal, Mali and Mauritania. One of the river's main characteristics is its strong inter-annual variability. During the twentieth century, the average yearly flow varies by a factor of six between dry and humid years, with record flows in 1936-1937 (1,349 m^3/s) and 1984-1985 (above 220 m^3/s). Such variability of course makes water management more difficult.

Water is decisive for agriculture and irrigation. In order to optimize its use, a dam was inaugurated in 1988, close to Manantali. A few years later, the dam started to supply electricity, adding to its expected benefits which were to improve river navigability and stimulate improved agriculture through irrigation. Seasonal forecasting is used to help manage the dam, as described in the Madrid conference proceedings.[1] The water resource management of the Manantali dam is notably based on the scheduling of water releases to flood the downstream valley and consequently to allow recession cultures. Will the end of the rainy season be good enough to allow a sufficient water release for recession cultures and the safety of hydropower production along the dry season? An outlook before the autumn for the next three months helps in taking relevant decisions, making it possible to answer that key question. The natural flow is forecast at Bakel station, far from the dam down the river.

Luckily, the Senegal River has been monitored for a long time. Based on historical flow records, a correlation could be established between seasonal forecasting and flows. Good scores are obtained, including for extreme events. Seasonal forecasting is especially able to capture the critical events — good or bad rainy years — for the dam management. The information is delivered by mid-August each year to OMVS, which can then contribute to the decision-making process, especially on the artificial flooding of the Senegal floodplain, allowing recession culture to start by mid-November.

The Manantali dam seasonal forecast is a brilliant example of climate information being fully integrated to the decision process, and is considered to be one of the necessary inputs leading to decision and then action. IRD and Météo-France also forecast the natural flow of the Niger river, at the Koulikouro station, far from the Sélingué and the future Fomi dams. The correlation is slightly weaker, one of the reasons being that the length of the observations is smaller. Such integrated application illustrates the ingredients required for a successful climate service while delivering benefits of high value:

- Optimization of electricity production with increases up to 40 per cent (in relationship with the year)
- Securing of 50,000 hectares for recession culture four years out of five (compared to one out of five with climatology alone)
- Savings of around 10 per cent of water resources.

Image: © Centre de Suivi Ecologique (CSE), Dakar

Cattle at Barkedji's pond, Ferlo, Senegal

Cross-cutting partnerships

Water management is a good example of the benefits of seasonal forecasting in Africa, and no doubt similar applications can be found elsewhere or in other domains such as crop yields or health management. Interesting investigations are underway in that field, which covers a large spectrum of potential application. Tackling vector-borne diseases is one of the biggest challenges, but of vital interest because of the high impact on human and animal health, and the economy. Rift Valley Fever (RVF), chikungunya, dengue and malaria, among other diseases, share a common factor: mosquitoes. The lifecycle of mosquitoes is a subtle balance between temperature and rainfall, and suitable sequences are necessary for the development of the larvae. Being able to better characterize the role and relationship between vector, virus and climate variability could lead to better adaptation strategies across the tropical belt, both for cattle management (in the case of RVF) and for humans.

This has been addressed in several projects tackling diseases and species with input from Météo-France, in French overseas territories (for example, dengue in New-Caledonia) or Africa. The main input to risk mapping is precipitation: a project carried out with the Centre National d'Études Spatiales (CNES), the Pasteur Institute, Météo-France and local sanitary agencies in Senegal, taking advantage of satellite images to capture risk areas, has focused on the contribution of seasonal forecasting for reducing the exposure to RVF vector risk. One result was a proposition for adapted strategies for cattle management, an area where many factors play a role. This clearly implies that local actors take part in the adaptation process and enrich the climate service with downstream real-life constraints in order to create a valuable service. It was proven that seasonal forecasting can contribute to an early warning system, taking advantage of various sources of information, and of a partnership between all stakeholders and experts able to deliver that information.

Another project is dealing with malaria — different disease, mosquito, and mechanisms to understand. It aims to use seasonal forecasting for shaping a departmental early warning system. It also follows the 'tele-epidemiology' conceptual framework built by CNES, based on the use of satellite images. Burkina Faso is at the interface between Northern Guinea and the Southern part of the Sahel. It has a temporally limited rainfall season. The climatology shows high seasonality (with important annual differences in terms of precipitation and temperature), causing mosquito populations to fall each year to levels that prevent transmission. For a malaria season to occur, the mosquito population must grow rapidly after the onset of the monsoon, with the right temperature, precipitation and relative humidity in place for at least three months.[2] These factors are the basis for a warning system taking advantage of climate information.

A field campaign has enabled the NMHS to deliver meteorological parameters for 11 villages of the Nouna area. The observations were employed to validate high-resolution meteorological products used with the remote sensing and entomological data in order to calibrate a mosquito environment malaria risk model and evaluate zones potentially occupied by mosquitoes. The second contribution of climatologists qualitatively evaluated the potential of departmental seasonal forecasts. The focus was on the meteorological parameters that are important for the mosquito environmental malaria risk model: temperature, rainfall and relative humidity. These are the same as the ones of the 'fuzzy logic' model for the distribution of stable malaria in sub-Saharan Africa.[3] This kind of approach is an extension of the Boolean ones, enabling the evaluation of meteorological conditions not only as fully suitable or not-suitable, but also to obtain a gradient of suitability. Climate information refines the assessment of the situation.

These types of model were first designed to estimate transmission potential and extrapolations were attempted to evaluate disease outcome. The results showed that there is no real direct possible extrapolation between transmission potential and disease outcome. Moreover, there is often no direct link between meteorological parameters and even transmission potential. This explains the additional use of remote sensing data in the mosquito environmental risk model to convert the meteorological parameters, not only as suitability gradients but also as productive suitability gradient information. Such studies illustrate how complicated the application of related climate information can be, and of course how critical interaction between various scientific communities is for solving such issues, as well as the implication of all existing information resources — satellite, epidemiological, climatological information etc.

Capacity building in Africa

One key issue when tackling societal application of seasonal forecasting is the knowledge available in both the climate and the user communities. From this perspective, capacity building becomes crucial. The Climate Outlook Forums (COFs) provide very good example of capacity building to the benefit of both communities, especially in West Africa with the Presao, one of the first COFs. During the pre-forum workshops, climate knowledge is built or improved thanks to the presence of regional and international climate experts. Such meetings can be tailored to the user domain (like for the water resource domain in

Presao) and they are one of the top priorities of the Commission for Climatology, including dedicated COFs like the Malaria Outlook Forums.

In the frame of the GFCS, a key issue is to ensure that the most advanced science is efficiently transferred to the operations, so the best climate science can be immediately used for decision-making and action. The capacity building done during the pre-forum workshops are a perfect opportunity to prepare these evolutions on both sides, including users. For example, the Presao Second Generation introduced the use of Global Production Centers (GPC) information to forecast the main characteristics of the rainy season and tailor products to regional and national users in a more sustainable and relevant way, as the products can be prepared for each period they are needed.

In addition, some countries are sharing climate characteristics across different World Meteorological Organization (WMO) regions like the Mediterranean Basin. This led to the concept of transregional COFs and to some challenging capacity building exercises as the climate knowledge, national capabilities, stakes, and consequently the impact of current climate variability can be very differently perceived across wide areas like these.

Météo-France, as GPC, leader of the RA VI Regional Climate Centre network node for long-range forecasting and also as NMHS, has been deeply involved in such activities since the beginning of the COFs in 1998. It is one of the driving forces of the Presao Second Generation in West Africa and supports new COF initiatives such as the one in South-East Europe or the COF planned for the South-West Indian Ocean (September 2012).

Lessons learned

Seasonal forecasting recalls for the need for — and benefit of — long-term observation and series.

The Manantali hydrological or vector-borne disease applications show that valuable climate information can be delivered today, taking advantage of the state-of-the-art products and knowledge available in the WMO GFCS framework. While direct application of seasonal forecasting into decision-making processes is not that simple, and there is a need for research efforts on subjects which are as yet poorly known, some examples already pave the way for further work and lessons can be learned from these. Clearly, the availability of long series of observation, both for climate data and impact data, is a determining factor. In previous centuries, various organizations have aimed at developing the economic use of the Senegal River waters, and for that purpose made observations. Long records are therefore available today, and of the utmost importance for setting up a climate service that can tackle a high variability and grasp some past occurrences of extreme events. And it stands to reason that monitoring the terrestrial system today is a key to understanding, predicting and optimizing activities in the future.

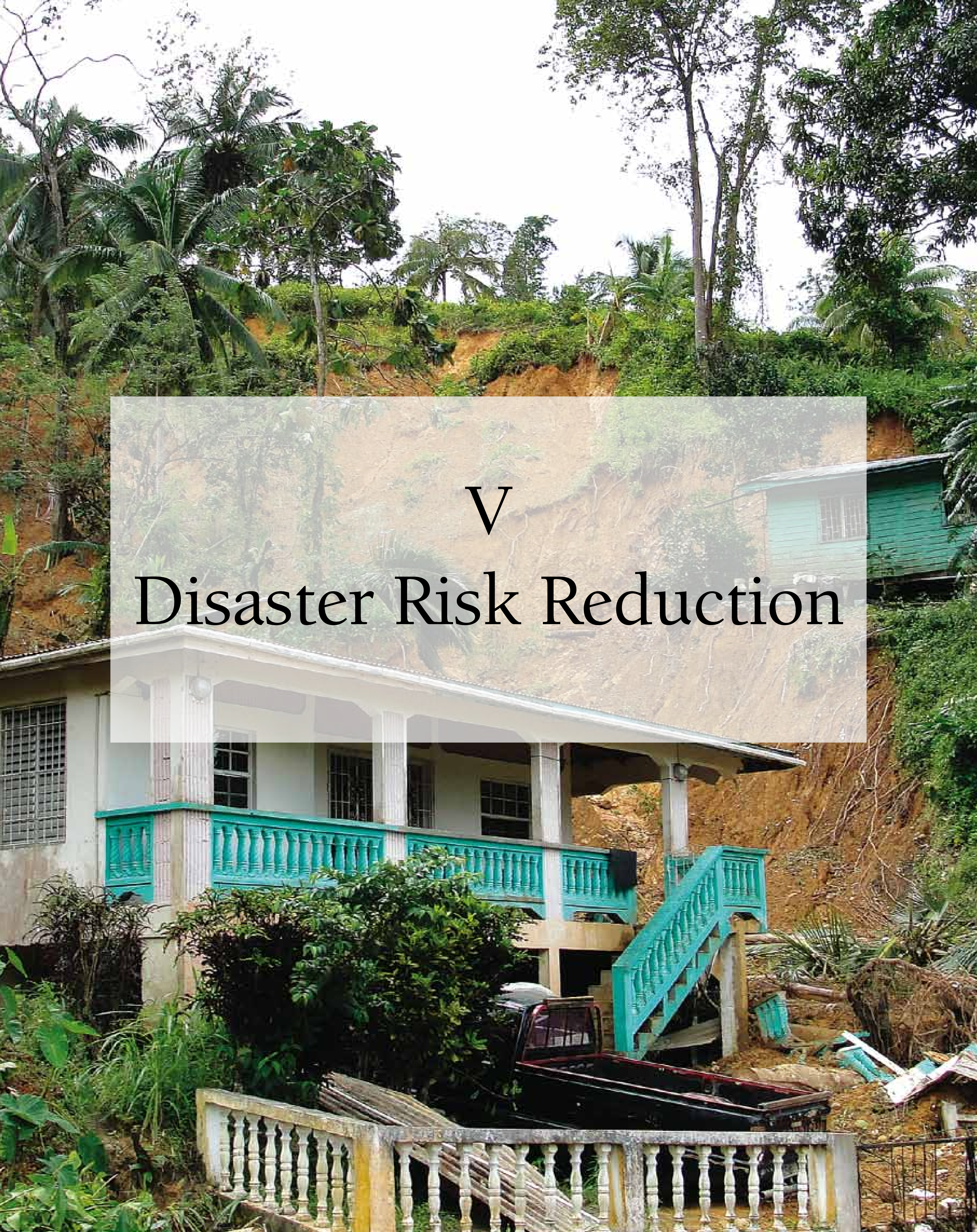
Hydrologists from the French Research for Development Institute and climatologists from Météo-France have worked together to build a predictive system based on seasonal forecasting. It was proven that seasonal forecasting could capture the yearly variability of precipitation, enabling flow and extreme events — being generated by extremely dry or wet years — to be reasonably well predicted. Meteorologists alone would never have achieved success in efficiently work on the Senegal River's flow regimes. They needed to join forces with hydrology scientists.

Similarly, without the user being at the core of the decision-making process, and without the strategy for the development of the Senegal River basin being structured as an international organization, having a perfect knowledge of all the requirements for the various uses of water in the area, knowing the ins and outs of the dam management and all other hidden agendas, the information would have been void. Science is difficult enough: all stakeholders have to join forces to make climate information alive and fruitful!

Image: © ACMAD

Météo-France, CCI and Western African climatologists exchange views on the coming rainfall season during the PRESAO meeting at ACMAD, Niger in 2008

V
Disaster Risk Reduction



The Devils Lake Decision Support System

Fiona Horsfall, National Oceanic and Atmospheric Administration

As part of an ongoing project, the National Oceanic and Atmospheric Administration (NOAA) is providing efficient and accessible climate information to support the communities of Devils Lake, North Dakota.

The years from 1990 to 2010 were the wettest 20-year period since 1895 in the Devils Lake Basin. Devils Lake, a closed natural lake with no significant drainage or outflow, and the adjacent Stump Lake collect the surface runoff, with Devils Lake collecting approximately 86 per cent. This runoff remains in the lake system until it evaporates, enters the groundwater table or — when the water level at Devils Lake reaches 1,458 ft above mean sea level — overflows into the Sheyenne River, which flows into the Red River of the North. The Red River of the North divides the states of North Dakota and Minnesota and then flows into Canada, which introduces an international component, in particular to water quality issues. In addition, overflow into the Sheyenne River could be catastrophic as the typically low flows could become significant, causing changes in the geomorphologic and ecologic characteristics of the Upper Sheyenne Basin and significant flooding to the cities downstream.

The water level within the lake has varied since measurements were first taken in 1895, reaching its lowest level in 1940 at 1,400.9 ft.[1] The recent wet period in the region has caused the lake level to rise to 1,453.2 ft as of 31 May 2012, resulting in inundation of the surrounding lands, including homes and agricultural land. The flooding has also caused significant damage to infrastructure, including roads, bridges, water and sewer systems, and flood control systems.[2] These dramatic changes have resulted in significant negative societal and economic impacts for local residents and communities in the region, including the Native American Spirit Lake Tribe, whose reservation adjacent to Devils Lake was established by treaty between the United States Government and the Sisseton Wahpeton Sioux Bands in 1867.[3] With over US$400 million already spent in flood protection measures[4] and more investment necessary by the United States Federal Government and the State of North Dakota, the economic impacts of the flooding are significant, and the risk of catastrophic flooding to the local communities is deemed unacceptable without further mitigation actions.

NOAA provides climate information support to the communities of Devils Lake, North Dakota, state and local level authorities and government, and other federal agencies responsible for addressing the flooding at Devils Lake. NOAA has provided on-site support

Image: NOAA

Recent flooding caused significant damage to infrastructure including roads, bridges, water and sewer systems, and flood control systems

Image: NOAA

The risk of catastrophic flooding to the local communities is deemed unacceptable without further mitigation actions

through briefings on weather and climate at public hearings held in the Devils Lake area. The team has also conducted outreach to the local at-risk communities.

Continued NOAA climate services in the region centre on the Devils Lake Decision Support System (DSS), an online climate information database designed, developed and implemented by the NOAA team. The DSS consolidates NOAA data specifically for the region, provides basic information necessary for decision makers, and makes that information easily accessible for all stakeholders. Examples of the information on the website include:

- Current weather conditions
- Current stream, river and lake levels
- Weather, water, and climate forecasts, including local weather forecasts out to seven days, streamflow forecasts for short-term flash flood guidance and probabilistic hydrologic outlooks out to four months, lake wind and wave forecasts, and probabilistic climate forecasts out to a year
- Data, including local climatology
- Satellite imagery
- Assessments such as hazard assessments and a NOAA Climate Assessment
- Inundation maps and other climatologic information specifically for Devils Lake
- Links to other information sources such as the US Geological Survey (USGS).

A detailed look at the service

In June 2010, NOAA, as part of the Department of Commerce and other federal agencies including the US Army Corps of Engineers (USACE), the US Environmental Protection Agency, the Office of Management and Budget, and the Departments of Agriculture, Defense, Homeland Security, Interior, Transportation and State, were charged with addressing the ongoing and potentially disastrous flooding issue at Devils Lake.

The NOAA team, already active in providing information for decision makers as part of its mission responsibilities through the National Weather Service (NWS), was alerted due to ongoing flooding in the Devils Lake area. The team subsequently developed strategies to support inter-agency efforts, which involved a 90-day response and included an inventory of existing agency activities in the Devils Lake area and a report with options and recommendations for near-term actions to assist the population affected by flooding. The North Dakota Delegation, made up of the two sitting Senators from North Dakota, Senators Kent Conrad and Byron Dorgan, and the at-large congressional member, Congressman Earl Pomeroy, asked the inter-agency team for unprecedented federal outreach and cooperation to assure the Devils Lake communities of NOAA's response to their critical situation.

The inter-agency effort included an assessment of activities focused on assisting communities affected by the flooding, such as Minnewauken, a city that will potentially be relocated as a result of it; the people of the Spirit Lake Nation, a Native American community on the south side of the lake; and other cities surrounding the lake that will be directly impacted by the flooding. NOAA's DSS provides information to these communities, the federal agencies with ongoing activities in the region, and communities downstream from the point of lake overflow, such as Fargo, North Dakota. As much of the information on the website is gathered from products already available across NOAA, funding for the project was needed only to support team travel to stakeholder locations and an external contractor, Prescient Weather, a privately owned firm with expertise in science-based, advanced technology

Many local community members and other federal agencies use the DSS site to monitor conditions at Devils Lake and inform their planning activities

applications, which developed specifically tailored products for the DSS not available from NOAA. Development of the website leveraged existing resources and capabilities from across NOAA.

Project evaluation has come from feedback from stakeholders, which has been extremely positive. The NOAA DSS website was advertised by North Dakota's Senator Conrad on the day of its launch, and the story was subsequently picked up by many local and state newspapers. Feedback indicates that many local community members, as well as other federal agencies, including USACE and USGS, use the site routinely to monitor conditions at Devils Lake to help their planning for ongoing activities, such as USACE's building of levees. The Federal Emergency Management Agency, Department of Transportation/Federal Highway Administration, and local authorities have access to inundation maps through the DSS to help them assess areas already flooded and the time of flooding, as well as potential areas that will be flooded as the water rises.

The DSS was implemented through a concerted effort by NOAA staff. Because of the short turnaround time required for launching the site, there was not time to engage in a formal process to gather stakeholder requirements, and thus staff familiar with user needs designed the site to answer frequently asked questions:

- What is it like now?
- What was it like before?
- What will it be like later today, tomorrow, next week, or next month?

Information already available across NOAA and partner agencies was brought into one location to make it easily accessible to answer the relevant stakeholder questions.

The greatest challenge was identifying resources to support the project, in particular, funding to support the external contractor. While some funds were identified, future work beyond the contract period in support of the DSS by the contractor is not funded. Also, while much of the website content is automated, updates to content have not been routinely made due to the lack of dedicated staff support.

Looking to the future

The DSS is automatically updated with the latest weather, water and climate information and will continue to operate this way as long as there is a strong threat of catastrophic overflow of the lake. The external contractor on the project continues to improve the site's science-based products and conduct research on the role of climate variability and large-scale atmospheric flow patterns in contributing to variations in the water level of Devils Lake.

While resourcing projects is always a challenge, this example demonstrates that leveraging existing resources to develop decision support services to stakeholders can be accomplished with little cost. In this case, relevant products and information already available or easily developed were brought together at one location to make them readily accessible to stakeholders. The DSS was made available within three weeks of initiation, and in the event that additional applications are needed and funding is identified to support their development, they can easily be integrated into the system.

Addressing GFCS principles

The DSS addresses several principles of the Global Framework on Climate Services (GFCS). By ensuring greater availability of and access to NOAA services, including climate, weather, and water services, it both meets and exceeds Principle 2. Using the DSS, NOAA was able to make use of global models to make predictions and meet the needs of regional and local stakeholders, in accordance with the third GFCS Principle of addressing global, regional, and national geographic domains.

Principle 4 states that operational climate services will be the core element of the GFCS. This project exemplifies the use of operational climate services as information on the site is updated in operational timeframes. Users are able to get the most up-to-date information on climate, weather, and water relevant to the region.

The website was built as a result of engagement with stakeholders who were faced with a particular challenge — in this case, the potential catastrophic overflow of Devils Lake. Other partners were engaged to provide the maximum benefit for stakeholders. For example, geographically relevant data from and links to other agencies are available on the DSS for use by Devils Lake decision makers. Thus, the project addresses GFCS Principle 8, building the framework through user-provider partnerships that includes all stakeholders.

The DSS has been an example of agency responsiveness to the needs of stakeholders. It provides information relevant to an ongoing environmental hazard to help stakeholders manage their risk and implement strategies to make the best use of their financial investment.

Provision of climate services in Tanzania

Dr Agnes L. Kijazi, Director General, Tanzania Meteorological Agency

Most people in Tanzania depend on rainfed agriculture as their main source of livelihood, and as the population increases, more land is needed for agriculture. More than 70 per cent of all natural disasters in Tanzania are linked to floods and droughts. Observed increases in climate variability, manifested through increased frequency and severity of floods and droughts, have significant impacts on agricultural production and people's livelihoods. Most recently, the city of Dar es Salaam experienced severe and catastrophic flooding from 20-22 December 2011 due to heavy rainfall, with severe socioeconomic implications for both the city and the country.

The Tanzania Meteorological Agency (TMA) is the designated authority for provision of meteorological services including early warning, alerts and advisories to the general public and other relevant authorities and stakeholders about impending severe weather and extreme climatic events. TMA also provides tailored weather and climate products to various sectors and stakeholders in support of sustainable socioeconomic development and for the protection of life and properties from hydrometeorological disasters.

Weather and climate services

TMA fosters strong relationships and collaboration with higher learning institutions, research institutions, non-governmental organizations and the general public to enhance the efficient and effective use of weather and climate information.

Image: TMA

Participants during a 2011 regional climate outlook forum in Arusha, Tanzania

The meteorological sector contributes to disaster management preparations, prevention, rescue and mitigation of natural disasters by providing timely weather forecasts, advisories and warnings. The early warning system for hydrometeorological hazards, including tsunamis, has four components:
- Warning centre
- Disaster management and civil protection authority
- Media
- Communities at risk.

As the warning centre, TMA needs to maintain strong links with other three components. Early warning is the most critical part of disaster management as it is an important tool for disaster preparedness and mitigation.

Seasonal climate outlooks

Seasonal climate outlooks are developed by considering the current and predicted state of global and regional climate systems such as the El Niño Southern Oscillation, Indian Ocean Dipole and Quasi-biennial Oscillation conditions, taking into consideration outputs from global and regional climate models.

In Tanzania, seasonal climate outlooks are developed in three phases. First, TMA scientists spend two days developing a preliminary outlook for the country. The second phase involves regional climate outlook forums based in the Southern African Development Community and Intergovernmental Authority on Development regional centres, where TMA scientists participate in developing a consensus regional outlook. In the third phase, the regional seasonal climate outlook is down-scaled to national level by TMA scientists, taking into consideration the results from the preliminary forecast and microclimatic features in various climatological zones. The consensus seasonal climate outlook is developed and its likely impacts on various socioeconomic sectors assessed. In this phase, stakeholders from climate-sensitive sectors including agriculture, water, energy, health and the media are invited to participate in the discussion.

The involvement of various stakeholders in the final phase of the development was introduced by TMA in 2006 with the objective of enhancing their understanding of the process and language used in packaging the information. A press conference involving members of the media and various stakeholders follows the third phase. This involves the Director General of TMA issuing a statement to the media and the public about the seasonal climate outlook and its implication for various socioeconomic sectors. The statement is then disseminated to the public, government institutions, local government authorities and other stakeholders through various channels including the internet, television, radio, newspapers and through agricultural extension officers.

Image: TMA

TMA Director General Dr Agnes Kijazi giving a statement during the press conference for March-May 2011 seasonal rainfall outlook

Evaluation and lessons learned

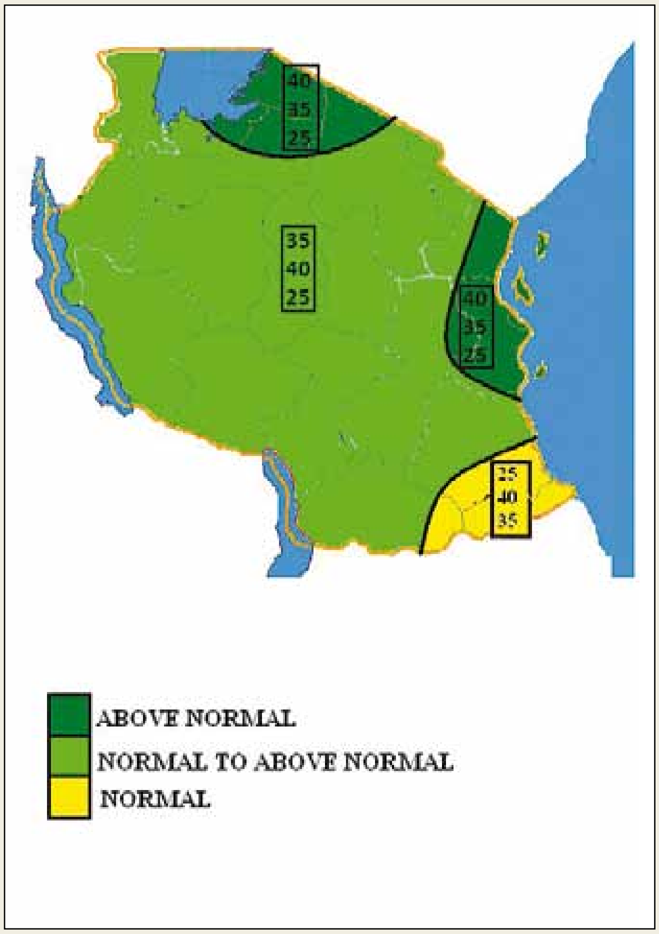
TMA usually verifies its forecast on a daily, weekly, monthly and seasonal basis. For example, in the case of the Dar es Salaam floods of December 2011, TMA verified that the weather system was well established three days before the floods, and a warning was disseminated to all relevant institutions, such as disaster management units and the media. Though, in general, people tend not to take weather forecasts seriously, the forecast was considered to be useful, since after a heavy downpour on the first day and the information from TMA, most people left lowland areas. This helped to reduce the number of deaths and loss of properties to a large extent. Nonetheless, the socioeconomic impacts of the floods were alarming and more than 43 fatalities were reported. Many people were left homeless and lost property when their houses were destroyed, and there was serious destruction of the infrastructure (houses, roads and bridges).

An effective multi-hazard early warning system is fundamental to disaster risk reduction. Due to a linkage between TMA and the Disaster Management Unit and Civil Protection Authorities, local government authorities and the communities at risk in Dar es Salaam, people were evacuated from low-lying areas at a cost of more than Tsh1 billion. Awareness of the climate services provided and the good relationship between TMA and other relevant institutions in the early warning system has significantly increased. Warnings were issued and disseminated through the media and the TMA website. Despite increased access to information through mobile phones by a large community, this technology has not been effectively used to improve Tanzania's early warning system. The effective early warning system needs be scaled up by increasing awareness about information access and response to different weather and climate-related disasters.

An effective multi-hazard early warning system could reduce the risks accompanying events like the Dar es Salaam floods, as well as being an instrument to help reduce the impact of other severe weather events such as floods, heavy rains, hailstorms and lightning strikes on crops, livestock, fishing, tourism and recreation activities. Besides timely dissemination of the warnings by TMA, it was found that response to the warning depends on available infrastructure and equipment, the communities at risk and rescue authorities.

Challenges and resources

Coordination of the four components of the early warning system (warning centre, operation unit, media and society at risk) must be enhanced. Sensitization, including drilling exercises for communities at risk, should be developed for mitigation purposes. However,



A climate forecast issued by TMA for December 2011: above-normal rainfall was predicted for the entire north coast of Tanzania and other areas in the October-December 2011 rainfall season; the government and community were informed of possible flooding and advised to take precautions

Source: TMA

due to increased climate variability and change, the demand for timely, high quality weather and climate information has increased.

TMA faces several challenges in its efforts to enhance quality and efficiency in the provision of services to the various socio-economic sectors, aggravated by increasing running costs, low community awareness and budgetary pressures.

Due to complex topographical features, Tanzania has unique and diverse climatic characteristics, ranging from tropical to arid and semi-arid lowlands. However, the current observational station network is not sufficient to capture all climatic regimes and the local climate. Currently there are no marine weather stations despite the fact that the country is surrounded by large water bodies, including Lake Victoria, Lake Tanganyika, Lake Nyasa and the Indian Ocean.

Some historical climate data are still in paper forms that are deteriorating with time and thus need to be rescued and digitized, and the meteorological database management system is outdated and needs to be replaced.

Maintaining the right expertise across all parts of the organization is an ongoing challenge due to ageing workforce and growing demand for services. TMA also faces challenges in training, recruiting and retaining qualified staff.

Goals for development

Tanzania faces many natural hazards and needs to develop an effective multi-hazard early warning system for disaster risk reduction. The Global Framework for Climate Services (GFCS) will increase the accuracy of climate prediction through coordination of the global, regional and national weather and climate prediction centres. Disseminating knowledge of natural disasters to the media and community will enhance awareness of the risks and impacts of natural disasters and measures to be taken for mitigation towards reducing risks.

The current status and needs of Tanzania's meteorological infrastructure

Description	Number of stations		
	Current Source: TMA	Operational	Needed
Conventional surface synoptic stations	28	28	32
AWS surface synoptic stations	14	5	113
Agrometeorological stations	13	13	20
Climatological stations	150	60	250
Rainfall stations	2056	600	2500
Marine weather station	0	0	12
Upper-air stattions	1	1	4
Pilot balloon	1	-	5
Weather radar	1	0	7
Lightning detector	0	0	10

Source: TMA three-year strategic plan (2010)

The GFCS outcomes are intended to contribute to the achievement of the United Nations Millennium Development Goals and broader United Nations climate goals, including the Hyogo Framework for Action on Disaster Risk Reduction. The GFCS goals complement global work underway to help societies adapt to climate change, providing support for:

- Enhanced institutional capacity to advance climate risk management practice in relevant sectors
- Sustained global climate observations across all relevant domains and timely data exchange
- Stewardship of the climate record and provision of open access to climate information
- Improved accuracy, resolution and scope of climate analyses and predictions
- Provision of mechanisms for widespread delivery of timely, authoritative and user-friendly predictions and assessments of their uncertainties
- Focused services to meet a wide variety of sectorally or regionally based vulnerabilities
- Capacity-building for activities, including training curricula, dissemination of best practices and knowledge management mechanisms
- Adequate resources to advance scientific understanding of the climate system, climate variability and change and its impacts on the environment and society
- Dedicated computation resources for climate analysis and prediction
- Climate risk management and adaptation to climate variability and change.

The current status of TMA in terms of meteorological infrastructure and human resources indicates low capacity. Tanzania is frequently impacted by natural disasters, many of which are attributed to weather and climate. Improving forecasting accuracy and early warning systems is crucial in facilitating effective decision-making in planning and implementing various socioeconomic activities, particularly agriculture and disaster risk reduction. This will be achieved through improved meteorological infrastructure and enhanced human capacities, which will facilitate the provision of reliable and effective weather and climate information, including severe weather and climatic events.

Images: TMA

The impacts of the December 2011 floods in Dar es Salaam included serious destruction of the infrastructure

Developing an early warning system to mitigate temperature stress on rice production

Yoshiji Yokote, Director, Climate Prediction Division, Global Environment and Marine Department, Japan Meteorological Agency

A recent pilot project jointly conducted by the Japan Meteorological Agency and the National Agriculture and Food Research Organization's Tohoku Agricultural Research Center saw the development of climate information services for the agricultural sector in the Tohoku region.

The accuracy of seasonal forecasts issued by the Japan Meteorological Agency (JMA) has increased thanks to improved prediction techniques and advances in understanding regarding the predictability of climate-related phenomena. However, seasonal forecasts have not been effectively deployed in some user sectors. One reason for this is that JMA's seasonal forecast is probabilistic in three categories (below-normal, near-normal and above-normal) on a regional scale, meaning that it is not necessarily easy to use or comprehend. Against such a background, JMA sought ways to develop easy-to-use information tailored to users' requirements in order to support their decision-making activities in various sectors. As part of such efforts, JMA began issuing Early Warning Information on Extreme Weather (EWIEW) in March 2008. EWIEW indicates the possibility of very high or low temperatures up to two weeks ahead, and contributes to the implementation of farming measures against damage caused by extreme weather phenomena such as very cold conditions.

The National Agriculture and Food Research Organization (NARO) is Japan's largest research organization addressing agriculture, food and rural communities. Its Tohoku Agricultural Research Center (TARC) is one of the leading institutions in the field of studies on the use of weather and climate information for the agricultural sector and provides such data to end users (farmers). NARO/TARC's recent activities have included consideration of how to supply improved information with a greater level of tailoring to end users. In addition, there have been good long-term relationships between NARO/TARC and local JMA observatories in the Tohoku region (in the northern part of Japan's mainland).

In July 2009, JMA hosted an international event titled The Tokyo Climate Conference: Better Climate Information for a Safe and Sustainable Society. The aims of the conference were:

- To identify actions and methods for the development of an effective framework involving users and providers in order to create user-oriented products and promote their utilization with a focus on the Asia-Pacific region
- To contribute to the World Climate Conference-3, which initiated the establishment of the Global Framework for Climate Services.

Building on the favourable long-term relationships between NARO/TARC and local JMA observatories in the Tohoku region, the conference provided an ideal opportunity for the two organizations to discuss how the use of climate information in the agricultural sector could be enhanced, and this exchange led to the idea of a pilot project that would benefit both JMA and NARO/TARC in their service and research activities.

As a result, the two organizations initiated a pilot project to promote the effective use of seasonal forecast data in Japan. The aims of the initiative were to develop climate information applicable to agriculture in the Tohoku region, which tends to be greatly affected by cold conditions, to provide customized climate information to end users (farmers) via a website, and to evaluate the information's effectiveness using a questionnaire survey. Future goals include enhancing the use of climate prediction information in various user sectors through lessons learned from the pilot project.

Dialogue and development

In the first stage of the project, JMA and NARO/TARC engaged in dialogue to determine related requirements and to exchange knowledge and information. JMA considered how to promote the better use of predictions covering the period up to two weeks ahead in user sectors, based on recent improvements in prediction skill. NARO/TARC also sought to improve the customized information it provides to end users so that better countermeasures could be taken to protect rice crops against the adverse effects of extreme temperatures, especially in the occasional cold summer conditions affecting its area of responsibility. As a result of this dialogue, the two organizations decided to target climate information towards the development of the pilot project for the farming of rice crops in the Tohoku region in summer. There were three key reasons for this choice:

- The Tohoku region is frequently affected in summer by cold north-easterly winds (known as Yamase winds), which have a great impact on rice crops
- Controlling water temperatures in rice fields by adjusting water levels is an effective countermeasure to combat the adverse effects of extreme temperatures on rice crops – for example, farmers

may increase the quantity of water to reduce the sterility effect that low temperatures can cause
- Climate prediction information is considered useful for water temperature control, as farmers require one to two weeks to prepare for the water level adjustment countermeasure mentioned above.

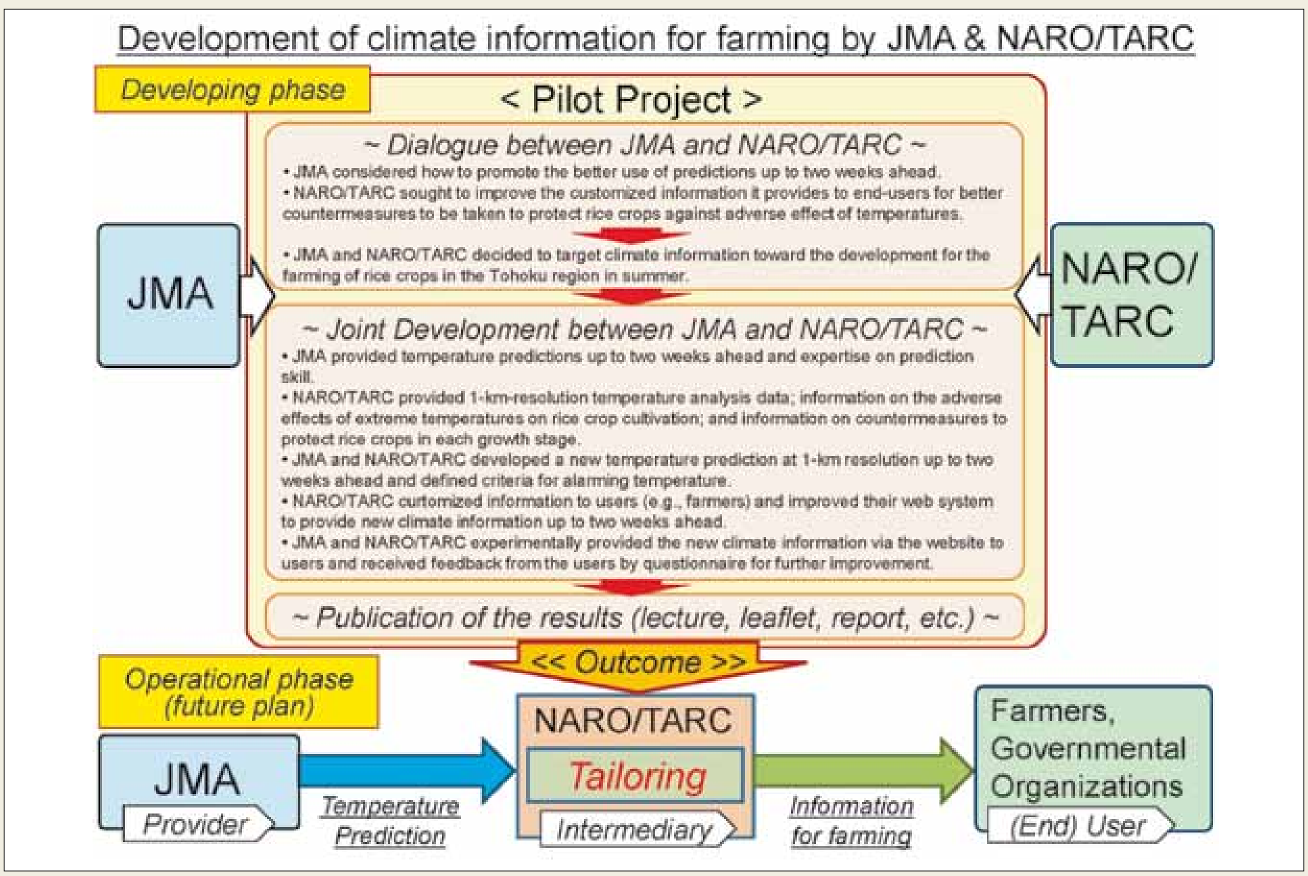
In the development phase, JMA and NARO/TARC first discussed the content of new climate prediction information suitable for the purposes at hand. JMA provided temperature predictions covering the period up to two weeks ahead and expertise on prediction skill. NARO/TARC provided:
- 1 km-resolution temperature analysis data formulated using JMA observation and local geographical data
- Information on the adverse effects of extreme temperatures on rice crop cultivation
- Information on countermeasures to protect rice crops in each growth stage.

Based on these exchanges of information and expertise, JMA and NARO/TARC developed a method to predict probability density functions (PDFs) of seven-day mean temperatures (T7d) at a resolution of 1 km for the Tohoku region covering the period up to two weeks ahead. The T7d prediction was based on a combination of two data sets: the climatological normal of T7d with a 1 km resolution covering the 30-year period from 1981 to 2010 (produced by NARO/TARC), and the PDF prediction for regional-scale T7d anomalies on the Sea of Japan side and the Pacific Ocean side of the Tohoku region (produced by JMA).

JMA and NARO/TARC then discussed criteria for alarming temperatures at which countermeasures should be taken in consideration of related issues such as the various growth stages of paddy rice, impacts on its development and countermeasures to be taken. The discussions in this phase were based on NARO/TARC's expertise and experience in agro-meteorology. As a result, two criteria were defined: temperatures of 20° C or below from the middle of July to the beginning of August, which increase the risk of sterility in rice crops; and temperatures of 27° C or above in August, which increase the risk of poor grain filling in rice crops.

To evaluate the effectiveness of this new prediction approach, JMA verified T7d prediction skill at a 1 km resolution using hindcast experiment (re-forecast) data for the 30-year period from 1981 to 2010. The predicted values were compared to actual temperatures recorded at 17 surface stations in the Tohoku region, and the results confirmed that the mean of the T7d predictions indicated

Key processes of the JMA NARO/TARC pilot project



Source: JMA

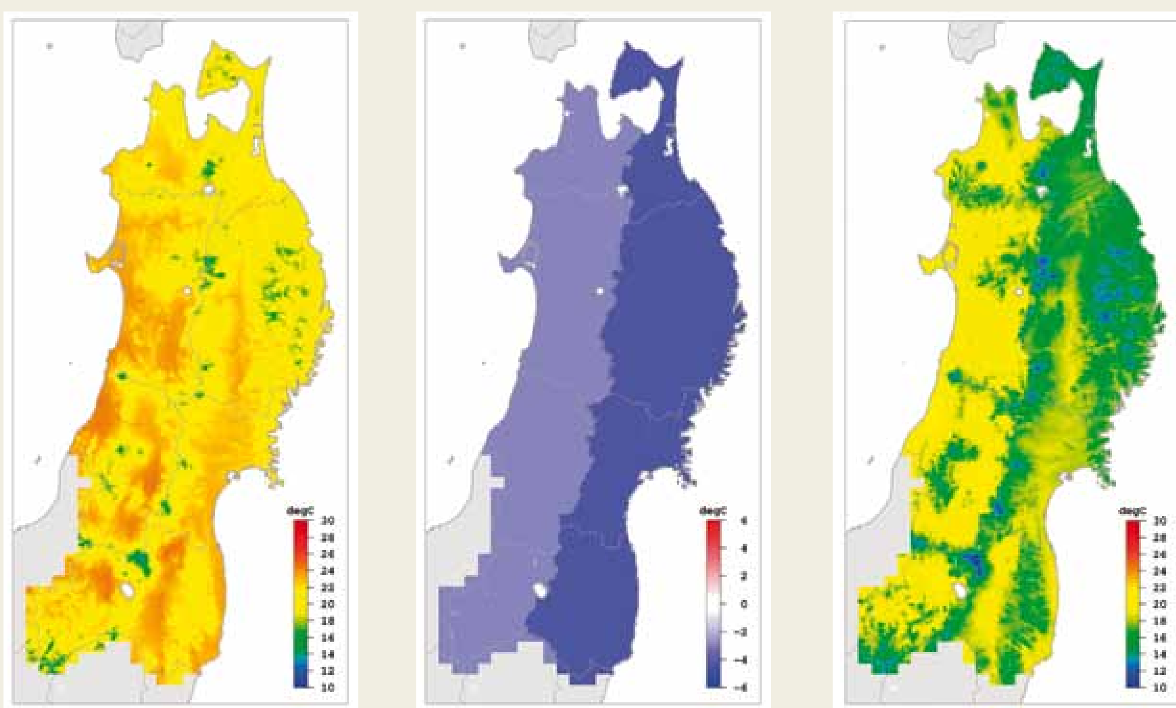
a higher level of skill than the climatological value of T7d for the period up to two weeks ahead. It was also found that the prediction skill for the probability of T7d values, at 20° C or below and 27° C or above, was reasonable. JMA verified this in relation to past extreme events, including the very high temperatures seen in 1994 and the very low temperatures seen in 2003, and found realistic temperature distributions and variations of the prediction comparable to actually observed values.

Experimental provision of climate information

During summer 2011, JMA and NARO/TARC experimentally provided the new climate information through a website to registered users (see map image on next page). In fact, NARO/TARC, in collaboration with the Faculty of Software and Information Science at Iwate Prefectural University (IPU) had operated a website providing weather and related tailored information aimed at reducing rice crop damage even before the pilot project was implemented. Under the project, NARO/TARC further customized information to users and improved the web system to provide new climate information covering the period up to two weeks ahead. The data included mean T7d predictions and the predicted probability of T7d values at 20° C or below and 27° C or above for each 1 km grid, covering the period from one to two weeks ahead. On the website, users could also view time-sequence information for specific registered points, including predicted T7d values and their variability (standard deviation) and the predicted probability of T7d values at the levels described above. The site also included maps showing the climatological occurrence of the high and low temperatures and related interpretation. When the predicted probability of T7d reaching the alarming temperature was high at a registered point, an alert was automatically sent to users' e-mail terminals and mobile phones. For example, if the possibility of temperatures at or below 20° C was high, users received an alert so that they could increase water levels in rice fields to protect against low-temperature-related damage.

After the experiment of July 2011, NARO/TARC and the IPU conducted an e-mail questionnaire survey. The questionnaire was distributed to the 154 users who participated in the experiment, and 89 replies were received. Unfortunately (as far as the experiment is concerned), no remarkably high or low temperatures occurred during the trial period, meaning that few alert messages were sent. Nonetheless, a number of respondents clearly indicated the usefulness of the information provided during the experimental period. Others underlined the need for climate information covering the period up to two weeks ahead. The results of the survey indicated that the experimental provision was fruitful, in that it highlighted agricultural users' need for longer-range forecasts in the Tohoku region and clarified that the provision of tailored climate information offers potential benefits to farmers. These findings were an important outcome of the pilot project. However, as no extremely cold conditions were seen during the experimental period in 2011, it is prema-

Seven-day mean temperature (T7d) prediction at a 1 km resolution in the Tohoku region of Japan



(a) Climatological normal of T7d at a 1 km resolution

(b) Mean value of predicted regional-scale T7d anomalies

(c) Mean value of predicted T7d at a 1 km resolution (= (a) + (b))

Source: JMA

ture to conclude the effectiveness of the new climate information services and identify possible related problems. JMA and NARO/TARC will continue to supply the new information on a trial basis in summer 2012 towards its operational provision in the near future.

Success factors

The pilot project was successful both for JMA and for NARO/TARC. In particular, JMA gained significant expertise on developing better climate information services. Some keys to the initiative's success and lessons learnt from it are summarized below:

- It is critical for climate information users and providers to engage in close and productive dialogue and to share knowledge due to the nature and difficulty of climate prediction and information. JMA and NARO/TARC frequently shared relevant information both by e-mail and at face-to-face meetings, which supported the success of the project.
- Intermediaries linking providers and end users of climate information are very important in promoting its use. In the pilot project, NARO/TARC and its researchers acted as intermediaries between JMA and end users in the agricultural sector.
- Effective use of existing systems, as well as support from partners, contributes to the smooth and successful launch of new services. In the project, experimental provision of the new information was effectively carried out using existing systems operated by NARO/TARC in collaboration with the IPU, which offered useful support as it specializes in information technology. Making the most of its experience to implement the pilot project, NARO/TARC took steps to improve its agro-meteorology information based on user feedback.

Future plans and expectations

Based on the success of the pilot project with NARO/TARC, JMA held discussions with NARO (the higher authority of NARO/TARC) with a view to efficiently expanding such collaboration to initiate similar projects in other regions. Currently, JMA is involved in four pilot projects in conjunction with four regional agricultural research centres under NARO. In addition, recognizing the effectiveness of tailored climate information in the agricultural sector, JMA has begun discussions with Japan's Ministry of Agriculture, Forestry and Fisheries (which oversees and connects all stakeholders in the agricultural sector, including those within local governments) to develop better partnerships with the sector and promote further development and effective use of climate information services beneficial to various agricultural activities.

JMA is further seeking opportunities to collaborate with operators in other fields, including the energy sector, in order to provide greater levels of usefulness and tailoring in its climate information services. Such collaboration is expected to promote efficient climate information services that are beneficial in a variety of socioeconomic activities.

A map for the experimental provision of temperature prediction to specific users (in Japanese)

Users can select mean values of the seven-day mean temperature (T7d) and the predicted probability of T7d values at or below (above) 20 (27)° C at a 1 km resolution for the period from one to two weeks ahead of 27 July, 2011, on the website

Source: JMA

Temperature prediction at a 1 km resolution

T7d prediction at a 1 km resolution was made based on a combination of two data sets: NARO/TARC provided climatological normals of T7d at a 1 km resolution covering the 30-year period from 1981 to 2010, while JMA provided PDF prediction data for regional-scale T7d anomalies for the Sea of Japan side and the Pacific Ocean side of the Tohoku region.

The climatological normals of T7d in more than 70,000 1 km grids in the Tohoku region were calculated from historical records of daily mean temperatures (T1d), which were statistically estimated using surface observation data of T1d and geographical information at a 1 km resolution. These observation data were obtained from a network of automated weather stations operated by JMA, known as the Automated Meteorological Data Acquisition System (AMeDAS).

JMA provided predicted PDFs of regional-scale T7d anomalies that are made twice a week for EWIEW. The PDFs were calculated using both numerical prediction data from JMA's operational one-month Ensemble Prediction System (EPS) and regression coefficients estimated from hindcast experiments (re-forecasts) for 1981-2010, which were carried out with the same system as that in operational use. To calculate the predicted PDFs of T7d at a 1 km resolution with respect to actual temperatures (rather than in three operational categories), two steps must be completed: statistical downscaling for predicted PDFs of T7d anomalies from a regional scale to a 1 km resolution, and addition of the PDFs to the climatological normal.

When the predicted PDFs were changed from a regional scale to a 1 km resolution, the mean values were assumed to be uniform and equal to that in each region. However, PDF variances are thought to differ for each 1 km grid even in the same region. Accordingly, differences in variances caused by the different spatial scale were estimated using historical records of temperature at a 1 km resolution provided by NARO/TARC. Based on this estimation, PDFs of the T7d anomaly at a 1 km resolution were calculated from the regional-scale values. After this process, the PDFs were added to the climatological normals for each 1 km grid so that users could use the PDFs in view of actual temperatures rather than anomalies. This facilitated user understanding and supported use in decision-making.

The North American Drought Monitor

Richard R. Heim Jr and Michael J. Brewer,
National Oceanic and Atmospheric Administration

The North American Drought Monitor (NADM) is a collaborative continental drought monitoring product prepared jointly by the United States, Canada and Mexico. It illustrates how individual nations can work together to provide climate services that benefit the participating countries — and users within those participating countries — individually and synergistically.

Agriculture has traditionally been the sector most harmed by drought, but all economic sectors are impacted. Historically, people have responded to drought in a reactive manner. However, the development of products and programmes such as the US Drought Monitor (USDM),[1] NADM, National Integrated Drought Information System (NIDIS) in the US[2] and drought response plans in many US states and other nations, has enabled people to begin to anticipate drought and act in a more proactive and efficient manner.

History and purpose of the NADM

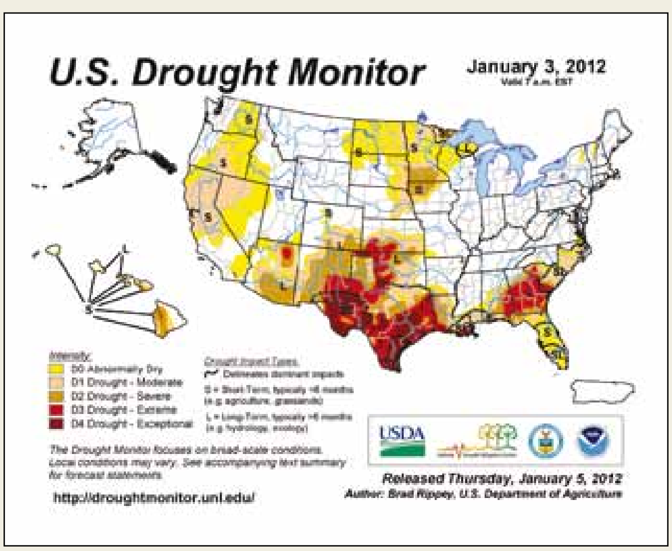
The USDM was inaugurated in 1999 as a monitoring tool depicting current conditions of drought within the 50 United States and Puerto Rico.[3] The NADM was initiated at a three-day workshop in late April 2002.[4] Representatives from the US, Canada and Mexico agreed to collaborate in continental monitoring of drought as the first step in a larger effort to improve the monitoring (and assessment of long-term variability and trends) of a wider suite of climate extremes on the continent, including heat waves, cold waves, drought, flooding and severe storms. The NADM maps were experimental from November 2002, becoming operational after April 2005. The drought depiction in Canada steadily expanded from the Prairies to all the southern provinces as drought assessment techniques and databases improved.

The NADM partners include:

- In the US, the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC), Climate Prediction Center (CPC), the US Department of Agriculture (USDA) and National Drought Mitigation Center (NDMC)
- In Canada, Agriculture and Agri-Food Canada (AAFC) and Meteorological Services of Canada (MSC)
- The National Meteorological Service (SMN) in Mexico.

These partners contribute time and personnel to NADM activity as part of their normal operational duties (and other duties as assigned), since there is no dedicated budget or any funds specifically allocated to the NADM activity.

The US Drought Monitor for 3 January 2012



Source: NOAA

Benefits of the NADM

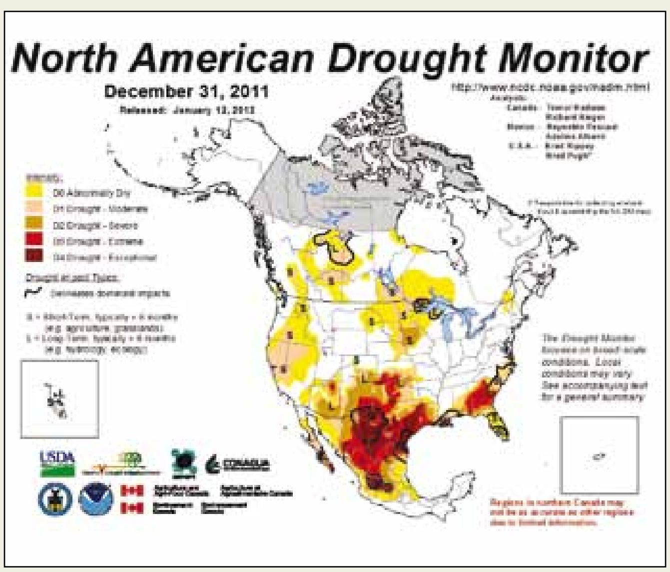
Coordinated monitoring of drought across North America benefits Government, agribusiness, water resources, utilities and similar user groups. These groups include policymakers and water resource planners and operators within each country, as well as corporate players and international government agencies with agricultural, commodity and water management interests across North America and, ultimately, the North American public. Private sector users of the NADM include agricultural, commodity and water management companies. Several Mexico-specific user groups were identified at the recent NADM Forum in Cancun,[5] including the Directorate General for Economic Research of the Bank of Mexico, the Institute for Sustainable Development in Mesoamerica, and the Municipal Planning Institute Comitan Implan. The benefits of using the NADM are centred on reducing drought vulnerability and risk, and comprise a variety of socioeconomic and public security applications (such as disaster mitigation measures), including reduced economic loss due to drought and more efficient management of water resources across international boundaries. In the early 2000s, drought afflicting the southern US and northern Mexico reduced streamflow along the Rio Grande/Bravo River system. The NADM provided a collaborative drought monitoring tool which assessed the severity of drought in the region, providing valuable information which could be used by decision makers on both sides of the border to better manage water resources held in US and Mexican reservoirs along the river system.

Academic studies have attempted to estimate the costs associated with drought. According to Anil Markandya, Director of the Basque Centre for Climate Change, drought affects around 25 per cent of gross domestic product in developed countries – and more in developing countries.[6] The total cost of droughts over the past 30 years in Europe amounts to €100 billion (about US$132 billion or US$4.4 billion per year on average).[7] In the US, droughts cause direct losses that average between US$6 billion and US$8 billion per year.[8] According to a Manitoba government study in 2002, the 2001 Prairie drought cost the Canadian economy over Can$5 billion in agricultural losses.[9]

Since the NADM is an operational activity with no specific line-item budget, funding has not been available to engage an economist to perform an NADM cost-benefit analysis. Furthermore, while many commercial users have indicated that they use the NADM in their business decisions, they are reluctant to release proprietary financial information that could help NADM producers determine the savings achieved by using the product. However, some estimate of NADM-based cost savings can be obtained from data released by Government agencies.

Government agencies and academic institutions such as universities and research institutes in Mexico, the US and Canada are heavy users of the NADM. In Mexico, the NADM is an important criterion for drought-related decisions made at the highest levels of Government.[10] According to a Reuters news report,[11] the Government has allotted MXN34 billion (US$2.65 billion) in emergency aid to confront the 2011-2012 drought; and water authority CONAGUA says it must invest over MXN300 billion (US$23.68 billion) by 2030 to safeguard and modernize infrastructure by sealing leaky pipes, expanding reservoirs and recycling household wastewater.

The North American Drought Monitor for the end of December 2011



Source: NOAA

In Canada, the Pasture Recovery Program was an initiative to encourage producers not to put cattle on damaged pasture early in the spring of 2010, and to assist them in purchasing extra feed supplies. NADM products were used in designating the producers eligible to receive the payments, which were based on the number of cattle the producer had within the impacted region and totalled Can$67.2 million in Alberta and Can$16.9 million in Saskatchewan.[12]

In the US, the USDM, which becomes the US portion of the NADM each month, is used by many states as a trigger in their drought plans, and by the USDA as a criterion for allocating drought relief funds. The USDA's Farm Service Agency (FSA) and its predecessors administer commodity, conservation and farm lending programmes to about two million agricultural producers. The FSA programmes are legislated through farm bills (passed by the US Congress every five to six years), annual appropriations and disaster emergency acts. In 2006, state block grants totalling US$50 million were allocated through the Livestock Assistance Grant Program, and in fiscal year 2010 the USDA provided US$1.9 billion in supplemental agricultural disaster assistance outlays where the damage was due to drought or other adverse weather.[13] Drought relief funds allocated through the Livestock Forage Program totalled US$165 million in 2008, US$99 million in 2009, US$33 million in 2010 and US$255 million in 2011.[14] In the 2008 Farm Bill's disaster declaration and designation process, the USDM provides a quantifiable standard for determining a qualified county: those that experienced a USDM drought category of D2 (severe drought) for a minimum period of two months would qualify, while D3 (extreme drought) or worse automatically qualified the county as a disaster area.

Operational production of the NADM

The NADM is not imposed on participants by an outside agency; it is a bottom-up collaborative activity by the participants. Experts within each participating country independently determine that country's drought depiction and construct a narrative describing its drought conditions. The NADM is produced monthly in an ArcGIS environment by a lead author who integrates the national drought depictions and narrative discussions from the three countries into a continental map and narrative. The lead author changes every month, rotating from among personnel at six of the NADM partner agencies and organizations. The 2012 author schedule is typical of an annual schedule, including:

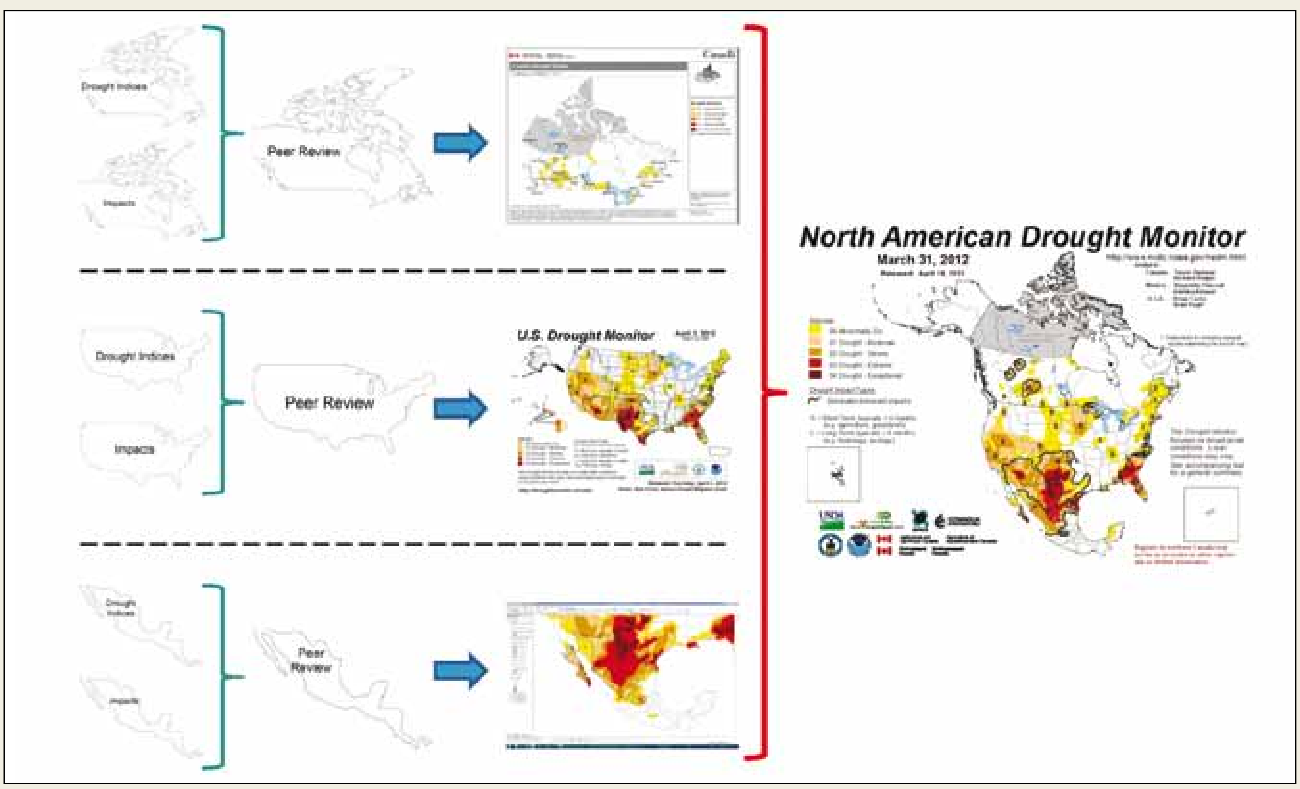
- Canada: AAFC personnel lead authoring for two of the 12 months
- Mexico: SMN personnel lead authoring for two months
- US: NDMC personnel lead authoring for two months, USDA personnel lead authoring for one month, CPC personnel lead authoring for two months, and NCDC personnel lead authoring for three months.

The USDM is used for the US drought depiction. It is produced on a weekly basis by NOAA, USDA and NDMC partners from a large suite of in situ and satellite-based objective drought indicators (including the Standardized Precipitation Index (SPI), Palmer Drought Index, streamflow, mountain snow pack, precipitation percentiles, modelled soil moisture, Vegetation Drought Response Index and many others), impacts information (such as reduced agricultural production), and local field input from over 300 participants. The indices and indicators are combined using a simple D0-D4 scheme and a percentile ranking methodology to address both short-term and long-term drought. The USDM undergoes a peer-review process through an e-mail based discussion list each week during its preparation, to ensure that the weekly drought depiction represents the best 'blended convergence of evidence'.[15] The weekly USDM map from the week closest to the end of the month is used for the US depiction on the NADM map for that month. The national Drought Monitors (DMs) for Canada (by AAFC) and Mexico (by SMN) are prepared in a similar manner.

Each of the three countries provides daily and/or monthly temperature and precipitation data to the NCDC for the computation of monthly station and climate division-based continental drought indices (SPI, Palmer Drought Index, and percentage of long-term average precipitation). These continental drought indices, computed using the same methodology and calibration periods, are used by the lead author in conjunction with other drought indicators with North American coverage (such as the NOAA satellite-derived Vegetative Health Index and continental scale modelled soil moisture), as guidance to prepare a consistent NADM drought depiction along the international borders. The NADM continental map and narrative are provided to the partner agencies and organizations for an iterative peer review. The NADM map is finalized, generally, by the tenth day of the month and put online by the NCDC by the eleventh and the NADM narrative is placed online a few days later. The NADM map GIS shape files are available online (restricted access), and the NADM is available at no cost on both a static website[16] and via the NIDIS drought portal.[17] Both the NADM map and narrative are provided in the languages of the three countries (English, French and Spanish). The continental drought indicators are also available at the website in both map format and ASCII data files.

Policy decisions are made at the top management level of the partner agencies and organizations and are guided by bilateral and trilateral agreements. Operational, technical, administrative, scientific and user issues are addressed and evaluated at biennial NADM Forum workshops hosted, on a rotating basis, by the three countries. These workshops provide a mechanism for valuable feedback, whereby users may express their drought monitoring needs to the NADM authors (resulting in improvements to the NADM product) and receive guidance on the appropriate use and interpretation of the NADM. Common user concerns expressed at NADM and USDM forums include appropriate ways to use the DM products and indices in their decision-making processes,

The flow of production of the NADM



Source: NOAA

The drought classification and ranking percentile scheme used by the NADM

Category	Description	Ranking percentile
D0	Abnormally dry	30
D1	Moderate drought	20
D2	Severe drought	10
D3	Extreme drought	5
D4	Exceptional drought	2

Source: NOAA

and how drought is defined in their region. In the US, several NIDIS pilot projects engage local feedback on user needs and requirements in order to develop drought information and early warning systems that are appropriate and effective for the local regions.

Goals, linkages and the future

Geographical coverage is a key goal. Currently, the NADM includes Canada, Mexico and the 50 United States and Puerto Rico. Discussions are in progress to include partners from countries in the Caribbean and Central America, US territories in the Pacific (Guam, American Samoa) and US-affiliated countries in the Pacific for which NOAA provides weather- and climate-related services (federated states of Micronesia, Republic of the Marshall Islands, Republic of Koror, Commonwealth of the Mariana Islands).

A further goal is to enhance the software. The national DMs in the US, Canada and Mexico are prepared independently within each country using similar ArcGIS software and the national shape files are then merged into continental shape files by the lead author. NIDIS web services are being developed to support a more streamlined and consistent process for producing these continental shape files.

The Global Drought Monitor

The NIDIS portal architecture, which supports the USDM and NADM, also supports drought information on a global scale. A Global Drought Monitor Portal (GDMP) has been developed using Open Geospatial Consortium (OGC) web mapping services to serve as the foundation for the development of a Global Drought Monitor (GDM).[18] The GDM was designed to incorporate existing regional/continental DMs that provide their information in an Open Geospatial Consortium-compliant format. As of early 2012, the GDM has incorporated regional drought information for North America via the NADM; Europe, via the European Drought Observatory (EDO); and Africa, using the African Drought Monitor (ADM). Groups representing Australia and South America have expressed interest and coordination with appropriate parties in Asia is also expected.

Due to the variety of climates across the world, the diverse nature of drought and the sectors it impacts, and the varying capabilities of participating nations, no single design will work for all parts of the world. The construction and functioning of each continental DM needs to be appropriate for the continent in question. The NADM, EDO and ADM provide examples of three models uniquely adapted to the requirements and resources of their respective regions. The table, detailing characteristics for the creation of continental drought monitors, summarizes the level of IT infrastructure, drought expertise, international collaboration and data exchange, drought assessment capability, and national climate observing systems for these three models.

The collaborative NADM model works for North America because:

- All three countries have compatible IT infrastructure, create national drought depictions on an operational basis, and produce their national drought depictions in an agreed-upon GIS format
- Extensive data networks and near-real time daily climate observations exist within each country
- Collaborative agreements are in place for international data exchange and sharing of drought expertise for monitoring, forecasting and research.

The NADM model may not work for other continents where these conditions are not met, such as Africa. Here, extensive data networks and near-real-time daily observations are available for some nations but not for others; the IT infrastructure varies from country to country; and national DM assessments generally are not made on a routine basis – and thus are not available for integration into a continental DM (CDM). Nations on such continents may need to request expertise from outside for drought monitoring and forecasting, coupled with in-house expertise for impacts, research, planning and education.

On continents such as Europe, the political infrastructure exists for the creation of international agreements that govern joint research, information sharing and provision of services, and each country has extensive data networks providing near-real-time daily observations, supplemented by satellite observations and modelled data. Thus, international centres can be established which assess, monitor and forecast droughts on a continental scale for all participating nations, complemented by regional, national and local expertise and assessments where available.

Continental or regional DMs are needed since current NIDIS IT resources are insufficient to integrate the dozens of national DMs that are – or will be – available. For consistent depiction of drought on a global scale, the integration of CDMs requires:

- The establishment of certain standards for drought depiction among CDMs (for example, using a drought classification scale similar to the NADM)
- The creation of CDM shape files in a GIS environment
- The smoothing of CDM drought depictions along continental boundaries.

The GDMP includes a suite of global drought indicators identified by experts and adopted by the World Meteorological Organization as the necessary measures to examine drought from a meteorological standpoint; these indicators provide a base to assist the global integration and interpretation of the CDMs.

The NADM illustrates collaborative drought monitoring on a continental scale that integrates national DMs into a synergistic continental whole, with continental drought indicators as guidance. The GDM takes this collaborative concept to the global scale.

Characteristics for the creation of continental drought monitors: NADM, EDO and ADM models

	NADM model	EDO model	ADM model
Drought experts	In-house expertise for monitoring, forecasting, impacts, research, planning, education	In-house expertise for continental monitoring, forecasting, impacts, research, planning, education. Combined with regional, national and local expertise	External expertise for monitoring, forecasting, coupled with in-house expertise for impacts, research, planning, education
National climate observing network	Extensive data networks and near-real time daily observations from all three countries; supplemented by continental satellite observations and modelled data	Extensive data networks providing near-real time daily observations (>30 countries) supplemented by satellite observations and modelled data	Extensive data networks and near-real time daily observations for some nations (more satellite observations than in situ observations for most regions)
National drought assessments	NDMs in each country already routinely produced (monthly or more frequently) and merged into CDM	Continental assessment done at EC-Joint Research Centre (JRC), complemented by regional, national and local (eg river basin) assessments where available. The latter are accessible through EDO	No currently existing NDM assessments (NDM assessments do not go into the continental assessment)
International data exchange	Station data exchange for creation of regional or continental standardized indicators	Station data from Global Telecommunication System (GTS) and other sources, forecasting data from ECMWF. Common drought indices for multi-scale asssessment, mutual exchange of knowledge. Local indicators accessible through EDO	Station data from GTS and CLIMAT transmissions are used for real-time data; historical data are from GHCN and similar complications
International collaboration	National experts collaborate to create regional or continental DM	Continental monitoring coordinated by EDO (JRC). National expert network to support development	Nations on the continent request experts from outside to create regional or continental DMs that are run in-house
IT infrastructure	ArcGIS, web, e-mail	Web, interoperable OWS map servers, ArcGIS, Oracle DB	Web, GIS GoogleMaps, e-mail

Source: NOAA

Extreme precipitation event: the Weather Public Alert System of the Chilean Weather Service

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Extreme weather events (EWEs) such as hurricanes, floods, heat waves and droughts have the potential to cause death and destruction that can reach catastrophic scales. Weather-related economic losses have significantly increased during the last 50 years or so, especially since the 1990s. This corresponds with the increase in extreme weather events, which is believed to be caused by the increased concentration of greenhouse gases. However, city growth, human modification of the topography and the use of potentially dangerous areas are among the factors that have contributed to increasing the number of disasters related to hazards.

An EWE, by its nature, is infrequent or rare and, therefore, lies outside of what is considered to be the normal range of weather intensity that characterizes a particular area. From the climate viewpoint, EWEs are within the tails of normal distribution, for example, those events whose intensity occurs only ten per cent or less of the time. Besides their rare occurrence, EWEs are part of the natural variability of the Earth's system. On the other hand, an EWE is not necessarily extreme in the meteorological sense, although it may trigger an extreme scenario (weather-related disaster) for areas

Image: La Tercera, junio 2002

Erosion caused by increased river flow

Image: La Prensa Latina, ONEMI, Newsport.cl

Flooding in urban areas

with special sensitivity. For example, a precipitation event whose amount is within the local normal range, but which occurs on a saturated terrain, can lead to a flooding event. Also, a combination of weather variables, such as precipitation and temperature, may trigger a weather-related disaster, although one or both variables by themselves are within their normal range. For example, precipitation on mountains areas with warm air temperature (isotherm 0 ° C far above its average altitude) can lead to alluviums and floods. Weather-related disasters might vary from place to place and even from time to time, not necessarily due to changes in the frequency and/or magnitude of the events (or the threshold value), but due to changes in other factors such as land use and topographic alteration by human activities.

The Weather related Public Alert System

The Dirección Meteorológica de Chile (DMC) is the national governmental agency responsible for providing weather services to the country. Among others, an important and permanent role is to preserve life and property from the changing atmospheric environment, particularly from weather systems that can develop to become a EWE, and therefore a threat to the national territory. When unusual meteorological conditions might lead to high-impact weather phenomena, the Weather Public Alarm System is activated by DMC, together with special reports and forecasts as required by the potential damage in view. The alert system includes:

- Weather advices — forecasts used in situations when the population is not affected, but should be aware of the occurrence of a certain event that could lead to situations that may threaten life and/or property
- 'Watch' and 'warning' — more urgent alerts for events that can affect people and produce moderate damage to public and private infrastructure, therefore necessary action should be adopted to mitigate their effects.

More specifically, 'watch' is used when the risk of a hazardous weather event has increased significantly, but its occurrence, location, and/or timing is still uncertain. However, the watch is issued to provide enough lead time for decision-makers to take some actions. 'Warning' is issued when a hazardous weather event is occurring, is imminent, or has a very high probability of occurring. A warning is used for conditions posing a threat to life or property. Based on the characteristics of alerts, they are released first of all to organizations in charge of civil protection and concurrently to all government organizations, mass media and the population in general.

In the case of Chile, these special forecasts are delivered to the National Emergency Office (ONEMI) of the Ministry of Internal Affairs and Public Security, which is responsible for adopting actions to prevent and mitigate possible threats to people and property. In particular, several agreements have been made between the DMC and ONEMI aimed at having precise procedures whether for the preparation of forecasts, advices, alerts and alarms; or for their dissemination. For that reason a Common Alerting Protocol has been established in 2012, which regulates these activities by means of detailed guidelines to personnel working in the different regional meteorological centres along the country for the preparation, validation and delivering of these forecasts.

Case study: an extreme event

The central and southern regions are permanently affected by passing weather systems that can originate weather-related disasters. The normal duration of the events exceeds two consecutive days with a recurrence of 7-10 days. Analysis of the 24-hour accumulated precipitation, when it has exceeded the 0.66 percentile (above normal event) at Santiago during the last 100 years, reveals a recurrence of about every two years. If we consider only those events that fall in the 0.9 percentile (extreme event) the recurrence is around 12 years. On 3 June 2002, a 24-hour accumulation of 111.1 mm and 95.5 mm were recorded at Santiago and Valparaiso respectively. These are 3.8 and 2.2 larger than the respective mean values. The event lasted three days (3-5 June) with a total precipitation accumulation of 215.9 mm in Santiago and 163.6 mm in Valparaíso, equivalent to 69 per cent and 44 per cent of the total annual accumulation respectively. The magnitude and intensity of the event can be considered as an EWE. The numerical weather forecasts for these days were able to predict the event at least three days in advance, and therefore to alert ONEMI.

The sequence of the storm event and actions taken were:

Day 1, Thursday 30 May — DMC concluded that an important precipitation event would occur in central Chile during 3 and 4 June. A watch was sent to ONEMI.

Day 2, Friday 31 May — DMC confirmed its prediction. A warning was issued to ONEMI, which informed the Minister of Internal Affairs about the imminent hazardous weather event. The National Committee for Emergency (NCE) was called to meet the next day.

Day 3, Saturday 1 June — The NCE met at the National Governmental Palace. The director of DMC informed the authorities about the extreme precipitation event that would affect the central part of Chile. First actions to face the event were taken by the Minister of Internal Affairs.

Day 4, Sunday 2 June — Precipitation began late in the afternoon. With updated information, DMC forecasted that the event could be worst than was first thought. A new warning was issued to ONEMI and the general public.

Day 5, Monday 3 June — At 12.00 Coordinated Universal Time (UTC) Santiago measured 56.2 mm in 12 hours. This is almost 72 per cent of the normal precipitation for June. First consequences of the storm were seen on the TV in the morning news. DMC continued to issue a warning to say the precipitation was expected to continue for two more days. The President called and presided over the second and third NCE meeting, which took place on this day.

Day 6, Tuesday 4 June — At 12.00 UTC Santiago measured 111.1 mm during the past 24 hours, the highest amount ever measured by this station. The NCE met twice again on this day to evaluate the current situation and the possible future scenario.

Day 7, Wednesday 5 June — Precipitation had decreased in intensity; at 12.00 UTC a total of 44.5 mm was measured for the past 24 hours. With updated information, DMC forecasted that the event would end sometime in the afternoon on this day, as it did. The NCE met twice on this day.

Day 8, Thursday 6 June — At 12.00 UTC Santiago measured only 4 mm for the past 24 hours. The event accumulated a total of 215.8 mm; about 70 per cent of the normal annual precipitation. The weather advices ended. The NCE met for the last time, as the emergency had passed. The President thanked all participants especially DMC through its Director.

Consequences

Damage to public and private goods totalled millions of dollars. The cost in public infrastructure was US$650 million. The building sector lost about US$10 million due to absenteeism and temporary stops. Around 25,000 houses were damaged and 272 destroyed, at a cost of US$29 million. Workforce absenteeism of 30 per cent on the first day and 50 on the second day carried an implied cost of U$176 million and 264 million, or 0.2 per cent and 0.4 per cent of gross domestic product respectively. Early closure of stores and malls implied an 80 per cent drop in sales. The cost related to the population was around U$2.2 million. Finally, seven people died due to the EWE.

Providing an accessible service

Even though EWE's are inevitable, early detection and forecasting can trigger actions that, in part, avoid and mitigate negative impacts for people and their property. DMC plays an essential role as it is responsible for alerting people when a weather-related disaster may occur. In this context, DMC is first in the chain of decision makers helping to prevent disasters in the community. The Common Alerting Protocol between DMC and ONEMI aims to establish a two-way communication in order to adequately inform the authorities and public. This enables them to take actions that will prevent and mitigate the threats of an extreme weather event or any weather system that can be threat. The event described here indicates that, because a warming was issued by DMC, the governmental authorities took administrative decisions that allowed them to better face the consequences associated with the event. The EWE was possible to forecast because of the availability of numerical weather prediction accessible through internet. In this regard, access to numerical forecast products is important for developing countries and countries with economies in transition. Finally, visibility of the weather service is important as the official source of weather related alerts; this enables confusion to be avoided and provides accurate information to authorities, private and public organizations and the general public.

Consequences associated with the EWE of 3-5 June 2002

Region	Affected people	People in shelters	Houses with minor damage	Houses with major damage	Houses destroyed
IV	727	57	220	51	0
V	24,441	1,793	9,294	1,795	242
VI	24,613	108	1,733	164	5
VII	1,962	16	226	11	0
VIII	820	0	185	0	0
IX	8	8	1	0	0
Metropolitan	133,156	4,278	9,965	1,306	25
Total	185,727	6,260	21,624	3,327	272

Source: DMC

Governing drought information systems

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National Integrated Drought Information System (NIDIS),
National Oceanic and Atmospheric Administration (NOAA),
United States National Integrated Drought Information System

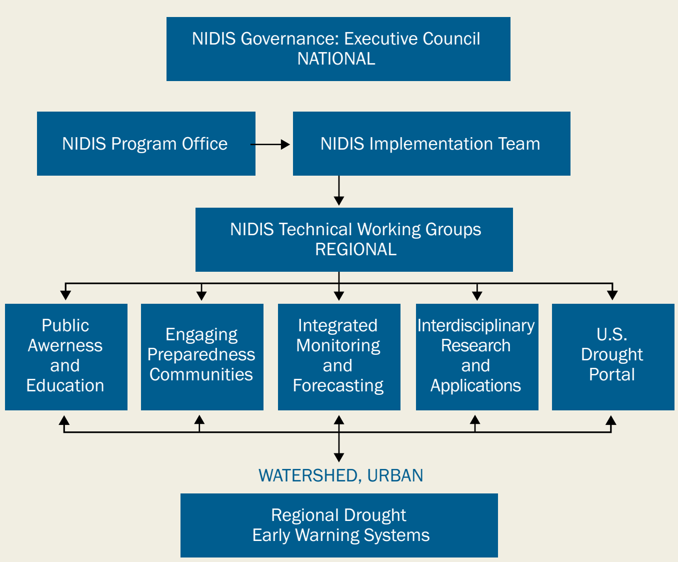
The National Integrated Drought Information System Act of 2006 (NIDIS Act) builds on longstanding efforts among agencies and institutions that had historically been focused on drought risk assessment and response. The NIDIS Act prescribes an inter-agency approach, led by the National Oceanic and Atmospheric Administration (NOAA), to "enable the nation to move from a reactive to a more proactive approach to managing drought risks and impacts".

NIDIS is authorized to provide an effective drought early warning system and to coordinate federal research in support of the system. The intention is to improve public awareness of drought and its attendant impacts and improve the capacity of counties and watershed organizations to reduce drought risks proactively.

At the national level, the multi-agency NIDIS Executive Council oversees the NIDIS Program Office. The NIDIS Program coordinates the multi-agency and multi-state NIDIS Program Implementation Team (NPIT). The NPIT is currently composed of representatives from federal, NOAA state and Native American tribal agencies, as well as academic and private entities. The group is chaired by the director of the NIDIS Program. An advisory Executive Council also acts as the interagency recipient of feedback from the Program Office on drought-related monitoring and research priorities and gaps.

NIDIS supports or conducts impacts assessments, forecast improvements, indicators and management triggers and the development of watershed scale information portals (web-based). In partnership with other agencies, tribes and states, the NIDIS teams coordinate and develop capacity to prototype and then implement Regional Drought Early Warning Systems (RDEWS) using the information portals and other sources of local drought knowledge.

NIDIS organization



Source: NIDIS

The role of Regional Drought Early Warning Systems prototypes

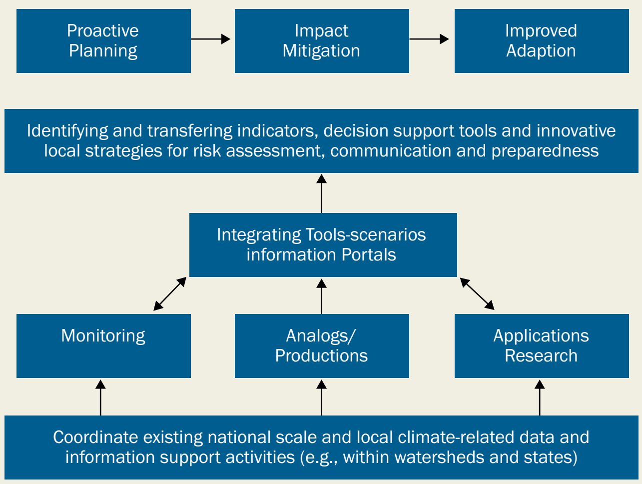
The functions of the NIDIS RDEWS prototypes are to derive and illustrate the benefits of:

- Improved knowledge management
- Better use of existing and new information products
- Coordination and capacity development for using early warning systems.

The locations for RDEWS prototypes and implementations are based on an assessment of drought sensitivity and criticality (including publicly identified information needs), drought type (snowpack or rainfall driven, short-term, multi-year), and administrative unit (such as watershed, city or county). The 'prototype' framing allows for existing barriers to cross-agency collaboration to be addressed, innovations and new information to be introduced and tested, and the benefits of participation in design, implementation and maintenance to be clarified. A mature and evaluated pilot becomes the implemented regional system and its lessons become more likely to be successfully transferred within or to other as yet underserved regions. NIDIS also conducts knowledge assessments to:

- Determine where major gaps in data, forecasts, communication and information delivery exist
- Identify innovations in drought risk assessment and management at state and local levels
- Engage constituents in improving the effectiveness of NIDIS.

NIDIS Regional information managment model



Source: NIDIS

NIDIS recently conducted the first ever assessment of the status of drought early warning systems across the United States. There is thus significant leveraging of existing system infrastructure, data and products produced by operational agencies. Examples include the Natural Resources Conservation Service snow-depth network, reservoir levels from federal agencies such as the Department of the Interior and the United States Army Corps of Engineers. NIDIS also reports on advances in hazards research and the development of early warning systems, as well as on new technologies and techniques that can improve the effectiveness of existing DEWS implementations.

NIDIS is increasingly acknowledged by Western Governors University and others as providing a natural prototype for achieving effective climate services, engaging both leadership and the public and establishing an authoritative basis for integrating monitoring and research to support risk management. As the first such prototype, the Colorado Basin EWS is used to illustrate the variety of scales on which NIDIS Early Warning Systems prototyping functions.

The Colorado River Basin Early Warning System

The Colorado River supplies much of the water needs of seven US states, two Mexican states and 34 Native American tribes, over an area covering almost 637,000 square kilometres. These communities constitute a population of 25 million inhabitants at present with a projection of 38 million by 2020. While the basin has experienced significant droughts, the period from 2000-2004 was the driest five-year interval on record, surpassing even the famous Dust Bowl years of the 1930s. After the critical year of 2002, during which streamflow was reduced to 25 per cent of average, it became clear to the states and the Federal Entities that an improved process was needed to integrate federal, state and local risk assessment and early warning needs for drought impact mitigation. The influence that warmer temperatures could have were seen in the winter of 2005-2006, when, with a snowpack of 100 per cent of normal, the combination of low antecedent soil moisture and the occurrence of the warmest January-July period on record (driving snow sublimation and evaporation) resulted in a flow 25 per cent below average. This occurred as the Southwestern US was experiencing very rapid urban growth and sprawl. Major Southwest cities have averaged over 25 per cent growth in the past ten years with attendant social, economic and environmental demands on water resources.

NIDIS convened a series of stakeholder workshops at different administrative units with water managers and resource specialists from federal, state, municipal, tribal and other governments of Utah, Wyoming and Colorado to identify information gaps and initiate the development of decision support tools and processes. Three critical problems were identified as NIDIS priorities:

- Coordinated reservoir operations: low flow shortage triggering criteria on Lakes Powell and Mead, the two largest man-made lakes in the US
- Inter- and intra-basin transfers (to the burgeoning Front Range)
- Ecosystem health and services.

Within this problem setting, three major efforts are underway:

- Identification of federal and state-level partnerships, decision support tools and actions needed (to improve information development, coordination and flow for risk reduction)
- Assessment and consolidation of drought indicators and triggers used in the Upper Basin
- Implementation of an Upper Colorado Basin Drought EWS.

Partners and end users of NIDIS information in this basin include: the Department of the Interior (Reclamation, United States Geological Survey, Fish and Wildlife Service), United States Department of Agriculture (Forest Service, Natural Resources Conservation Service), Native American tribes (Four Corners region), resource management personnel and state climatologists from the Basin States,[1] State of Colorado Conservancy District and Front Range Urban Community (Denver and Aurora Water), Colorado Climate Center, Western Regional Climate Center, and National Drought Mitigation Center.

NIDIS products and services in the Colorado Basin to date include development of new watershed-based drought indicators and triggers used in the Upper Basin; improved linkages between climate and streamflow modelling during drought; and a low flow impacts database for 164 National Weather Service forecast points. The Upper Colorado River Basin (UCRB) Community Colorado Basin-specific Drought Portal and the Weekly Drought and Water Outlook webinars and early warning discussions with resource managers are further examples.

The Colorado Basin Early Warning information now feeds into and informs the national level Drought Monitor that is regularly updated by NOAA and the US Department of Agriculture and the University of Nebraska's National Drought Mitigation Centre.

The Colorado Basin Early Warning information now informs the national level Drought Monitor that is regularly updated by NOAA

While the Colorado has been called the most managed system in the world, large areas of the basin are outside the reach of the mainstem water supply. The Navajo Nation is in an ecologically sensitive semi-arid to arid section of the southern Colorado Plateau that straddles the upper and lower Colorado Basin. It is the largest reservation in the United States. In this remote region, located at the corners of four states (Arizona, New Mexico, Colorado and Utah), traditional people live a subsistence lifestyle that is inextricably tied to, and dependent upon, landscape conditions and water supplies. Soft bedrock lithologies and sand dunes dominate the region, making it highly sensitive to fluctuations in precipitation intensity, percent vegetation cover, and local land-use practices.

Many residents, especially the elderly, rely on raising livestock as a significant part of their livelihood or as a supplement to food supplies.[2] Over half of the reservation population lives in housing without indoor plumbing or electricity.[3] Before the reservation demarcation (1868-1887) and grazing allotments, families in normal years moved their livestock around core customary grazing areas shared by networks of interrelated extended families, while during droughts they used other kinship ties to gain access to more distant places where conditions were better. This situation is becoming increasingly difficult for the more traditional elderly who tend to be the poorest of the Navajo people.

Currently, the Navajo Nation is hoping to recover from drought in the Four Corners Region that lasted officially from 1999-2009 (Fig 4).

These conditions, combined with increasing temperatures, are significantly altering the habitability of a region already characterized by harsh living conditions. More than 30 major surface water features on the reservation have disappeared. Dune deposits cover over one third of Navajo lands, but drought conditions are producing significant changes in dune mobility.[4] Sand and dust movement in the region is closely linked to regional aridity, ephemeral flood events in riparian corridors, and regional wind circulation patterns. Climatic factors controlling dune mobility include the ratio of precipitation to potential evapotranspiration (P/PE), because of its direct link to the amount of stabilizing vegetation.[5]

NIDIS is working to define monitoring needs, identify sub-regions at greatest risk of degradation and develop scenarios of future ecological conditions in the Four Corners region as part of the Colorado River Basin early warning system. The problem was brought to international attention by NIDIS as a featured case in the United Nations Office for Disaster Risk Reduction (UNISDR) Global Assessment Report on Disaster Risk Reduction 2011.[6] Work commenced

Image: Jolene Tallsalt Robertson, Navajo Nation Dept. of Water Resources

Image: Jolene Tallsalt Robertson, Navajo Nation Dept. of Water Resources

Stream flow in Wheatfields Creek, upstream of Wheatfields Lake, in April 2006 (left) and April 2005 (right)

to enhance tribal drought monitoring capabilities by developing additional weather monitoring stations, along with a more detailed historical climatology for determining appropriate drought triggers. The governance approach undertaken by NIDIS focuses on building longer-term collaborative partnerships and is also responsible for maintaining the structure for supporting ongoing indicators development and public engagement. NIDIS engages water resources and community level groups in:

- Setting goals and priorities, and involving partners in problem definitions
- Using professionals from relevant agencies to build and secure a common basis for action
- Producing collectively authored knowledge and information gaps assessments and agreement on the way forward
- Integrating different types of knowledge in EWS, particularly in terms of linking scientific and local knowledge
- Revisiting major or landmark drought events to show the benefits of new information and coordination processes.

Thus the DEWS in this organizational model involves more than simply disseminating a forecast. In each prototype location, the design is polycentric. It allows for major innovations from the research community, such as new information, technologies and applications for detecting and communicating risks and warnings, to be prototyped and introduced.

The centralized component of NIDIS (Program Office and Implementation Team) has oversight and fiscal responsibility, and provides political authority and policy coherence across sectors. As noted in several contexts, emergency management organizations can rarely play that role.[7] The decentralized components of problem definition, capacity-building and information resources are based on the location of prototype EWS development, taking advantage of local practices and innovations. This is key to cost-effectiveness and sustainability, at each level of governance.[8] While the local social process is critical and shows important practical pathways for action, these are rarely sustained over the long term. There are a growing number of positive examples of such partnerships that cross spatial scales. For other locations or countries, the NIDIS approach might likely entail a change in the culture of public administration. NIDIS is creating similar RDEWSs in others watersheds, including the US Southeast and the State of California. The lessons and tools from these systems are being transferred to other states and regions, including the Columbia Basin, the lower Great Plains and the Chesapeake Bay tributaries, to create a fully 'national' drought early warning presence.

Climate services and disaster risk reduction in the Caribbean

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Long term climate change and increasing climate variability globally are presenting unprecedented challenges to societies worldwide. These new challenges threaten the sustainable development of all nations, but more so, the development of developing and least developed countries by reversing gains made towards achieving the Millennium Development Goals. It is generally accepted that sustaining development in all countries will require a focused effort to integrate the best climate information available into national, regional and global activities.

The Global Framework for Climate Services (GFCS) is one of the several lasting legacies of the 3rd World Climate Conference (WCC-3) held in 2009 and represents a paradigm shift in the way climate information is developed, distributed and integrated into planning activities. The Framework aims to be transformational as it is expected to transform the operations of National Meteorological and Hydrological Services and affiliated institutions by strengthening their ability to generate and distribute targeted climate products and services through greater interaction with users of such information.

The factors driving the development of the GFCS are well documented in this publicaton. The GFCS conceptualization outlined the following prerequisites for the delivery of effective climate services[1]: (i) the services must be provided at time and space scales that the user needs, (ii) services must be delivered regularly and on time, (iii) products and services must be readily usable by the user community, (iv) products and services must be credible and authentic so that user community will embrace them in decision making processes, (v) services should be responsive and flexible to accommodate changing needs and (vi) the development of products and services must be sustainable. Meeting these prerequisites and sustaining such efforts requires a range of commitments including foremost long term financial, policy and political commitments as well as the establishment of new and innovative interactions between various actors and new models for doing business.

The GFCS offers many new opportunities for local, national, regional and global communities with many of these opportunities being focused in the least developed countries and developing countries whose socioeconomic development are strongly influenced by weather and climatic factors. A significant challenge will be the ability of many countries and regions to adapt and integrate many of the opportunities that will be made available through the GFCS into their national activities.

The Caribbean region is expected to derive significant benefits from the implementation of the GFCS as all countries fall within the categories of developing countries and least developing countries with climate sensitive economies. The region is recognized as being extremely prone to natural disasters. The World Bank estimates that from 1979-2008, aggregate economic losses due to storms were estimated at US$16.6 billion, or US$613 million annually.

The relationship between climate services and disaster risk reduction in the English-speaking Caribbean is critical and strengthening this relationship by implementing and sustaining actions consistent with the GFCS is essential for the long term socioeconomic development of the English-speaking Caribbean. Recognizing this relationship, the Caribbean Institute for Meteorology & Hydrology (CIMH) works with partners to develop suites of climate products and services to support disaster risk reduction.

The English-speaking Caribbean

The English-speaking Caribbean consists of Belize, Trinidad and Tobago, Grenada, St. Vincent and the Grenadines, Barbados, Saint Lucia, Dominica, Antigua and Barbuda, St. Kitts and Nevis, Anguilla, the Virgin Islands, Montserrat, Turks and Caicos Islands, Jamaica, the Cayman Islands and the Bahamas. Guyana is often consider part of the English-speaking Caribbean, because of its shared history of colonization and post colonization development.

Most countries of the English-speaking Caribbean are small islands developing states with the majority having achieved their political independence from the UK within the last 50 years. All countries are either full Members or Associate Members of the Caribbean Community (www.caricom.org). Political independence has meant that countries are responsible for financing their socio-economic development. Difficult choices are made annually with regards to the allocation of budgetary resources to various activities based on identified national priorities. Although disaster risk reduction is often cited by national governments in the English-speaking Caribbean as important, those local and regional institutions that support disaster risk reduction associated with climate and weather hazards are often under-funded. Such institutions are expected to derive benefits from the GFCS in the areas of training and equipment procurement among others. However, acquiring the level of human resources essential to transform these institutions to sustain the delivery of the products and services required to support the GFCS is expected to be a challenge if appropriate levels of

Image: CIMH

Miracle Lake Dominica: (top) 2008 prior to the dam failure and (bottom) August 2011 following the dam failure

support from governments is not forth coming. As a result, innovative approaches to sharing and utilizing the scarce human resources in the region are essential.

Many English-speaking countries in the Caribbean have significant coastal infrastructure that is prone to flooding and storm surge. Flash flooding is common in coastal areas due to the steep topography of most islands. Climate dependent industries, rain-fed agriculture, tourism and related industries are the primary foreign exchange earners and sources of employment in most English-speaking Caribbean. The economies of the English-speaking Caribbean are tightly integrated through trade and common financial institutions and businesses. As a result, economic shocks in one country can have knock-on effects in other countries.

Population growth is still occurring on many islands leading to increasing population densities at the national level. Within countries, there is increasing rural to urban migration leading to increasing demands for housing, water and sanitation services among others in urban areas. This has resulted in increasing demand for land and has driven the settlement on marginal lands including landslide prone slopes and floodplains. Addressing the needs of growing national populations well into the future will require among other things stable economic growth with few economic shocks such as those caused by natural disasters.

Recent examples of weather and climate impacts in the Caribbean

Losses associated with climate related disasters in the English-speaking Caribbean can be extremely high and in extreme cases exceed the national Gross Domestic Product (GDP). For example, Hurricane Ivan in 2004 resulted in estimated financial losses on Grenada of approximately 200 per cent of national GDP. A significant amount of this damage was due to high winds causing damage to the housing stock, agriculture and infrastructure. The passage of Hurricane Tomas over Saint Lucia in October 2010 caused financial losses of approximately US$600 million (approximately two-thirds of the national GDP). Much of the estimated losses were due to the extreme nature of the rainfall associated with the system, with recorded rainfalls at some locations in excess of 24 inches over a 24-hour period. CIMH estimated the return period for this rainfall event to be greater than 180 years at some stations. The extreme nature of the rainfall was not captured in forecasts prior to the event and, as a result, the inherent risks to the population and the infrastructure were not fully assessed. The event caused significant impacts to the John Compton Reservoir and associated distribution network which accounts for approximately 70 per cent of the water consumed on the island. The event exposed significant risks inherent in the water distribution system on the island.

While tropical storms inflict significant losses on communities in the English-speaking Caribbean, highly localized systems have caused significant damage on some islands. On 12 April 2011, a poorly-forecast localized rainfall event produced in excess of 200mm of rainfall (with a peak 1-hour rainfall of 100mm) over the mountainous terrain of northeast St. Vincent. The flash flooding and landslides caused by the event inflicted significant damage to the road and water networks and the marine environment. The damage caused by this event was approximately US$10 million. This coming on the heels of the significant financial losses (approximately US$90 million) inflicted on the island by Tropical Storm Tomas six months earlier. Similar events have also been experienced in other islands in the English-speaking Caribbean.

In the late 1990s, a series of large landslides in western Dominica dammed the Matthieu River to produce 'Miracle Lake'. The formed lake and dam were periodically, but not continuously, monitored. Early in the morning of 28 August 2011, following several months of above average rainfall over the island, the dam underwent catastrophic failure releasing all of the stored water and resulting in massive sediment and debris flows in the downstream Layou River. This resulted in significant impacts to businesses and residents downstream in the Layou Valley and raised several health concerns. The potential impacts of the prevailing climatic conditions on the water levels in the lake and the resulting instability of the dam were not assessed prior to the failure and, as a result, no remote monitoring of water levels in Miracle Lake were implemented. Hence, no early warning system was in place to warn residents in the event of the dam failing. Following the recommendations contained in a post-assessment report of the event performed by CIMH, the Government of Dominica is in the process of establishing a monitoring and early warning system for the watershed.

Following the severe drought of experienced in the Caribbean from the second half of 2009 through the first half of 2010, the Caribbean Disaster Emergency Management Agency (CDEMA) formally recognized drought as one of its supported natural disasters. The drought caused increased food prices in the English-speaking Caribbean. The onset of the drought was not forecast due in part to (i) the lack of operational regional and national drought forecasting tools and (ii) limited regional and national climate data sharing. Prior to the onset of the drought, no formal regional drought forecasting tools were being routinely applied across the region. The Caribbean Precipitation Outlook, which is available to the public on the CIMH website (www.cimh.edu.bb/?p=precipoutlook), provides some guidance on the likelihood of above, below and normal rainfall which, if used properly, gives some indication of possible drought conditions over the coming three month period. In response to the evolving drought conditions and the need for information to support national responses, the CIMH operationalized its Caribbean Drought and Precipitation Monitoring Network (CDPMN) that was in development well ahead of its scheduled operational date. The tool proved to be extremely useful at forecasting the intensity and duration of the event. The tool continues to be used routinely to assess the state of rainfall across the region and therefore informs on both drought and locations of likely excess rainfall that could indicate an increased likelihood of flooding across the region. Both tools, along with other tools, are being used to inform the recently re-established Caribbean Climate Outlook Forum which brings together the region's climate scientists and international experts (including NOAA) to produce seasonal climate forecasts which are then tailored for specific economic sectors in the region including disaster risk reduction.

Integration of national and regional resources to develop new robust early warning decision support tools

Although the English-speaking Caribbean has limited resources to tackle many of its climate risks, the increasing use of technology in the region coupled with increasing donor support has led to new innovative approaches to addressing disaster risk reduction at the local national and regional levels. The CIMH is involved in several of these new initiatives including among others: (i) the Enhancing Resilience to Reduce Vulnerability in the Caribbean funded by the Government of Italy and executed by the United Nations Development Programme Office for Barbados and the Organization of Eastern Caribbean States and (ii) the Japan International Cooperation Agency Caribbean Disaster Management Project Phase 2.

Component 1 of the ERC project adapts the Italian Civil Protection web-based Dewetra Platform to the Caribbean approach to disaster risk reduction by establishing a network of real-time decision support centres to inform early warning and post disaster recovery related to hydro-meteorological events. The platform integrates

Image: CIMH

Rainfall triggered landslides on Saint Lucia following the passage of Hurricane Tomas (October 2010)

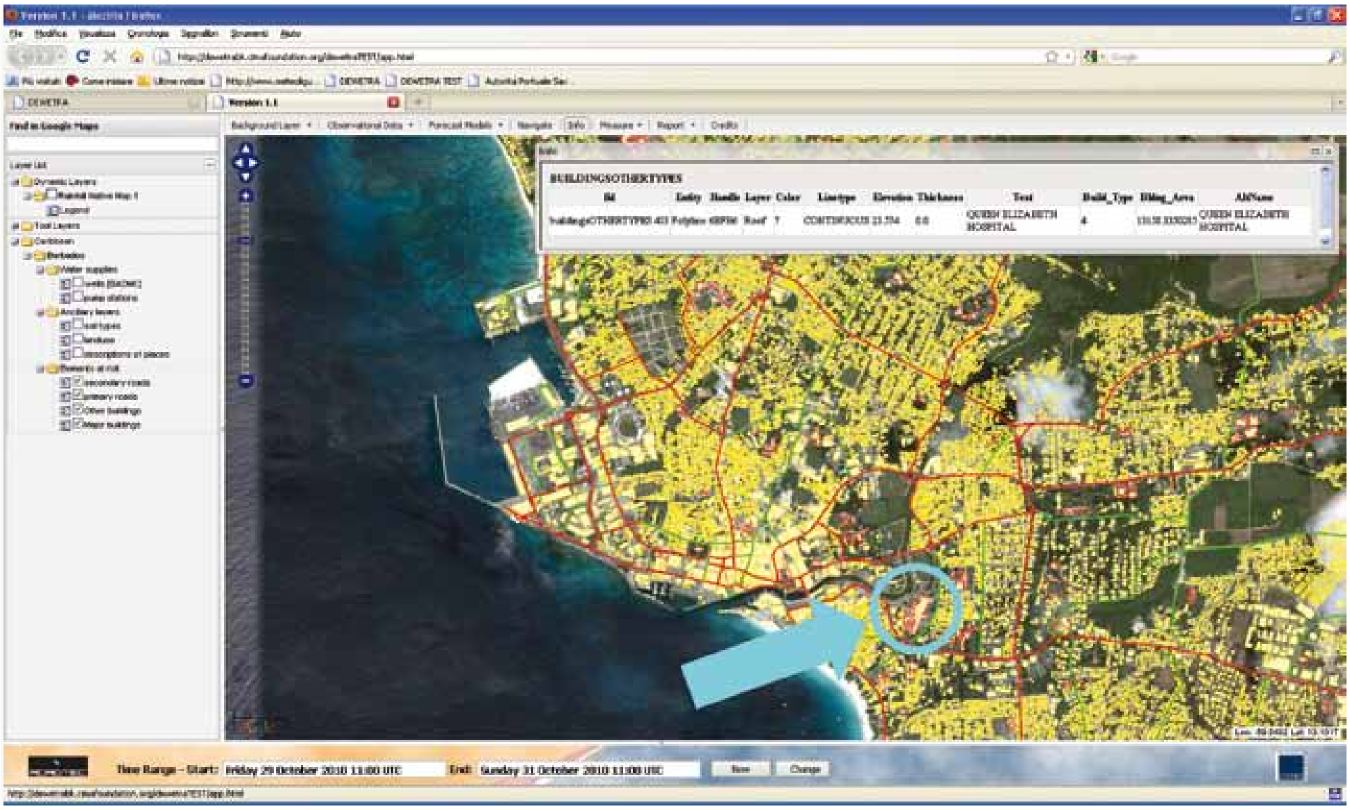


Image: CIMH

Elements of exposure on Barbados as visualized through the Dewetra platform

weather, climate, physical environment and socioeconomic data to provide critical information on hazard, vulnerability, exposure and risk to decision makers. The platform address several aspects of the GFCS: (i) it provides an online environment in which producers of weather and climate information can interact in real time with users of the information and (ii) because the platform contains information which scales from regional to local as well as across multiple timescales it readily supports the delivery of a range scalable products and services. Because of its online nature, the platform has provided an effective and efficient approach for the sharing of human resources to support decision-making between countries and institutions. For example, during the 2011 and 2012 Atlantic Hurricane Seasons, the platform was used to support online discussions or possible impact scenarios between National Disaster Management Offices, National Meteorological and Hydrological Services, CIMH, the CIMA Foundation in Italy and the Caribbean Disaster Emergency Management Agency among others. The project has also provided extensive training for participants in areas such as GIS and remote sensing. The project is also in the process of developing cheap low cost rain gauge loggers with the software and hardware schematics being made publicly available.

An important requirement of the GFCS is the ingestion of global data by regional centres to produce products and services for national services and entities. The GFCS also requires that regional centres acquire data from national entities and make it available to global product producing and archiving centres. Component 1 of the ERC project supports this objective in that 14 automatic weather stations were installed in the ten participating eastern Caribbean states. While all of these stations have not been installed at this time, those that are transmit weather and hydro-meteorological data in near real time to the platform as part of the sub-regional early warning monitoring programme. Plans are underway to archive this data into the recently upgraded climate database at CIMH prior to making it available to national, regional and international users. In this way, the project is filling important national and regional climate data gaps.

From 2008 to 2012, JICA implemented the CADM Phase 2 project in Belize, Saint Lucia, Grenada, Guyana and Dominica. The project included (i) the establishment of early warning real-time monitoring networks consisting of rainfall measurement stations and stream level gauges in critical watershed on participating countries and (ii) the development of flood hazard maps for selected watersheds in participating countries. The early warning network was established with message passing occurring via either cellular networks or other wireless methods. As part of the sustainable plan for the project, real-time data from the observing network along with flood hazards maps are being integrated into the Dewetra platform. The data collected will be made available to the global production and archiving centres.

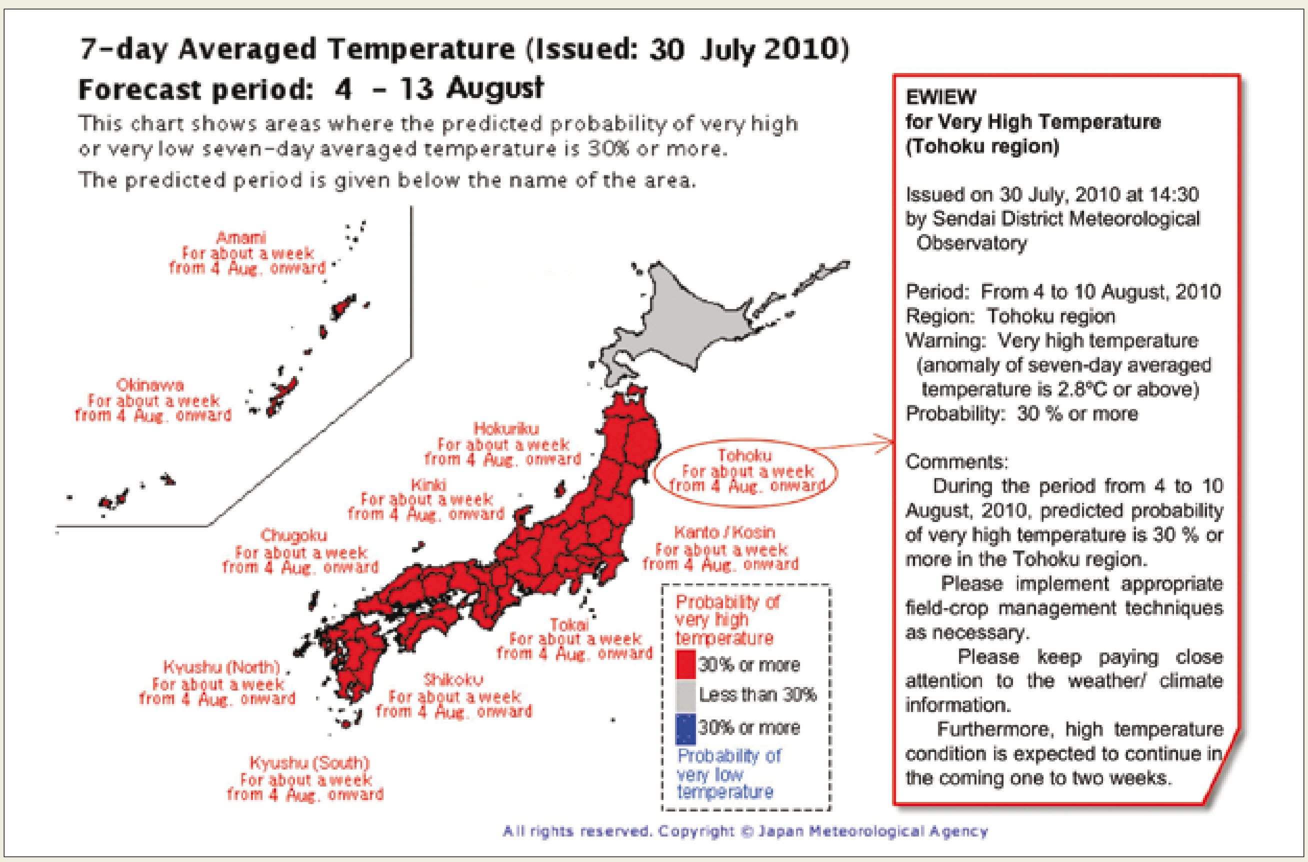
The GFCS represents an important achievement of the WMO and its global partners that has the ability to transform the generation and application of climate services to reduce losses from weather and climate disasters in the Caribbean. Recognizing the full benefits will require a concerted effort by the range of stakeholders in the region to integrate resources to develop common platforms that support the sharing of data, information and human resources in near real time. Efforts are underway to demonstrate the value of such an approach, however, it is recognized that while this transformation will be slow, it is essential.

Early warning information on extreme events

Yoshiji Yokote, Director, Climate Prediction Division, Global Environment and Marine Department, Japan Meteorological Agency

As recognized by the High-Level Taskforce on the Global Framework for Climate Services (GFCS), people around the world are affected by climatic conditions. This is particularly the case with extreme weather and climate events, which represent fundamental risks to climate-sensitive sectors. In this regard, early warning of extreme events, including periods of very high or very low temperatures, should be positioned as an important element in climate risk management. In Japan, there is demand for such information with a higher level of user-friendliness in the agricultural sector to complement the development of effective measures against extreme temperatures. Other sectors, including those of health and energy, also require such information due to the high risk of heatstroke and possible power shortages caused by the increased use of air conditioners in hot summer conditions.

The Japan Meteorological Agency (JMA) has a long history of providing climate information, including climate monitoring, seasonal forecasts, El Niño moni-



An EWIEW map issued on 30 July 2010. EWIEW is in effect in the red and blue areas (with a 30 per cent or more probability of very high or low seven-day mean temperatures respectively). The box on the right shows text information issued for the Tohoku region (originally in Japanese)

Source: JMA

toring and outlooks, and climate change projections. Until recently, however, no climate information was supplied to specifically urge the implementation of appropriate measures against high temperatures and other extreme events. Based on the increased skill of seasonal forecasts and the above-mentioned social demand, JMA therefore commenced the operational provision of Early Warning Information on Extreme Weather (EWIEW) in March 2008 with the aim of contributing to meteorological risk management in climate-sensitive sectors. EWIEW is a probabilistic forecast highlighting the possibility of extreme events (such as very high or low temperatures) from one to two weeks ahead, and is issued to 11 regions in Japan.

EWIEW is provided in a number of ways. JMA makes the information widely available on its website[1] in map, table and text format indicating current nationwide issuance, and its local offices issue EWIEW in text form within their areas of responsibility. In addition to information for use by the general public on the website, EWIEW is also sent directly to national and local governmental organizations, media providers and private weather-related companies so that they can broadcast the warnings themselves and/or prepare and issue information tailored to users' needs. For example, local governments may send messages to farmers urging them to take measures against potential damage from high temperatures.

Scientific basis

JMA operates the Ensemble Prediction System (EPS) for one-month forecasts, using the Atmospheric Global Circulation Model, which provides one-month numerical prediction data on temperature and other conditions. EWIEW is based on predicted data for regional-scale seven-day mean temperatures (T7d) in individual regions for each day during periods of 5-14 days ahead. When a high probability (30 per cent or more) of a very high or very low regional-scale T7d anomaly is predicted for one or more regions of Japan, JMA issues EWIEW including:

- Estimates of predicted temperatures meeting the criteria for EWIEW issuance
- The relevant duration, region and a brief message on the possible social impacts of such high/low temperatures
- The predicted probability of the expected condition occurring
- Details of expected general weather conditions considered likely to induce extreme climate situations.

Criteria for announcing the probability of very high or low temperatures in EWIEW are calculated for each region using JMA's historical records of regionally averaged observed T7d values covering the 30-year period from 1981 to 2010. The criteria for very high and very low are the 90th and 10th percentiles

Probability of predicted seven-day mean temperature anomaly for five categories for 4-10 August 2010, issued on 30 July for the Tohoku region (originally in Japanese)

Very Low	Low	Normal	High	Very High
– -2.9 °C	-2.8 – -0.9 °C	-0.8 – +1.1 °C	+1.2 – +2.7 °C	+2.8 °C –
0%	3%	26%	41%	30%

Source: JMA

of these historical records, respectively. On Tuesdays and Fridays, JMA predicts whether temperatures will reach these criteria for each region and issues EWIEW accordingly. If an expected criterion is not met, the agency issues information to notify of a change in its outlook and reports on the progress of temperature conditions since the latest EWIEW.

JMA roughly estimated the skill of EWIEW based on 3,600 cases for all regions in Japan from March 2008 (when EWIEW was first issued) to January 2011. For the categories of very high and low temperatures, the hit ratios (that is, the number of occurrences of the predicted phenomenon against the number of EWIEW issuances) were 62 per cent and 57 per cent respectively. While there is certainly room for improvement in these rates, the information is well received and appreciated by various user sectors.

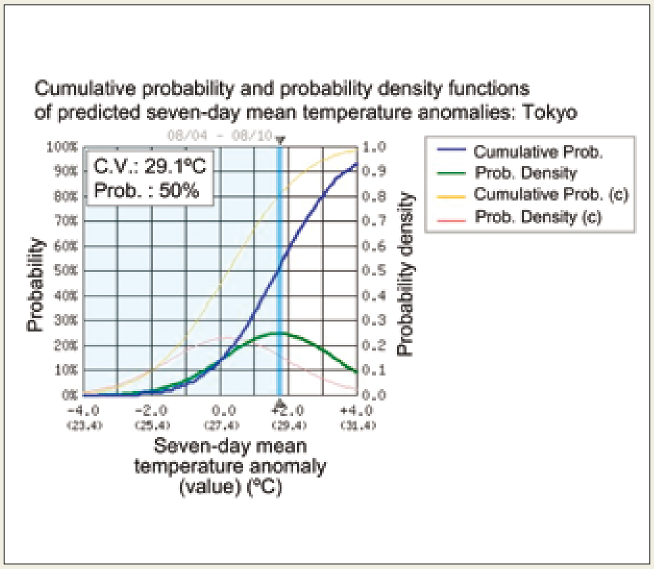
In addition to the four elements of EWIEW listed above, JMA also provides detailed probabilistic prediction products for individual regions through the same website independently of EWIEW issuance. These products show the scientific basis of EWIEW and provide users with information on probabilities within the range of their own threshold values. The products are:

- Daily tables of predicted T7d anomaly probabilities in five categories (very high, high, normal, low, and very low)
- Time sequences of these probabilities
- Cumulative probability functions (CPFs) and probability density functions (PDFs) of predicted T7d anomalies.

These data are provided not only for the 11 EWIEW regions but also for 152 stations where JMA performed observations from 1981 to 2010. The information is calculated using both numerical prediction data from EPS and regression coefficients estimated from hindcast experiments (re-forecasts) conducted using the same EPS for the 30-year period 1981-2010. The skill levels of these products were evaluated using hindcast experiment data and were found to be satisfactory in terms of probabilistic prediction metrics such as Brier skill scores. CPF and PDF graphs are considered to have high potential for possible future customized use of the scientific basics used to produce EWIEW. For example, JMA regularly provides the energy (electric power supply) sector with information on the most likely predicted T7d value together with more tailored information covering the period one week ahead, which can be estimated from its graph-form representation. Using this newly available data, operators in the sector can now estimate electric power demand for the coming two weeks more efficiently and reasonably.

Use of EWIEW

EWIEW is expected to be used in a variety of fields in addition to its current main user sectors of agriculture and health. In one notable case, the information



Cumulative probability function (CPF) and probability density function (PDF) of predicted T7d anomalies for 4-10 August 2010, issued on 30 July for Tokyo. The horizontal axis shows the T7d anomaly. The blue and green lines show the CPF and PDF for the prediction, while the yellow and pink lines show those for the occurrence of climatology values. Users can change the critical value (the light-blue line) on the website to see the cumulative probability applicable to the area shaded in light blue (originally in Japanese)

Source: JMA

led local agricultural organizations in Japan's northern Tohoku region to provide local farmers with guidance in relation to an extremely high-temperature event in April 2008. The Sendai District Meteorological Observatory responsible for the Tohoku region issued successive EWIEW on high local temperatures on 8, 11, 15, 22 and 25 April 2008, advising attention to farm product management. In response to the EWIEW issued on 8 April, the Aomori Prefectural Government in Tohoku issued special information for agricultural production on 11 April calling for frequent ventilation in greenhouses to avoid poor germination of rice crops, vegetables, flowers and ornamental plants due to soaring temperatures. The prefectural governments of Akita, Miyagi and Yamagata in Tohoku also called for similar measures against predicted high temperatures. Farmers use such special information to implement appropriate field-crop management techniques as necessary.

EWIEW is also efficiently used in the health sector. When very high temperatures are predicted and EWIEW is issued, relevant local governments inform the public of the increased potential risk of heatstroke as well as efficient countermeasures to be taken. As heatstroke can be prevented by appropriate behaviour, such caution is considered highly effective and important. Schoolteachers also use EWIEW to give appropriate guidance to pupils.

Future issues

In the last four years since JMA started providing EWIEW operationally, a number of governmental agricultural organizations in Japan have leveraged the information in their activities to provide farmers with agricultural technical guidance. JMA also promotes the use of EWIEW in other sectors, and operators in various fields are expected to use the probabilistic prediction products provided on the JMA website in their climate risk reduction activities. An example of this may be the use of the information in creating plans for sales of commodities, which are sensitive to climate conditions. CPFs and PDFs are expected to support next-generation forecasting that will advise users of the probability of temperatures moving above or below their self-set threshold values.

JMA is currently working to address four major challenges regarding EWIEW:

Dissemination of EWIEW and strengthening of related interpretive activities

EWIEW is not yet widely known in Japan. As many potential users may be able to make good use of such information in their decision-making activities, JMA is seeking and exploring further opportunities for dialogue with such users in order to interpret the characteristics and usage of EWIEW. The provision of briefings to broadcasting-organization meteorologists and members of the press is also important. Such activities are expected to support the dissemination of EWIEW in Japan.

Addition of more meteorological elements to EWIEW

To complement the temperature information already provided, JMA is currently considering the addition of other meteorological elements as targets of prediction. In terms of prediction skill and the impact of such information on society, JMA plans to add data on expected snowfall for the Sea of Japan side of the country in winter.

Improvement of prediction techniques

To support better prediction of extreme events with greater accuracy, there is a need to develop and improve prediction tools and techniques such as the numerical atmospheric model and ensemble prediction techniques, application methods including calibration of numerical prediction results based on hindcast experiments, and approaches to downscaling.

Provision of seamless weather/climate information to users

Seamless information on weather and the climate will help users to prepare and take countermeasures using EWIEW in combination with analysis of current climate conditions and weekly forecasts.

In response to these challenges, JMA engages in activities in collaboration with research organizations on the user side with the aim of producing user-friendly climate information that supports decision-making. One such activity is a pilot project to promote the use of climate information in the agricultural sector in collaboration with Japan's National Agriculture and Food Research Organization Tohoku Agricultural Research Center.

Insurance against droughts and destabilization of energy costs in Uruguay

Mario Bidegain, Dirección Nacional de Meteorología – Dep. de Climatología and Guillermo Failache, Usinas y Transmisiones Eléctricas de Uruguay

The Uruguay River covers a total area of approximately 225,000 km² and is, along with the Parana River, one of the largest contributors to the Rio de la Plata river basin. The Uruguay River forms in the southern region of Brazil. It is a transboundary basin forming at first the border between Brazil and Argentina. This situation continues up to the confluence with the river Cuarein, where the Uruguay River goes on to define the border between Argentina and Uruguay and forms the Rio de la Plata estuary, together with the Parana River.

Average annual precipitation ranges from about 2,000 mm in the northern basin (26-29° S, 54-49° E) to over 1,300 mm in the region immediately south of the basin to the dam of Salto Grande (29-34° S, 59-54° E). Rainfall is relatively evenly distributed throughout the year. Nonetheless, in the northern basin rainfall maximums occur in spring (October), while in the central region and southern basin a double peak can be seen in the autumn and spring (April and October). Around the northern part of basin, enhanced rainfall in summer is a signature of the Southern Atlantic Convergence Zone development, especially towards the east. In winter and spring, on the other hand, enhanced rainfall is a signature of increased baroclinic activity.

The mean annual temperature in the region ranges from around 17° C in the south to more than 22° C in the north. The higher altitudes in the northeastern part of the Brazilian state of Rio Grande do Sul are substantially cooler than their surroundings. In winter, monthly mean temperatures have a clear north-south gradient. In July, for example, the mean temperature over the northwest part of the region is more than 20° C, while that in Uruguay is around 13° C cooler. In summer the gradient is more zonal, reacting to the land-ocean distribution. In January, the maximum mean temperatures reach more than 25° C in the north of Argentina, while they are less than 22.5° C in the coastal areas of southern Brazil and Uruguay.

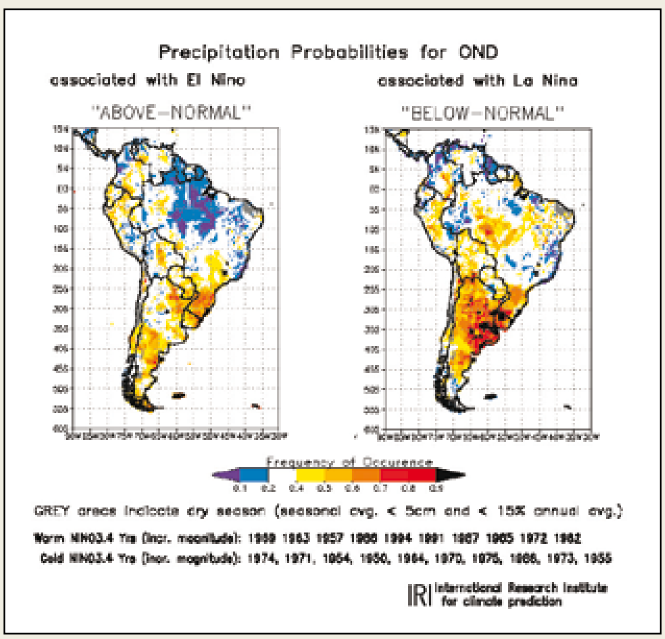
Image: Tamara Avellán, WMO

Time series observed during the past 30 years indicate significant variability in the amount of rainfall in the Uruguay River basin

Image: Tamara Avellán WMO

Periods of above- or below-normal rainfall can cause energy prices to fluctuate

Rainfall probabilities associated with ENSO



Source: IRI

Climate variability of the Uruguay basin

Time series observed during the past 30 years indicate significant variability in the amount of rainfall in the basin. The decade 1993-2002 was the wettest, while 2003-2011 showed frequent dry events. The monthly mean flows for 1979-2010 show an absolute minimum for the summer months (December-February), while a very significant increase is observed during the autumn. The decrease in rainfall during winter is observed in the southern part of the basin where flows are lower during August and September. Surges of flows associated with the arrival of the spring rainy season can be seen from October onwards in the basin.

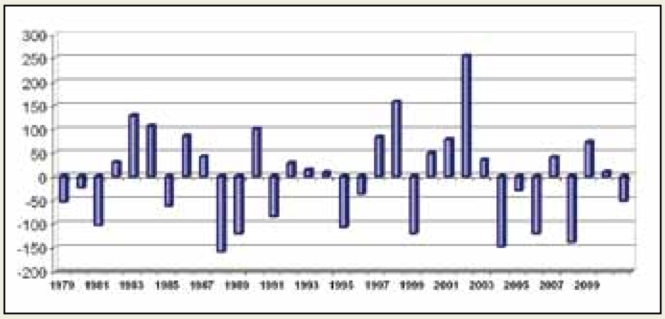
It is characteristic of the basin that river flow is regulated by evapotranspiration in the summer months and by rainfall in the winter months. The El Niño Southern Oscillation (ENSO) also influences rainfall and climate patterns. The warm phase of ENSO causes strong positive anomalies from October to December whereas the cold phase shows significant negative anomalies in the same period.

A strong ENSO warm phase effect was experienced in 1997-1998 with exceptionally high rainfall events between October 1997 and January 1998. In 2008-2009, the opposite was observed.

Hydropower generation in Uruguay

From 1965 to 2011, total electricity consumption (demand) has been growing at an annual average of 4 per cent. Until 1980, the demand was supplied using thermal and hydro generation in similar percentages. With the incorporation of the Salto Grande power station in 1981 and Constitución in 1983, national electricity production began to be greater than the total demand and the surplus energy was exported to Argentina and Brazil.

Annual rainfall anomalies (%) Uruguay river basin 1979-2011



Source: Mario Bidegain DNM

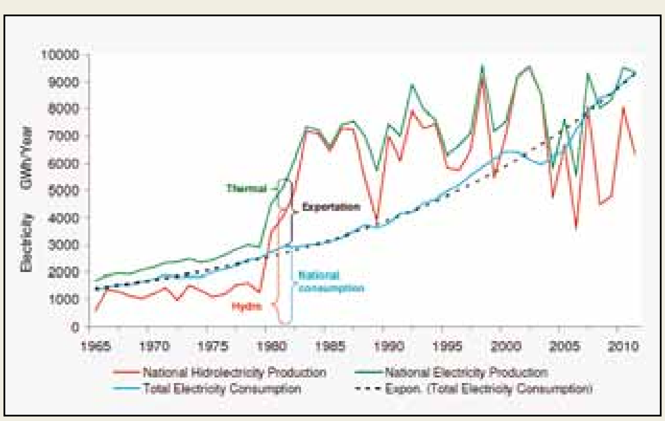
By the end of the 1990s, the total demand began to be greater than the hydroelectricity production, depending on the hydrological conditions of the river basins. Today, the Uruguayan electrical system still has a very strong hydropower component with four large power plants: Terra, Baygorria and Constitución on the Negro River, and Salto Grande on the Uruguay River (shared with Argentina). The amount of energy generated by these hydroelectric power stations depends on the hydro-climatic conditions in the river basins of both the Uruguay and Negro rivers.

In humid years, these hydroelectric power stations could supply 85-90 per cent of the country's total electricity demand. In dry years, such as 2008, these values are smaller than 50 per cent.

From 2003 onward, negative anomalies of precipitation (2003-2009) have occurred in the Uruguay River basin with consequent negative anomalies in flows. Only in 2010 were positive anomalies reported, in conjunction with a cold-phase ENSO.

The fluctuations in available water determine significant year-to-year variability in the cost of energy production. In dry years, energy production has to be supplemented with the costly import of crude oil and electricity from neighbouring countries, exceeding by far the revenues collected from consumers. For instance, during 2001-2003 the stream flow reached positive monthly anomalies of 200-300 per cent and no import was necessary. In contrast, during the La Niña event of 2008-2009, the level of the reservoirs along these basins reached values below the 20 per

Electricity production and consumption (1965-2011)



Source: UTE (Uruguay)

cent margin of their long-term averages. This drought forced thermoelectric plants into full operation, burning expensive imported oil to feed the power grid and draining the Government treasury of more than US$500 million in losses.

Coping with cost variations

Since 2009, the Electric Company of Uruguay (UTE) has started to analyse the development of tools to cope with the financial cost variations in supplying electricity. Measures include building up savings from successful hydropower years, obtaining grants from international organizations for enhanced management of risks, and a pilot risk transfer insurance that will cover losses during extreme climate events.

This insurance is based on the estimation of hydro-energy contributions to the electric system, using a hydrological model for estimating monthly water inputs in the Uruguay basin at Salto Grande hydroelectric dam and Negro River basin hydroelectric power plants. This hydro-electrical model relies on the input of daily rainfall data from the stations located in these basins as well as monthly semi-annual forecasts of rainfall.

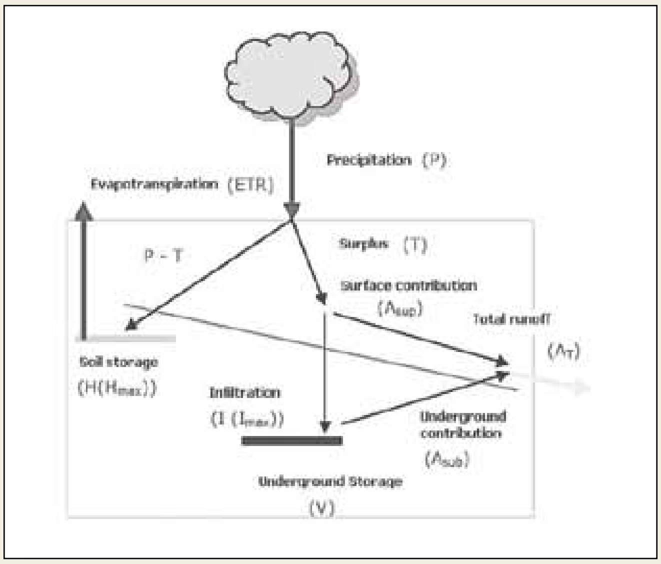
Although UTE has its own rain gauges throughout the river basin for dam management purposes, the insurance company requested independent and mandated rainfall data, including historic ones, from stations operated by the National Weather Service in Uruguay (DNM) and from the network of the National Meteorological Institute of Brazil (INMET). These datasets are then further used to create rainfall indices with defined thresholds for drought events.

The hydro-energy contribution to the electric system (Uruguayan Potential Hydroelectric Energy Input or UPHEI) varies significantly from low to high precipitation years. In the first semester of 1989, with very low precipitation, the hydro-energy input was approximately 1,500 GWh per semester, while in the first semester of 1998 with high precipitation, the energy input was near 7,000 GWh for the semester.

The first step was to create an agreement between Direccion Nacional de Meteorología and UTE to develop the technical aspects of the insurance. This cooperation began with talks to reach a working agreement, which includes the exchange of rainfall information, precipitation indexes and maintenance of rain gauges within the Uruguay River basin. This first stage has not been easy because it was necessary to overcome barriers such as access to databases in real time, commitment of rainfall stations, and database certification and quality control procedures

First, UTE contacted DNM to investigate the possibilities of carrying out this project. DNM established the connection to INMET Brazil for the delivery of rainfall information from the Uruguay River basin in Brazil. UTE requested support from the World Bank to

The Temez conceptual model



The Temez conceptual model: A surplus (T) part of the water which precipitates (P), is infiltrated (I) to the second layer, and goes to the stream-flow (Asup), whiles the rest of this water (P) is stored in the first layer of soil. Here, evapotranspiration occurs and the soil may also store water from one month to another. In the second layer, the water can drain to the stream-flow and may also be stored

Source: UTE (Uruguay)

develop an insurance against water deficit and achieve reinsurance from an international insurance company.

The development of the insurance involved a second step: the calibration and validation of the parameters of the hydrological model over the period 1981-2010. Here, historic daily rainfall data and average monthly evapo-transpiration of the basins was used.

DNM, INMET and the Joint Technical Commission of Salto Grande (URU-ARG) provide daily fields of precipitation over the basins of the Uruguay and Negro rivers. Homogenization of the data had to occur across the borders, as data from two different meteorological services were used.

UTE provides the analysis and calculations for rainfall-flow transformation on these basins in order to estimate using a hydrological model and the expected inflow to Salto Grande (Uruguay-Argentina), Gabriel Terra and Constitución (Uruguay) hydroelectric reservoirs.

The hydrological model proposed is the Temez model. This is a model of four parameters, expressed in an aggregated format over the Thiessen polygons of each rain gauge, since it works with average values of variables and parameters and reproduced in a simple and conceptual hydrological cycle in monthly steps. The model considers two layers, essentially representing the upper unsaturated zone and the lower saturated zone. These two layers can be considered as storages, generating fast and slow surface flows respectively.

Monthly precipitation in a rain gauge used in the Temez model is time–displaced, to take into account the delay of the flow from the rain gauge out of the basin. The total inflow of a basin is then calculated as a sum of the flow derived of the Thiessen polygons of each rain gauge in the basin. With the estimated total inflow in each basin in a semester, the UPHEI can be calculated.

The insurance was defined in terms of the values of UPHEI in the semester. If the estimated UPHEI is smaller than a defined trigger, a corresponding payment will be made; otherwise the payment is null.

In a third stage, during the operational phase, the insurance company requires semi-annual forecasts of monthly discharges in the basins. Daily rainfall records of selected stations, at the end of each month during the operation, will be used as input for the hydro-electrical model. DNM has established a standardized rainfall index (SPI) which will define the occurrence of drought events. The SPI is an index based on the probability of recording a given amount of precipitation, and the probabilities are standardized so that an index of zero indicates the median precipitation amount (half of the historical precipitation amounts are below the median and half are above it). The index is negative for drought, and positive for wet conditions. As the dry or wet conditions become more severe, the index becomes more negative or positive. The SPI is computed for several time scales ranging from one month to 12 months, to capture the various scales of both short-term and long-term drought. Inferences of shortcomings in the upcoming six months can then be made in advance and preparatory measures can be taken. At the same time the insurance company can prepare for potential payments. The insurance will work in a pilot phase until 2016. An extension will then be considered depending on the successful implementation of the system.

Ongoing provision

The provision of this service requires the combination of the capabilities of at least four institutions: DNM, INMET, URU-ARG and UTE. For the effective and timely delivery of this service by DNM, the hydrometeorological database (in operation since 2010) was widely used. A team of external engineers and programmers supported this database. As well as developing an effective and easy-to-use maintenance system, they also expanded the data extraction, transformation and processing routines of the available rainfall information. Financing for this team came from state resources transferred to the Dirección Nacional de Meteorología.

Future goals for the service include improving the availability of rainfall data in the basins under study, by incorporating automatic stations and satellite rainfall estimation. New automatic pluviometer stations have been acquired in the Negro River basin by UTE, and URU-ARG has also acquired new rainfall stations for the Rio Cuareim basin. DNM plans to address the installation of automatic stations in cities such as Salto, Rivera and Bella Union.

In future, the service could be expanded to include other countries and other sub-basins of the Rio de la Plata basin. An extensive cost-benefit analysis is being conducted by the insurance company which will provide insight on the economic value of providing this climate service.

IV
Energy

Developing climate services: the role of the energy sector

Laurent Dubus and Sylvie Parey,
EDF Research and Development/Atmospheric Environment and Applied Meteorology, France

The energy industry is exposed to weather and climate variability in the whole range of its activities. The impacts concern all time and space scales[1] and are now frequently documented in corporate communication. In 2010, the impact of climate on EDF's sales was positive and estimated to be €337 million. Weather and climate information is vitally important in everyday operations, and there is a need for new climate services to ensure the resilience of energy systems facing new environmental constraints and development needs.

Image: © EDF, Marc Didier

Aerial view of Gamsheim's hydraulic arrangement on the Rhine river, hydroelectric power plant and dam

The energy sector

The energy sector has been one of the most important users of weather and climate information and forecasts for several decades now. Forecasting parameters describing the state and the evolution of the atmosphere, the ocean and the hydrosphere are essential for both the physical and technical management of energy systems and their financial optimization in national or regional competitive markets. Moreover, the sector's quick evolutions constantly create new needs. This is notably the case with the rapid development of renewable energy systems (wind and solar in particular), which increase the dependence of energy systems on weather variability. New uses of electricity and new power systems organizations (electric vehicles, smart buildings and smart grids) increasingly demand new types of observations and forecasts as well. In addition, some climate events which can already be attributed to global change, demand new products and services.

The increasing exposure of the energy sector to weather and climate variability reinforces the already observed upward trend in the number, complexity and value of data provided by national meteorological and hydrological services (NMHSs) and requests made by users.

Existing information

Numerical weather prediction models have significantly improved in the last 10-15 years, in particular at lead-times of a few days up to one month. In parallel, many efforts have been made to better assess the quality and benefits of weather and climate forecasts with regard to the energy sector's economic needs.

Temperature and precipitation are the basic variables useful to many power companies. If high forecasting errors can occur on some occasions, the forecasts' quality for these variables has regularly improved and still does so. But with the development of wind and solar power, wind and solar radiation observations and short-term forecasts have become invaluable, and their quality will certainly be among the drivers for the development of renewable energy systems in the coming years. The energy sector generally uses state-of-the-art numerical weather prediction models, for instance those from ECMWF, the National Centers for Environmental Prediction, Météo-France or the UK Met Office among others. But while much progress has been made in short-term and medium-term weather forecasts, the need for longer-term forecasts and climate projections have only been partly addressed.

Long-range forecasts (seasonal to annual and even decadal) have indeed become ever more important to the (physical and financial) optimization of the systems, especially for temperature and precipitation, which drive demand and hydropower production. The development of accurate and skilful monthly and seasonal forecasting systems in the last decade has begun to provide solutions and helped increase the reliability in energy production and demand forecasts.[2] However, this type of information, essentially probabilistic, is far from trivial for the users, and requires the development of partnerships or organized services in order to ensure a scientifically correct use, notwithstanding its usefulness for the operational processes at stake. The operational use of such information can then be achieved only if close collaboration is established between providers and users of the data.

Long-term investment strategy and planning are important for the energy sector as well, with the scope between 10 and 50-60 years ahead. Currently running facilities are challenged by unprecedented extreme events like summer heat waves and droughts. There is now growing presumption that the occurrence of such events will increase with anthropogenically-induced climate evolutions. It is therefore important to project climate change impacts on temperature and precipitation extremes, both to adapt current facilities and design new ones. New methodologies have to be developed, and EDF Research and Development has proposed and compared different ways to derive future extreme temperature levels within the next decades or at the end of the century.[3] The future evolutions of water availability and temperature are equally crucial and such studies are absolutely necessary. Up to now, one of the main difficulties has lain in the access to climate simulation results suitable for such local impact studies involving different meteorological parameters. Both spatial and temporal scales often do not match.

Development of climate services

Climate services are currently under development and are prone to provide the needed climatic information. The requirements mainly concern the facilitation of access to climate science results, both in terms of information and of datasets. Information should include synthetic analyses of climate models' capabilities to represent the needed parameters, a selection of a minimal model ensemble to conduct relevant impact studies and guidance for the use of such results. On the other hand, it could be useful to download climate simulation results (both raw data and bias-corrected

EDF accompanies local authorities in the development of their territory, with projects such as Bordeaux's streetcars ones) more easily. It is our intention at EDF to develop a common platform with climatic information and datasets to share data and practices among the different directions and subsidiaries. This initiative, called Pact Energy, could be enormously facilitated by the development of climate services in the previously described way. Efforts like those done in the framework of the European WATCH project (water for utilities: climate change impacts on water quality and water availability for utilities in Europe), to make forcing and driving datasets available for hydrological and water thermal studies, are very welcome. But such initiatives should get a more perennial status. At the French national level, a new website called Drias: les futurs du climat has recently been launched. It is designed to answer the needs of the French practitioners and impact scientist communities by providing information on climate models and climate science and an access to raw and bias-corrected climate results. Even though the geographical coverage of these results is still limited to continental France, it is an important step toward useful climate services and appreciable progress in the access to climate science results. Following this movement toward climate services, different initiatives are taking shape, such as the recent climate Knowledge and Innovation Consortium (Climate KiC) launched by the European Commission. In this framework, projects involve climate scientists and people from the industry around important impact and adaptation issues, such as the E3P (Extreme Events and Energy Providers) project. Similar projects exist at the national level as well.

The links between weather, climate and the energy industry have also been focused in international conferences in recent years. If the first of these were specialized sessions during conferences organized by industry-specific organizations related to wind energy (such as the American Wind Energy Association), solar energy (such as SolarPACES) and meteorology (such as the European Meteorological Society), the first International Conference, Energy and Meteorology[4] provided a dedicated forum where people from both fields could discuss recent research findings and emerging practices, ranging from operational activities to long-term investment planning and policy-making.

All these initiatives enable us to be optimistic regarding the coming facilitation of impact studies, and thus of an easier consideration of climate change in the strategy and development plans of the energy industry, for which weather and climate issues are crucial.

Progress in science and knowledge on its own is not sufficient to increase the value of weather and climate forecasts for any sector. This value can be increased in three ways:[5] by an increase in the quality of weather and climate information on the providers' side, by an improvement in communication between providers and users, and by an improvement in the decision-making processes on the users' side. The three components can be improved separately, but the whole process will be more efficient if the whole chain is improved. This can be achieved only if an active collaboration exists between the parties. Although state-of-the-art scientific knowledge may put some limitations on possible developments, it remains that users' needs should be taken into account upstream, and then considered in an iterative process. This basic statement should be considered carefully when developing climate services, in particular in the Global Framework for Climate Services.

Further communication, collaboration and partnerships between NMHSs and energy companies are therefore essential. This should allow us to develop better answers to operational needs, but also to add extra value to products provided by weather services. Finally, it will be beneficial to society as a whole.

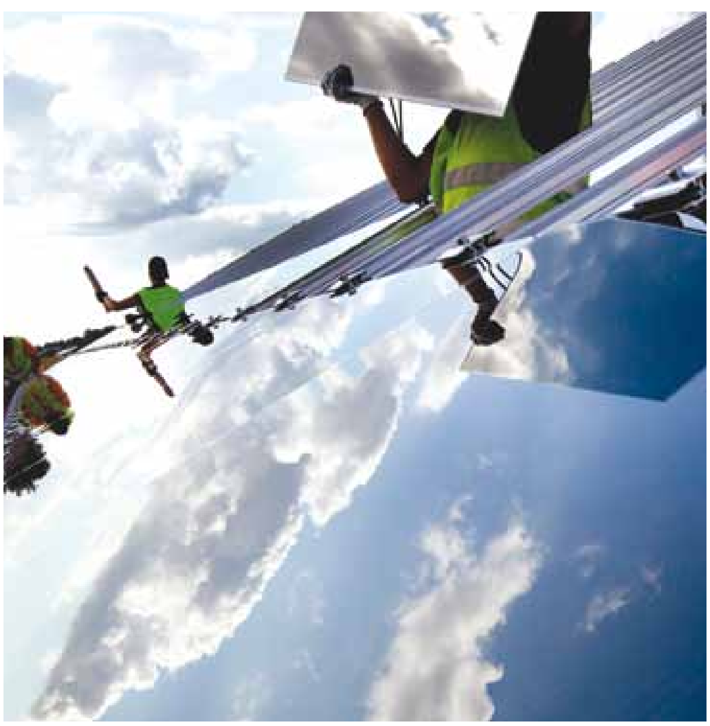


Image: © EDF, Philippe Eranian

Installation of solar panels

Image: © MEEDDAT, Laurent Mignaux

Small wind turbine at SEPEN (Site Experimental pour le Petit Eolien de Narbonne), located at domaine de Montplaisir

The use of seasonal climate forecasts to inform decision-making and management in the renewable energy sector of Samoa

J.A. Smith, E. Thompson and A. Amjadali, Australian Bureau of Meteorology;
S. Seuseu, Samoa Meteorological Service and W.J. Young, Electric Power Corporation

The climate of the Pacific region is heavily influenced by El Niño Southern Oscillation (ENSO) phenomena resulting in significant seasonal variability in rainfall and temperature, which often causes droughts, flooding and temperature extremes. Fortunately for the region, many climatic effects associated with ENSO are predictable using statistical and dynamical climate models, allowing for a degree of preparedness and proactive management of the most severe impacts.

The Government of Australia supports the Pacific Island countries' (PICs) response to climate variability and change, including financing a range of climate-related programmes through the Australian Agency for International Development's (AusAID) bilateral and regional programmes. The Australian Bureau of Meteorology (BoM) implemented Pacific Islands Climate Prediction Project (PI-CPP), which operated between 2004 and 2012, was one such project. A key component of the PI-CPP was the pilot project programme, which demonstrated the use of seasonal forecasts in vulnerable sectors.

Climate variability and energy security

One such pilot project focused on mitigating the risks posed by ENSO-based climate variability to the energy sector in Samoa. Afulilo Dam is a freshwater reservoir located south-east of the Samoan capital, Apia, on the island of Upolu. Afulilo Dam supplies the islands' main hydropower station, at Ta'elefaga on the coast of Fagaloa Bay. Together, the dam and the Ta'elefaga Powerhouse constitute the Afulilo hydropower scheme. When commissioned in 1993, the scheme accounted for 80 per cent of Samoa's electricity needs.[1] However, growing demand due to provision of electricity to a wider population and the uptake of improved electricity services has reduced the total proportion of energy produced by hydropower in Samoa to around 30-45 per cent, depending on local conditions.[2]

Hydropower production is susceptible to variability in streamflow, so seasonal climate variability creates significant operational challenges. Under present conditions, the dam capacity at Afulilo has a usable storage that could supply hydropower for only a few months in the absence of recharge, putting power production at significant risk from climate variability. This issue is exacerbated by the fact that Afulilo Dam provides an important nursery ground for tilapia fish which are a key aquacultural[3] asset

Image: Australian BoM

A penstock carries water from Afulilo Dam to the Ta'elefaga Powerhouse at Fagaloa Bay

A map of Samoa, showing the main islands of Savai'i and Upolu

Source: Australian BoM

for Samoa, reducing pressure on coastal fish stocks.[4] To ensure the health of tilapia in the dam while maximizing energy production efficiency, the dead storage level is set at around 30 per cent of capacity, greatly limiting the usable water supply for hydropower purposes.

To hedge against climate risk, the Electric Power Corporation (EPC) sets conservative production goals. However, in most years, when drought does not occur, this leads to suboptimal energy production, reducing the overall efficiency of the hydropower operation.

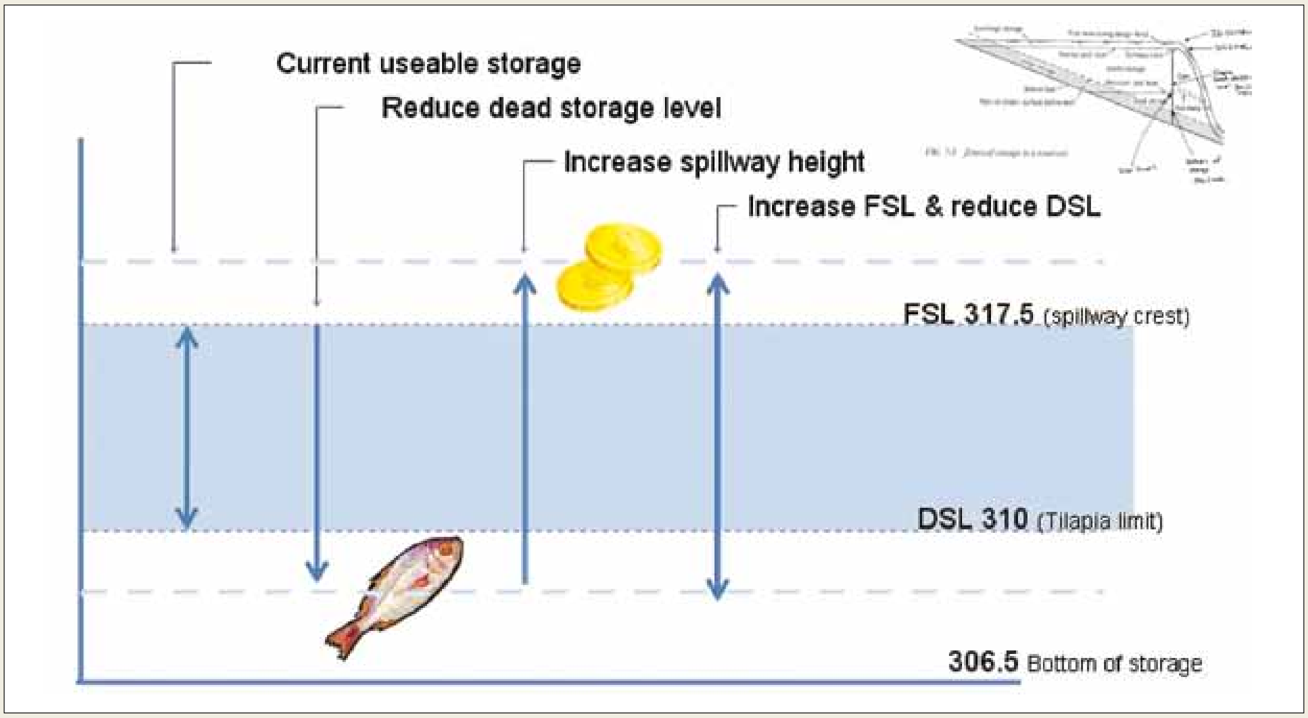
Considering the options

The Government of Samoa aims to increase the proportion of energy produced by renewable sources by 20 per cent before 2030. EPC is prioritizing the research and use of locally-appropriate renewable energy sources. Hydropower has been recognized as one of the most reliable and cost effective forms of renewable energy, and EPC's effort in using this includes maximizing the output of existing facilities as well as assessing the feasibility of additional hydropower schemes.

There are various options for mitigating the effects of climate variability on the energy sector of Samoa. One option involves expanding the dam and increasing the production capacity at Ta'elefaga Powerhouse by raising the dam wall and adding a third turbine to the powerhouse. However, due to local topography, the additional inflow would need to be sourced from lower elevations than the dam itself, requiring the water to be pumped to the dam and partially offsetting the increased power production that would be achieved.[5] An approximate 30 per cent dead storage level is also required to maintain the long-term health of the Afulilo Dam ecosystem, which is important to its use as a tilapia nursery ground. Thus, lowering the dead storage level to increase the overall volume of water available for hydropower production is not a viable option.

A second option is to increase thermal power production and the proportion of energy sourced from diesel fuel. EPC is building a new thermal station at Fiaga, in central Upolu, to add capacity to the power grid. However, this strategy increases Samoa's exposure to global energy markets, where the cost of diesel is already high and expected to rise. It also makes Samoa more vulnerable to price shocks and market fluctuations which pose significant economic risks to countries that are reliant on imported energy sources and raises additional associated environmental concerns from increased emissions of CO_2 and other pollutants.

A third option is to improve the operational efficiency of the Afulilo hydropower scheme by incorporating information on likely variations from normal rainfall. This would allow for short-term climate forecasts provided by the Samoa Meteorological Division (SMD) to be an integral component of the scheme's management strategy. Under this strategy, seasonal climate forecasts would be used to predict the risk of energy shortfalls with sufficient lead time to allow the application of more flexible operating procedures, thus ensuring that the water supply is managed in the most practical and efficient manner for prevailing and likely climate conditions. These forecasts could also be used to inform forward planning with regard to sourcing supplementary energy supplies in high risk years. Given the strong relationship between climate predictors and rainfall in Samoa, the use of climate forecasts for the management of hydropower production is seen as the most feasible and cost effective option, at least in the short term. In the longer term, improved management of hydropower production could also work hand in hand with other infrastructure upgrades while protecting the health of Afulilo Dam as a tilapia nursery.



Capacity improvement options at Afulilo Dam

Source: Australian BoM

Methodology
With the assistance of EPC and SMD, rainfall data for Afulilo Dam and surrounding stations were obtained, along with storage, streamflow and power generation records from the Ta'elefaga Powerhouse.

Data requirements for calibrating the hydrological model included:

- Climate (rainfall, temperature and evaporation data)
- Inflow to the dam (catchment streamflow)
- Rainfall-runoff relationship for Afulilo catchment
- Dam release downstream from the dam
- Dam release to Ta'elefaga Powerhouse for power generation
- Dam storage characteristics (full storage/dead storage levels, cross-section of spillway)
- Storage area-volume-elevation relationship for Afulilo Dam
- Estimated seepage rates and losses
- Turbine efficiency (or rating curves)
- Outflow-to-power-generation relationship at different storage levels (change in turbine efficiency).

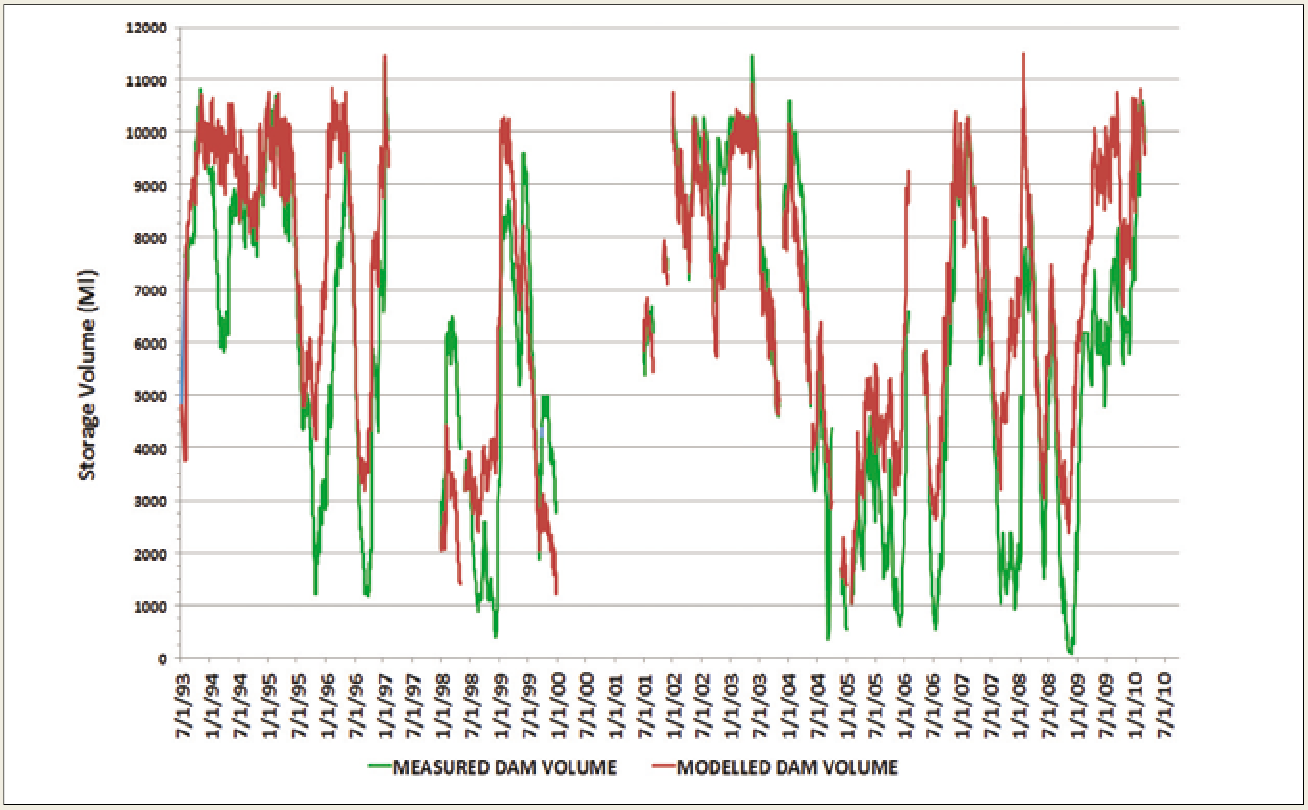
Long-term (1900-2010) daily climate data for Afulilo were generated, based on Apia climate data and using the stochastic weather generator, WeatherMan.[6] Since daily streamflow data were limited for the Afulilo catchment, an appropriate rainfall-runoff relationship had to be derived from the streamflow records of the neighbouring Vaipu catchment using the IHACRES software package.[7] This relationship was then used to calculate inflow to Afulilo Dam. Outflow to the Ta'elefaga Powerhouse was calculated based on daily records of electricity generation from EPC.

Using the derived inflow and outflow rates, a hydrological water balance model for Afulilo Dam was developed and calibrated against historical dam levels as well as power generation data for 1993-2010. Analysis showed a significant correlation between seasonal storage volumes and ENSO, with El Niño periods tending to coincide with lower storage volumes and La Niña periods tending to coincide with higher ones.

Results
A comparison of observed and modelled storage levels was made for a validation period of 1 August 1993 to 28 February 2010. While the model will become more accurate as more hydrological data become available for EPC, it was considered sufficiently accurate to begin considering long-term supply and demand scenarios.

Several variables were incorporated into this ensemble of long-term supply and demand simulations to assess each of their effects on dam storage and energy generation potential, and to assess dam performance under different scenarios. These variables consisted of a matrix of power demand, power generation capacity, water storage capacity and rainfall variability.

The simulations showed that under the current average power demand, the dam storage level falls below 10 per cent of usable capacity on an average of five days per year. If energy demand continues to grow at the projected 4 per cent per year, then by 2020 the number of days where usable storage drops below 10 per cent will rise to 70 days per year. The results also showed a 20 per cent increase in the frequency of low storage volume under El Niño as compared to La Niña conditions, further underlining the significant effect of climate variability on energy security in Samoa.



Capacity improvement options at Afulilo Dam

Source: Australian BoM

Application

These results clearly highlight the risks to meeting current demand for hydropower generation, particularly in drier El Niño years. With electricity demand continuing to increase at around 4 per cent a year, and with substantial variation between El Niño and La Niña years, there is a strong case for using seasonal climate forecasts to inform seasonal water management decisions. Implementing this strategy should improve the reliability of energy supply while reducing the risk of acute power shortages, protecting the habitat of the tilapia fish nursery and easing the immediate need for expensive infrastructure upgrades. In the longer term however, the results of these scenarios reinforce the need for further infrastructure and energy capacity upgrades.

Another important consideration is that energy production efficiency is highly sensitive to changes in water flow through the power-generating turbine, particularly at the likely low rates of flow in drought periods.[8] This is especially pertinent considering the current strategy of generating power at conservative levels to mitigate drought risk; a strategy that is likely to be significantly less efficient than setting targets based on seasonal climate forecasts.

Capacity

During a visit to Afulilo Dam and the EPC offices in November 2007, Dr Abawi made a number of recommendations regarding storage of data records and possible improvements that could be made to instrumentation, measurement techniques and record keeping practices, a number of which were subsequently implemented.[9] A new water height gauge has been installed at the dam wall, which measures the water level more accurately, overcoming errors associated with the poor positioning of the original gauge. In addition, the local rainfall gauge has been shifted from an area obstructed by large trees to an area without foliage cover. Given the large rainfall gradient across the small Afulilo catchment, small measurement errors could have significant impacts on the measured water balance of the dam; these improvements represent a substantial increase in measurement and data collection capacity within EPC.[10]

In July 2012, a meeting was held between representatives of the Climate and Ocean Support Programme in the Pacific (COSPPac)[11], SMD and EPC to discuss the current status and future directions of the project in Samoa. Wairarapa Young, EPC's Renewable Energy Officer, acknowledged the effect of the project so far, noting that the pilot project had helped in the positive development of EPC's data collection strategy. He also indicated that due to the demonstrated benefits of the project and the necessity for valid data, EPC was installing new rain gauges and repairing existing ones.

SMD also reported on its ability to supply EPC with customized outlooks for energy management purposes; a step being taken for a number of industries. Mr Young indicated that EPC had begun supplying

Amanda Amjadali (COSPPac), Sunny Seuseu (SMD), Bobby Ah To and Wairaarapa Young (EPC) discuss future directions for the renewable energy pilot project in Samoa

hydrology data to SMD at irregular intervals. These developments point to a growing operational relationship and associated data sharing between EPC and SMD, which the PI-CPP pilot projects have helped to foster. This relationship is likely to improve these agencies' response to climate variability and climate change. The improved interlinkages and networking between the agencies will improve the Samoan Government's capacity to respond to climate challenges that require concerted action and cooperation across multiple government divisions.

Towards an operational energy management system

The results of the long-term supply and demand scenarios will be presented at an in-country workshop undertaken by COSPPac in the near future. The workshop will also provide an opportunity for further discussions with SMD and EPC on how best to utilize the tools and results of the pilot project. Formal correspondence between managers at EPC and SMD would then be required to develop a prototype risk management plan, which would involve the provision of customized climate forecasts from SMD to be used by EPC to inform energy production and water management strategy.

The aim is for EPC and SMD to have the necessary tools to develop a sustainable, operational system capable of being maintained independently by the two organizations. This outcome would include providing the developed water balance model to the two organizations and ensuring access to the tools — such as the IHACRES and WeatherMan software — required to maintain and update it. Further training and capacity building efforts would be conducted by COSPPac as part of this handover.

Future projects

The processes developed through this project could be implemented elsewhere in the Pacific region, within catchments containing similar sized or larger dams. There are two such catchments in Fiji: the Vaturu Dam, which is used for water supply and was also the subject of a PI-CPP pilot project; and the Monasavu Dam, which is used to supply a hydropower station. The Fiji Meteorological Service has expressed an interest in incorporating the hydropower scheme at Monasavu Dam into its own pilot project programme. Incorporating the methodologies developed during the Samoa project into a customized water balance software-modelling tool for more general operational use in informing risk management strategies in the hydropower sector remains an ongoing goal.

To achieve this would require additional investigation of the underlying assumptions made in this particular case as well as the inclusion of downscaled climate change factors for accurate simulation of power demand under future climate scenarios. The future strategy of the climate application projects[12] under COSPPac is to improve the supply of documentation and online tools, enabling other countries to have access to a framework that would allow them to undertake similar projects on their own.

Principles of the GFCS

The primary aim of the Samoan hydropower project was to build the capacity of SMD and EPC to respond effectively to the challenges posed by climate variability and climate change. SMD's capacity to produce customized seasonal forecasts and communicate climate information to the hydropower sector has certainly increased, as has the capacity in hydrological modelling, data collection and the use of climate information to inform management decisions in EPC. Additionally, BoM has gained valuable experience in working with the short and incomplete datasets that are common in the developing countries of the Pacific, thus exemplifying Principle 1 of the Global Framework for Climate Services (GFCS).

The collaboration between the Government of Australia, through AusAID and BoM with the Government of Samoa, through SMD and EPC, is a cogent example of the application of GFCS Principle 5. The development and implementation of this project involved the exchange of data and expertise between SMD and EPC as well as the provision of data from both parties to BoM, enabling the development of a water balance model for Afulilo Dam. This form of cooperation and collaboration is the core focus of GFCS Principle 6.

The anticipated end point of this project is an operational climate risk management system for the Afulilo hydropower scheme. This would have SMD acting as an information provider through the dissemination of customized climate forecasts and warning bulletins, while EPC acted in a client role, processing these bulletins into a useable energy management framework. The outcome would provide greater flexibility in water storage and energy generating potential as well as mitigation of the risks posed by climate variability. The structure of this project therefore aligns closely with GFCS Principles 4 and 8, which focus on operational climate services and user-client relationships respectively.

The Low Carbon Growth Plan for Australia: providing climate services to businesses

Professor David Griggs, Megan Argyriou and Scott McKenry, ClimateWorks Australia

When people think of the provision of climate services to business or industry they probably think of the provision of weather and climate information. Most businesses are dependent on the weather in some way and many are vulnerable to changes in climate, particularly those in climate vulnerable sectors such as agriculture. Increasingly businesses are starting to take weather and, to a lesser extent, climate change into account in their business planning and climate services are starting to be developed to address these needs. However, there is a whole other area of climate service required by business. Climate policies and the need to reduce greenhouse gas emissions present both challenges and opportunities for business. Businesses may be required, legally or morally, to reduce the carbon footprint of their operations and climate services are required to inform business of the most efficient and cost effective ways of doing this. There are also opportunities for businesses to innovate and to diversify into new markets created as a result of the need to reduce greenhouse gas emissions.

The Low Carbon Growth Plan for Australia described below is an example of a climate service to business and provides an analysis of how Australia could reduce its greenhouse gas emissions at the lowest cost and an examination of the barriers to achieving these emissions reductions and how they may be overcome.

The volume of abatement required against buinsess as usual (BAU) projections

Source: ClimateWorks

What's happening in Australia?

The centrepiece of Australian Government policy to address greenhouse gas emissions is the Clean Energy Future package, which represents a suite of legislative measures including a price on carbon. The carbon price package (introduced on 1 July 2012) will impact on the business community in three ways:

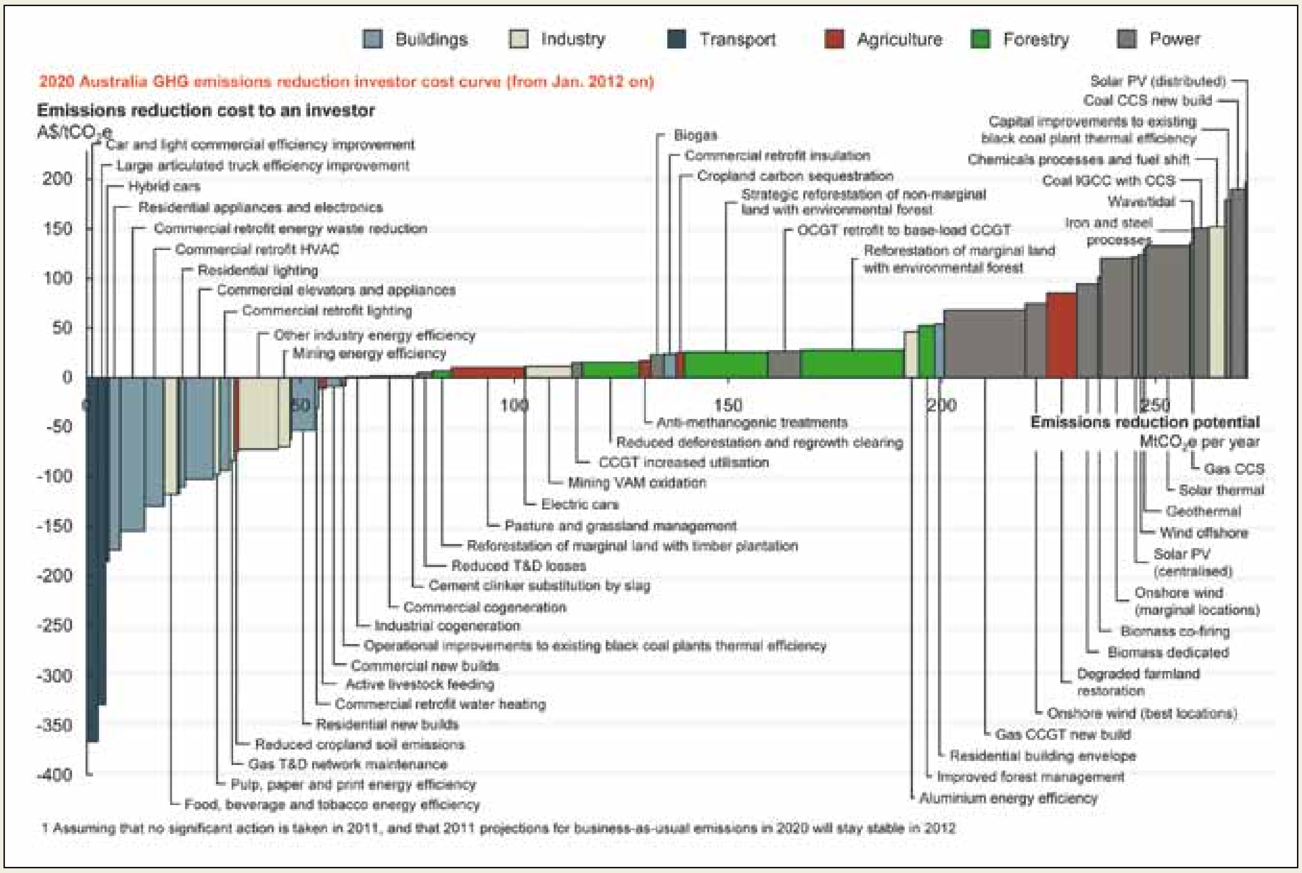
- For businesses that are included in the emissions trading scheme, every tonne emitted will require a permit, whose value will be equal to the carbon price in the year in which it is sold. These businesses include power generators and large energy intensive businesses.
- For businesses that can provide offsets (through the Carbon Farming Initiative), every tonne of abatement can earn a certificate which can then be sold to emitters as equivalent to an emissions permit.
- For other businesses and individuals, the impact of the carbon price will be experienced mostly through an increase in electricity prices, passed on by electricity generators who need to buy permits for their emissions. This provides an incentive to invest in energy efficiency and cleaner technologies.

In order to deliver the required emission reductions, it is critical that we harness the power of business and the ability of the markets to develop innovative technologies and efficient abatement solutions. To achieve this in the most cost effective manner, decision makers require a framework to understand where the lowest cost abatement opportunities can be found, and which opportunities should be prioritised in the short, medium and long term. In 2010, ClimateWorks Australia developed the Low Carbon Growth Plan for Australia to fill this critical information gap.

What is the Low Carbon Growth Plan?

The Low Carbon Growth Plan for Australia identifies 62 opportunities to reduce Australia's national emissions from activities in energy efficiency, land and power. It found that by 2020 Australia could reduce its greenhouse gas emissions by 272 $MtCO_2e$ for a lower than expected cost. This represented a reduction of 25 per cent below 2000 levels[1].

2020 greenhouse gas emissions reduction investor cost curve (from Jan 2012 on) for Australia



How to read an emissions reduction cost curve: Each box on the cost curve represents a different abatement opportunity. The width of each box represents how many tonnes of emissions can be reduced if there is reasonable uptake of the opportunity across the economy. Added up, the width of all boxes on the cost curve represents the total volume of abatement potential that can be achieved by 2020. The height represents the average cost of abating one tonne of CO_2e (carbon dioxide equivalent) in 2020 by implementing that opportunity. Opportunities that fall below the horizontal axis offer financial savings to businesses and households - even after factoring in the costs associated with capturing that opportunity

Source: ClimateWorks

The Plan is unique as each of these 62 opportunities are quantified and ranked by their relative merit order. These 'best bang for buck' opportunities are presented in an emissions reduction cost curve (see diagram above).

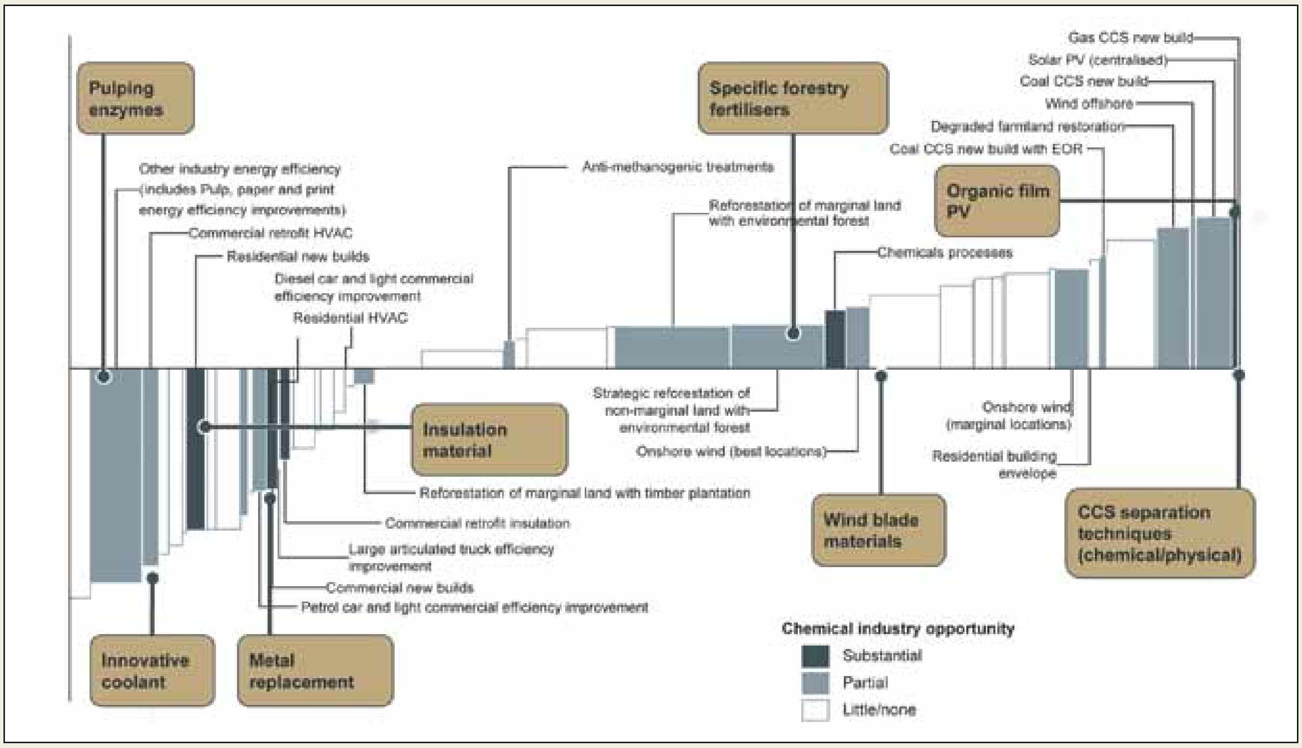
The opportunities focus on current technology or best practice and emerging technologies expected to be commercially viable by 2020. This is important, as the Plan highlights readily implementable actions that don't require technology breakthrough or changes to the business mix of our economy.

Consequently, the Plan has emerged as a critical tool for business and government by establishing a clear vision and roadmap to a low carbon economy. This technically robust and accessible Plan has helped to bridge the gap between research and action, helping to build momentum in the business community and identify cost-effective first steps in the transition to a low carbon future.

What climate services does the Plan offer?

Effective carbon management remains a key challenge for Australian businesses. Compared with other countries, Australia's coal-dominated electricity supply is particularly emissions intensive, which consequently skews the abatement opportunities available to an organisation. A robust approach to carbon management typically requires methodical carbon foot-printing, identification of efficiency opportunities, development of carbon management plans, implementation of opportunities, monitoring and reporting progress. These processes lay beyond the capability of many businesses and the opportunities therefore often go uncaptured.

The complexity of these tasks highlights the importance of the Low Carbon Growth Plan as a decision making framework. For businesses, it can highlight key areas of opportunity relevant to their sector including indicative costs and potential financial returns to inform investment decisions. The diagram over page demonstrates how the Plan could assist a chemicals company capture new low carbon growth opportunities. For policy makers, the Low Carbon Growth Plan provides a clear understanding of where to direct policy to best enable businesses to identify and implement emissions reduction opportunities.



A more detailed example of new opportunities that a low carbon economy can create for the chemical industry, especially in the basic materials and products manufacturing sub-sectors

Source: ClimateWorks

One fifth of the opportunities identified in the Low Carbon Growth Plan (or 53 $MtCO_2e$) generate a positive return for businesses, even after taking account of the upfront costs and before factoring in the impact of carbon pricing (which will amplify potential financial savings available through energy efficiency, for example). By using resources more efficiently and thus reducing input costs, many businesses will be able to achieve returns above their cost of capital while at the same time reducing their greenhouse gas emissions.

Despite the fact that many of the opportunities identified in the Plan are profitable for investors, emission reduction opportunities are often not implemented due to a range of financial and non-financial barriers. These include project profitability, capital constraints, information gaps and structural problems in the market that prevent the opportunity from being captured. Importantly, the Plan articulates a clear 'roadmap' with recommendations and strategies to overcome these barriers which allows policy makers and opportunity owners to compare different options and make informed decisions about where to invest their time and resources.

Reducing GHG emissions can also provide additional growth opportunities for businesses. As the world moves towards a low carbon economy, demand for carbon-efficient products and services will steadily increase, providing significant opportunities for businesses that supply these, such as engineering and construction companies and equipment and product manufacturers and installers. The Low Carbon Growth Plan can provide insight for these businesses about where potential business growth opportunities may exist.

What action can businesses take?

Many of the profitable opportunities identified in the Plan are concentrated in the built environment, transport and industry. Opportunities from land-based activities and power generation come at a moderate to high cost, but may become profitable under Australia's emissions trading scheme, or through complementary measures such as Government programs that support or incentivise the uptake of clean technology.

Businesses can expect significant financial benefits through improving the energy efficiency of existing buildings. Across all types of commercial buildings, the most cost effective opportunity comes from reducing energy waste, through actions such as reducing oversized and unnecessary equipment and better management of control systems. These often simple actions can reduce energy use by an average of 10 per cent for a low upfront cost of AU $4 per square metre of floor space. TThe Plan also demonstrates that the installation of distributed energy technologies – such as cogeneration – can be expected to offer attractive financial savings with even a modest carbon price.

Without further action, emissions from Australia's industrial activities are expected to grow by 40 per cent between 2000 and 2020, driven largely by growth in the mining and gas subsectors (extraction and resource processing). However, many energy efficiency opportunities in industry are financially

Image: ClimateWorks

Cogeneration, also called combined heat and power or CHP, is a technological opportunity which provides energy savings by creating heat and electricity from the same fuel source

attractive. The Low Carbon Growth Plan highlights the relative merit of categories of opportunities that are typically available across a sub-sector regardless of differences in plant or kit, such as motor system upgrades, process improvements or installation of cogeneration technologies.

The Plan also demonstrates that businesses in the agriculture sector can cut emissions principally through changes to land management practices to align with current best practice approaches. This includes increasing carbon sequestered in soils through improved cropland, pastureland and grassland management, and reducing emissions from livestock through improved feed quality. Land owners also control significant potential to reduce emissions through forestry activities – in particular through reforestation, reduced deforestation and improving forest management practices to increase woody growth. Some land based opportunities offer land owners the potential to generate additional revenue via offset schemes (such as the Carbon Farming Initiative).

In a country such as Australia where electricity is typically generated from coal, substantial potential to reduce emissions also comes from solutions for less-emissions intensive power generation. By comparing the abatement potential and relative cost that a range of different power generation technologies offer, the Low Carbon Growth Plan can provide an input to decision making for investors in the power generation sector. Further the Plan compares the total electricity production mix under a business-as-usual scenario for Australia in 2020 against a low carbon scenario to illustrate the changes that will need to happen on a low carbon transition pathway.

How is the Plan being applied?

Experience shows that the Plan is not only limited to a decision making framework to prioritise abatement opportunities, but is also being adopted and modified for other purposes. For instance, one of Australia's leading banks, the National Australia Bank, has recently used the Low Carbon Growth Plan to develop a targeted information package for their retail customers on how they can reduce risks from rising energy costs through energy efficiency.

Similarly, the Plan has been used by the education sector as a means of understanding future market needs for 'green' or 'low carbon' skills. By mapping key roles and skillsets against each of the opportunities identified in the Plan, universities have been able to profile areas of emerging skill needs and develop appropriate response strategies (for instance, new educational products and courses).

ClimateWorks is also working with regions across Australia to develop their own Low Carbon Growth Plans. These regional plans can shine a spotlight on opportunities that can help to mitigate the economic impacts that a transition to a low carbon future may have on regional communities, helping to build community resilience. It achieves this by showing where businesses can reduce costs, thereby increasing business productivity and resilience, where landowners can improve land management practices to either improve agricultural productivity or earn carbon farming revenue, and where business growth and employment opportunities may exist across a regional economy, such as through the provision of energy services.

Regional Low Carbon Growth Plans empower regional communities to self-manage their emission reduction activities. To date, three regional plans have been developed in Gippsland, Geelong and Macquarie Park.

The Low Carbon Growth Plan for Australia therefore provides a range of climate services to businesses. It prioritises the lowest cost emissions reduction activities available across all sectors of the economy, focusing on solutions that businesses can implement today. It articulates the barriers those opportunities face, and outlines approaches to address those barriers. It allows 'value-adding' to services provided by other businesses such as financial institutions and education providers. And the methodology itself is adaptable to regions and cities, where it can highlight a clear transition pathway that not only reduces a community's emissions, but can help to build business and community resilience in a changing climate.

The Low Carbon Growth Plan for Australia was developed by ClimateWorks Australia – a non-profit organisation created in 2009, through a partnership between the Myer Foundation and Monash University. Read the Low Carbon Growth Plan and ClimateWorks' other reports here: www.climateworksaustralia.org

Enhancing cooperation in climate services through the sub-regional virtual climate change centre

Milan Dacić, Republic Hydrometeorological Service of Serbia

Following the World Meteorological Organization's (WMO) invitation to its member states to intensify their international cooperation through appropriate national, sub-regional and regional climate centres, in 2006 the Republic Hydrometeorological Service of Serbia (RHMSS, serving as a national meteorological and hydrological service (NMHS) of Serbia), launched an initiative to establish a sub-regional centre for climate change for South East Europe (SEE).

The initiative was included as a priority for sub-regional cooperation under the United Nations Economic Commission for Europe (UNECE) 'Environment for Europe' process. As a result, the Sixth UNECE Ministerial Conference in Belgrade, Serbia in 2007 adopted the Belgrade Initiative for the enhancement of SEE cooperation in the field of climate change.

In line with the Belgrade climate change initiative, the sub-regional South East European Virtual Climate Change Centre (SEEVCCC) was established in late 2007, and is hosted by the Republic Hydrometeorological Service of Serbia.

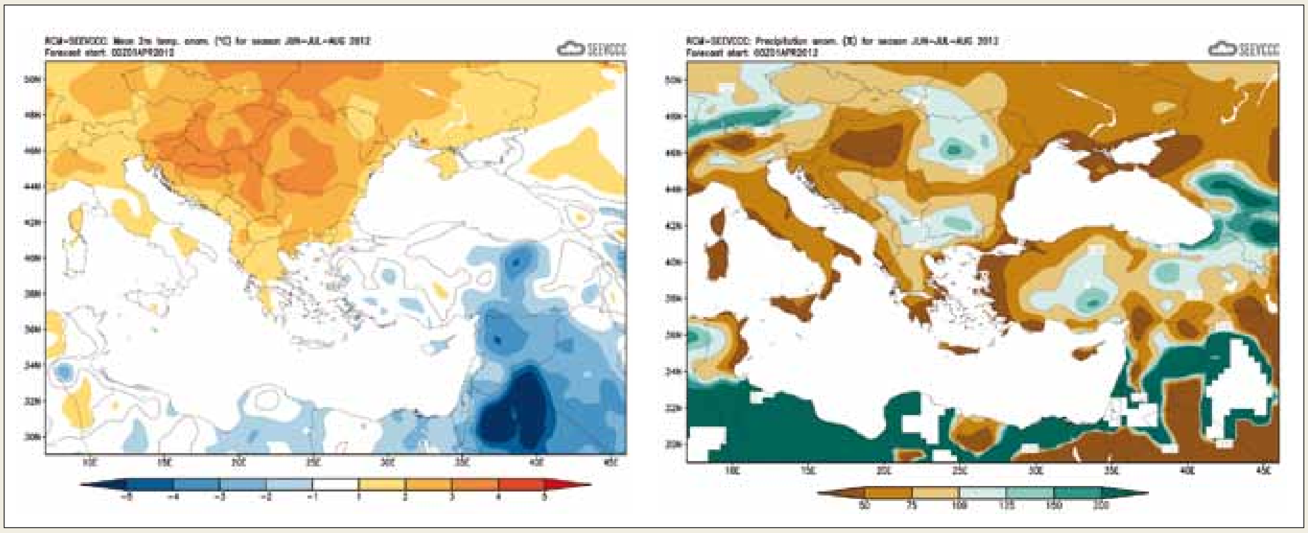
Objectives of the SEEVCCC

The goals of the centre are to:

- Provide operational functions in climate monitoring, generate sub-regional analysis, seasonal and inter-annual prediction products, and share climate information including modelled data sets
- Perform research and advance scientific understanding of climate change impacts, vulnerabilities and adaptation opportunities

Image: RHMSS

The EPS hydropower plant 'Djerdap 1'



An SEEVCCC seasonal forecast of the anomalies of mean temperature and precipitation during the June-August 2012 season, issued on 1 April 2012

Source: RHMSS

- Provide training and share the best experience and practice in climate change, particularly in climate modelling and interpretation of model outputs
- Build capacities of the SEE NMHSs in terms of human resources and improvements to climate change products and services
- Connect the science and policy communities in adaptation planning and climate risk management
- Facilitate partnerships between the NMHSs in the region and other interested institutions dealing with climate change, as well as with relevant international organizations, regional climate centres, donor communities and so on.

Work to set up the SEEVCCC functions proceeded simultaneously in two directions:

- Development of the South East European Climate Change Framework Action Plan for Adaptation[1]
- Participation in WMO activities under the framework of the Regional Climate Centre (RCC) Network in Regional Association (RA) VI (Europe).

Operations in the WMO RA-VI Pilot RCC Network

The WMO RA-VI RCC Network is envisaged to provide mandatory regional-scale tailored climate services on climate data, climate monitoring, long-range forecasting and capacity building, as well as to perform coordination functions and highly recommended research and development activities. As a member of the network, SEEVCCC has a mandate to provide all the above-mentioned tailored climate services to the SEE sub-region, including the coordination of different programmes and projects on the impact of climate change on various sectors of the economy.

SEEVCCC issues seasonal forecasts for SEE which are based on dynamical downscaling of the European Centre for Medium-Range Weather Forecasts' global seasonal forecasts with seven months' lead time. SEEVCCC uses its own seasonal prediction system based on a regional interactively coupled atmosphere-ocean model. The centre has been operational since June 2009. The forecasts consist of 51 ensemble members and are issued on a monthly basis. The results are available from the website in the form of maps and diagrams for ensemble mean and anomaly values.[2] Binary values are reachable on request to access the centre's data archives.

The main activities of SEEVCCC under the RA-VI RCC Climate Monitoring Node relate to:

- Collecting actual climate data for around 400-500 meteorological stations within SEE — those included in the international data exchange
- Climate data processing and operational issuing of monthly and three-monthly climate monitoring maps for SEE.

SEEVCCC provides regional climate projection data covering SEE and the Mediterranean area. The centre's regional climate model (RCM-SEEVCCC) was also applied in the climate change simulations based on the A1B and A2 Special Report on Emissions Scenarios used in the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report. These results are further employed in different impact studies in the agriculture, forestry, hydrology and energy sectors. The model database includes 1961-1990 (present climate), 2001-2030 (A1B scenario), and 2071-2100 (A1B and A2 scenarios) data.

In pursuing the highly-recommended functions related to research and development, SEEVCCC is particularly interested in the application and further development of the National Centers for Environmental Prediction unified nonhydrostatic multi-scale model (NMMB) designed for a broad range of spatial (global to sub-regional and local) and temporal scales. This model, which is considered to be well suited for the mission of the centre, has been adopted and presently runs operationally as a

Image: RHMSS

Participants at the ministerial meeting 'Climate Change Research for Environmental Protection, Adaptation and Risk Reduction' in Belgrade, April 2011

medium-term weather forecasting model at RHMSS. The long-term vision in research and development activities has been defined in the 'South East European Research and Development Programme of Regional Climate Modeling for 2012-2017', developed by the international Expert Workshop which was supported by the ministerial meeting 'Climate Change Research for Environmental Protection, Adaptation and Risk Reduction' in Belgrade, Serbia, on 13 April 2011.[3]

Capacity building

SEEVCCC supports the activities of NMHSs in issuing climate watches, based on monthly climate diagnostics bulletins, anomaly maps, climate extremes indices, weekly and monthly forecasts and seasonal predictions. SEEVCCC runs an experimental climate watch system, which is designed to provide advisories (climate watches) informing partner NMHSs on ongoing, pending or expected climate anomalies and their possible negative impacts. Experimental work in this area is based on the connection of probabilistic long-term forecast of the standardized precipitation index (SPI), obtained from the SEEVCCC seasonal prediction modelling system with the SPI calculated from observations.

Based on SEEVCCC climate monitoring, seasonal forecasting and climate watch advisories issued on 1 April 2012, which related to the hot summer and lack of precipitation in the Balkan Peninsula, RHMSS was able to issue a timely (April/May), detailed climate warning. Warnings were issued in connection with the heat wave, drought and weather conditions conducive to the onset of forest fires, all of which were recorded across the whole territory of Serbia and SEE during June and July 2012.

The WMO Regional Climate Outlook Forum (RCOF) is a regional mechanism for the formulation and dissemination of climate outlooks. RCOF's consensus forecast process stimulates capacity development in NMHSs and supports the decisions and activities which mitigate adverse impacts of climate, while helping communities to adapt to climate variability and change. In the European region the RCOF process was launched in 2008, by establishing the South-East European Climate Outlook Forum (SEECOF) covering the countries of the SEE and Caucasus region. The first SEECOF was held in Zagreb, Croatia in June 2008, and the second (SEECOF-2) in Budapest, Hungary in November 2009. SEECOF-3, focusing on summer 2010, was carried out as an online collaborative exercise for the first time since the RCOF mechanism was established by WMO. This exercise was co-facilitated by SEEVCCC, the RA-VI Working Group on Climate and Hydrology and the WMO Secretariat. It proved that, in the RCOF mechanism, online collaboration could be used as an efficient and effective alternative to physical meetings. In line with that, taking into consideration the capacity-building component of the RCOFs, it has been agreed that face-to-face meetings of regional experts moderated by leading climate experts should continue to be organized once a year. As a follow-up of the fifteenth RA-VI recommendation, SEEVCCC/RHMSS hosted the SEECOF-4; six face-to-face sessions focusing on the winter season 2010/2011 and 2011/2012 respectively[4] as well as the SEECOF-5; seven online meetings. Efforts are underway to strengthen the climate change section in SEECOF, and to achieve sustainability by linking COF with RCC and promoting their roles in the Global Framework for Climate Services (GFCS), bridging the gap between providers and users of climate information.

Other SEEVCCC capacity building activities cover sub-regional training workshops and the development of user awareness through participation in regional projects and joint or co-sponsored workshops, think tank and brainstorming events (Regional Environmental Center and SEEVCCC; Food and Agriculture Organization and SEEVCCC).

Roles and responsibilities

The basic mission of SEEVCCC under the Belgrade climate change initiative is to support the SEE countries in meeting their needs for information on the sub-regional climate change projections, impacts, vulnerability and adaptation options on a continuous basis, through its operational, research, coordination and educational functions. The centre participates in the development and implementation of the SEE Climate Change Framework Action Plan for Adaptation, for 2009-2015. Further updates and implementation of the action plan aim at implementing the United Nations Framework Convention on Climate Change Capacity Building Framework, its Articles 5 and 6, and the Nairobi work programme on impacts, vulnerability and adaptation to climate change.[5]

Building a partnership

The most important end users of weather and climate information in SEE are those that could provide a substantial part of the national income — sectors such as energy, agriculture, tourism, traffic and insurance. Naturally, from the viewpoint of saving life and property, the most important end users are the risk management authorities with their structures on regional, national and local levels.

Being aware that energy is the key economic driver in all SEE countries, RHMSS/SEEVCCC decided to establish closer links and promote collaboration within the energy sector.

The historical turmoil in the Western Balkans during the 1990s led to the disintegration of a unified energy system that stretched from the Adriatic to the Black and Aegean Seas. What was once a single system suddenly became a patchwork of several. Nevertheless, the separate entities still relied on each other for the smooth functioning of their power supplies. Hence, the Treaty Establishing the Energy Community was signed in October 2005 in Athens, Greece, and came into force on 1 July 2006.[6]

The established Energy Community has extended the European Union internal energy market to SEE and beyond on the grounds of a legally binding framework. It has thereby provided a stable investment environment based on the rule of law, and tied the contracting parties with the European Union. Through its actions, the Energy Community contributed to the security of supply in wider Europe.

In the words of the European Commission,[7] "the Energy Community is about investments, economic development, security of energy supply and social stability; but — more than this — the Energy Community is also about solidarity, mutual trust and peace."

It is crucial that the improvement of the balance between energy supply and demand should go hand in hand with economic development in the region. This also means that countries should be prepared to draw fully on the substantial gains which can result from trading energy among themselves and with their neighbours.

Bearing that in mind, and in order to prepare for enhanced sub-regional cooperation, RHMSS/SEEVCCC established closer links with the Public Enterprise Electric Power Industry of Serbia (EPS). EPS joined the efforts to hold regular SEECOFs with a view to providing tailored climate services for the benefit of the energy sector in the region. The support coming from EPS is twofold: a financial one, enabling regular SEECOFs to take place, and the one realized through the contribution of EPS experts to SEECOF deliberations and improving the dialogue between provider and end user. Very important knowledge is shared regarding the energy production/consumption planning and related dependence on weather and climate conditions.

Building on the existing collaboration and future requirements of the energy sector, but also taking into account the potential of both entities, RHMSS/SEEVCCC and EPS are considering formalizing the partnership through the long-term agreement which would also involve private entities (establishing a public private partnership). The main areas of collaboration include, but are not limited to, a climate watch system, observational networks, computational resources and telecommunications.

Further developments

The long-term vision in research and development activities is focused on the creation of a regional centre of excellence in the frame of the European network of WMO climate centres. This vision will be achieved through:

- Strengthening research and development capacities in SEE
- Setting up a sub-regional climate prediction system in collaboration with the scientific diaspora from SEE
- Joining in new world climate systems (GFCS, WMO/Atmospheric Research and Environment Programme Sand and Dust Storm Warning Advisory and Assessment System, World Climate Research Programme)
- Adhering to the activities of the IPCC
- Further enhancing partnerships with regional and international organizations active in climate-related matters.

Image: RHMSS

Tailored climate services for the benefit of the energy sector lead to more efficient energy supplies

VI
Transport and Infrastructure

Climate services for large engineering projects in China

Song Lianchun, Chao Qingchen, Zhou Botao, Xu Hongmei, Chen Xianyan, Xu Ying
Beijing Climate Center, China Meteorological Administration

Large engineering projects are extremely sensitive to environment, especially to climate change and extreme events. Climate factors have been key influences on the secure design, investment cost and operational profit of engineering projects. Climate change can alter the current status of water cycle and energy balance, which in turn results in the change in the theoretical functional relationship of historical data that the engineering design is based on, thereby affecting the design and operational management of the project and the life of the building materials. Moreover, the intensity of extreme climate events and probabilistic risks has also become an important factor restricting the construction of large engineering projects.

Thus, the following are very helpful in promoting the climate adaption of large engineering projects:

- Objectively assessing climate demands during the design, construction and operational management of the project
- Strengthening tailored climate monitoring, impact assessment and projection
- Providing effective climate information.

Qinghai-Tibet railway project

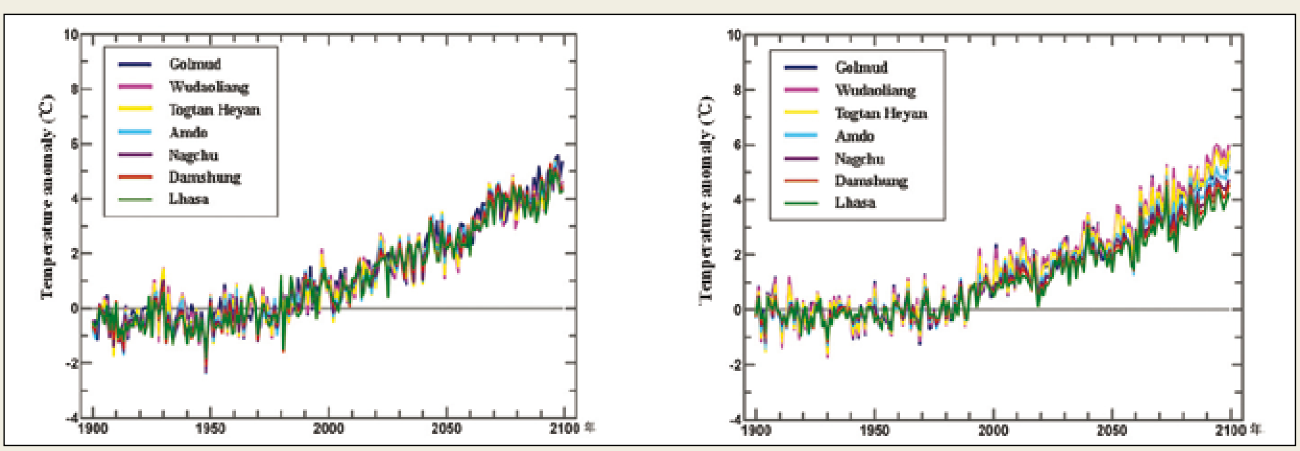
The Qinghai-Tibet railway begins in Xining, Qinghai Province in the north and passes through Golmud before ending in Lhasa, in the Tibet Autonomous Region. It spans about 1,956 km with a permafrost length of 632 km, of which continuous permafrost is about 550 km in length and 82 km is island discontinuous permafrost.

Permafrost is the foremost challenge faced by the Qinghai-Tibet railway construction project. Most of the permafrost on the Qinghai-Tibet plateau is warm permafrost which is

Adverse impacts of snow cover on the normal railway transport

Image: Qinghai Meteorological Bureau

Changes in the lowest winter temperature (left) and the highest summer temperature (right) over the stations along the Qinghai-Tibet railway



Source: CMA

easily affected by engineering processes and climate change, and this can produce thaw settlement. In addition, mountain torrents and debris flow in summer, snow storms and ice cover in spring and winter, low temperature, frost and sand storms all have adverse impacts on normal railway transport.

Intensive climate monitoring

The linear structure of the railway means that a natural disaster affecting part of the line will affect its overall operations. In order to provide better climate services for the Qinghai-Tibet railway, on the basis of the full application of existing meteorological data, 2009 saw the addition of 21 new observation stations to monitor precipitation and air temperature along the Xining-Golmud line and 16 observation stations to monitor the ground temperature for permafrost between Golmud and Lhasa.

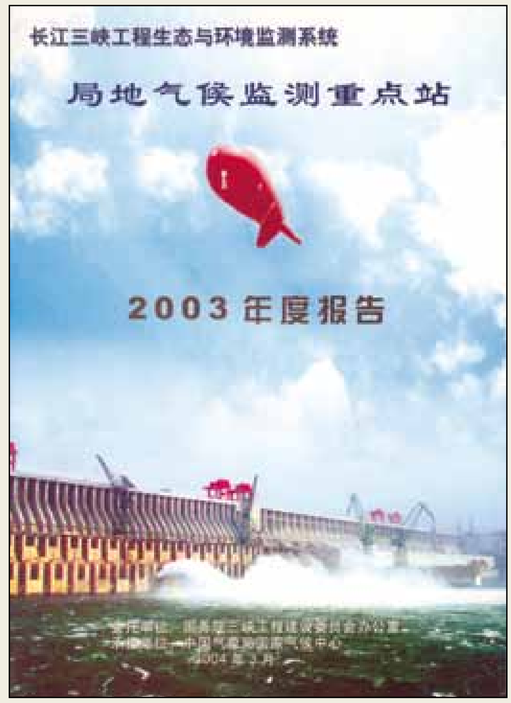
The permafrost environment along the Qinghai-Tibet railway is extremely sensitive to climate change. In order to provide climate information regarding the impacts of long-term climate change (30-50 years in the future), future climate change on the Qinghai-Tibet plateau and along the Qinghai-Tibet railway was projected using results from global and regional climate models. Related climate change information was also issued, including the annual mean temperature, the highest and lowest temperature, and the highest summer temperature as well as the lowest winter temperature over the Qinghai-Tibet plateau and along the Qinghai-Tibet railway.

Landslides, debris flow and other events resulting from intensive or continuous rainfall along the Qinghai-Tibet railway during flood seasons (June-September) may cause transport failure. In response to this, a tailored rainfall forecast is conducted along the railway. Special forecast information on important weather processes is issued one or two days in advance if moderate or above-normal rain occurs during the flooding season. In response to the frost heave phenomenon happening along the north section of the Xining-Golmud line around Qinghai Lake in winter (late November to January of the following year), soil freezing and melting indexes were developed with the use of observational permafrost data around the Qinghai Lake to monitor and assess permafrost change. Monitoring information on changes in permafrost depth is also issued. Relevant climate information and products are issued by national and provincial special websites, light-emitting diode electronic displays, mobile short messages, special information reports and so on.

Image: Qinghai Meteorological Bureau

The Qinghai-Tibet railway crosses the permafrost area

The *Annual Report on Climate Monitoring of the Three Gorges Reservoir Area*



Source: CMA

Service benefits

During the construction of the Qinghai-Tibet railway various permafrost-protective measures have been taken to increase the stability of frozen road bases, according to climate models and statistical projection results and in reference to the experience and lessons of other countries in the high latitudes. In operation, based on the relevant climate information, the Qinghai-Tibet Railway Corporation prepares flood-prevention resources in flood-prone regions, with timely management of freezing or melting events in winter. These measures guarantee the safe running of trains, and play important roles in disaster prevention and mitigation.

The Three Gorges project

The Three Gorges project spans the Yangtze River by the town of Sandouping, which is located in Xiling Gorge, Yichang, Hubei Province. The drainage area controlled by the Three Gorges project is about one million square km. Its total reservoir capacity is 39.3 billion cubic metres, which can reduce the peak flow by around 27,000-33,000 cubic metres per second when handled properly. In order to ensure its safe operation, local climate monitoring, assessment and projection services are needed.

Local climate monitoring

The National Climate Center (NCC), China Meteorological Administration (CMA) have initiated special climate observations in the Three Gorges area since 1996. This has been fully formed as a climate monitoring net between

Local climate observation station near the Three Gorges Reservoir Area

NCC, Hubei Meteorological Bureau and Chongqing Meteorological Bureau, which is targeted to provide climate information for the Three Gorges project. In 2009, three 100-metre gradient tower observation stations, 12 visibility observation stations and 15 multi-variable automatic weather observation stations were added in response to the need for safe operation of the Three Gorges project.

Based on the data provided by the local climate monitoring system of the Three Gorges reservoir area, an annual monitoring report including general climate characteristics, major disasters and their impacts has been produced since 1996. Climate monitoring reports for four seasons have been added since 2000. In 2005, a direct instant response system for climate events and meteorological disasters in the Three Gorges reservoir area was established, with the addition of a *Special Report on Eco-environmental Monitoring of the Three Gorges Project (Express)* to issue timely information on the occurrence and impacts of climate disasters. Up to July 2012, NCC CMA has published 16 issues of the *Climate Monitoring Bulletin of the Three Gorges Project,* 45 issues of the *Local Climate Monitoring Quarterly Report of the Three Gorges Project and 226 issues of the Special Report on Eco-Environment Monitoring of the Three Gorges Project.*

In response to the influence of future climate change on the safe operation of the Three Gorges project, expected changes of the mean climate and extreme climate events in the Three Gorges during 2015 to 2050 were projected based on the results of global and regional climate models.

Experiences

Different design philosophies, project characteristics and functions of large engineering projects have different sensitivities to climate change and extreme events. We need to build on the lessons learned from our experience of working with climate adaptation on large engineering projects.

First, the right climate data and information is needed to support decision- and policy-making.

Descriptions of current and future climate and impacts are necessary, but often insufficient. The data and information must be relevant, interpreted in the context of the decision required and able to be integrated with other relevant information within the decision- or policy-making processes.

The climate services needed for large engineering projects require the continuous assessment of climate information during the different stages of confirmation, construction and operation of large engineering projects. Users' needs for the climate information change during different stages. In order to meet users' demands, climate monitoring, impact assessment, adaptation options and climate information publishing need to be adjusted based on user feedback.

Climate monitoring data are the basis of climate services for large engineering projects. If existing climate monitoring can't fully meet the climate service demands of these projects, intensive climate observation should be conducted to meet their construction and operation requirements. This can be approached from the observation network layout, observation elements and frequency.

The timescale of climate services for large engineering projects covers pre-evaluation, real-time evaluation and projection. The content includes environmental impact and risk assessment before project creation; assessment during the construction and operation; the influence of regional climate on the security of large engineering projects; and adaption measures to climate change. Therefore, assessment methods should be diversified for different timescales and content.

Experience has also shown that sustained engagement of users and providers of climate information, supporting continuous learning and sharing, offers the potential for effectively addressing limitations. This engagement can promote continuous improvements in products and their delivery informed by an understanding of users' needs and science capabilities and developments (both of which are continually evolving).

Remaining challenges and continuing efforts

Climate data and information is traditionally targeted to describe past, present and – in the case of scenarios and projections – future climates. These are essential, but in the case of supporting adaptation decision-making, they can fall short of meeting requirements and lead to inaction. Addressing this challenge is easier said than done, but is increasingly being recognized as necessary for successful adaptation.

With rapid economic growth, the demand for climate services among large engineering projects in China is constantly increasing. We should apply our successful experiences into other fields by summarizing past climate service practice on large engineering projects.

There is limited understanding of the nature and capacities of the evolving, diverse and growing user communities, especially the decision- and policy-making communities. There is a need to improve understanding of what climate data and information are needed and how they can inform decision-making and policy development processes, especially when faced with the associated uncertainties and complexities of climate vulnerabilities and risks, and adaptation responses.

Understanding is also limited when it comes to the real needs of user communities as they strive to understand vulnerabilities and risks and to assess, implement and evaluate adaptation responses. Sustained engagement is needed among users and providers of climate information, reflecting the evolving nature and scope of users and their needs and the updating of available climate information.

Building resilience to future climate change in ports: Terminal Marítimo Muelles el Bosque in Colombia

Jean-Christophe Amado and Richenda Connell, Acclimatise

Ports are on the frontlines of climate change, by virtue of their locations on coasts exposed to sea level rise and storms or on rivers susceptible to flooding or droughts.

Weather impacts on ports have made headlines this past decade. In 2005, Hurricane Katrina's seven-meter-high storm surge destroyed most of the infrastructure of Gulfport, the third busiest port in the US Gulf of Mexico, knocking down container cranes, blowing apart storage sheds and pushing barges hundreds of feet inland. In 2010, after repairs worth over US$250 million and new investments, the port still only operated at 80 per cent of its pre-Katrina capacity.[1] Meanwhile, Hurricane Ike caused US$2.4 billion of damage to Texas ports and waterways. To a certain degree, these storms indicate the scale of the future costs that could be suffered because of more extreme weather.

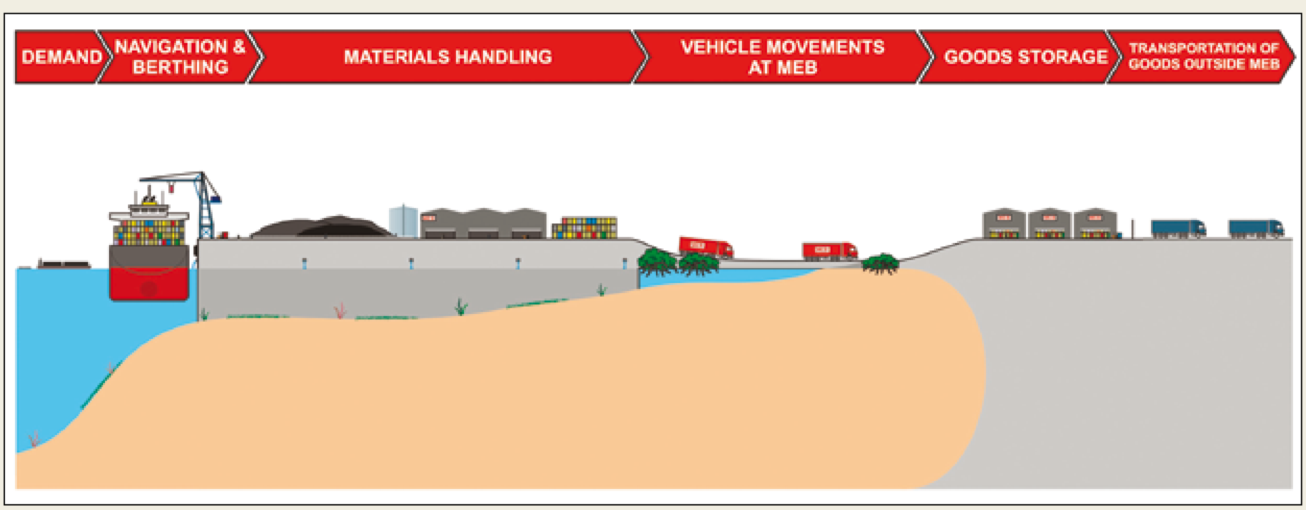
A recent Bloomberg article singled out 20 port cities worldwide for the high risks they face due to climate change, putting assets worth billions of dollars at risk.[2] A 2011 Stanford University survey of port authorities revealed that climate change, together with rising sea levels, ranks high on their list of concerns, though few have concrete plans to adapt to this new reality.

Beyond concerns about greenhouse gas emissions, climate change risk for ports worldwide is multifaceted. It does not stop at increased risk of flooding or reduced navigability of access channels, but also includes potential shifts in shipping levels or patterns, and effects on environmental performance. Such risks can bear significant costs for port operators if nothing is done to avoid impacts and reduce vulnerability.

A port's reputation for reliability is key to its commercial success, and as such ports that build resilience against the expected impacts of climate change stand to fare better than their competitors.[3]

Recognizing the potential significance of climate change to port performance, the International Financial Corporation together with Terminal Marítimo Muelles el Bosque (MEB), a large port in Cartagena, Colombia, collaborated in a study to assess risks and opportunities for MEB as well as for ports in general.

Led by the specialized climate risk management consultancy Acclimatise, a group of international consultants joined respected Colombian academics and experts in an evaluation of financial impacts for the port based on a detailed analysis of climate observations and climate change projections. Also considered were the available measures

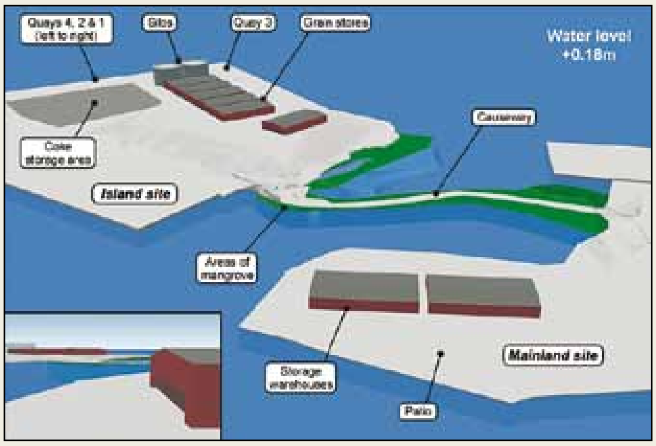


Key port activities which can be affected by climate change

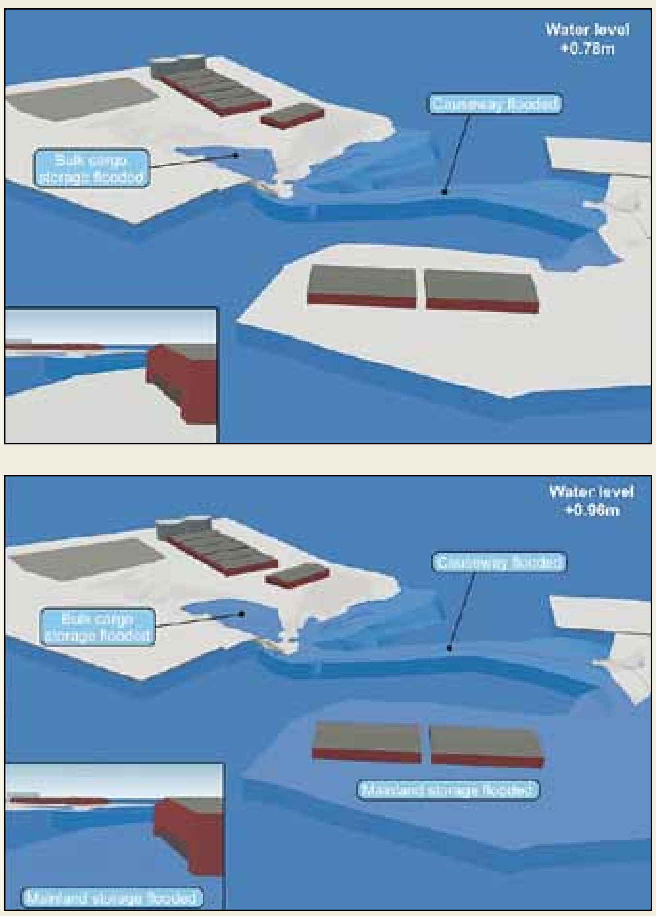
Source: International Finance Corporation

Interruptions to vehicle movements due to seawater flooding of the port

- Lowest area: causeway linking mainland and island sites (0.6m above port plan datum)
- Causeway projected to flood at highest tides by 2018 and 2015 (observed and accelerated SLR scenarios).
- Mainland patio and storage warehouses projected to flood at highest tides by 2070 and 2050 (observed and accelerated SLR scenarios).
- Quays not projected to flood.



Mean sea level at MEB in 2000



Projected flooding (areas in blue) during highest spring tides and highest water level in 2050 in the observed (middle) and accelerated (bottom) scenarios

Source: International Finance Corporation

that the port operator could take to increase the resilience of its activities and assets over the coming decades.

There are a number of ways ports could be affected by climate change. Risks will depend on the location (for example, tropical or extra-tropical, areas with permafrost or sea ice, lakes or rivers) and functions of ports (such as cargo handling, warehousing, pilotage, dredging or passenger cruises). Thanks to its location on a natural harbour, MEB is relatively sheltered from harsh climatic and oceanic conditions. As such, overall there are only a small number of ways that MEB's performance could be significantly affected by climate change. These include:

- Reduced vehicle movements inside the port due to seawater flooding
- Decreased global trade and US grain exports to Colombia affecting MEB's cargo transport revenues
- Increased risk of damage to goods stored in the port due to flooding
- Degradation of mangroves around the port.

Other ports around the world could suffer a wider range of risks associated with a changing climate.

Of all these expected climate change impacts, flooding due to local sea level rise constitutes the most serious issue for the port. Following the study, the port announced that it would invest in additional flood protection.

Project details

MEB is the second-largest port in the bay of Cartagena in Colombia. Although it benefits from one of the most secure locations on Colombia's Caribbean coast, offering natural shelter from high winds, high waves and storm surges, MEB remains exposed to some of the effects of climate change, such as sea level rise, increased rainfall intensity and warmer temperatures.

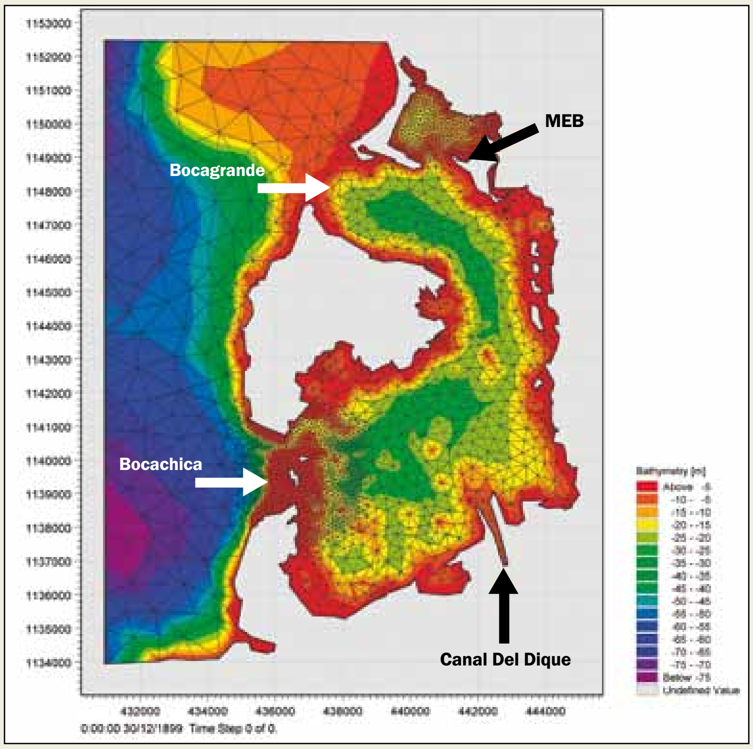
Experts from the University of Oxford in the UK and Universidad Nacional de Colombia assisted the team in analysing observed climate variables and trends, as well as climate model projections for the Cartagena region.

Climate and ocean observations clearly show that climate change is already underway in Cartagena, where average temperatures have risen by more than 0.7° C since the early twentieth century, precipitation has become more intense, and sea level has been creeping up at a rate of 5.6 mm a year.

However, there is a dearth of local data about short-term, extreme weather and oceanic events such as gust winds, heavy downpours or storm surges. Climate data analysis is complicated in countries like Colombia by the fact that there is so far little agreement between climate models over future precipitation, due to complex local topography and the lack of understanding of how tropical cyclones may change in the future.

To overcome these limitations, the study relied on different sources of climate data to explore a wide envelope of plausible changes in climate. Where outputs diverge between different datasets or methods, a set of climate scenarios was considered in the risk and adaptation assessment.

Navigation and berthing



2D model grid of Bay of Cartagena. The two access channels are indicated in white font

- Bay of Cartagena offers protection against waves and storm surges
- Characterized by low tides and infrequent navigation problems
- MEB's quays and operability ranges of cranes and fenders can cope with observed or accelerated SLR scenarios this century
- No indication of change in sedimentation rates from Canal del Dique
- Plans by other port operators to increase water depths in Bay to accommodate Post-Panamax ships
- Increased draft due to SLR will reduce dredging: total savings by 2100 of $325,000 to $400,000
- In comparison, dredging higher in competing ports where sedimentation from runoff is a key factor (e.g. Buenaventura and Barranquilla)

Source: International Finance Corporation

Of the eight areas of vulnerability that the study assessed, future flood risk and the associated impacts on vehicle movements and stored goods inside the port showed the most interesting results, bearing lessons for many coastal ports worldwide.

Coastal and port experts worked alongside climate risk experts to model projected seawater flooding. Using a 3D model of the port, flood maps were drawn for the years 2050 and 2100 by comparing port elevation in different sea level rise scenarios during the highest recorded water levels on the bay of Cartagena and during a 1-in-300-year storm surge.

Whichever sea level rise scenario is considered, the lowest part of the port (a causeway road) will flood during the highest spring tide by 2018 if nothing is done to adapt. Associated costs will depend on flood depth; for instance, during flooding greater than 30 cm vehicles will not be able to move, halting cargo movements and leading to costly delays for the port operator. More importantly, such problems can degrade a port's reputation and push customers to look for alternative transport routes.

In the case of MEB, flooding losses could amount to 3-7 per cent of annual projected earnings by 2032. Without action, MEB's earnings could be strongly affected, if not totally wiped out, in the second half of this century.

Among the measures that a coastal port like MEB can take to increase its resilience against climate change, the costs and benefits of raising parts of the port were considered. Results overwhelmingly prove that it is much cheaper for MEB to invest in adaptation than to suffer increased flood risk. Further, it appears to be economically sounder for MEB to raise its causeway in increments rather than all at once; this has the added advantage of adapting the causeway height to the observed rate of sea level rise.

Lessons for ports worldwide

Due to the vital role they play in international trade and global supply chains, climate change impacts on ports stand to have wider economic effects. Studies such as this one demonstrate that adaptation investments make economic sense in some cases.

MEB is a prime example of a company investing in climate resilience for business reasons. The study detailed a number of risks associated with climate change, and sketched out a path towards climate resilience for the port. At the launch of the study results in April 2011, MEB's President, Gabriel Echavarría, announced a US$10 million investment to protect the port against future flood risk.

An enduring lesson from this work is that achieving meaningful climate risk and adaptation assessments without the collaboration of government agencies, local experts and trusted financial institutions is impossible. Such alliances guarantee access to quality data and information, and possibly lay the foundation for getting finance to support climate resilience investments. This integrated work model (more than four Colombian government departments and 10 research groups contributed data, information or knowledge to this study) bore very positive results in this study. Further, this work produced a rigorous methodology which can be used by other ports wishing to undertake similar assessments.

This article summarises reports that are available in full at www.ifc.org/climaterisks

Exploiting the changing global climate

Chihito Kusabiraki, President, Representative Managing Director, Weathernews

Weathernews founder Hiro Ishibashi regarded changing global temperatures as "a convenient truth." The company he founded to help protect the lives of sailors through better maritime weather information has evolved into a full service 'weather-mall' that provides risk information for all modes of transportation, plus a diverse range of other industries and the general public. However, the final frontier of Ishibashi's vision for his company was not space, but the Arctic Ocean. In the unconventional fashion typical of the company's culture, the key to challenging this final frontier was actually to reach into space to build infrastructure for monitoring the progressive seasonal melting seen over the last five years in the Arctic. This ultimate goal of safer, faster and 'eco-friendly' routing is now on the verge of becoming realized, as a revolutionary route advisory service for the shipping industry.

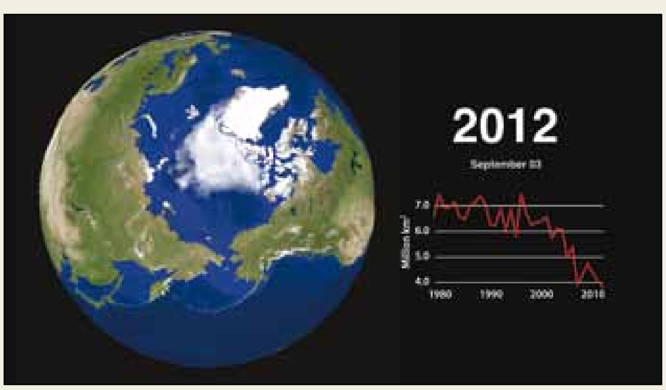
Until now, commercial shipping traffic had only two options to get from Europe to Asia:

- A 6,000 kilometre-long route through the Suez Canal that puts the vessel at risk of piracy
- An even longer 8,000 kilometre route around the tip of South Africa which puts the vessel at risk of freak waves.

Both of these options consume many metric tons of fuel which accounts for much of the CO_2 released into the Earth's atmosphere. However, thanks to progressively receding ice extent in the arctic ocean observed in recent years, there is now a third option: the considerably shorter (and cleaner) Polar Route.

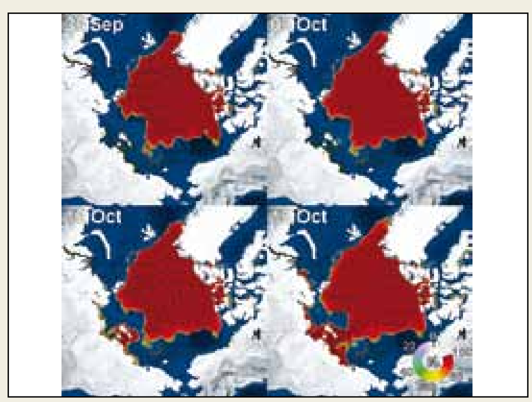
By sailing the Polar Route (also known as the Northern Sea Route), a vessel can make the trip in a fraction of the time that the traditional options would take, thus burning less fuel and releasing fewer carbon emissions. Weathernews has been a passionate advocate of this alternative route in the shipping industry, and has already assisted voyages through the passage by means of the Weathernews Global Ice Center (GIC). To foster the adoption of this route by global shipping companies, Weathernews has committed its human and financial resources to providing more reliable information to confirm and predict favourable sailing conditions along the Arctic Ocean's northeast and northwest passages. At Weathernews, the key for success is low-cost satellite monitoring.

Decreasing Arctic ice area



Source: Weathernews

The Polar Route (4,000 km), offering shorter, cleaner alternative to the Suez Canal Route (6,000 km)



Simulation model output from the I-SEE Engine, which analyzes factors like sea temperature, current, and sea-ice observations

Source: Weathernews

In November 2012, Weathernews will witness the launch of WNISAT-1 to increase the data available to the GIC at a reasonable cost. This will be the first of several compact and inexpensive satellites with a 5-10 year lifespan that will provide real-time monitoring data on ice conditions in the Arctic Ocean. Eventually, the accumulated data will allow for the prediction of ice distribution, thickness and movement using our simulation model, the I-SEE Engine. Only by predicting the seasonal ice extent in the Arctic can the shipping industry make the necessary long-term planning for total optimization of voyage operations that will significantly reduce carbon emissions.

Evolved weather routing for fuel efficient voyages

Traditionally, weather routing services have been used by the shipping industry to ensure the safe arrival of a vessel and its crew and cargo. However, as a natural by-product of sailing the safest route through fair weather, a vessel also often benefits from increased engine efficiency and fuel savings. Over the course of three decades at Weathernews, this core service has evolved into a service for optimizing voyage fuel efficiency. The primary merit of these services for the shipping industry is reduced operating costs through safer and shorter voyages. However, pressure from the International Maritime Organization on the shipping industry to reduce emissions has made the industry realize that the 'eco' in ecology is really the same 'eco' as in economy. The next stage in the evolution of optimized voyage planning is to offer the Polar Route as an alternative to the longer traditional trade routes, in order to help the shipping industry meet its eco-targets.

Global Ice Center: using existing resources

At Weathernews, our tradition is always to first ask what we can do to help this issue. How can we help our partners in the shipping industry optimize their operations and reduce carbon emissions from ship engine exhaust? The answer was to establish the GIC in 2008 at Weathernews Global Center in Japan with help from the Center for Environmental Remote Sensing at Chiba University. The role of the GIC is collection, analysis and distribution of all relevant information from related organizations on global ice conditions that can be used not only by our customers in the shipping industry, but also by the general public through the GIC website.[1]

The WNISAT-1 nano-satellite has a laser for measuring CO_2 levels

Source: Weathernews

One of the GIC's special contributions is a two-week forecast of changes in ice concentration, thickness and distribution. This forecast is produced using simulation model output from the GIC's I-SEE Engine, which analyzes factors like sea temperature, current, and sea-ice observations. Although a voyage through the Arctic Ocean takes about a month, the I-SEE Engine's predictions are enough to assist operators in planning and making a final go/no-go decision for polar transit voyages. Last summer, the GIC assisted in the safe passage of a Japanese-owned/Danish-operated bulk carrier's voyage from Murmansk to Jintang through the Polar Route. Thanks to the combined efforts of the owner, operator, a pair of Russian ice-breakers and real-time navigation support from Weathernews, the vessel completed the icy voyage without incident in only 22 days; half the time it would have taken through the Suez Canal, or a third of the days at sea sailing around the Cape of Good Hope.

WNISAT-1: Cost effective-monitoring

Hiro Ishibashi's shared dream for Weathernews service will be realized in November 2012 with the launch of a satellite designed and built by Weathernews in conjunction with Axel Space, a small domestic start-up founded by Tokyo University graduates. Data from the satellite will monitor and eventually help predict conditions in the Arctic necessary to providing Polar routing to the shipping industry. Unlike traditionally large and expensive satellites designed to fulfil a number of roles, WNISAT-1 is a nano-satellite only 27 cm wide and weighing less than 10 kilograms. Equipped with only a camera for observing sea-ice and laser for measuring CO_2 levels, WNISAT-1 represents the new generation of modern satellites developed for highly-focused applications. These two measuring instruments provide just enough functionality to facilitate the GIC's monitoring infrastructure for a Polar routing service. Moreover, the goal was to add this functionality at a reasonable development, deployment and operating cost so as to provide services cost-effective enough to encourage widespread use in the shipping industry, as well as being accessible to the general public to raise awareness of the issue.

Raising awareness to reduce energy consumption

Weathernews also hopes to use the satellite to conduct public science experiments where ordinary people can participate in CO_2 monitoring to help raise awareness and inspire everyone, as Weathernews has done, to ask: "What can we do to help the issue?" Japan is one of the world's biggest consumers of electricity, and the many bright lights of the Tokyo metropolitan area can easily be spotted from Earth orbit. It is our hope that raising awareness will allow Japan to make an even more substantial contribution to the reduction of CO_2 emissions, not only in the global shipping industry, but in Japan's domestic energy industry as well.

Climate services to support development: the Qatar Meteorological Department

Ahmed Abdullah Mohamed, Director, Qatar Meteorological Department

The State of Qatar occupies a peninsula on the western coast of the Arabian Gulf. The general climate of Qatar is described as being a hot desert climate of the type BWh, according to Köppen's climate classification scheme. Studies of meteorological data accumulated over a sufficiently long period in the region demonstrate various aspects of the climate.

The Qatar climate is dry with very little rainfall, mostly confined to winter and spring. In addition, most of the rainfall is contributed by thunderstorm activity due to occasional extra-tropical (synoptic scale) systems approaching the region from the west.

The summer season is characterized by extreme high temperatures and 'shamals' (strong north-westerly winds) with disturbed sea-state conditions during shamal periods. At times sand and dust storms are associated with these strong winds. Increased humidity coupled with the high temperature makes the weather very sultry in this season.

The State of Qatar is a peninsula on the western coast of the Arabian Gulf, with a hot desert climate

Source: QMD

Winter is pleasant and on a few occasions, under the influence of shamals, the sea state becomes rough, adversely affecting the offshore oil and gas operations. Most of the annual rainfall is confined to this season and the majority of it is contributed by thunderstorms triggered by middle latitude systems passing over the region.

The region has developed rapidly in the past few decades in terms of industrialization, urbanization and standards of living with modern amenities. Whether linked with these factors or not, many climatic parameters are showing significant changes.

The climate of Qatar is basically an arid one. Winter months are characterized by mean monthly temperatures of less than 20º C and the summer season by temperatures above 30º C. Some rainfall occurs in winter and spring. Although land heating is very high during the summer months of June, July and August, the region is free from rainfall activity under the influence of a subtropical high. The mean daily temperatures during June, July and August are 33.9º C, 34.7º C and 34.3º C respectively in Doha. The mean daily maximum temperatures in these months are 41.2º C, 41.5º C and 40.7º C. The climatic normal (1962-1990) values of mean minimum temperature for December, January and February are 14.9º C, 12.7º C and 13.7º C respectively. In March, this rises to 16.8º C. Mean minimum temperatures do not drop below 10º C in any winter month.

The prevailing wind direction over the state is mostly north-westerly. Other wind directions do occur but with a lesser frequency. When these winds are strong in summer, they are called 'summer shamals' and in winter they are known as 'winter shamals'. The summer shamals usually occur for about 40 days between May and July with considerable inter-annual variation. On some occasions, sand and dust storms are observed, associated with the shamals.

The frequency of thunderstorms in the Arabian Gulf is well correlated with rainfall distribution. The migration of middle latitude lows and highs over the Arabian region from the north-west takes place from the end of November to March, and in some years continues until April. The triggering mechanism needed for the development of thunderstorm activity lies mainly with these middle latitude synoptic systems approaching the state from the northwest.

Qatar Meteorological Department (QMD), one of the departments of the Qatar Civil Aviation Authority, consists of four sections:
- Climate
- Forecast and Analysis
- Observation
- Network.

Major improvements

Having realized the need to better our services, and to migrate all our operations to state-of-the-art technology, QMD underwent, and successfully completed, a full modernization and upgrading project in all sections including various facilities with Météo-France International, using the latest equipment and infrastructure. Major achievements in this respect include:
- 12 automatic weather stations in addition to two buoys for marine observations
- Four manned observing stations
- The latest forecast techniques using Synergie
- Climate database management using CliSys
- Accurate rainfall tracking and forecasts using stationary and mobile weather radar
- Mobile meteorological assistance for major events and exhibitions using Meteo Mobile vehicles
- Modern communication and IT systems for the Network section
- State-of-the-art facilities for forecasting and aviation services
- A numerical weather prediction unit for short and medium-term forecasts
- Interaction with the public using social networks like Facebook and Twitter, and the *www.qweather.net* website.

The Climate section has very good records of climatological data for all working stations, with more than 50 years of records for Doha Airport station. User-friendly meteorological applications have been developed for mobile, tablet and PC users and a major project is underway to create a regional climate centre in Doha.

Images: QMD

New Doha International Airport (NDIA) is currently under construction. The design takes account of the present and future climate, with extensive planting of indigenous plants and innovative use of recycled water

At the beginning of 2012 the numerical weather prediction unit was initialized in the forecast office, as an ongoing project to be self-sufficient in the modelling aspect of meteorology, at least for the State of Qatar. Improvements were made to communication lines with the relevant Government agencies for severe weather occurrences.

In addition, in December 2011 QMD was proud to be accredited with the ISO 9001:2008 Quality Management System by the certification authority Quality Austria, for the provision of meteorological services. This means the added responsibility of maintaining a superior level of services compliant with national and international standards set by the World Meteorological Organization.

During the last decade the State of Qatar has carried out massive development in different sectors such as infrastructure projects, especially as a boom in construction led to an increase in enquiries related to meteorological data from 2006 onwards. This has been achieved in a very professional way. The types of information include forecasting data, climate data, tidal predictions and specialized reports. These data have been provided in hard and soft copy at very low cost. As Qatar is now embarking on very large developments projects in all fields, which will include almost all aspects of the infrastructure, QMD has a part to play by providing all climatological data for structural works, planning, transport, water desalination, energy projects, and its evolving role in petroleum and gas works.

QMD is an active member of the Qatar Environment Committee and participates in all local and international meetings. In addition, QMD is one of the parties that contributed to the Qatar Initial National Communication to the United Nations Framework Convention on Climate Change issued in 2011.

Climate services for major projects

Through its modernization, QMD is very much qualified to provide professional and accurate meteorological services. The State of Qatar is to host major international events during the coming years, the most remarkable of these being the FIFA World Cup 2022, which will be a welcome challenge for the Qatar Government and its people. We expect that QMD will have an excellent chance to show its competence in contributing to the success of the tournament. QMD was involved in all stages of preparing the bid to host the tournament, supplying all meteorological and climatological data as required by the committee – including data relating to temperature, relative humidity, wind speed and direction and rainfall.

In preparation for the FIFA World Cup, the Qatar 2022 team, alongside international climate control experts, have developed environmentally friendly outdoor technologies and strategies to be deployed at stadiums, training sites and fan zones. This has involved the design of areas of comfort for fans, delegates, teams, media, match officials and the FIFA family.

The parameters used were identified with specific reference to local climatic conditions. Any evaluation of climate conditions cannot be defined solely in terms of outside air temperature. Solar radiation, wind and humidity also need to be factored into the equation. Pioneering architectural and climate engineering strategies have been created and applied.

The cooling strategy for Qatar 2022 ensures comfort for all, with innovative fully solar powered cooling systems keeping the tournament's carbon footprint low and the comfort high. The strategy has three main elements:

- Focusing on low energy concepts to create a thermal comfort
- Apply innovative green highly effective cooling technology
- Produce electrical energy by integrated photovoltaic systems.

Enhanced outdoor comfort is achieved through a combination of passive and active strategies. Passive strategies involve architectural design including sun shading and wind protection. Active strategies involve climate engineering, including night radiation, radiation cooling and soft conditioning.

Images: Qatar 2022

QMD was involved in all stages of preparing the bid to host the Fifa World Cup 2022, and is continuing to support the project to ensure comfort for visitors at all stadiums and related facilities

We are now continuing with the preparations and planning for the event, from structural works to environmental aspects and forecasts, and weather and climatological reports for players, participants and visitors – not to mention the huge project of adapting and changing the weather by providing air conditioning for the football grounds and the areas around them.

QMD gained valuable experience for the World Cup project during the 16th Asian Games in 2006 in Doha and the Arab Olympic games in 2010. This and the strategies developed for 2022 can serve as valuable models for other countries.

Other specific services provided include climatological data and analysis and special weather reports for the Doha Olympic Committee teams, and services for the new Doha International Airport steering committee, including data on temperature, relative humidity, wind speed and direction, rainfall, visibility, cloud cover and wind gust, in addition to long term climatological reports.

QMD regularly supports contractors for large infrastructure project, providing climatological data in the first stages of designing their projects, including towering buildings, roads, planning of towns and factories. In most cases, QMD continues to provide support throughout the course of a project, remaining in contact with project teams throughout. When required, QMD can establish special offices or stations at the sites until the end of the project.

Research initiatives

QMD has made a significant contribution in the research field with universities and institutes. We recently partnered with the Qatar Environment and Energy Research Institute (a member of Qatar Foundation) in a major research project about heat hazard modelling for predicting heat waves in Qatar during next five years. This will show how they affect people, and helping health authorities. In addition, QMD is involved in an ongoing project with the Qatar National Food Security Programme in a study of an extensive plan for food security in Qatar.

The QMD Climate section provides customers from Government departments, companies, contractors and other sectors with all types of climatological services and requested specified reports alongside the routine climatological summaries.

The Forecast and Analysis section is an integral part of QMD, with an enormous responsibility as it raises awareness of the quality of the services we must provide and the wide spectrum of customers we serve. The responsibility of providing accurate and true forecasts to our customers is of the utmost importance for the section. In addition to providing forecasts to the various Government entities in the State of Qatar (military and civilian), and for the aeronautical services (all the various airlines that pass over Qatar skies, in addition to our national airline, Qatar Airways), the section also provides forecasts to the private sector — and of course, to the ordinary citizens and expatriates as well as visitors to Qatar.

Climate change adaptation: when there is a will, there is a rail way!

Alexander Veitch and Camille Bailly, Sustainable Development Unit, International Union of Railways

Despite efforts at mitigation, our climate is changing and all sectors of the economy need to adapt to it, especially large infrastructure managers and landowners like the railway industry. Research and information sharing by the International Union of Railways (UIC) illustrates that if the right information is given in time to the right stakeholders, then good adaptation strategies can be implemented, providing the possibility to mitigate the consequences of climate change.

Railways have been forming part of our landscapes for years and, as such, they have been constantly subject to the effects of the weather. Now, due to climate change, railways are more than ever exposed to hard weather conditions and thus, the need for adaptation is growing urgently. To survive extreme weather and to recover quickly from it, various strategies have been implemented by different railway companies aimed at coping with the impacts of flooding, storms and gales, intense short-time-period rainfall, extended rain periods, thunderstorms, hot temperatures and changing vegetation.

Many railways need to cope with Nordic conditions

ARISCC project

Following an initial feasibility study, which revealed how much its members were willing to implement adaptation strategies, UIC launched the Adaptation of Railway Infrastructure to Climate Change (ARISCC) project, which found good practice examples and case studies of adaptation plans and made recommendations on how to develop these strategies. One prerequisite for adaptation strategies in the railways, or indeed any other sector, is high-quality forecasts of likely future climate conditions, which in turn requires close cooperation with national meteorological associations.

Developing an adaptation plan

The ARISCC project team devised a clear process to guide railways through the process of developing their adaption plans. The first proposed step is to create a Vulnerability Map, which requires combining extreme weather and natural hazards data (using historical records, daily information and future forecasts), and overlaying this against parts of the railway network vulnerable to these extreme conditions.

To achieve the first step (the identification of possible hazards), it is recommended to use past weather information and natural hazard information to find the most risky areas of the railway network. Railways can be informed by climate institutions or in many cases keep their own records. This information can be stored in geographic information systems (GIS) to enable overlaying with other data sources. Railways also store a vast amount of data on historical weather and natural hazards – for example, Austrian and Swiss railways hold GIS databases of rockslides and avalanches over several decades.

In addition to past weather and natural hazard data, it is vital to have accurate and up-to-date weather information. Most railways have close working relationships with their national meterological agencies, and some actually collect their own weather data. The East Japan Railway Company, JR East, installed a monitoring system composed of an anemometer, a water gauge, a seismographic, a landslide detector, a snow gauge, a rail temperature gauge and a scouring detector. All data are sent to the Office of Climate Change, and monitored there in one centralized loca-

Increasing summer temperatures take their toll on existing rail infrastructure

tion. With the information, JR East can decide to restrict speed or suspend traffic, to protect the passengers and infrastructures.

The weather information enables companies to act quickly. For example, the Austrian company OBB launched a programme called InfraWeather. The preparative work included the development of a regional, meteorological model and GIS-based overlay of railway tracks and meteorological data. Thanks to all this information, OBB now has an online portal giving the storm, flood and snowfall forecast.

When predefined warning levels are reached, alert message are automatically generated by the system and sent by text messages, email, fax and telephone to all responsible people inside the company.

This allows more efficiency, improves management, saves costs and achieves the capacity building process.

The final piece of the jigsaw in terms of weather and natural hazard information is future climate and weather forecasts. This is the point at which meteorological organizations become crucial to the planning and future condition of the railway, as only they can provide this data. One challenge is to achieve the right level of detail in both temporal and spatial terms: climate adaptation is primarily a local issue, affecting very specific parts of the railway network. However, climate models tend to provide an overview on a regional or national scale. Also, railway infrastructure (track, signals, trains) lasts a long time (parts of the European railway network are well over 100 years old), and so it is important to have a reasonably long-term approach to climate forecasting.

Moving on from the weather and natural hazard data gathering, the vulnerability map then requires the identification of the railways' infrastructure assets in areas prone to hazards, and assessing the likely resilience of these assets. Overlaying the natural hazard zones and the areas where the infrastructure assets (such as, track, earthworks, bridges, tunnels, drainage systems, protective structures and signalling) are in a poor condition, it is possible to identify the priority zones.

From vulnerability mapping to risk management

Once the vulnerability mapping is completed, it is possible to carry out a risk evaluation relating to elements such as property, people, environment, reputation and finances. Having analysed the most endangered areas, railways can then act concretely by taking preventive and reactive measures. They can have a better weather warning system, improve technical standards, reinforce protective structures, take measures during incidents which aim at minimizing damage by rapid and targeted intervention, and improve resilience with more specific engineering recommendations.

With the right information given in time, railways have many ways to handle new hazards created by climate change. All these good practices can be exchanged to enable widespread information and act as a model for those who want to adapt to climate change.

Improving reliability

Tomorrow's Railways and Climate Change Adaptation (TRaCCA) was a research project aimed at providing tools and knowledge to improve the reliability of the railway network and at finding solutions to these problems. To do so, Britain's Network Rail collaborated with experts at the UK Met Office Hadley Centre, enabling the company to prioritize and scope exercises to meet statutory reporting deadlines aligned to Control Period 5 work covering the 2020s, 2030s and 2040s. Network Rail used detailed climate impact analyses on the selected priorities and implemented various tools.

Improving resilience

There are many practical ways in which railways are making their networks more resilient to extreme weather and natural hazards.

Wind

To face strong winds and gales, JR East equipped its tracks with windbreak fences.

Humid conditions

To manage hard rains, JR East decided to reinforce slopes and to protect scours. Train manufacturers are developing systems to cope with hot and humid conditions by managing air-flow, protecting the electronic control panel and installing condensers in the machines area.

Desert conditions

It is also possible to prepare railways infrastructure to resist desert conditions through measures such as equipping rolling stock with cyclonic filters, resizing the electronic equipment, cooling the power supply system or power converter and reinforcing the air-conditioning system.

Nordic conditions

Many railways companies need to handle Nordic conditions. For instance, JR East now benefits from anti-avalanche facilities and good snow removal equipment. Train manufacturers use systems that protect the mechanic components, the cabling, the coupler and local heating system and reinforce the isolation and the heating systems.

Once again, the need for relevant information is paramount. For instance, Finnish Railways duly considers weather forecasts in order to act locally. Indeed, as the temperature distributions in wintertime are extremely cold, the company decided to introduce specific materials in its rolling stocks to resist these conditions, such as stronger lubricants, new insulation methods or specific coating materials to prevent snow and ice adhesion.

Technical standards

Another way to adapt to new conditions is to develop standards; indeed, if new infrastructures are built to resist to such weather conditions, this will avoid future costs and damages. The European Federation of Railway Contractors advocates a change in standards. For instance, if bridges are built higher than currently, this will enable the railways to accommodate larger tidal ranges due to sea level rise over their lifespan, and the reinforcement of foundations will allow them to cope with higher magnitude flood events.

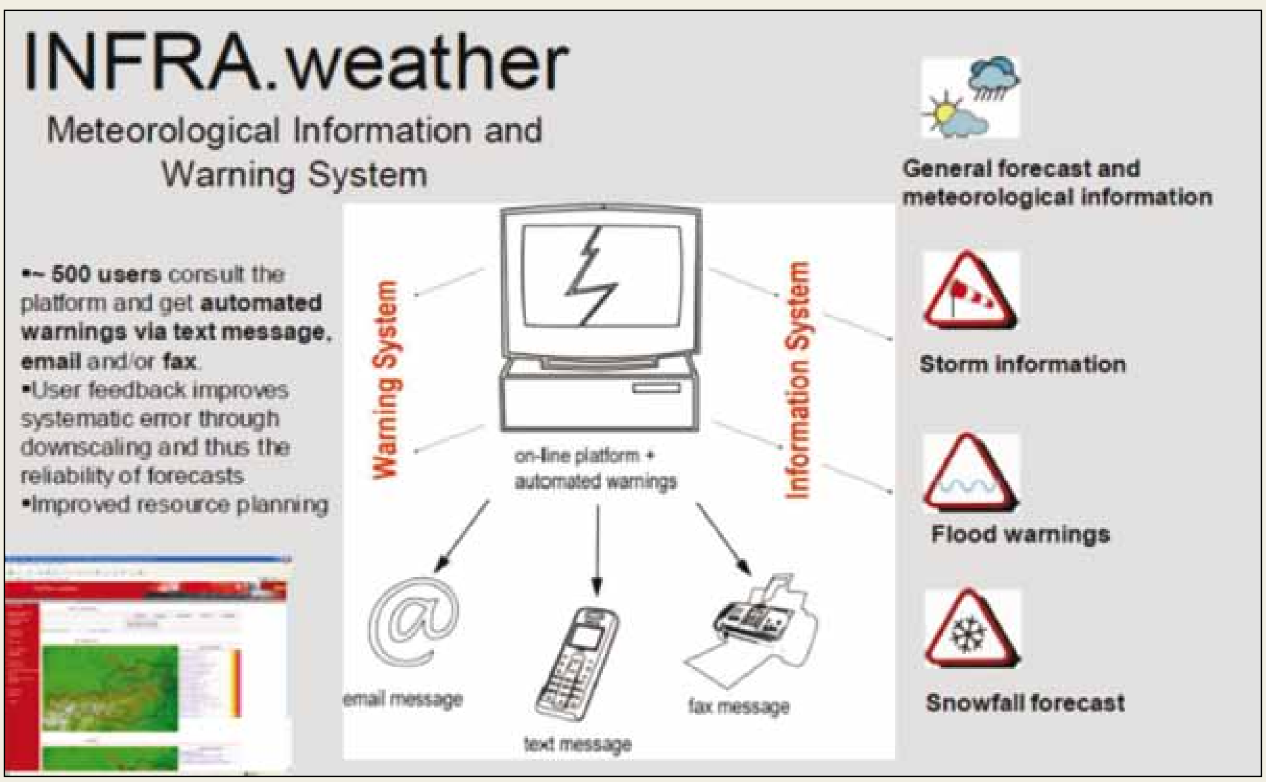
In Northern Europe, climate change will result in wetter winters, and more snow and ice episodes that will further threaten structures such as catenaries or switches and crosses. To address this issue, railway companies implemented a new standard for catenaries, which now have to have a pantograph of carbon/aluminum and an Auto-Drop Device. It is not easy to change norms as standards are often voluntary and not legally binding. The timescale for change can be long, and it may be difficult to find good experts, but all these issues can be solved with good financing and lobbying, and by the exchange of knowledge.

Sharing information

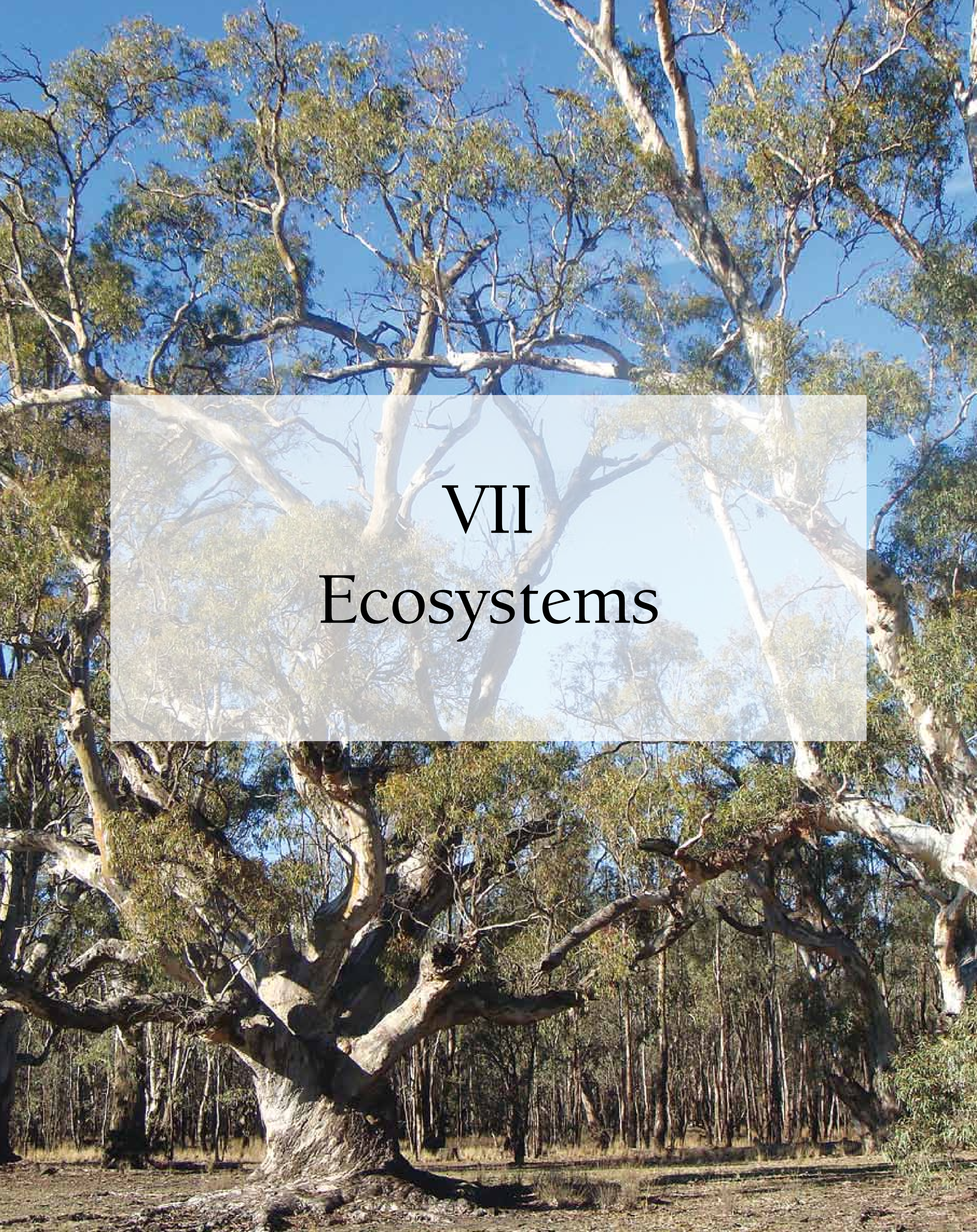
The exchange of knowledge is essential to quickly adapt to climate change. Information can be transferred within a company: for example, JR East created a training centre that helps train employees based on past events. But everyone can learn from the past, including civil society: for instance, the Accident History Exhibition Hall in Japan allows widespread access to information. What is more, the information can be exchanged between climate services and companies, in order to help them adapt to climate change. Finally, the exchange of good practices between companies is also possible; UIC serves this purpose, namely with the ARISCC project.

Among the tools available are the holistic rail system vulnerability tool which supports information on climate vulnerability and adaptation actions at entire railway system level; the sub-system vulnerability tools which support information on climate vulnerability and adaptation actions for railway sub-systems such as rolling stock; and decision support tools for local/policy managers – a set of tools to help local managers select appropriate adaptation actions. In addition, the UK's TRaCCA project has researched climate change impact up to the 2040s.

The InfraWeather online portal developed by Austrian railway company OBB



Source: UIC



VII
Ecosystems

Indigenous stories and climate services

David Griggs, Monash Sustainability Institute, Monash University; and Lee Joachim, Yorta Yorta Nation

The history of indigenous people in Australia is thought to go back 40,000 to 45,000 years, although some estimates have put the figure at up to 80,000 years before European settlement. These people can claim to be the oldest continuous living culture. The traditional aboriginal way of life was nomadic, following the seasons and the food. With incredible skill, aboriginal people became extremely well adapted to the highly variable and often extremely harsh Australian climate, learning to take care of sparse natural resources whilst maintaining limited population growth suited to the scarcity of those resources.

While aboriginal people only make up about 2.5 per cent of the Australian population, they own or control about 20 per cent of the land in Australia. Much of this land is located in remote parts of the country, making indigenous Australians living there particularly vulnerable to climate change. But equally, there are unprecedented opportunities for indigenous people to offer climate services in support of climate mitigation and adaptation through carbon sequestration activities and changing land use practices.

Vulnerability to climate change

Indigenous Australians experience high levels of social disadvantage and poor health compared to non-indigenous Australians, making them disproportionately vulnerable to climate change. Many indigenous communities, especially those in remote parts of the country, have inadequate health and education services, deficient infrastructure and housing and limited employment opportunities. It is widely agreed that indigenous people will be adversely impacted by increasing heat stress, extreme weather events and increased disease. There is also growing evidence that indigenous exposure and sensitivity to climate change will be increased because of these people's high dependence on climate-vulnerable economic activities connected to the land, and that already inadequate infrastructure and services will be adversely impacted by temperature increases, sea level rise, storms and floods. Thus the development of climate services targeted at reducing the vulnerability of indigenous Australians to climate change and increasing their capacity to adapt should be a high priority.

Spiritual song of the Aborigine

I am a child of the Dreamtime People
Part of this Land, like the gnarled gumtree
I am the river, softly singing
Chanting our songs on my way to the sea
My spirit is the dust-devils
Mirages, that dance on the plain
I'm the snow, the wind and the falling rain
I'm part of the rocks and the red desert earth
Red as the blood that flows in my veins
I am eagle, crow and snake that glides
Thorough the rain-forest that clings to the mountainside
I awakened here when the Earth was new
There was emu, wombat, kangaroo
No other man of a different hue
I am this land
And this land is me
I am Australia.

Hyllus Maris, Yorta Yorta woman

Learning from indigenous connections to country

"To understand our law, our culture and our relationship to the physical and spiritual world, you must begin with land. Everything about aboriginal society is inextricably woven with, and connected to, land. Culture is the land, the land and spirituality of aboriginal people, our cultural beliefs or reason for existence is the land. You take that away and you take away our reason for existence. We have grown that land up. We are dancing, singing, and painting for the land. We are celebrating the land. Removed from our lands, we are literally removed from ourselves."
Mick Dodson, former Aboriginal and Torres Strait Islander Justice Commissioner

Aboriginal people have a fundamental spiritual connection to the land, often expressed as 'connection to country'. For aboriginal people the health of land and water is central to their culture. Land is their home and their mother and is imbued in their culture. It gives them the responsibility to care for it and its connections.

Land sustains aboriginal lives in every respect: spiritually, physically, socially and culturally. Through this connection to country, aboriginal people have developed a deep care for the land, only taking what was necessary to support themselves and making sure there was always enough left for the future. In modern terminology this could be described as sustainable land management in a highly variable climate. This is in marked contrast to some of the extremely unsustainable land management practices that are currently commonplace across Australia and worldwide, such as the destruction of forests in the Amazon and Indonesia.

Image: Monash Sustainability Institute

River Red gum trees in the Barmah forest

Using indigenous knowledge to provide climate services

Before white settlement, indigenous people created an intricate system of land management. There was no 'pristine wilderness', rather a patchwork of burned and regrown areas. In using fire, aboriginal people could plan and predict plant growth and, with it, attract animals for hunting. They converted the land to grasslands for the 'maintenance' of animals, plants and fresh drinking water. Indigenous peoples' knowledge of, rights to and interests in land, through oral histories and wide knowledge of natural indicators, along with their presence in some of the most remote areas of Australia, means that they can play a key role in monitoring and cultivating the health of Australia's ecosystems in the face of climate change. Indigenous people have thousands of years of data, knowledge and practice relating to the diverse landscapes that span the country: sea country, river country, desert country, rainforest, bush and island country. Aboriginal people's understanding of species variation, the seasons and natural events was embedded within culture, people, landscapes and tradition long before white settlement.

Increasingly, indigenous knowledge of past climate is being integrated into conventional climate data sets and various cultural mapping exercises are underway in the country to capture indigenous knowledge and practices and integrate these with more conventional forms of knowledge, in order to provide climate services in the form of improved land and water management. However, in doing so it is vital to recognize and protect that indigenous knowledge through various forms of intellectual property protection.

As an example, the pictures on these pages are taken from a project with the Yorta Yorta people of northern Victoria in Australia. Their traditional lands encompass parts of the Murray River with a rich network of creeks, lagoons and wetlands, and these support the internationally significant River Red gum forest known as the Barmah forest. Indigenous knowledge of the functioning of these unique systems is captured using voice and image recording and global positioning systems. This is then combined with more conventional forms of knowledge within a global information system database to create integrated products that, it is hoped, will lead to improved forest and river management practices.

Indigenous involvement in carbon markets

Improved land management through the reduction of greenhouse gas emissions and the uptake of carbon

Image: Monash Sustainability Institute

Capturing the stories of Australia's indigenous people

in soils and ecosystems is becoming increasingly important in efforts to mitigate climate change. About 23 per cent of Australia's greenhouse gas emissions come from the land sector, but there are opportunities to offset a significant proportion of these emissions through carbon sequestration activities and changing land use practices. Fire abatement, feral animal management, improved grazing management and avoidance of deforestation (emissions avoidance), together with reforestation and revegetation (carbon sequestration), are all land management activities that offer important opportunities to offset carbon emissions in Australia. Much of the carbon stored in northern and inland Australia occurs on indigenous-owned land and many indigenous peoples are well placed to provide climate services in the form of greenhouse gas abatement and carbon sequestration services.

In August 2011 the Australian Government passed legislation to establish a Carbon Farming Initiative (CFI). This is a voluntary carbon-crediting mechanism to provide market-based incentives for activities that reduce greenhouse gas emissions in the land sector. In addition to the greenhouse gas emissions reductions, the CFI also seeks to promote the community and environmental benefits – or 'co-benefits' – associated with eligible carbon offset projects, including indigenous co-benefits. To enable projects to generate CFI credits that also deliver indigenous co-benefits, the proponent will need to demonstrate that their project delivers benefits to one or more indigenous communities. Indigenous people's participation in carbon markets has the potential to offset greenhouse gas emissions while providing an avenue to pursue culturally appropriate activities that meet their local livelihood and economic development aspirations by broadening opportunities for aboriginal people to work on the land while maintaining a physical and spiritual connection to it, and grow their knowledge and practices for future generations.

"People talk about country in the same way that they would talk about a person: they speak to country, sing to country, visit country, worry about country, feel sorry for country, and long for country. People say that country knows, hears, smells, takes notice, takes care, is sorry or happy. Country is a living entity with a yesterday, today and tomorrow, with a consciousness, and a will towards life. Because of this richness, country is home, and peace; nourishment for body, mind, and spirit; heart's ease."
Deborah Bird Rose, anthropologist.

Adaptation to climate change in the mountain forest ecosystems of Armenia

Anahit Hovsepyan, Head of Climate Research Division, Armenian State Hydrometeorological and Monitoring Service;
Levon Vardanyan, Director, Armenian State Hydrometeorological and Monitoring Service;
Aram Ter-Zakaryan, Task Leader, Adaptation to Climate Change Impacts in Mountain Forest Ecosystems of Armenia, UNDP & GEF-SPA Project, UNDP Armenia

Armenia's forests are unevenly distributed across the country. The area of forest lands in the Syunik region in the south-east of the country extends to 94,243 hectares, including a forest-covered area of approximately 65,000 hectares (20 per cent of the country's forests). In contrast, cropland totals 27,345 hectares. The high level of biodiversity is one of the most important features of the Syunik region. Various types of ecosystems are represented here, including semi-deserts, arid open forests, oak forests, steppes and tragacanth formations as well as aquatic and marsh growth, alpine and sub-alpine vegetation, and petrophilous vegetation.

Based on assessments of the impacts of climate change, including variability, the Syunik region has been identified as critically vulnerable, especially in terms of the risk posed by climate change to its unique mountain forest ecosystems[1]. The climate of the Syunik region is remarkably diverse due to its complex relief and large fluctuation of altitudes. The highest point is Mount Kaputdzhukh (3,906m above sea level) and the lowest is the depression in the Megrin gorge (375m above sea level). The high altitude, orientations of the mountain ranges and occluded borders of the river valleys and basins have a significant impact on the region's climate. Most of the mountain slopes have an eastern orientation, so the air masses blowing from the east move up the mountain slopes and cool rapidly, causing a gradual increase in relative humidity. Vertical climate zoning is a typical feature and air masses become significantly drier as they pass over the mountain ranges. Air temperature fluctuates within a large range due to altitude differences, and the spatial distribution of annual precipitation is irregular.

Addressing climate change impacts in mountain forests

In 2008, the Government of the Republic of Armenia launched a project funded by the Global Environment Facility (GEF) to enhance national capacities in the forest and biodiversity sectors to adapt to the anticipated climate change impacts in the mountain forest ecosystems. The implementation of the project 'Adaptation to climate change impacts in mountain forest ecosystems of Armenia' is on-going and the project will be completed in 2013.

UNDP is the implementing agency of the project and the project's main national counterparts are the Ministry of Agriculture and ArmStateHydromet under the Ministry of Emergency Situations. At the local level, the main counterparts are the Syunik Marz Department of Agriculture and Environment Protection, Forest Enterprises and Administrations of the Specially Protected Areas.

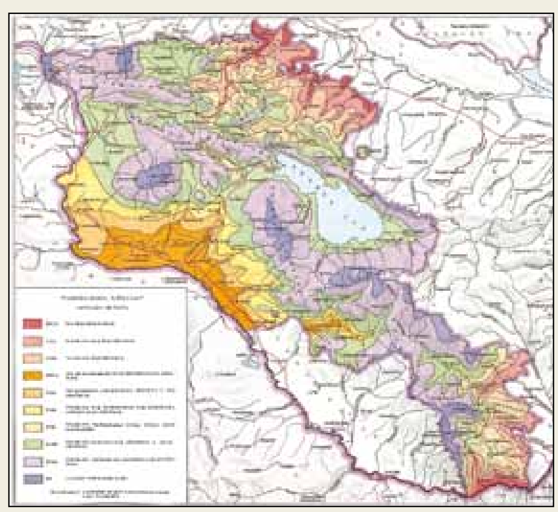
The main objective of the project is to assist Armenia in enhancing the adaptive capacity of the vulnerable mountainous forests ecosystems to climate change. One key expected output is the development of products and information that will assist national and local authorities in reducing the climate change related risks and improving forest and protected area management planning and management practices.

Institutional framework of forest areas management in Armenia

Various forest-related laws are in place in Armenia. In 2005 the Government approved the National Forest Policy and Strategy of the Republic of Armenia[2] and the National Forest Programme[3], which to some extent address issues pertinent to climate change. In 2005, the National Assembly also passed the new Forest Code of the Republic of Armenia.[4]

Forest governance is under the republican body ArmForest, a State Non-Commercial Organization under the Ministry of Agriculture. In the Syunik region, forest

Climate zones over Armenia



Source: Armenian State Hydrometeorological and Monitoring Service management is implemented by three Forest Enterprises: Sisian, Syunik and Kapan. Specially protected forest areas, which cover about 28% of Armenia's forests, are managed by respective State Non-Commercial Organizations under the Ministry of Nature Protection. Several protected areas, including the Arevik National Park and the Shikahogh State Reserve are located in the Syunik region, which is identified both nationally and internationally for its conservation priority.

Climate variability and climate change

Climate patterns across the Syunik region, historical trends and observed changes were estimated at local scale under the project to support the assessment of climate change impacts on forest ecosystems.

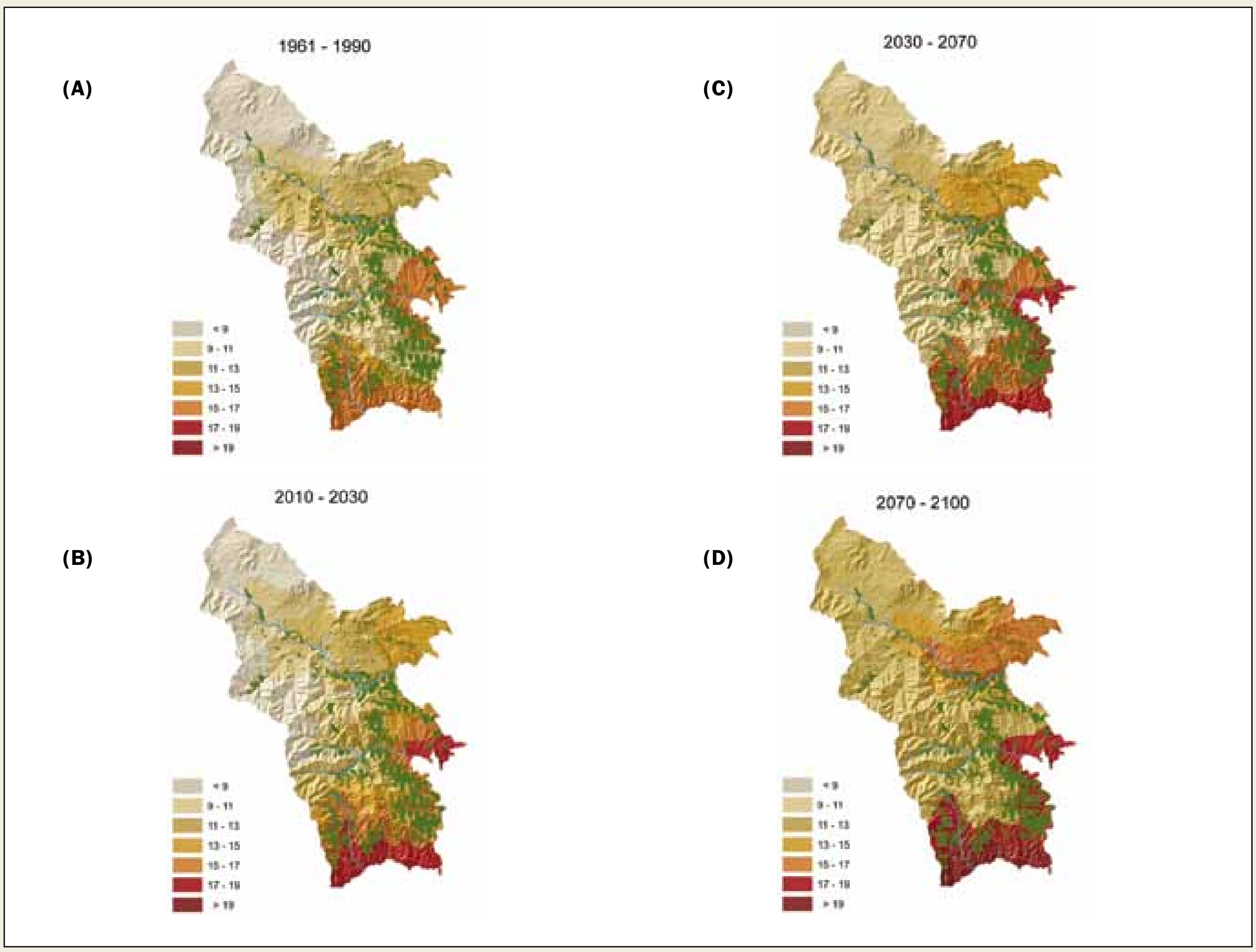
This involved the analysis of average, maximum and minimum air temperatures, total precipitation, wind velocity and air humidity time series as well as intra-annual variability, with a focus on the growing period. The results showed a persistent increase in temperature of 0.7°-0.9°C between 1935 and 2010, becoming more pronounced in the last two decades. The analysis also revealed some intra-annual features: the largest increase in monthly mean temperature was in March, which may result in more frequent early onset of vegetation growth. Furthermore, there was a trend towards increases in monthly total precipitation for the autumn months, which may have an impact on forest growth.

Consultations with forest specialists identified the need for specific assessment of forest ecosystem vulnerability to hydrometeorological conditions to support the improvement of forest management planning. ArmStateHydromet carried out the assessment using the multivariable analogue method, which takes into account maximum and minimum temperature, daily maximum precipitation and wind velocity. The results showed that, in general, the Syunik region is moderately vulnerable, with relatively high vulnerability in selected forest areas such as Meghri and Kapan. Daily maximum precipitation was the most significant among the climate parameters.

Climate change future scenarios

To improve forest and protected area management planning under changing conditions, area-specific climate change scenarios were developed under the project for the

Average air temperature for warm half-years over the Syunik region for (A) baseline period (1961-1990); and future projections: (B) 2010-2030; (C) 2030-2070 and (D) 2070-2100



Source: Armenian State Hydrometeorological and Monitoring Service

Syunik region to help identify how communities of forest species will be affected by climate change, e.g. what physical and biological changes could result from changes in temperature, precipitation and aggravation of situations with extreme climate events. The project is advocating the use of scenario planning to become a routine part of forest and national park management planning processes.

The outputs of the PRECIS regional climate model were used to estimate future changes in temperature and precipitation for different seasons, and warm periods at different altitudes, for the years 2030, 2070 and 2100[5]. The results indicate a gradual increase in air temperature, which is more strongly pronounced in the main forest areas to the south of the Syunik region. This will result in the vertical shift of climate zones and subsequent shifting of the suitable ranges of forest species. Similar projections were prepared for all the seasons, and were provided to stakeholders to be used in long-term forest management planning.

Threats to biodiversity

The rise in temperature and decrease in precipitation can significantly affect the ability of forests to regenerate through tree seeds. Although the negative humidity balance creates unfavourable conditions for seed restoration in the lower-bound forest area, in the upper-bound forest area the changing climate conditions contribute to the improvement of the temperature regime, enabling regeneration through the seed base. Consequently, this facilitates a gradual elevation of the upper-bound forest area. The advancement of the forest belt, however, is limited by for example grazing activities. In addition to the expected gradual forest recession at the lower forest border, the area will be penetrated by semi-desert and arid open forest plant species. Because forests at altitudes of 1,700m and above generally have higher adaptive capacity, significant changes in forest ecosystems at this altitude will be seen mostly in previously degraded areas. In lower-bound forests the changes in the climatic conditions can lead to significant degradation of the ecosystem[6]. In the Syunik region, the vulnerability of endemic species, including those listed in the Red Data Book of the Republic of Armenia, is more detectable in the lower-bound forest areas, where they are prevalent.

Climate change and variability have led to water stress in mountainous forest ecosystems, which has resulted in increased susceptibility of forests to pests and exaggeration of occurrence of pest outbreaks[2]. Climate change has had negative impacts on the sanitary conditions of the forests in the Syunik region over the last decade. Over this period, pest infestations have affected approximately 20,000 hectares of forests in the region, and it is expected that in the south-eastern forests, pest-holes of leaf-eating insects will grow significantly. Forest pests have caused the most damage in the Meghri region, where also significant reductions in tree growth rates and mortality have been observed. Moreover, the occurrence of forest fires has increased significantly in the recent years in the region and especially in Meghri[7]. Pests and fires continue to contribute to the process of forest decline.

The Syunik region in general is characterized by a high frequency of extreme climatic events, mainly heavy rainfalls, which lead to landslides and mudflows. As a result, this region is ranked first in Armenia for landslide areas and high risk of mudflows. Further, the incidence of extreme events has increased over the last 20 years. These climatic events can impact natural ecosystems significantly by leading to undesired changes and destruction of many plant and animal species' habitats.

Climate extremes and early warning systems

Climate extremes have long been a matter of concern for forest management policymakers. An efficient warning system is needed to provide alerts and advice on extreme weather and climate events. The climate watch system (CWS) is an example of such a warning system, providing a proactive mechanism for interacting with users and alerting them of major climate anomalies and extremes. The main components of CWS include observation and data, comprehensive monitoring of climate systems and long-term forecasting products. In order to develop such a system, all these components have to be in place.

As a part of the project activities, the status of the observation network and the availability of historical datasets of variables in the Syunik region were assessed. The project focused on the availability of reliable, quality-controlled, homogenized long time series of climate data[8]. Furthermore, the gaps and shortcomings of the existing hydrometeorological observation system were identified and data-sharing mechanisms to support sustainable forest management were discussed with interested partners in the Syunik region. The consultations furthermore helped to identify the needs in terms of climate products and information for effective forest management and long-term planning. Based on the results, a proposal is being developed for improving the observation and forecasting system.

More specific information on the current level of use of climate products in forest and protected area management practices, the challenges met during the application of climate information and needs of forest and protected area managers for specialized products was collected in a survey study under the project. One major user requirement was an urgent need for improved seasonal prediction and forest fire alerts. The fire risk index (FRI) by Nesterov — a complex index based on air temperature, dew point and number of days with precipitation more than 3mm/day — is being assessed for this purpose[9]. The fire risk index can be used for monitoring current fire risk conditions as well as forecasting fire risk on a seasonal scale. Based on the monitoring of current climate conditions and the seasonal outlook, three-day and monthly forest fire alerts can be issued and provided to users via e-mail and facsimile.

To further facilitate the implementation of an early warning system in the Syunik region, climate extremes have also been studied under the project. Several climate indices have been estimated for the towns of Kapan, Goris and Meghri and their trends were analysed.The results revealed a statistically significant increase in the number of summer days with a daily maximum temperature higher than 25° C, as well as increased duration of dry spells and length of the growing season in all three locations[10].

Increasing public awareness on climate change risks

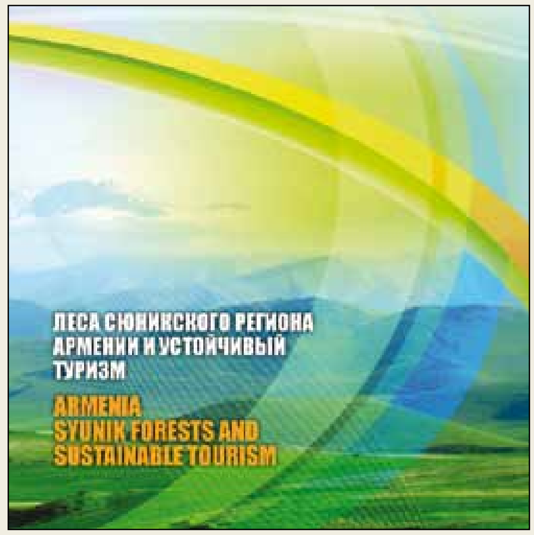
Under the project, a wide range of stakeholders at various levels (national to local) have been engaged in public awareness campaigns aiming to increase awareness of climate change risks in natural ecosystems and to reduce further human induced impacts on mountain forests.

Climate products and information, including informational posters, brochures and multimedia products, have been presented at seminars and lectures held in educational institutions in Yerevan and Syunik for students and teachers.

Image: Adaptation to Climate Change Impacts in Mountain Forest Ecosystems of Armenia" UNDP/GEF Project

Seminars on (A) forest biodiversity and climate change issues for teachers and pupils in the Syunik region, and (B) sustainable tourism in forest areas under climate change conditions

Armenia – Syunik Forests and Sustainable Tourism – one of the brochures helping to disseminate information about the project



Source: Armenian State Hydrometeorological and Monitoring Service

A specifically designed brochure on sustainable tourism, developed and published under the project, was presented during a seminar bringing together representatives from a range of governmental, non-governmental, educational and tourism organizations[11]. Additionally, representatives of local administrations and community leaders have participated in trainings on fire prevention and suppression organized by the project with other partners.

Challenges and requirements

Several challenges in the use of climate information have been revealed during the implementation of project activities. A lack of corresponding technical means, software and communication capabilities created difficulties during the assessment of changing climate conditions at the local scale, and there was a lack of appropriately trained staff at the hydrometeorological service to carry out tasks such as producing tailored information for specific user groups and applying downscaling techniques to outputs.

There are still significant uncertainties in the climate change assessments. Seasonal prediction skills are low providing only a general estimate of the possibility of forest fire without specifying the location, time and intensity. There is also scope for improvement of the seasonal outlooks, which serve as a basis for producing fire risk alerts. Furthermore, the suggested FRI index has certain weaknesses. The work to improve the index by including factors such as wind velocity and duration of dry spells is on-going.

Some technical issues have been resolved through interaction with experts from other countries, e.g. fire risk methodology was provided by Russian colleagues and certain tools and programmes were obtained free from the Internet[12]. A weather research and forecasting model is being developed by ArmStateHydromet with the Academy of Science of Armenia[9]. Nevertheless, building new and developing existing human capacities remains a challenge, which needs to be overcome.

Moving beyond a successful pilot

The project targeting the Syunik region has made great advances and the information produced under the project meets the interests and expectations of the stakeholders. It has reflected several principles of the Global Framework for Climate Services:

- Ensuring greater availability of, access to, and use of climate services
- Building the capacity of climate-vulnerable developing countries
- Establishing operational climate services as the core element of the framework
- Affirming that climate information is primarily an international public good provided by governments, which will have a central role in its management through the framework
- Committing to build the framework through user provider partnerships that include all stakeholders.

The project experiences and lessons learned will not be limited to the south-eastern mountainous forests of the Syunik region. They will also be applied in forest and protected area management in the central and northern regions of Armenia and shared with the global community through the Adaptation and Learning Mechanism (www.adaptationlearning.net).

Understanding climatic processes on Earth: the invaluable contribution of satellites

Volker Liebig, Director Earth Observation, European Space Agency

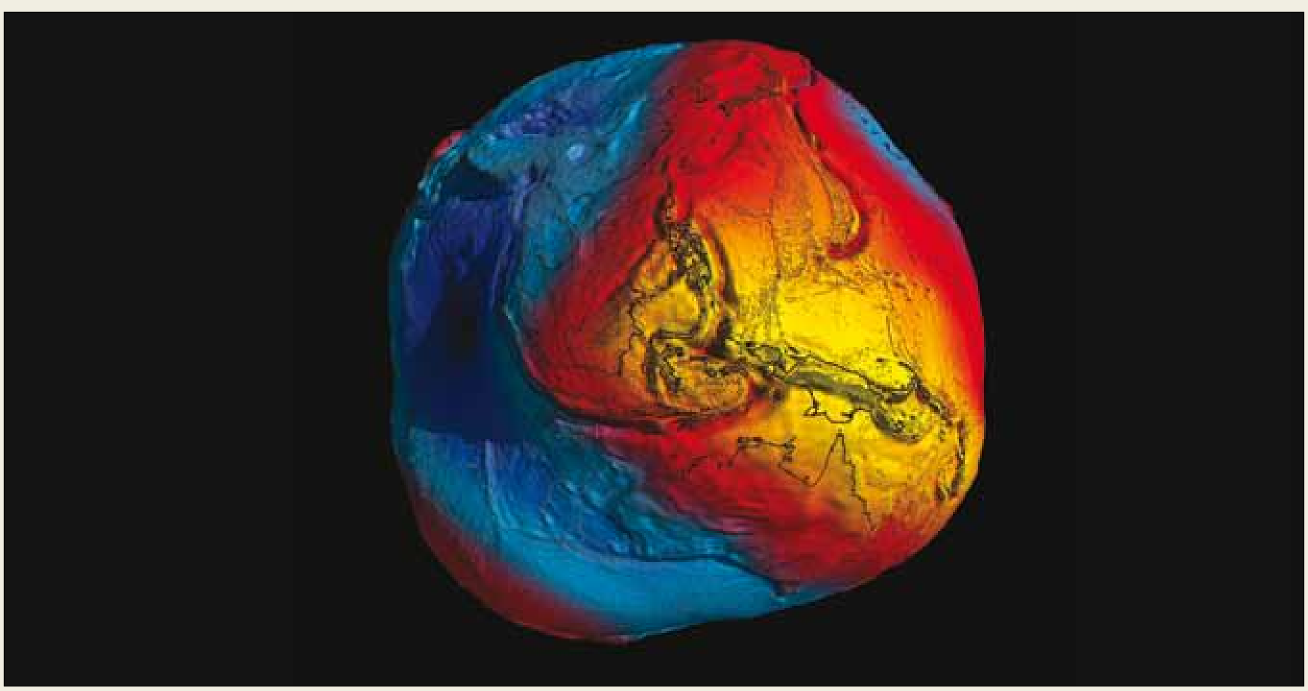
Earth is a complex planet: the only one known today that carries life — in abundance and for billions of years. Powered by the interplay of its spherical, hot inner structure and energy received from outside, particularly from the sun, various spheres of the planet make up the environment we live in: atmosphere, oceans, land and cryosphere.

Climatic change processes have accompanied most of Earth's existence. Today, however, these changes take place at — so far as can be said from scientific sources — unprecedented speed. Human actions could be a direct cause of some accelerated climatic phenomena, like an unusually strong warming of the Arctic or an increase in frequency of extreme weather events around the globe.

With eight billion humans on the planet, the question of efficient mitigation of negative climatic consequences, and of a more sustainable way of acting, has become imperative. But both the assessment of the current situation and the planning of the future necessitate a sound scientific collection of Earth-related data, as well as their careful interpretation to become the basis of societal consequences.

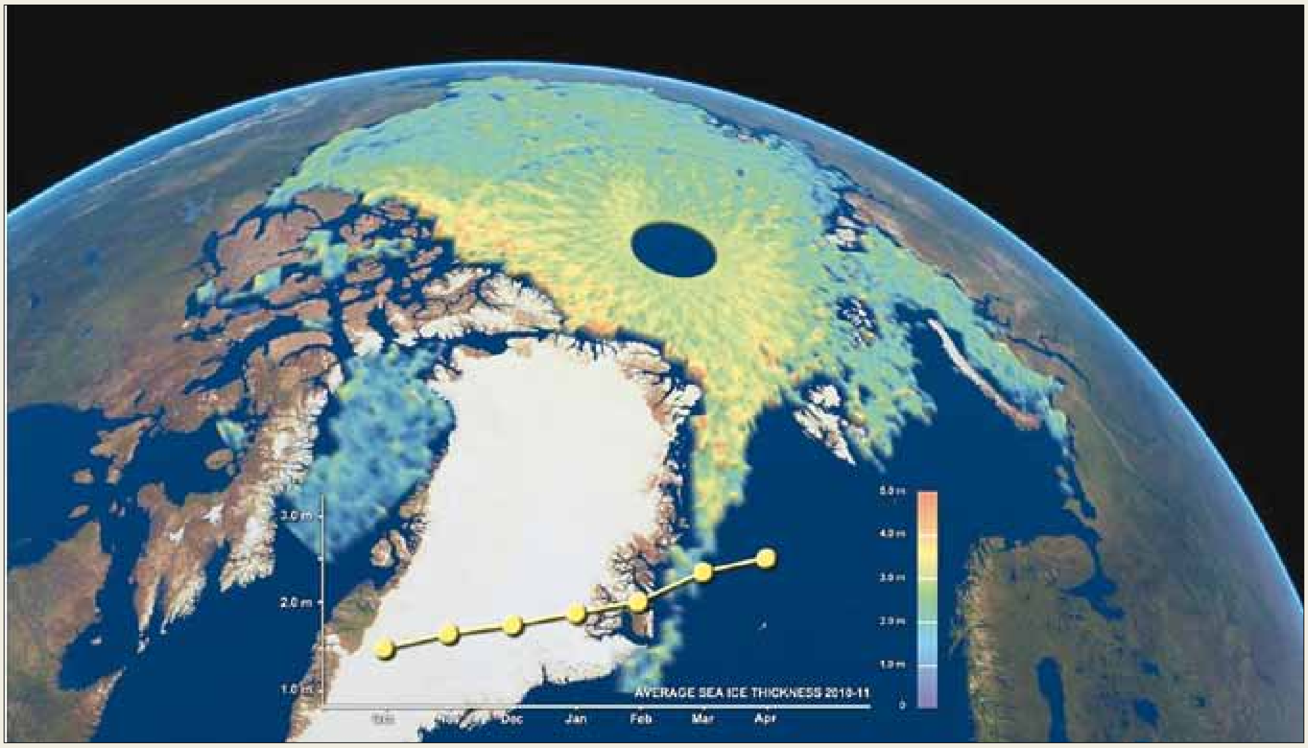
Just as the cartographers of earlier centuries climbed mountains to have a better overview over their surroundings, satellites in space get a better picture of our planet at large. It is not only photographs of the Earth's surface that scientists are looking for; much more can be achieved through more sophisticated satellite applications. The fleet of those sentinels in space helps us to better understand global processes that shape our environment and also our future.

Nothing within the Earth's systems is an isolated event. When it comes to mapping and understanding climate change processes complex questions arise, also impacting political and scientific debate. The impact of observed or forecasted variations of our environment is far-reaching. It is imperative to provide a basis to put factual evidence, scientific models, social debate and



The most accurate geoid delivered by the GOCE mission

Source: ESA 2012



A scientific novelty – the first Arctic seasonal ice volume change data delivered by Cryosat

Source: ESA 2012

political action upon climate-related data. Satellites deliver such data in a reliable way.

The European Space Agency (ESA) is a pioneer in terms of Earth observation satellites. It has been instrumental in making meteorology one of the first sustainable and operational space applications in Europe, having put efforts into the development of the Meteosat missions since the 1970s. The long-lasting ERS-1 and ERS-2 missions, as well as Envisat, the world's largest Earth observation satellite ever, have provided an immense amount of valuable research data to more than 4,000 scientific projects worldwide and, routinely, to service providers every day. The data collected by sophisticated sensors over decades form a vast archive that is still far from being completely exploited.

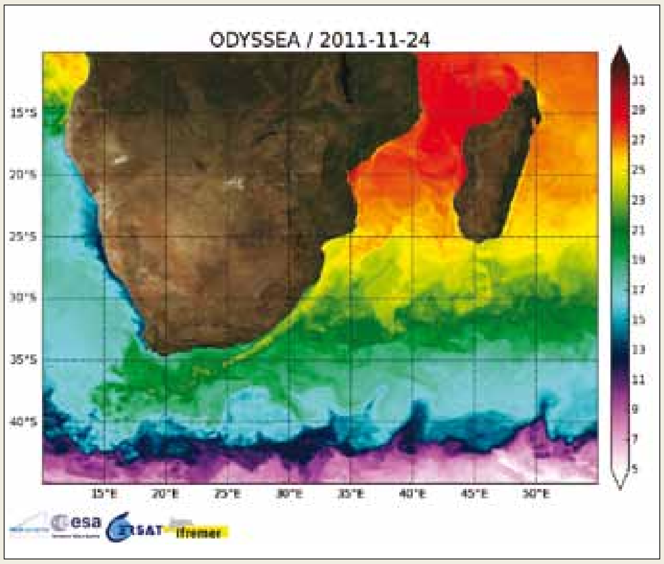
One of the most urgent topics is the understanding of the underlying mechanisms of climatic change, and the contribution of humankind to it. In order to arrive to useful findings it is indispensable to look at the state of and, more importantly, the changes in the Earth's climate which come about as the result of the interaction between components such as the atmosphere, cryosphere, hydrosphere, land masses and not least the human sphere of influence. ESA is developing a veritable fleet of Earth Explorer missions that shed light on open questions regarding these Earth systems. Three Earth Explorers are already in space.

Gravity field and steady-state Ocean Circulation Explorer (GOCE), a mission to map the Earth's gravity field with unprecedented accuracy, was launched in March 2009. GOCE has produced the most accurate model of the geoid ever produced. In doing so, the satellite carries the first gradiometer in space at one of the lowest satellite orbits ever (about 255 km). GOCE's geoid has been created using more than 50 million measurements of variations in gravitational attraction. For the first time, its measurements also allow global currents to be extracted directly from satellite altimetry data: ocean currents are understood as a major engine of our global climate.

The ESA Soil Moisture and Ocean Salinity (SMOS) mission followed in November 2009. SMOS provides the first global measurements of two key variables in the water cycle – soil moisture and ocean salinity. Thus, scientists are able to trace the inter-annual variation of water available in soils and produce accurate ocean surface salinity maps around Earth.

Only five months after the launch of SMOS, the third Earth Explorer — ESA's Ice mission Cryosat — was delivered into orbit in April 2010. The CryoSat mission measures ice sheet thickness and volume in the Arctic and Antarctic for the first time ever. This allows a new understanding of the complex relationship between ice and climate. In April 2012, scientists published the first Cryosat seasonal cycle of arctic ice thickness (October 2010 to April 2011). A few months later, satellites witnessed an alarming record: the lowest Arctic sea ice extension since the beginning of systematic measurements.

The next mission, ready for launch, is ESA's magnetic field mission Swarm, which will provide the best ever survey of the Earth's geomagnetic field and its variation in time while enabling new insights into the Earth's interior and climate. Further Explorers are under development or selection. Each mission uses the most



An example of daily monitoring services from space – sea surface temperature around Southern Africa

Source: Medspiration, ESA

modern technology, often never flown before, to close observation gaps and deliver accurate and reliable data for measuring the pulse of the planet.

With the help of new satellite systems such as the Sentinel missions developed under the Global Monitoring for Environment and Security (GMES) programme of the European Union and ESA, and the exploitation of the infrastructure already in space, it is possible to advance both scientific and political ambitions. Earth observation is a perfect example to link research and technology development with the care urgently needed to work towards a sustainable and self-conscious future for all of us.

As important as satellites in space are, they nevertheless represent only one part of the quest to better understand climate patterns. Less spectacular but equally important is the use of many years of archived data sets, their reprocessing with the newest scientific algorithms, their comparison and their interpretation. Satellite data are thus not used only once, but reprocessed time and again, integrated into the newest scientific models and evaluated as part of crucial long-time observations.

With its missions, ESA is at the forefront of Earth observation and climate research worldwide. Yet the importance of global observation for understanding climate change has also triggered concerted action on the international scene. The Global Climate Observing System (GCOS), in the context of the United Nations Framework Convention on Climate Change (UNFCCC), defined a set of Essential Climate Variables (ECVs) which will be systematically monitored in order to quantify the state of our climate in an objective and effective way. In response, the ESA Climate Change Initiative aims to "systematically generate, preserve and give access to long-term data sets of the ECVs."

The ESA Climate Change Initiative provides and uses climate data records of ongoing and planned missions in Europe. The systematic generation of relevant ECVs includes recalibration, periodic reprocessing, algorithm development, product generation and validation, and quality assessment of climate records in the context of climate models.

But the Climate Change Initiative goes beyond that, introducing a feedback loop mechanism whereby new user feedback and the latest scientific knowledge can be easily integrated within each reprocessing phase. A Scientific Advisory Group, involving world-leading scientists representing key stakeholder organizations, provides scientific guidance on the programme. This allows optimal use of decades of space-borne, climate-related data for the benefit of all of us.

The Climate Change Initiative has already enabled ESA and European scientists to contribute significantly to coordinated international action on climate observations from space (GCOS, UNFCCC, the Intergovernmental Panel on Climate Change). Work has been initiated on 13 ECVs: cloud properties, greenhouse gases, ozone, aerosol properties, sea surface temperature, sea level, sea ice, ocean colour, glaciers and ice caps, ice sheets, land cover, fire, and soil moisture. Of particular merit is the interaction developed between the various ECV teams to determine specific user needs, including the involvement of user communities well beyond European climate research groups.

The ESA Climate Science Advisory Board recently concluded that the Climate Change Initiative should be seen as a critical beginning in laying the foundation for long-term activity, spreading over several decades to fulfil long-term and high quality observational records required for use in climate research, modelling and prediction.

Likewise, it is imperative to enable next-generation missions. The ESA Earth Observation programmes are well set to continue the heritage they have provided in the past. Through the Earth Observation Envelope Programme, ESA will develop and launch new cutting-edge technology Earth Explorer missions and foster scientific exploitation, application development and the generation of new user communities. With GMES, and in particular the launch of the first Sentinel mission at the end of 2013, systematic, operational Earth observation data provision will be ensured – for decision-makers, service providers and scientists alike. With the development of the newest generation meteorology missions, MeteoSat Third Generation and MetOp Second Generation, in cooperation with ESA's partner EUMETSAT, weather and climate monitoring from space will be secured for decades to come.

The past years have shown more than ever the close link between human dependence on our environment – natural resources, climate, and space for living and developing. Science has long since left the infamous ivory tower. It has become a prerequisite for political action. This moves satellites to the centre stage of interest.

Through its Earth observation missions, ESA is developing and operating climate-quality observing systems, providing free access to the worldwide science community and working with its partners to ensure long-term observations of fundamental climate data records.

Better localised CO_2 measurement as a component of accurate climate forecasting

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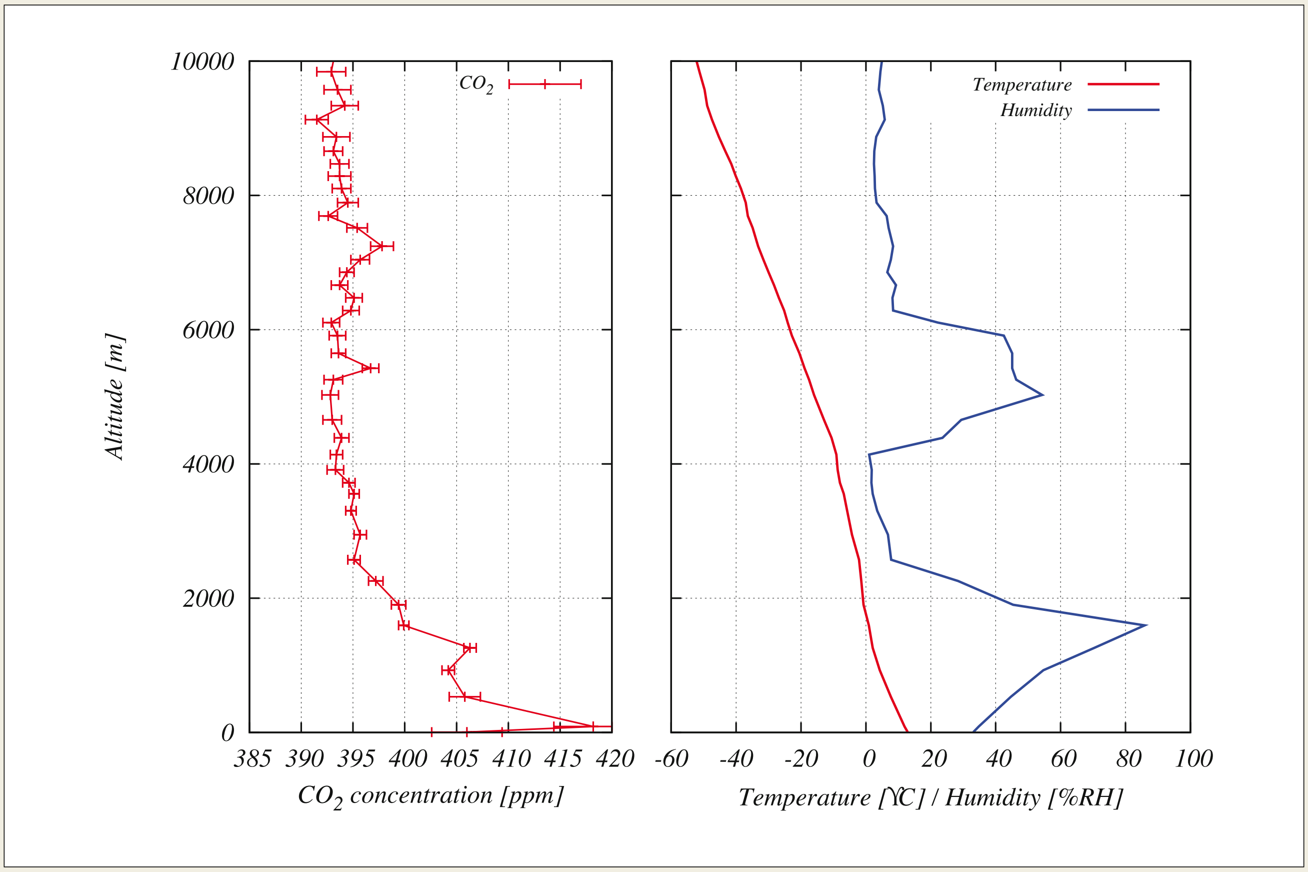
Meisei Electric is an enthusiastic supporter of the Global Framework on Climate Services and all its principles, particularly those that give high priority to the needs of climate-vulnerable developing countries. The long-term monitoring of atmospheric carbon dioxide (CO_2) concentrations is an important aspect in forecasting accurately the increasing threat of global warming, and its inevitable impact on weather and climate. Such long-term global observations allow the prediction of global warming feedback into the carbon balance and contribute to global warming prevention strategy decisions on what controls to implement on anthropogenic emissions.

At present, *in situ* methods are used for CO_2 measurements at about 100 continuous observation stations in the world. However, the observation points are concentrated in the mid-latitude belt of the Northern Hemisphere, where most developed countries are situated. In contrast, there are very few observation points in tropical areas and developing countries. If more observations points were implemented, then more precise climate forecasts might be made by region or country, particularly in those developing nations most vulnerable to extreme weather and changes in climate,

Image: Meisei Electric

FES-C (foreground) and the CO_2 sonde



Vertical profiles of CO_2, temperature and humidity measured by the CO_2 sonde launched at 14:30 LT on 26 November 2011 at Moriya Ibaragi, Japan

Source: Meisei Electric

and whose CO_2 emissions are growing most alarmingly. This method can be applied to the weak but widely spread sink/source, forest or grassland, for example, and for less non-predictable local emissions such as forest fires. World Meteorological Organization has made great efforts to establish a CO_2 observation network to fill these gaps, and we applaud their commitment. With their continued support, the impact of CO_2 emissions on local habitats can be more clearly planned, and this vital component better integrated into local climate forecasts. If those who continue to increase their emissions were made more clear of the effects locally on their climate by way of greater incidence of weather related disasters or greater challenges in agriculture, water management and health, then it may even convince them sooner of the importance of reducing their emissions.

On the other hand, satellite observations such as the Greenhouse Gases Observing Satellite are already operating and similar satellites are planned by the United States, Europe and China. Satellite observations have the advantage that high-density observations can be made over the entire world; however, no measurements can be made in areas under cloud cover, and even on clear days, measurement accuracy is reduced in the presence of aerosols and cirrus. Aerosol is emitted, along with CO_2, from cities and factories, and it is difficult to evaluate the amount of emission reduction there. Moreover, the large forest areas, which are major CO_2 sinks, are frequently covered by clouds because of the active transpiration of water vapour from trees. As a result, observations from space do not adequately cover some important carbon source and sink areas.

In order to solve these above-mentioned problems, Meisei Electric has developed a low-cost, easy-to-operate, all-weather sonde to measure vertical CO_2 distribution, and is developing a low-cost and robust CO_2 column densitometer by using an optical fiber etalon (Fiber Etalon Solar measurement for Carbon dioxide, or FES-C).

Instrument development

Meisei Electric received financial support from the Japan Science and Technology Agency (JST) between 2008 and 2010, to develop a CO_2 sonde that can measure the vertical profile of CO_2 under the research area titled 'Small measurement device for CO_2 monitoring'. This CO_2 sonde has already achieved about 1 part per million (ppm) accuracy (one standard deviation), independent of the observation site, time and weather. The sonde went into practical use in 2012, and improvements to make measurements possible in the tropopause (10-15 km) are in progress.

Meisei Electric has also been participating in the 'Development of automatic optical CO_2 instrument aimed at the global standard' project, which runs from 2011 to 2013, with the support of JST. The advantages of the FES-C

Image: Meisei Electric

The FES-C observing peat and forest fires, in Central Kalimantan, Indonesia

CO_2 column densitometer, based on optical filtering using a fibre etalon, are the low initial and running costs compared with existing instruments such as Fourier transform spectrometer (FTS), its quick installation and the fact that it performs automatic measurements. Furthermore, the measurements are not affected by aerosols or cirrus clouds, and measurements are possible if the sun appears through a break in the clouds.

Field applications

Two applications are of particular interest: the vertical distribution of CO_2 measured by the sonde near Tokyo and a peat and forest fires measurement campaign using the FES-C in Kalimantan Island, Indonesia.

CO_2 vertical profile measurement in the Tokyo area

The CO_2 sonde was used to take measurements at Moriya, which is situated 35 km north-west of Tokyo. The sonde was launched at 14:30 local time (LT) on 26 November 2011. The ascent rate of the balloon was about four metres per second, and the vertical CO_2 measurement resolution was about 300 m. The vertical profile below the atmospheric boundary layer showed that the CO_2 concentration was high because of intense emission from metropolitan Tokyo. The CO_2 concentration above the atmospheric boundary layer was close to background values at the same latitude. Thus, the CO_2 sonde data reflect surface emission and absorption.

Peat and forest fires observation campaign in Indonesia

As part of the measurement, reporting and validation (MRV) of carbon emission reduction activities, Sumitomo Corporation requested us to evaluate the CO_2 emission from the peat and forest fires in Central Kalimantan, Indonesia. In this campaign, two sets of FES-C were deployed parallel to the predominant wind direction and three months of column density data were automatically obtained. The carbon emission between the two observation sites was evaluated by considering the differences between the upstream and downstream column data and factoring in the wind velocity, which carries the emitted CO_2 horizontally. Automated and continuous monitoring has an important advantage because it is impossible to predict when and where fires will happen. However, it was difficult to estimate the entire quantity of emitted CO_2 by using the data from only two observation points. According to a numeric simulation, the installation of 16 sets of FES-C would be necessary to evaluate the CO_2 emission from an area of 2,000 square kilometres with 10 per cent accuracy.

Further development

Meisei Electric has developed a low-cost, easy-to-operate, all-weather CO_2 sonde, which is flown on a meteorological balloon, to measure the vertical profile of CO_2 from the ground up to 10 km with an accuracy of about 1 ppm. The sonde has already been delivered to the market and has been used by Japanese researchers. FES-C that can measure the CO_2 column density is under development. These two developments are financially supported by JST. Field tests to compare the CO_2 sonde and FES-C observations with aircraft and FTS observations have been conducted to confirm their reliability.

Meisei Electric believes that the development of tools to measure CO_2 emissions and sinks is important to support the international strategy of greenhouse gas reduction. Direct surface flux measurements using the chamber or eddy covariance methods and the vertical and horizontal transportation after surface-atmosphere interactions using a CO_2 balloon sonde and FES-C can be measured using Meisei products.

VIII
Urban Issues

When worlds collide: urbanization, climate change and disasters

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The world is constantly changing, but today this change is more complex and uncertain than in the past. At least four major processes — population growth, urbanization, globalization and climate change — are converging to create much more complex sets of challenges, particularly disaster risks.

To see the magnitude of these new challenges, consider this: while population growth simply increases the exposure to hazards, rapid urbanization (and especially development in marginal areas) increases the vulnerability of those exposed. Worse yet, globalization creates vulnerabilities in interdependent economies and supply chains, while climate change drastically impacts 'normal' environmental conditions, amplifying the severity and frequency of hydrometeorological hazards such as floods, drought, storms and so on.

Managing the dramatically increasing scope and complexity of disaster risks overall, and those associated with urban areas in particular, presents two major challenges:

- How to approach present and future impacts of climate change
- How to simultaneously address the existing and future challenges of evolving natural and human-induced disasters.

Drivers of urban risks

Population growth, urbanization, globalization and climate change individually and collectively are major contributors to increasing urban risk.

Population increased from 1 billion in 1804 to 3 billion in 1950, continuing to increase at a rate of 1 billion every 15 years to reach 7 billion in 2012. Significant proportions of this increase have been absorbed into rapidly expanding, often high-risk urban areas in developing countries — areas that are growing five times as fast as cities in developed countries.

In 2007, urbanization marked a turning point in history. Over 50 per cent of the world's population lives in cities. That is projected to increase to 60 per cent by 2030. Already, 1.5 billion live in the 776 urban areas of more than 1 million inhabitants. Within this urban population approximately 60 per cent, or 890 million people, live in areas of high risk and exposure to at least one natural hazard.

Flooding is the most frequent and greatest hazard for the 633 largest cities and urban agglomerates.[1] Drought is the second most frequent hazard, followed by cyclones and earthquakes. Among the 63 most populated urban areas (>5 million inhabitants) 39 are in locations exposed to risk from at least one natural hazard, with 72 per cent on or near a coastline. More than a quarter of these cities are in Asia.

Globalization, through its creation of linked economies, production and supply chains, transportation and communication networks, and contributions to greenhouse gas (GHG) emissions, extends disaster impacts beyond the immediate localities where they occur. Floods in Southeast Asia cause US auto production to stall, and drought in the US puts food security in Asia at risk.

Climate change, which has the potential to damage every natural and human system on the planet, is arguably the greatest challenge facing humanity. The scale and scope of needed action is hugely varied. At present, the main response to climate change worldwide is focused on mitigation, especially the lowering of GHG emissions across a variety of scales.[2] Unfortunately, to date, effective and collective global action is lacking and some climate change effects are now inevitable.[3] Their impact will likely be felt to an increasing degree over the coming decades and beyond, presenting enormous challenges for the disaster management community.

Image: PDC

The Disaster Alert mobile application

Increasingly, the focus of climate research is being directed toward the development of strategies and tools for adaptation. This is a necessary and effective means of addressing unavoidable climate change impacts. Given the broad range of potential climate impacts and the ways in which these may affect populations and natural systems, adaptation strategies and tools must work across a variety of systems and they must be appropriate to the conditions and culture of individual urban areas that present complex sets of climate change related impacts.

Evolving urban disaster risk

Urban disaster risk assessment, management and planning is particularly challenging because sufficiently detailed science-based assessments of the spatial and temporal impacts of climate change are needed, and because the urban environment is inherently risk-multiplying.[4] Overall, urban environments are risk-multiplying largely because they increase both exposure and the vulnerability of their populations as a result of:

- Increasing/larger concentration of people at risk
- Rapid spatial expansion of urban areas beyond physical and social support infrastructure, stressing available resources
- Increasingly complex development with an admixture of urban, slum, industrial and agricultural areas
- Ecosystem and biodiversity 'services' impacts that reduce mitigation capacities and the overlapping impact of climate change that can increase:
  - Urban-induced microclimatic changes (heat island effect, micro-droughts)
  - Shifts from 'traditional' disasters to more complex, synergistic and cascading disasters
  - Traditional and newly emerging infectious diseases.
- Disadvantaged urban populations, which are impacted most due to:
  - Greater exposure to disasters in less desirable areas and, often, unplanned and poorly constructed housing
  - Limited access to infrastructure generally and disaster-reducing infrastructure specifically
  - Less adaptive capacity in terms of wealth, education etc.
  - Limited capacity to improve their situation by moving to less dangerous areas.[5]

These factors are compounded by the fact that the areas inhabited by the urban poor commonly have the highest population density, meaning that even modest disasters affect greater numbers of individuals.

Global urban development is spatially and temporally a highly complex, evolving process that is made more difficult by the risk-multiplying aspect of the process itself. However, there are positive attributes of urbanization that compensate somewhat for the risk uncertainty:

- Urban areas are normally the economic centres of nations and, as such, have access to the resources and expertise required to more effectively deal with emerging issues of climate change
- Through appropriate 'green' planning and development, enterprises, vehicles and populations, GHG emissions can be reduced and more disaster-resilient communities developed
- Urban areas are centres of innovation where new and diverse types of planning, programmes and

Image: PDC

PDC Executive Director Ray Shirkhodai with disaster managers using DisasterAWARE to view the travel times of a tsunami

projects may be developed for adapting to climate change and enhancing sustainability and resilience
- Economies of scale, as well as proximity and concentration of enterprises, make it cheaper and easier to take actions and provide services when disasters occur.

Planning for climate-related disasters

Although there is considerable uncertainty with respect to the specific impacts of climate change, it is almost certain that climate-related natural hazards will continue to occur, that they will impact more populations in both urban and rural areas, and that they will cause more complex disruptions and emergencies as they impact vulnerable urban areas in a global economy. As a result, the development and application of new knowledge, technology and paradigms for disaster management in anticipation of the impending changes is of the highest importance. Among the new technologies already in use are mobile devices and related applications, but their place in disaster management is still developing, and certainly has not reached its full potential.

To date, most urban adaptation strategies are seriously handicapped by an inability to define the specific risks particular to a given city, defaulting to general assumptions of global climate change that lack the details needed for meaningful planning. Generic climate change adaptation planning (CCAP) does not provide adequate solutions. The needed solutions must be based on reliable and actionable data that reflects the current and trending geography, hydrometeorology, demography, socio-cultural realities, and coping capacity of the specific urban area. At present, detailed CCAP is an evolving science, only fully implemented in a few major urban centres such as London, Toronto, New York City and Chicago.[6] An assessment of the CCAP programmes in these four cities provides several useful insights in terms of planning for effective adaptation:
- Follow a strategy of adaptive management that recognizes that CCAP is a dynamic and inclusive 'whole of the city' process, requiring inputs from all sectors with continual monitoring and periodic adjustment
- Develop a science-based programme to define and prioritize specific risks and develop appropriate programmes and evaluation benchmarks
- Incorporate CCAP into broader regional planning to ensure collaboration within and across jurisdictions, agencies and populations and reduce 'unexpected consequences' resulting from conflicts between various programmes
- Recognize and accommodate the fact that the impacts of climate change most often fall on those with the least resources and fewest choices in terms of dealing with risk.

Data collection, analysis and delivery

The need for new, more place-specific data and science-based planning has become urgent, driven by rapid urbanization and climate change. The same factors are forcing the prioritization of developing new methods of analyzing, retaining and providing access to data that realistically reflect risks, hazards and potential impacts vastly different from those in historical records. Thanks to advances in monitoring and sensing and to teams willing to do the difficult and often dangerous field-collection and field-verification of data, new resources are being developed. However, the unprecedented types, rates and scale of change in technology will have to increase to keep pace with climate change, urbanization and a skyrocketing population. Better exploitation of existing technologies is of paramount importance, too.

In this context, the delivery of useable information is at least as important as data collection. It might seem that highly concentrated urban populations would be ones in which the 'last mile' of an early warning or evacuation order could be easily delivered. That is often not the case. When the very poor move into and around urban centres, they often "end up in informal settlements where housing is unplanned, difficult to reach and not connected to either physical or social services."[7] To overcome these challenges, innovative technologies are needed to collect, integrate, analyse and disseminate actionable information.

The Pacific Disaster Center (PDC) is among the innovators in the development of new data and information resources, and in the creation and advancement of a flexible, reliable and easily accessed medium for understanding and sharing information. The PDC's Disaster All-hazards Warning, Analysis and Risk Evaluation (DisasterAWARE), is a wide-ranging, global decision support system. It is a mature technology that has been developed and enhanced over more than a decade. DisasterAWARE continually 'listens' to trusted hazard data sources, and integrates impact modelling, risk exposure and a host of other information to deliver web- and mobile-accessible mapping and geographical information service capabilities to the public and disaster managers worldwide.

One significant advantage of DisasterAWARE is its extreme scalability to display information not only at global, regional or national scales, but to visualize highly localized data in a map viewer, including the assets potentially at risk and the hazards that threaten them. The value of such an application for urban planning purposes was first demonstrated by PDC in 2003-4 in Marikina City, where a multi-hazard risk and vulnerability study was done to inform development plans for an 8.3 square mile component of Metro Manila, Philippines. The Internet-based map viewer for the 'Multi-hazard Risk Assessment for Marikina City, Philippines' allowed the user community to see the flood and earthquake hazards, for instance, that specifically affected City Hall. At the other end of the scale, DisasterAWARE includes layers of global hazard risk exposure such as storm and earthquake intensity zones. The system also offers a vast archive of historical hazards, and serves a variety of near-real-time warnings, integrated with impact modelling and observational data. Many of the near-real-time hazard data are also made available on iOS and Android mobile devices through a free app, Disaster Alert. The system does not yet incorporate the climate change information currently being developed (impacts of rising sea levels, infrastructure fragility etc), but the functionality has been designed and is growing to meet such needs.

With each new release of DisasterAWARE, several times a year, new data layers become available. As new national, international and multinational authorities adopt the system, it becomes better able to respond to a wider range of needs. For example, in 2011 the platform started offering multi-language support and as of September 2012 supports users with English, Vietnamese, Spanish, Indonesian, and Thai.

Development of new data, including calculations of potential climate change impacts, is underway around the world. The process may need to be accelerated, but not at the expense of rigour or the greatest level of detail and smallest level of scale possible. The demand for innovation in information and communications technologies will continue to grow with the pressures of population growth, urbanization and climate change. If developments in meaningful technology do not come fast enough, these changes in the human situation will overwhelm coping capacity, again multiplying the impacts of disasters.

New technologies, data and uses

Given all the pressures of population, urbanization and climate change, effective emergency management is possible only in an environment where data flows rapidly both to hazard-affected populations and emergency service providers. Mobile devices make it possible to deliver real-time, place-specific information to those who need it — victims and service providers alike. Mobile applications, including PDC's Disaster Alert, also increase real-time situational awareness for those who are threatened by disaster and those responding with assistance. The disaster data that is collected and analysed is, more quickly than ever before, reaching those in peril, but new technologies also offer a tantalizing possibility that they will become sources of new data as well.

There are challenges to be overcome in order to access and make use of the wealth of new data from social media and mobile messaging. Tapping these vast open sources of information means gathering misleading statements along with great stores of accurate facts, for instance. Analysts will have to learn to deal with these outliers, and to recognize the points of information that either define or contradict the core reality — and they will. Already, disaster information can reasonably and reliably move in one direction using services like blogs, SMS, instant messaging, chat rooms, online forums, wikis, YouTube channels, LinkedIn, Facebook and Twitter. At the same time, mobile phones have proven their value when responders, especially search-and-rescue teams, can use them to locate victims.

Despite the seemingly inexorable collision of population, urbanization, globalization and climate change risk, as well as an overriding uncertainty about the future, there are distinct rays of hope in the planning for future climate change. In particular, increasing knowledge of the causes and effects of climate change allows for a clearer definition and prioritization of risks essential for both mitigation and adaptation planning. As a result of these inputs, many of the world's largest urban centres are developing new and innovative approaches for disaster risk reduction, and most importantly, climate change mitigation and adaptation is rapidly becoming a 'whole of society' concern. While the world and the urban centres prepare for the future, disaster managers worldwide are a step away from being able to collect, consume, analyze and share the massive amount of data being generated worldwide and by users of mobile devices and online services. These activities will catapult all phases of disaster management to previously unknown levels of responsiveness and effectiveness, giving reason to hope that we can overcome the current challenges, including climate change, even in a world of billions and among people who are concentrated in megacities.

The power of information fusion: a DisasterAWARE screenshot from 28 August 2012 showing three tropical cyclones overlaid on storm intensity zones, seven-day cumulative rainfall (observed), sea surface temperature (observed) and expected rainfall (modeled)

Source: PDC

Climate services in Hong Kong: accomplishment through partnership and outreach

Hilda Lam, Assistant Director and Tsz-cheung Lee, Senior Scientific Officer, Hong Kong Observatory

Hong Kong has a sub-tropical climate, situated off the coast of south China with a land area of about 1,100 square kilometres. It has developed from a small fishing village in the mid-nineteenth century into a modern and vibrant metropolis with seven million people today. With the first observational post set up in 1883, the Hong Kong Observatory (HKO) has been making meteorological measurements for almost 130 years. These serve as a valuable basis for its climate research and services. During the rapid modernization period in the second half of the twentieth century, HKO rendered high-quality climate services in support of the infrastructural build of the city. In the last few years, with a view to addressing the increasing needs of society for climate services for policy and decision-making (including for climate change mitigation and adaptation), HKO has lent itself to building partnerships with various stakeholders and engaging in outreach activities to broaden the scope and applications of its climate services.

Climate services in the twentieth century

During the twentieth century, the main thrusts of HKO's climate services were:

- To conduct climate observations and monitoring and to maintain proper climate records
- To use relatively simple statistical methods to determine the average climate conditions of Hong Kong
- To use extreme value analyses to estimate return periods of specified values of meteorological parameters.

With government departments and the engineering community as its main clients, HKO was often called on to provide meteorological data, analyses and advice for the establishment and regular review of the engineering design standards and codes of practice appropriate to local conditions for protecting public safety. These included:

Image: HKO

The Central and Wan Chai Reclamation Project in the Victoria Harbour – a new harbour-front development in Hong Kong

- Providing information relating to the Code of Practice on Wind Effects to ensure that local buildings were strong enough to withstand hurricane force winds, a threat brought about by the occasional passage of typhoons
- Estimating probable maximum precipitation for the design of drains with sufficient capacity to prevent flooding (Hong Kong's annual rainfall of some 2,300 millimetres is normally concentrated in the May-September period)
- Anticipating maximum sea level, taking into account the tidal cycle and storm surge brought by typhoons for incorporation in the Port Work Design Manual for designing port, reclamation and coastal engineering facilities to protect the city from sea flooding.

Climate services in recent years

With the advancement of society, demand for climate services has extended from supporting the building of infrastructure to the improvement of people's health and quality of life. Advances in information technology and numerical climate prediction also provide the opportunity to enhance the accuracy and variety of climate forecast products ranging from weeks to months, to seasons, and to the year ahead. The concern about global climate change spawns a growing demand for projecting future climate conditions to support mitigation and adaptation decision-making, policy and development planning. Thus, HKO's climate services have acquired new dimensions in recent years. Through a series of collaborations and outreach activities, HKO has successfully built close partnership with a diversity of stakeholders to enhance climate services and the use of climate information in Hong Kong. These projects and activities cover various areas including public health, water resources, urban planning, flower cultivation and public education on climate change.

Climate and public health

It is well known that climate conditions can impact public health. In collaboration with other government departments, tertiary institutions and social enterprises, HKO has been studying the impact of climate on public health in Hong Kong with particular focus on thermal stress and the occurrence of infectious and vector-borne diseases.

Influenza epidemics

Influenza is a common seasonal communicable disease in the city. HKO collaborated with microbiologists from the Chinese University of Hong Kong to study the seasonal variations of influenza occurrence, using the laboratory-confirmed influenza cases admitted to a local hospital and the meteorological data recorded in a nearby weather station. The study identified the favourable climatic conditions for the occurrence of seasonal peaks of influenza in Hong Kong and provided useful information on the timing and duration of the application of vaccinations for protecting the public.[1]

Ovitrap index

To study the effect of weather on the abundance of Aedes mosquitoes (a common mosquitoes which can transmit dengue fever) in the city, HKO worked with the Department of Food and Environmental Hygiene (DFEH) to set up ovitraps at an experimental site undisturbed by human intervention and to record an ovitrap index (the percentage of ovitraps set up at site with breeding of Aedes mosquitoes) for about two years. By analysing the ovitrap records and the meteorological data from a nearby weather station, a model was devel-

Image: HKO

The High Island Reservoir was opened in 1978, helping to alleviate water shortage problems in Hong Kong oped to predict the abundance of Aedes mosquitoes in Hong Kong based on climate data.[2] With climate information regularly provided by HKO, DFEH makes reference to forecasts from this model in the planning and execution of preventive and control measures against Aedes mosquitoes.

Care of senior citizens

In the past few decades, flats in Hong Kong have become smaller due to intense urbanization. More senior citizens are left to live on their own after their children have grown up and moved out to start their own family. There is a need to provide more care for the elderly in the city. The Senior Citizen Home Safety Association (SCHSA) is a social enterprise which operates a 24-hour emergency support and care system for over 80,000 senior citizens. SCHSA calls up to check on its members from time to time, and members can push a button on a special device to request help from the association when necessary. SCHSA's workload is highly weather-sensitive, and to provide better care for the elderly, HKO cooperates with the association on a number of activities. Using SCHSA's member contact data, HKO studied the effect of hot and cold weather on the elderly.[3] Weather forecasts as well as the experimental monthly climate forecasts prepared by the Observatory are made available to SCHSA. When cold weather is expected, SCHSA will call up and send out volunteers to visit its most vulnerable members to help them prepare. It will also disseminate telephone messages recorded by HKO senior staff to alert all members about the impending cold weather. SCHSA also makes use of the weather and climate forecasts for planning manpower requirements for its outreach operations.

Urban planning and building environment

The dense development of a crowded city like Hong Kong may have significant impacts on the urban climate (such as higher average temperatures, lower wind speed etc), resulting in uncomfortable habitats and increases in energy consumption. To help mitigate these negative effects and improve the quality of the living environment through integrating climatic considerations in urban planning and design, HKO has been providing meteorological support for the Planning Department and its consultants to establish guidelines to assess and regulate the impact of potential city, community and building developments on air ventilation. Furthermore, urban climatic maps have been drawn up by analysing and evaluating climate data together with different geometric and urban development data (such as land use, building density and topography) to classify Hong Kong into different urban climatic zones, each with recommended planning and development actions.[4] HKO's involvement includes provision of climate data (such as winds and temperature) over the territory, and advice on the local wind climate and the interpretation of analysis results.

Water resources

The two main sources of fresh water supply in Hong Kong are rainfall collected from local catchments and water imported from the neighbouring Guangdong province of mainland China, with the latter supplying about 70-80 per cent of local demand. Agreement has been made between the water authority in Hong Kong (the Water Supplies Department or WSD) and its Guangdong counterpart to secure a reliable and flexible supply of water to meet Hong Kong's needs. The water supply should tie in with the seasonal or monthly variation of yield collected at local reservoirs so as to have a better control of water storage levels, minimizing overflow and pumping costs.

To enable a better informed decision-making process on water supply, HKO has collaborated with WSD in exploring the feasibility of forecasting yield collected in local reservoirs. First, the statistical relationship between monthly yield collected at a number of reservoirs and contemporaneous rainfall recorded at stations nearby was investigated and regression models were built to forecast yield, using station rainfall as a predictor. HKO provided station-specific rainfall forecasts, generated from statistical downscaling of climate model outputs provided by the Global Producing Centres for Long-Range Forecasts. Results in the past two years suggested that this two-step forecast method (rainfall forecast followed by yield forecast) generally gave a good indication of the yield anomaly in the coming month. However, the gain in terms of absolute error when compared to the climatological yield forecast was just marginal and the fluctuation of forecast performance could be large at times. This might be due to the relatively short period of rainfall records in some stations and to error amplification through the two-step approach. To further enhance the forecast performance, HKO has directly downscaled global model outputs to forecast the total yield to WSD since mid-2011 (one-step approach). Verification of the two-step approach and one-step approach shows that, in the last year or so, the former could achieve 12 per cent error reduction compared to the climatological forecast while the latter could push the figure up to 21 per cent. This investigation has demonstrated the benefits of climate prediction for managing water resources in Hong Kong.

Flower cultivation

In Hong Kong, flower cultivation has gained importance in recent years, especially for festival flowers for the celebration of the Lunar New Year in January/February. Unseasonably warm or cold weather before the Lunar New Year will affect the flowering time of popular flowers such as peach blossom, lily and gladiolus, which have a growing period of up to 100 days. Traditionally, flower farmers have relied on climatology and folk wisdom to make decisions regarding the timing of planting and the need for adaptation measures to protect their flowers or to control growth rate to ensure the flowers will blossom just before the Lunar New Year. To better serve the flower farming community and other agricultural sectors, HKO is working closely with the Agriculture, Fisheries and Conservation Department (AFCD) to improve climate information and prediction services for the local farmers. Some of the plans on hand include:

- Organizing seminars/workshops to facilitate communications with local flower farmers and promote the use of climate information and predictions in various farming activities
- Providing seasonal and experimental monthly forecast with timely updates for local flower farmers
- Establishing a new climate station in AFCD's experimental farm, to study the effect of weather and climate on plant cultivation for long-term enhancement of climate services to the farming sector.

Delivering climate change messages to the public

Climate change has been a hot topic of discussion across the world in recent years. Besides conducting scientific studies, HKO has been working proactively to keep all sectors of the public informed about the latest scientific basis and research findings on climate change, and to raise awareness of climate change impacts. HKO has packaged relevant information on climate change into comprehensible messages that strike a chord with the layman, and has partnered with different organizations to communicate the information to the public through various channels and activities.

Mobilizing the media

HKO officers proactively engage the media to promulgate information on climate change to the public through press conferences and feature interviews in newspapers, radio and TV programmes. HKO meteorologists have also taken part in the filming of the climate change TV documentary ‘Sinking Islands’ and the documentary ‘Sixteen Degrees’ shown on TV, public buses and the Internet to explain the scientific basis and potential impacts of climate change both locally and worldwide.

One-stop climate change webpage

Since 2007, HKO has launched and maintained a climate change webpage on its website for public access. The webpage serves to provide the public with a one-stop shop for information on local and global climate change.[5]

School and public education on climate change

HKO has produced an educational package on climate change for free distribution to schools and libraries in Hong Kong. Presented in Chinese and English, the package includes an animated cartoon DVD, a cartoon booklet, PowerPoint presentations and list of reference materials. The package is very well received by schools, non-governmental organizations (NGOs) and academic institutions.

HKO also organized student project competitions to enhance students’ understanding of climate change and its impacts. Furthermore, a team of professional meteorologists from HKO has been formed to deliver talks on climate change for schools and to give free public lectures. In the past five years, the HKO Speaker Team on Climate Change has delivered over 250 talks with most encouraging feedback.

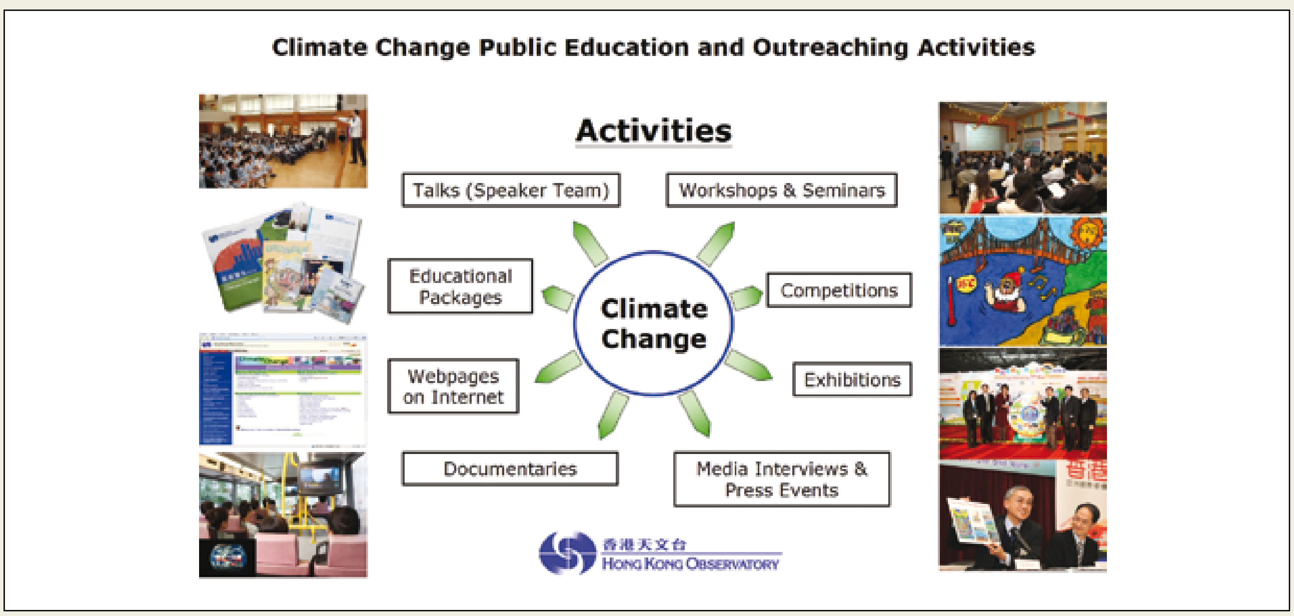
Stakeholder engagement

HKO organizes or supports local and regional workshops on climate change and climate prediction for the benefit of operational meteorologists, students, government departments, NGOs, and the business and engineering sectors among others. HKO also joined forces with the meteorological authorities in neighbouring Guangdong province and Macao and a major bank, to stage a large-scale exhibition — ‘Climate is changing, act now!’ — to enhance public understanding of the causes of climate change, its impacts and what we can do to mitigate its effects.

The way forward

Looking ahead, along with the implementation of the World Meteorological Organization Global Framework for Climate Services, HKO will continue to develop and enhance climate services to meet local and regional needs through user and stakeholder engagement and a sector-by-sector approach. It will continue to focus on promoting awareness and use of climatic information, developing channels of communication to deliver information to users in comprehensible formats, enhancing the skills and effectiveness of climate forecasts with emphasis on high impact climate events as well as quantifying and communicating uncertainties of the climate predictions.

HKO’s climate change public education and outreaching activities



Source: HKO

Towards climate risk resilient cities: spatially explicit land-use scenarios

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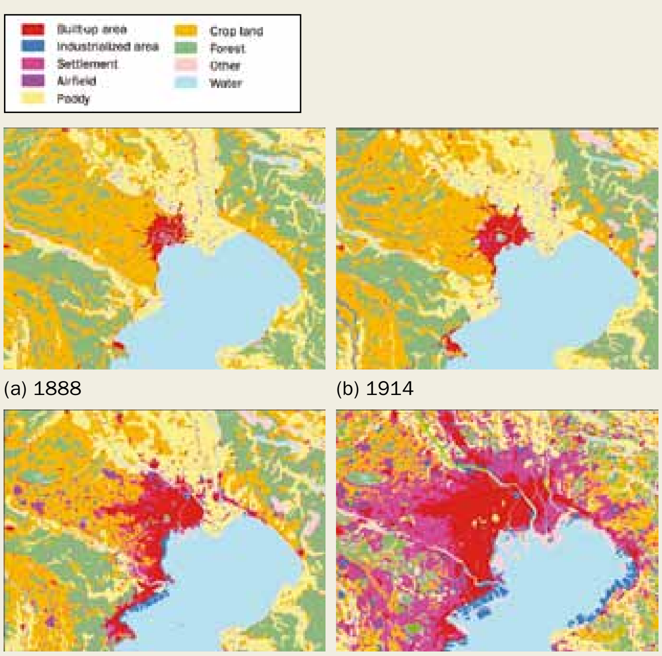
National Institute for Environmental Studies, Japan

As we face a future of human-induced increase of greenhouse gases in the atmosphere, we need to prepare for climate change impacts that will see temperatures increasing 3-5° C since the industrial revolution. In the process of urban planning, it is necessary to consider not only climate change mitigation but also adaptation measures. The Tokyo Metropolitan Area, which is still by far the largest megacity in the world, is extremely vulnerable against climate risks (especially flooding) because a large part of important infrastructure is concentrated near the bay area. Climate research projects increasing flooding risks in Tokyo due to climate change as well as tsunamis from large earthquakes in the future. We need to consider appropriate land uses that are more resilient to climate risks.

Recently, in connection with the planning of low-carbon cities, many urban planners have become aware of the 'compact city' concept. Because sprawled cities with low residential density depend inevitably on heavy car use, it is suggested that a reduction in CO_2 emissions could be achieved by changing urban form to a more compact style, to increase the use of public transport. We should also point out that compact cities are not necessarily more vulnerable to climate and disaster risks.

We need to carefully analyse the implications of different land-use scenarios. For instance, it is important to consider the co-benefits of climate change mitigation and adaptation measures. In order to come up with an appropriate urban design in terms of climate risk management, we need a tool that allows us to conduct city-level scenario assessments. For that purpose, we have created a new, spatially explicit urban land-use model.

Spatial explosion of the Tokyo Metropolitan Area, 1888-1975



(a) 1888 (b) 1914 (c) 1946 (d) 1975

Source: The National Atlas of Japan, GSI

Urban development in Tokyo

Before looking into the future, let us look back on the past 100 years of urban development in the Tokyo Metropolitan Area. The images on this page show the historical growth of the urban built-up area, estimated from *The National Atlas of Japan*.[1] The maps were digitized for the years 1888, 1914, 1946 and 1975, then geographically registered, and urban areas were delineated using a geographic information system technology for conducting quantitative analyses. The images illustrate the dynamic urban centre expansion pattern, especially after the Second World War (1950s) and the rapid suburbanization during the fast gross domestic product growth period (1970s). Urban expansion has continued and reached almost a maximum during the bubble period (1990s). Since 2010, Japanese society has entered the phase of the 'over-aged, population decreasing period'. One of the most difficult urban issues in the near future will be to consider how to achieve this shrinking phase in a sustainable manner. It is financially impossible to maintain all urban infrastructures equally, so we need to make wise urban land-use scenarios.

Land-use scenarios and the heat island effect

The Center for Global Environmental Research, National Institute for Environmental Studies urban economics model calculates the interaction between land, transport and energy use in cities. It describes the behaviours of the associated household/developer agents using parameters such as the spatial distribution of households, land rent, building rent, land demand and supply, and building floor demand and supply.[2] The model has been calibrated with recent socioeconomic data at the district level (around 1 km grid). Next, we projected two different land-use scenarios: compact city and dispersion. The two scenarios were produced by calculating the equilibrium of housing location due to the change of land-use policies (incentive) in both compact and dispersion directions. For the two scenarios, we estimated the CO_2 emissions, heat emissions from buildings and transport (road), the green space ratio, building density and so on.

Following this, we simulated and compared the heat island effect for the compact and dispersion scenarios by inputting all the parameters of the two scenarios into an urban climate model.[3] Interestingly, the results showed that in the compact city case, the urban heat island effect will decrease by 0.5 of a degree if the suburban areas, where housing is moved from, are re-vegetated. However in the dispersed city case, the heat island effect will worsen, with a 0.5 degree increase due to both urbanization and a decrease in vegetation in the suburban areas. Spatially explicit land-use scenarios were only recently introduced as a part of the Intergovernmental Panel on Climate Change's global climate modelling. However, as our preliminary modelling attempt suggests, such scenarios would be more important for urban and regional planners who need to look at specific local adaptation measures against climate change. For achieving sustainability, nothing is more important than the need for stakeholders to come up with an appropriate plan with scientific knowledge about possible risks.

Possible synergies between scenarios

Using the urban simulation model, we also analysed the possible synergies between climate change mitigation and adaptation. We considered a case where, as a climate change adaptation measure, houses in the high flood risk area are moved. Then, in addition to the compact city scenario, we assumed that electric vehicles replace conventional cars and photovoltaic panels are introduced as climate change mitigation measures.

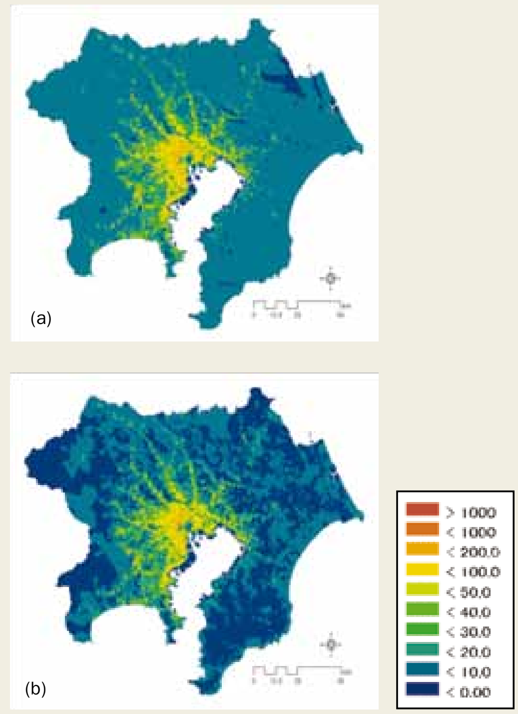
The CO_2 emissions for the current business as usual (BAU) and the above-mentioned adaptation/mitigation scenario suggest that potential for a large reduction in CO_2 emissions exists in the adaptation/mitigation scenario if a solar power plant could be constructed in the high flood risk area that houses are moved from.

A sustainable future

We have created future land-use change scenarios with geographical distribution in Tokyo and tested them for climate change measures. To support designing future sustainable cities, it will be important to:

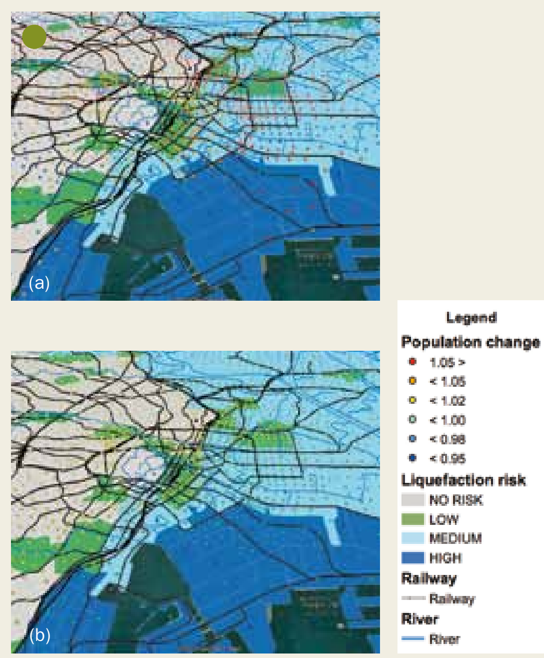
- Create an urban simulation platform that offers climate risk information required for making cities more resilient to climate extreme events with more advanced meteorological modeling
- Support integrated assessments to deal with complex impacts of extreme climate events and other risks including earthquakes
- Provide policymakers with the implications of different land-use scenarios based on various sustainability indicators.

The spatial distribution of CO_2 emissions showing (a) BAU and (b) the mitigation/adaptation scenario



Source: Yamagata et al. (2012)

A comparison of the flooding risk between (left) BAU and (right) the adaptation/mitigation scenario



Scenario (a) is 'business as usual'. In the mitigation and adaptation scenario (b), people avoid the high-risk areas, achieving 'compactness' of the city

Source: Yamagata et al. (2012)

New Zealand's climate change and urban impacts toolbox

Andrew Tait, Principal Climate Scientist,
National Institute of Water and Atmospheric Research, New Zealand[1]

New Zealand needs communities that are resilient to climate change and the hazards that come with it. The *Impacts of Climate Change on Urban Infrastructure and the Built Environment Toolbox* is designed to help city, district, regional and central government identify opportunities and reduce the impacts of climate change.[2]

Around 75 per cent of the NZ$1.5 billion insurance payout for damages from natural hazards in New Zealand over the last 40 years (prior to the recent Canterbury earthquakes) was for weather related hazards.[3] These hazards are expected to increase in future because of climate change, perhaps greatly so if international efforts to reduce greenhouse gases are not significant.[4]

Urban environments are particularly vulnerable to extreme weather and flooding events (including coastal storm surge), and are also where the majority of New Zealanders live for all or most of their lives.[5] Urban environments contribute significantly to economic activity and the country's gross domestic and gross national product, and contain most of the country's educational, cultural and health facilities, both in number and significance. Urban environments also contain the majority of the country's public and community investment, and much of its private investment.

The *Impacts of Climate Change on Urban Infrastructure and the Built Environment Toolbox* is designed to provide guidance and decision tools that can be used by urban council staff and policy makers to reduce the potential harm caused by projected climate changes. The toolbox will help city, district, regional and central government identify opportunities and reduce the impacts of climate change. It follows a science-based risk assessment process[6] and demonstrates methods of identifying adaptation options and evaluating their benefits. The tools build on and frequently reference existing climate change guidance material, available from New Zealand's Ministry for the Environment.

Image: West Coast Regional Council

Flooding of the Buller River on 25 July 2012

Flooding in Westport on 5 November 1926: situated on the floodplain between the Buller River and the Orowaiti Estuary

Who should use the toolbox?

The toolbox is primarily designed to help planners, engineers, asset managers and hazard analysts working in councils in New Zealand understand and evaluate the potential impacts of climate change in their cities. Thus, the principal end-users are New Zealand council staff with the following roles and responsibilities:

- Infrastructure management
- Asset management
- Consents
- Transport
- Urban development
- Strategic planning
- Emergency management.

How is the toolbox structured?

The central purpose of the toolbox is as a fundamental reference for councils that are undertaking analyses of the potential effects of climate change on their city. It describes an end-to-end evaluation process of:

- Understanding the issues
- Assessing the likely hazard (or change in the hazard)
- Identifying the risks
- Evaluating options and their costs and benefits
- Using the tools and improving practice.

The toolbox structure follows these five stages of the evaluation process. Consistent with the toolbox concept, each of these stages can be considered a 'tray' in the box. Users can choose tools from any tray, depending upon their information needs. Each tool is a standalone document, designed to help the user with a specific task in the evaluation process. Some tools provide information and guidance, while others describe models or approaches for estimating impacts and dealing with uncertainty. Wherever possible, worked-through examples are provided as well as critical sections on data needs, model assumptions and limitations.

Overview and Linkage tools have been included throughout the toolbox, to provide higher level summaries and 'where-to-from-here' guidance, respectively. Furthermore, the authors of every tool have been identified and can be contacted directly for more information, particularly regarding the use of models and other analytical methods.

Types of tool

There are two types of tool available in the toolbox; guidance and decision tools. The guidance tools come in three forms:

- General information and reference tools provide background knowledge and complement other existing sources of information such as the Ministry for the Environment guidance manuals
- Models and methodology descriptions with examples detail the models and methods that can be used to assess climate change effects, with sections on data needs, assumptions and limitations as well as linkages to other tools, including decision tools
- Messages for improving practice are found in the fifth tray and provide information on how to integrate climate change assessments into council planning and operations.

Decision tools are provided to inform the decision-making process. They present a set of methods and examples for filtering and summarizing complex information based on repeatable standardized criteria so that decisions can be rationalized and traced. In most cases, it is suggested that these tools be implemented in a workshop environment, where there is scope for multiple iterations.

A decision framework for climate change adaptation

A decision framework has been developed that provides for a balanced and justifiable prioritisation of sustainable adaptations to climate change and which is flexible to change. The current level of uncertainty surrounding the timing and geographic location of future climate effects requires this risk-based framework. It incorporates formal decision-making processes and employs a toolbox approach because the diversity of decisions to be made is not conducive to a one-size-fits-all approach.

While there are many ways that priorities for action could be established, it is likely that a staged and risk-centred approach, involving a successive narrowing down and refinement of the issues of concern, will be an important part of setting priorities.[7] With climate change singled out for attention, an example three-stage approach is as follows:

- Stage 1 involves an assessment of priorities across all the climate change effects of relevance for the geographical region of interest, to identify priority climate change effects and areas most vulnerable to them
- Stage 2 involves risk mapping of priority (high risk) areas for the selected climate change effects, as identified in Stage 1
- Stage 3 involves identifying preferences among alternative adaptation schemes to address the priority climate change effect (identified in Stage 1) and the risk identified in the priority locations (identified in Stage 2).

Funding for the toolbox was provided by New Zealand's Ministry of Business, Innovation and Employment. It was produced by researchers in the National Institute of Water and Atmospheric Research, MWH New Zealand, Allan Planning and Research, GNS Science and the Building Research Association of New Zealand.

Case study: Modelling future flooding in Westport, New Zealand

Flooding is the most frequent natural hazard in New Zealand.[8] Under climate change, rainfall events in New Zealand are forecast to become more intense, causing greater storm run-off and a decrease in the protection afforded by measures such as levees.[9] Urban environments in New Zealand and around the world are particularly vulnerable to extreme weather and flooding events. A key finding of the New Zealand Government's review of flood risk management was that good information on the nature of the flood hazard was crucial to the management of flood risk.[10] This is backed up by Regional Council Strategy documents which state that more research is needed for "development and implementation of updated techniques for modelling and mapping to determine the economic risk of river flood hazards that are applied consistently regionally and nationally"[11] and "to provide a more robust and defensible position to address hazard risk more effectively, and to give decision makers confidence".[12]

The Impacts of Climate Change on Urban Infrastructure and the Built Environment toolbox was used in Westport, which is particularly vulnerable to flooding because it is on the flood plain between the Buller River and the Orowaiti Estuary, an old channel of the Buller River that carries a substantial flow during large floods. Westport is vulnerable to inundation from a combination of river floods and high sea levels. It is therefore important to understand whether climate change could lead to any further increase in flood risk for Westport.

Experience in Westport shows how physically-based climate, hydrological and hydrodynamic models can be used together to simulate changes in meteorological and hydrological processes under future climates, and how the effect of those changes on projections of flood inundation and risks to people and assets can be evaluated. Using a historic 1-in-50-year event as a baseline, we predicted how the severity of that event would change under several future climate and sea level rise scenarios. Statistically downscaled projections from global climate models were used to define appropriate adjustments to the historical rainfall and temperature measurements. Using a hydrological model, these data were used to simulate flood hydrographs at the Te Kuha gauging station upstream of Westport. The resulting hydrographs predicted for the future time period 2080-2099 correspond to events in the current climate with recurrence intervals of 78, 98 and 113 years for the B1, A1B and A2 IPCC SRES scenarios respectively. The flood hydrographs provided upstream boundary conditions for a 2D hydrodynamic model simulating inundation of the Buller flood plain. Predictions for the inundated area increase from 50 per cent of Westport town in the current climate to 67 per cent, 70 per cent, and 72 per cent for the B1, A1B and A2 scenarios for the 2080-2099 time period. Resulting maps of inundation depths and velocities allow detailed planning for the mitigation of flood events. We used the hazard assessment tool RiskScape[13] to calculate the impact of the flood on people and assets (buildings, contents and vehicles) within the inundated area. The predictions showed that under the A1B 2080-2099 scenario, present day Westport could expect risk to life classified as 'medium' or greater to 560 people, building damage of NZ$72 million and contents damage of NZ$68 million.

This and other flood assessment information is currently being considered by the decision-makers and public of Westport and surrounding communities. Several flood adaptation options for Westport are being considered and compared, and an early indication is that improvements to stopbanks are likely to be the best option for flood protection and are worthy of further detailed investigation and consultation. Additionally, raising houses above the flood level is feasible in many parts of Westport's residential areas, but is less feasible for large buildings and commercial areas. A long-term plan to renew/rebuild structures at higher foundation levels to progressively reduce flood risks is also being discussed.

IX
Communities

Making climate science useful: cross-regional learning from Kenya and Senegal

Emma Visman, Humanitarian Futures Programe, King's College London; Dr Arame Tall, Consultative Group on International Agricultural Research (CGIAR) Climate Change, Agriculture and Food Security Programme; Richard Ewbank, Christian Aid; Professor Dominic Kniveton, University of Sussex; Dr Mariane Diop Kane, Head of Forecasting and Observational Networks Department, Agence Nationale de l'Aviation Civile et de la Météorologie du Sénégal; Dr Richard Jones, UK Met Office Hadley Centre; Ezekiel M Njoroge, Kenya Meteorological Department; and Dr Andy Morse, University of Liverpool

In 2009 the Humanitarian Futures Programme (HFP) based at King's College London initiated a series of pilot two-way exchanges between a number of international climate scientists and humanitarian organizations. This process led to the development of a collaborative proposal between climate scientists and meteorologists from national meteorological departments and universities in Kenya, Senegal and the UK,[1] and policymakers from a number of international humanitarian organizations[2] and the partners and communities with whom they work. Together, these partners are undertaking two demonstration studies to assess how climate science can better support humanitarian, disaster risk reduction and development decision-making.

Communities living in the arid and semi-arid areas of Kenya are largely dependent on rain-fed agriculture and livestock production and are increasingly vulnerable. More than 75 per cent of Kenya's population works in the agriculture sector, and is highly vulnerable to climate shocks. In recent years, the Mbeere district has frequently received inadequate rainfall and experienced a succession of poor harvests and associated high levels of livestock mortality.

Mbeere district is the focus of a demonstration study that involves climate scientists from national meteorological departments and universities in Kenya and the UK partnering with policymakers from national and international humanitarian and development organizations. The study supports the development of an integrated cross-disciplinary approach with the aim of helping to improve the capacity of vulnerable communities to respond to climate and weather risks and advance climate scientists' understanding of the climate information needs of humanitarian users. It is one of a series of two pilot exchanges initiated in 2011 by the HFP based at King's College London, and embedded within a three-year Christian Aid Sustainable Agriculture and Livelihoods Innovation project (SALI). A parallel demonstration study in the Kaffrine district of Senegal is also underway (see the following case study). This article seeks to identify and draw together generic learning from across the demonstration studies in both Senegal and Kenya.

The exchange approach has provided an unforeseen framework for innovation, creating the linkages and space to develop new approaches which offer the potential to better meet users' information needs including regular forecast updates by SMS in local languages direct to key community actors. The process includes community-based evaluation, technical reviews of the provision and use of climate information following each season and the development of approaches which support direct and more effective dialogue between the providers and users of emerging climate science.

Building on past efforts

Efforts to strengthen systematic response to risks identified by science are not new. There are a multitude of early-warning systems, including seasonal rainfall and crop forecasts; nutritional and epidemiological surveys; networks of earthquake and tsunami early warning systems; and volcano monitoring stations. Each operates at different geographic and temporal scales, offering forecasts with differing levels of certainty. Often the barriers to effective use of scientific forecasts are not related to a lack of information, but to lack of political will to act; inability or unwillingness to invest in risk-based prevention; lack of understanding regarding probabilistic information or appropriate forms of action to take; or not ensuring that timely, relevant information reaches those who are able to take independent action.

There is a need to break the cyclical nature of crises in regions vulnerable to climate hazards, and to contextualize weather and climate information within the complex multi-hazard environments in which these crises occur.

There are a number of major international frameworks guiding humanitarian and development initiatives due for review in the coming few years. This exchange project answers the principles of the World Meteorological Organization (WMO) Global Framework for Climate Services, offering significant opportunities to establish more systematic and integrated use of weather and climate information at all levels of humanitarian, disaster risk reduction (DRR) and development decision-making and so to address some of the drivers of persisting vulnerability.

Farmers in Mbeere District, Kenya discuss the seasonal forecast results

To develop relevant climate services, weather and climate information needs to be:

- Contextualized within the multi-hazard environments in which vulnerable communities live
- Integrated within all relevant sectors, including agriculture, health, livestock, water and sanitation, infrastructure (including housing), transport and marketing
- Considered within an integrated risk management approach, which allows for consideration of combinations of risks and hazards within communities, countries and regions as well as globally.

While recognizing the importance of developing a framework for systematic use and response to weather and climate information across humanitarian, DRR and development planning, it is just as vital to develop channels for community decision-making to be directly informed by weather and climate information. While international and national governmental and non-governmental organizations may have funding and other constraints preventing them from acting on uncertain information, communities may still be able to take a number of appropriate actions themselves if given access to relevant, timely information.

Efforts to support greater and more appropriate application of forecasts also highlight the importance of strengthening the scientific literacy of community and humanitarian users, as well as extension services, about the levels of confidence and uncertainties within the weather and climate information available at different timeframes and across different regions. Efforts to build understanding about the probabilistic nature of climate information and the levels of reliability will build a body of 'demanding customers' more confident and better able to ask 'the right kind of questions'. Better use of climate information also requires that users receive the information in probabilistic rather than deterministic formats. Exchange activities have found that those living in multi-risk environments are used to taking decisions in situations of uncertainty. Participating farmers groups in Mbeere, for example, eagerly took to probabilistic information once it had been explained in straightforward terms with practical examples.

It is equally important to develop two-way channels for the development of weather and climate information which is best able to support the priority concerns of at-risk communities. It is, for example, clear that meteorologists and climate scientists need to maximize the relevance of forecast timings and ensure that these are best able to support critical livelihood decision-making processes. A number of the farmers participating in the SALI project in Mbeere urged that the forecast for the long rain season be issued by at latest mid-February instead of early March, as this was too late for their main pre-season decisions, while scientists are keen to ensure that the forecast is informed by key climate factors influencing the atmosphere, the timing of which may at present prevent the meeting of farmers' preferences. Developing user-driver climate services requires the identification of mechanisms which enable these communities to inform both the process through which information is provided and the focus of current and future climate research, wherever relevant. In support of existing governmental extension services, the humanitarian, DRR and development communities can play a key role here. Working through existing networks and partnerships, these organizations provide conduits through which weather and climate information can be disseminated and feedback can be received about community concerns.

Stakeholder involvement

In Kenya, the exchange has supported a forum bringing together the Kenya Meteorological Department (KMD) with service providers and extension workers from the Government departments of livestock, agriculture, agricultural research and cooperation, as well as marketing expertise from the Traidcraft fair-trade organization, to provide the integrated climate information relevant to participating farmers' groups in the drought-prone Mbeere district. The exchange approach offers opportunities to try out more relevant forms of communication and, for example, initiated the provision of SMS forecast updates in Kiswahili direct to participating farmers group in Mbeere. In the future, there is scope to further develop the range of sectoral and scientific expertise engaged to support other types and levels of decision-making processes.

Funding

While there are significant funds available for both climate change adaptation and climate science research, funding for activities which support dialogue between the two and enable the operationalization of climate information is difficult to identify, particularly where efforts are focused on meeting the climate information needs of community and non-governmental users. In July 2011, the Climate and Development Network approved £120,000 for a 12-month pilot.[3] The award is held by King's College London, with sub-award contracts with CRS and Christian Aid, which lead in-country activities in Senegal and Kenya respectively.

Project funding covers the costs of exchange activities and a very small percentage of staff time for those leading the coordination of activities. While implementation is to some degree dependent on all partners being willing to contribute expertise for free, it is also clear that all benefit from the engagement. Scientists are able to demonstrate the tangible impact of their work, humanitarian and development policymakers can develop more effective forms of support, and community decision-makers have access to relevant sources of expertise. The approach has not required infrastructural investment, and the potential and appetite for upscaling the approach is evident.

Involving the community

Community-based evaluations at the end of the rainy season review the process to ensure that communities receive timely, relevant information and allow partners to undertake the changes in format, channels and types of information required to better support community deci-

Case study: Senegal

This two-way exchange in the Kaffrine district of Senegal has brought together climate science and meteorological expertise from national, regional and international institutions with humanitarian decision-makers acting at community, district, national, regional and international levels. This project has been led by the National Senegalese Civil Aviation and Meteorology Agency (Agence Nationale de l'Aviation Civile et de la Météorologie du Sénégal – ANACIM) together with the Senegal Red Cross (Croix Rouge Sénégalaise – CRS) as part of its national disaster risk reduction efforts and undertaken through its countrywide network of community volunteers and coordinated with HFP at King's College London. The study aims to:

- Contextualize understanding of weather and climate hazards alongside other threats to human vulnerability
- Strengthen access to, understanding, and appropriate application of climate information among humanitarian and development organizations
- Improve climate scientists' understanding of humanitarian users' climate information needs.

More than three quarters of Senegal's population works in the agricultural sector. Since the mid-1990s, Senegal has witnessed an increase in flood disasters, while in 2011 the rains were poor. Both types of climate event have destroyed harvests, depriving agriculture-dependent families of income and driving them to migrate to flood-prone informal settlements in urban centres. The Kaffrine district has 500,000 inhabitants, 90 per cent of whom are rural.[7] On average, 20,000 people in the district are affected by are affected by rain damage and flooding each year.

Exchange activities are timed around Senegal's seasonal rains and embedded within ongoing humanitarian and development frameworks to support flood-prone communities. Focused on using forecasts in the near term – where the outcome of the forecast can be quickly assessed – the exchange uses a workshop methodology developed by Dr Arame Tall to bridge the gap between providers of climate science and users of climate services. The approach was developed and tested within the auspices of Red Cross work, and aims to build the confidence of communities to make greater use of information on longer-term climate change.

The initial section of each workshop comprises a series of modules tailored to promote user understanding of relevant areas of climate information. As well as information on seasonal, medium and short-term forecasts and climate change, the workshop in Senegal included modules on hydrological impact, environmental mapping, health and climate. A number of other dialogue approaches incorporated in the workshop format are specifically designed to support users' understanding of the levels of confidence and uncertainties within the science and how these might be downscaled to support national and community-level decision-making. These include:

- Knowledge Timelines, comparing community and scientific indicators
- Probabilistic downscaling, comparing local experience of impact with national observations and forecasts
- Joint scientist/policymaker/community decision maker Early Warning>Early Action forecast scenario game, supporting appropriate application of climate information at different timeframes in specific contexts[8]
- A joint scientist/policymaker/community decision maker visit to the community where exchange activities are being undertaken.

Many participants in the exchange have welcomed the creation of space for cross-sectoral, cross-departmental dialogue to support community resilience, recognizing its current absence at many levels of decision-making. In Senegal, exchange workshops have brought together extension workers from the Government Departments of Agriculture with the National Meteorological Agency, hydrologists and university climate modellers with humanitarian and community decision makers to share institutional expertise in climate research and environmental mapping. There is scope to further develop the range of bodies relevant to other decision-making processes as the exchange approach is upscaled and developed.

The study has identified gender-differentiated vulnerabilities and capacities in the community to cope with hydrometeorological disasters – for example, women were particularly keen to receive further information on dry periods as their planting takes place after men's, leaving a very short period for their crops to mature – and helped to define priority adaptation needs beyond the local capacity to cope. It has enabled meteorologists and climate scientists to better understand the types of climate services which users need to inform specific livelihood decision-making processes.

As in Kenya, the exchange approach allowed an opportunity to consider the range of information needs identified through the community-based evaluation within technical consultations among exchange partners in order to identity areas where existing climate data might better strengthen the information currently available. This process identified data which are not currently being made available to national meteorological agencies, but which easily could be – for example, it found that the National Meteorological Services have restricted access to detailed short-range forecasts and products from the European Centre for Medium-Range Weather Forecasts, particularly monthly forecasts.

The exchange offers the opportunity to make greater use of humanitarian and development organizations and faith networks as conduits for both the dissemination of climate information and feedback to scientists on ways in which climate services may better meet the needs of those most vulnerable to climate impacts. For communities in the Kaffrine district, SMS text messages in local languages, blackboards with assigned neighbourhood relays and mosques were among the media that were relevant to community members, with women finding locations such as water boreholes – where they tend to meet in the course of their daily routines – useful for disseminating information. By making use of these dissemination methods, information can empower communities so they are better prepared for hydrometeorological disasters.

Climate information is often difficult to understand, either because of the terminology used or because it isn't translated into local languages. Participants also felt that the formats used to provide information did not always convey inherent uncertainties to users, and that the timing of climate information did not always meet the communities' needs. There is a need to transform scientific information, which is often complex and in the form of maps or percentages, into simple and accessible messages that would allow people at risk to make sensible decisions on how to respond to an impending threat.

sion-making. Each exchange has also included a technical review, to see if there are additional sources of climate data and information that can enable exchange activities to better meet users' needs, as well as a number of activities to support cross-exchange learning, including participation of partners within one another's demonstration studies and an end-of-project workshop.

The exchange has already been able to demonstrate the following:

Increased ability for climate information to appropriately inform specific decision-making processes in vulnerable communities – In Kenya's 'short rains' of October, November and December 2011, based on a seasonal forecast projecting an early start to the rains and arising in part from the capacities developed within the exchange, farmers participating in the SALI project in the Mbeere District planted early-maturing crop varieties and/or deployed agricultural techniques that could withstand early cessation of the rains.[4] Farmers also used the forecast to make decisions on the amount of crops to grow, for example, whether to grow more or less sorghum or maize. It remains challenging to fully understand the more quantitative impact of increased access to, understanding and application of seasonal and other forecasts on production, yields and outputs in a way that reliably attributes this to forecasts, given the multiple other facts that influence them. While the project is working on the basis of a potential 10-20 per cent yield effect, some of the participating farmers thought the impact could be greater with a 'good' forecast. Further livelihoods impacts resulting from the uptake of weather and climate information are likely to emerge from ongoing work and evaluation processes due to be undertaken.

Strengthened dialogue between climate scientists, humanitarian and development policymakers and community partners – Each of the demonstration studies has included separate initial questionnaires with both the providers and users of climate information, to create a baseline of the current state of climate science-user dialogue against which to measure impact of exchange activities. Questionnaire findings have made clear that both providers and users of climate information recognize the need for, and welcome opportunities for, strengthened dialogue. Informal feedback and questionnaire findings have demonstrated that both community-based and national workshops have often given vulnerable communities and humanitarian policymakers their first opportunity to directly discuss weather and climate information with meteorological services and climate scientists. The exchange activities have also provided climate scientists with a rare, first-hand and contextualized understanding of users' climate information needs.

Creation of space for communities to come up with innovative ways to support more effective dissemination of climate information – Community-based evaluation has made clear the importance of revising the languages, format, channels, content and media through which information is disseminated. With most community members not having access to the Internet, through which the majority of climate information is currently disseminated, communities participating in the demonstration studies each came up with innovative, gender- and age-specific suggestions for communicating climate information, including via community leaders' meetings, posters, faith networks, forecast blackboards and a climate radio 'road show'.

Development of channels to enable users' climate information needs to inform the focus of current and proposed research – The exchange offers the opportunity of making greater use of humanitarian and development organizations and faith networks as conduits for both the dissemination of climate information and feedback to scientists on ways in which climate services may better meet the needs of those most vulnerable to climate impacts.

The information needs identified through the community-based evaluation were considered within technical consultations amongst exchange partners in order to identify areas where existing climate data might better strengthen the information currently available. This process identified data which are not currently being made available to

Image: A.Tall, 2011

Women in Malem Thierigne watching a video in the local language, Wolof, summarizing the results of the Vulnerability and Capacity Assessment and ensuring project activities are validated and owned by the community for 2011-2012

A memorandum of understanding signed in July 2011 between ANACIM and the CRS supports the transmission of flood early warning information at 72, 24 and three hours, as well as seasonal forecasts, to designated community leaders in Kaffrine. Information is transmitted both directly and via Red Cross volunteers to village chiefs, leaders of women's groups, representatives of agricultural cooperatives and community radio broadcasters, who are then responsible for onward dissemination within the community. Communities have used this information to make a range of decisions regarding livelihood and personal security.

The study has shown that timely, relevant information can empower the Kaffrine communities to be better prepared for hydrometeorological disasters. Partnerships are needed at all levels – with communities and their needs firmly at the centre – to put climate science at the service of communities at risk.

National and international partners are keen to secure the financial support required to extend the national reach of the exchange approach in Senegal, to comprise three key elements:

- Creating a framework for systematic and sustained dialogue between the providers and users of climate information
- Developing the integrated climate services required to support communities living in multi-hazard environments
- Identifying channels to develop and share learning about those forms of dialogue which are most effective in supporting appropriate use of climate information within different levels of decision-making.

national meteorological agencies, but which easily could be. Discussion within the exchange in Kenya highlighted the potential for KMD to access the Ensemble Prediction System, a graphical representation of forecast distributions of rain out to ten days, which could support improved information on dry spells within the season.

The exchange has also identified opportunities for user information needs to be addressed within ongoing and future research. Colleagues from both the Senegal and Kenya Meteorological Services undertaking fellowships within the Climate Science Research Partnership, a joint initiative by the UK Department for International Development and the UK Met Office, are, within their ongoing research, considering the performance of rain within the season and so approaching the community-identified need for better information on dry periods within the rainy season.

Building capacities

The exchange is based on identifying the complementary competencies across the broad range of actors required to ensure that climate science is able to better support community resilience. The approach seeks to strengthen the capacities of all partners. It is as much about strengthening climate scientists' and meteorologists' understanding of the information needs of climate-vulnerable users as it is about strengthening users' access to, understanding of and appropriate application of climate information.

There is a wide range of understanding of weather and climate information amongst humanitarian and development policymakers interviewed and consulted during the course of developing this exchange. Organizations have adopted a variety of processes, with varying levels of success, for enabling their policies, projects and programmes to be informed by climate science. Among the processes employed are:

- Development of new posts
- Hiring of specific climate science expertise
- Reliance on intermediary organizations and consultants
- Use of summary materials designed for non-specialists and policymakers.[5]

For many policymakers and community users, exchange activities have offered their first opportunity for direct discussion between meteorologists and climate scientists. The exchange has sought to address the following constraints:

- Developing approaches which support effective communication to non-specialist and community users of the levels of confidence and uncertainties within weather and climate information at different geographic and temporal scales
- Current lack of space for systematic dialogue between the providers and users of climate information at community, district, national, regional and international levels
- Contextualization of weather and climate information within the complex decision-making processes involved in strengthening the resilience of communities living in multi-hazard environments.

The exchange has identified the need to afford the resources and strengthen capacity for national meteorological agencies to fully realise their commitment to the mandate of providing climate information to at-risk communities and the humanitarian, disaster risk reduction and development bodies which seek to support these communities. Interestingly, the exchange has identified that for some national meteorological agencies, the constraints to better supporting users' climate information needs are less an issue of human resource capacities than of the logistical and financial resources required for national outreach. Equally, while similar efforts to strengthen the use of weather and climate information have often highlighted the impossibility of enabling direct access to climate science expertise for the wide range of users demanding their services, the exchange has identified a tremendous wealth of expertise available both nationally and internationally, which is at present underused and which is very open to the creation of channels to more directly support users' climate information needs. Furthermore, while there are many complementary pilot initiatives to strengthen effective use of climate information within at-risk communities, there remains insufficient opportunity to pool, sustain and scale up learning from across these initiatives.

Ongoing collaboration among exchange partners over a period of years has also created a network of trust and an emerging community of practice amongst those who are keen to develop approaches which strengthen effective dialogue between the providers and users of science. In 2010 HFP initiated a climate science humanitarian policy working group. Although principally based in the UK, this group has been informed by dialogue initiatives underway internationally. Hosted by a revolving series of institutions engaged in efforts to promote better use of climate science, longer-term coordination of the group has now been taken on by Dr Ros Cornforth of Reading University, and supported by AfClix, the web portal of the Africa Climate Exchange Project.

Future developments and challenges

National and international partners are keen to secure the financial support required to extend the national reach of the exchange approach in both Senegal and Kenya, with the intention of creating a framework for systematic and sustained dialogue between the providers and users of climate information. The aim is also to develop the integrated climate services required to support communities living in multi-hazard environments; and to identify channels to develop and share learning about those forms of dialogue which are most effective in supporting appropriate use of climate information within different levels of decision-making.[6]

The current state of dialogue between the providers and users of climate science

All participants in the demonstration studies in Kenya and Senegal were given questionnaires, to enable the development of a baseline of the current state of dialogue between community users, humanitarian and development policymakers and climate scientists. Their responses revealed that:

- All participating climate scientists, community decision makers and humanitarian and development policymakers agreed on the need for increased dialogue, and considered that this would strengthen their respective work
- The principal channels and formats through which climate information is currently disseminated are not readily accessible to community users
- The majority of community users and humanitarian policymakers said that climate information was increasingly important for their decision making
- Climate scientists in Kenya think that community organisations and national NGOs understand climate information less well than national, regional and international agencies and international NGOs
- All participating climate scientists said that greater dialogue with users would lead them to target their work to better support their specific climate information needs.

Development of climate services in Sweden to support climate change adaptation

Lena Lindström and Elin Löwendahl, Swedish Meteorological and Hydrological Institute

In 2005 the Swedish Government established a Commission on Climate and Vulnerability. The Commission analysed how Sweden's climate may develop over the next hundred years as well as the consequences of climate change for a number of societal sectors. Its work resulted in the 2007 report 'Sweden Facing Climate Change — Threats and Opportunities', with various assignments to authorities as well as other activities and measures concerning adaptation to climate change. In 2009 this was followed up by the Governmental bill, 'A Coordinated Policy for Climate and Energy,' which addressed the challenges identified in the commission's final report.

Climate change adaptation at the regional level

In 2009 the Swedish Government designated the county administrative boards in Sweden to coordinate climate change adaptation work on a regional level. Sweden is divided into 21 counties, each with a county administrative board. These are governmental bodies working in direct and continuous contact with the people they serve. They have a unique position in the Swedish democracy as important links between people and municipalities on the one hand, and the Government and central authorities on the other.

At the same time as the county administrative boards got their assignments in 2009, the Government gave the Swedish Meteorological and Hydrological Institute (SMHI) the task of supporting boards with climate change information in order to facilitate their coordinative and knowledge disseminative role. Within this assignment, SMHI has developed and provided different types of climate services on national and regional level. Among other things, SMHI has provided climate and climate change information such as climate indicators on, for example, yearly temperature anomalies, events of extreme precipitation, annual precipitation, changes in sea level, wind, global radiation, sea ice extent and the length of the vegetation period. Visualizations of the historical and projected future climate on county level are also provided on the SMHI website. Similar information is provided specifically for hydrological catchment areas and regions used in the delivery of weather forecasts. SMHI has also provided advice on how to interpret climate information and reviewed material such as regional climate change adaptation decision-support material produced by the county administrative boards, as well as presenting lectures at seminars and workshops in the counties. Addressing the uncertainties surrounding future climate scenarios is essential in the dialogue both between SMHI and the county administrative boards, and in the county administrative boards' communication with the municipalities.

Development of climate services in Sweden

As a part of climate services in Sweden, SMHI provides climate scenarios on the national and regional (subnational) scales. Until now these scenarios have been based on some of the emission scenarios from the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (SRES), a selection of global climate model projections and regional climate modelling. One of the challenges has been how to explain both the SRES scenarios and climate modelling to different users, especially in the context of considering the overall climate change scenario uncertainty. Also, there has been a great demand for information on how climate scenarios can best be interpreted, including their limitations. The channels for communication that support the scenario provision have mainly been reports and fact sheets, the SMHI website, and information delivered in meetings and seminars. The best outcome has been from meetings in which scientists and stakeholders have truly shared experiences, ideas, questions, answers and overall information.

In 2008 SMHI and the Swedish Geotechnical Institute (SGI) visited the 21 county administrative boards to map needs and expectations regarding climate services provided by the national authorities. Since then, SMHI and SGI have organized thematic meetings with the regional climate change adaptation coordinators, in collaboration with additional national authorities. The aim has been a continuous process of exchanging experiences and discussing climate change adaptation activities.

During 2012, updated regional climate scenarios have been derived from more recent global and regional climate models, with the climate forcing scenarios being based on the new Representative Concentration Pathways. Many of the earlier challenges to the provision of supporting information will remain even with the new scenarios.

SMHI will continue to approach the users of climate scenario information and maintain the dialogue in order to expand perspectives on useful ways to present updated climate scenarios. Developing pedagogic and efficient ways to present the new scenarios, including how they relate (similarities, differences) to the earlier ones, is of great importance, and so is the dialogue with stakeholders on how to select a scenario or scenarios

Image: SMHI

A climate expert communicating the Swedish annual mean temperature and annual mean precipitation to stakeholders

appropriate for their needs. In this discussion the alternative of using results from many climate model simulations (ensembles) is an important topic for consideration. Results from ensembles might facilitate estimates of changing climate conditions, including mean conditions, variability and the probability of extremes that are better suited for risk assessment, as they carry more information on alternative futures.

Nordic collaboration on climate services

During 2011 a framework for climate services was initiated within NORDMET, a cooperation between the Nordic national meteorological services. The aim of NORDMET is to achieve better cost efficiency by sharing resources in such areas as observation, information management, production and education. The main objective for a new group, the Nordic Framework for Climate Services, is to boost the availability of climate information in the Nordic countries by developing and sharing best practice in data handling, products and communication.

The Swedish climate change adaptation web portal

The Swedish climate change adaptation web portal (www.klimatanpassning.se) has been active since 2007. At that time it was an outcome of a collaborative discussion among four national authorities with operations in fields with inherent relevance to Swedish climate change adaptation efforts. The participating network authorities were: the National Board of Housing, Building and Planning, the Swedish Environmental Protection Agency, SMHI, the Swedish Rescue Department and SGI.

The primary user group for the portal has been the municipalities and county administrative boards. In addition, the national authorities themselves have benefited from the informal information exchange and learning process within the web portal network. Nevertheless, the main task for the web portal has been to collect, categorize and supply information of interest for the target groups, such as short information and web links to other websites where the actual information is published. This includes information on climate change, climate change impacts and tools for adaptation processes, as well as information on the roles and responsibilities for the different actors dealing with climate change adaptation efforts in Sweden.

Since 2007, the web portal has been managed in collaboration between national authorities, and the number of participating authorities in the network has now grown. The network includes: the Swedish Environmental Protection Agency, the National Board of Housing, Building and Planning, The Swedish Board of Agriculture, Swedish Forest Agency, SMHI, SGI, the Swedish National Heritage Board, the Swedish Energy Agency, Swedish Civil Contingencies Agency, National Food Agency, Geological Survey of Sweden and the Swedish Mapping, Cadastre and Land Registration Authority. The Swedish Association of Local Authorities and Regions and the county councils throughout the country are also included in the collaboration.

The authorities contribute in the network with their expert knowledge and time. The portal is managed from SMHI. Since 2009, a news feed has been added with climate change adaptation news interesting Swedish stakeholders, mostly concerning domestic activities and services. The authorities' network also has arranged a number of seminars and workshops for Swedish stakeholders concerning the ongoing national climate change adaptation activities within authorities and research efforts.

Image: SMHI

The inflatable Geodome theatre, which is used for the communication of climate services

A National Knowledge Centre for Climate Change Adaptation

Following SMHI's work with climate information, the Swedish Government requested the institute to establish a national centre of knowledge for climate change adaptation. Inaugurated in 2012, the Swedish National Knowledge Centre for Climate Change Adaptation (the centre) will serve as a node where knowledge on climate change adaptation is collected, developed and conveyed to different parts of society. The centre will compile regional, national and international knowledge on climate change adaptation. The intention is also to increase dialogue with different stakeholders, in order to enhance understanding of current and future needs for knowledge within the broad field of climate change adaptation. The Swedish web portal for climate change adaptation will serve as the main information channel. Naturally, the centre will also provide arenas for discussions of difficulties and solutions related to climate change adaptation.

With the centre, cooperation and dialogue with other actors in society has intensified, focusing on issues concerning capacity building on climate change uncertainties. This includes a continuous dialogue with the county administrative boards and other national authorities which contribute knowledge from their fields of expertise. Other important partners are a range of knowledge producers and stakeholders such as universities, industry and trade associations. Visualization of information is appreciated by users as a method for provision of appropriate decision support to various actors in society. Appropriate communication with decision-makers in different ways is fundamental overall. One form of communication that has shown much promise is interactive decision support in the inflatable Geodome theatre, in which people can be part of an interactive visualization. A climate expert is present at all times and ready to answer any questions and to give new perspectives on the presented subject by providing information in the 180° by 135° projection inside the Geodome.

The target group for the Swedish climate change adaptation web portal has so far been officers at national, regional and local level in Sweden. With the portal as the main information channel for the centre, the target groups are now more numerous. Also actors in Swedish society such as businesses, universities, non-governmental organizations and the public are now targeted by the centre and the web portal. An important objective for the centre is to categorize the existing climate change adaptation process tools, developed by researchers and decision-makers, relevant to the needs for different target groups.

To facilitate the transfer of knowledge between research projects, the centre involves dialogues with and efforts within the climate change adaptation projects in which SMHI is involved. One of those is the Swedish Research Programme on Climate, Impacts and Adaptation, which deals with how climate change, economy, climate change impacts and climate change adaptation are related globally, on the regional scale and locally. The programme aims to develop actionable new knowledge, methods and processes for climate change adaptation efforts. This is facilitated by involving users more in dialogue than is often the case in research efforts. Another example of dialogue that the centre engages in concerns adaptation efforts around the Baltic Sea, which are being carried out in the Baltadapt flagship project under the European Union (EU) Strategy for the Baltic Sea Region. SMHI is a partner in the Baltadapt project, which aims to produce an adaptation strategy for the region, focusing on the regional sea and coastal areas. An important part of the strategy is the collaboration between the Russian Federation and the EU countries around the Baltic Sea.

A user-centred design approach to the Seasonal Climate Outlook

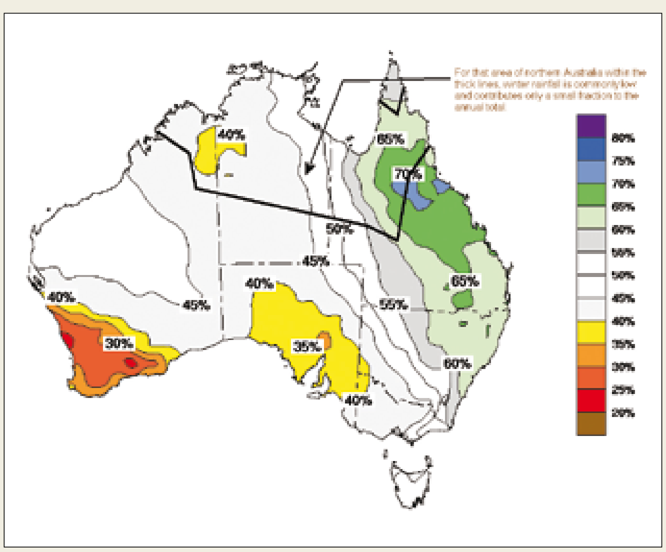
Elizabeth Boulton, Andrew Watkins and David Perry, Climate Information Services, Australian Bureau of Meteorology

The Australian Bureau of Meteorology's Seasonal Climate Outlook (SCO) product provides a forecast for the likely shifts in temperature and rainfall for the coming three months and is released on a monthly basis. Information is presented in probabilistic terms; reflecting the probability or likelihood that rainfall or temperature will be above the long-term median.

The website includes an ancillary product — the El Nino Southern Oscillation (ENSO) Wrap-Up, also known as the El Niño / La Niña Status Update.[1] The ENSO Wrap-Up provides detail on key indicators such as cloudiness, trade winds, sea surface temperature, and the Southern Oscillation Index (SOI). Indirectly related to ENSO, and important for predicting the Australian climate, information on the Indian Ocean Dipole and the results of a range of international climate models is also provided. All of this information is distilled into a short written description on the status of key climate drivers and their prediction.

Both the SCO and the ENSO Wrap-Up are popular with the Australian community, industry and Government. Many of Australia's economically important industries, such as tourism and agriculture, are crucially dependent on seasonal forecasting.[2] Each month (for the SCO) and fortnight (for the ENSO Wrap-Up), an e-mail with a link to the updated website is distributed to a wide range of stakeholders, including media outlets, Ministers, many Federal, State and local government agencies and a range of stakeholders in sectors such as finance, emergency services and aviation. Advance warning of likely rainfall and temperature facilitates risk management decisions on planting activity, fertilization, irrigation regimes and dam management, and supports forward planning in the emergency services, insurance and tourism sectors.

Chance of exceeding the median rainfall June to August 2012



Source: National Climate Centre

Seasonal Climate Outlook Review Project

The Bureau's National Climate Centre (NCC) had received anecdotal evidence suggesting that users found the SCO product difficult to understand. A review of international efforts to convey seasonal forecasts[3] found that other agencies presented information in a similar way and thus were likely to face the same communication issues as Australia. At the same time, the NCC was undertaking stakeholder engagement training and revising its stakeholder engagement plans. All of these deliberations led to a decision to launch the SCO Review Project in October 2010.

The multidisciplinary project team, led by a generalist Project Manager, included scientists from the Bureau of Meteorology's Climate Prediction subsection, communications experts from the Communication and Adoption Team (CAT) and a marketing advisor from the Bureau's Public Relations section. It also utilized the services of two specialist consultants: a marketing company and a user-centred design (UCD) company. The aim of the project was to investigate users' experience with the SCO and determine how it could be improved.

An iterative process

The project was conducted over 11 months between September 2010 and July 2011. It involved five stages of market research, with the user-centred design activity occurring in an iterative fashion, in response to information gained at each stage of the market research. This allowed for the proposed SCO designs to move from broad concepts to more detailed designs.

Stage 1: Interviews with 10 internal Bureau experts

The aim here was to mine existing internal knowledge so that the marketing research agency staff could be as informed as possible before they approached external users.

Image: Australian Bureau of Meteorology

National Climate Centre staff considering stakeholder engagement plans

Stage 2: Interviews with 10 high-level external SCO users
High profile experts in key stakeholder groups such as emergency services and agriculture provided their views on short-term and strategic needs. This input helped ensure that the mass-user online survey was targeted towards the key issues. The project team strove to achieve some gender balance through deliberately seeking some senior female users; two were found.

Stage 3: Online survey of mass user group
Members of the group of 961 respondents were quizzed about their experiences of the SCO. Qualitative information was captured through open-ended questions, for example: "How satisfied are you with the Seasonal Climate Outlook?" "Why do you say that?" "How can it be improved?" Quantitative information was gained through testing respondents to see if they interpreted the maps correctly. For example, users were provided with a statement about an SCO map such as: "It will rain across less than 40 per cent of northern Queensland" and asked to respond with: "true", "false", "don't know" or "don't understand".

Stage 4: User-workshop — 12 representative users
At this workshop, users were presented a very wide range of alternative design concepts (over 40 designs) and asked for feedback. This helped to create a 'short list' of preferred design concepts.

Stage 5: User-testing — interviews with 37 users across regional locations
Regional Climate Service Managers (RCSMs) in each state conducted the final set of interviews. To assist them, the project's marketing representative provided a valuable training session on how to conduct effective and neutral interviews. Using RCSM to conduct these interviews had a side benefit of helping to strengthen stakeholder relations in the regions.

The online survey (Stage 3) provided clear detail on the demographics of the user group. The majority of respondents were from the agricultural (46 per cent) or national resource management (13 per cent) sectors; male (73 per cent); university educated (58 per cent); and 45 years or older (56 per cent). When asked why they used the site, the majority used it for planting and cropping (25 per cent), business planning (24 per cent), general interest (18 per cent) and risk management (9 per cent). These results reveal a concentration of older males in the user group; this might reflect the unique demographics of both the dominant sector user group (agriculture) and the tendency for there to be fewer women in management roles.

What the SCO means to users

This project highlighted how important the SCO is to users. This was reflected in the high response rate to the survey; in user eagerness to participate in workshops and interviews; and in the level of effort, thought and detail of user contributions at all stages of the consultation. The market research consultants advised that user

User response

Illustrating the range of perspectives, typical verbatim comments included:
"I find some of these wrap-ups are too technical in language terms."
"Mostly it isn't specific enough for my needs."
"I don't understand the whole ENSO thing."
"You need to remind me in full, not just use the acronym!"
"I get everything I need from it."
"Graphs very cluttered."
"I love the ability to be able to interact with the data and see firsthand what the report is saying with backup from observations."
"Less jargon, easier access, ability to overlay information onto other data."
"It delivers all the info that I would normally use to devise my own opinion of likely rainfall in the near future, in a very accessible format, well done!"
"Don't dumb it down. I want to know the detail."
"It'd be useful to be able to see my district...is this possible?"

interest and engagement was above the industry norm. The statistics tell a similar story. The online survey found that 21 per cent of respondents relied solely upon the Bureau SCO site for seasonal forecast information, while 71 per cent said it accounted for 60 per cent or more of their information source. In terms of how important the SCO is to users, 19 per cent said the site was "vitally important — my livelihood or those I advise rely heavily on decisions based upon this information". A large percentage of these people (38 per cent) were those who also said they relied almost exclusively (90-100 per cent) upon the Bureau site for seasonal forecasts.

The most important findings of this review project were that users found probabilistic information very difficult to understand and that their comprehension levels were low. Although users highly valued and relied upon the forecast, they were also dissatisfied with how it was presented. Many users found the language too technical and complicated, had difficulty navigating around the website and had little understanding of the concept of 'forecast skill'.

The project revealed that in broad terms there were two distinct user groups: 'simple' users and 'advanced' users. Simple users wanted key headings, simple graphics, easy navigation, educational features and laypersons' language: a broad overview that they could digest quickly and simply. Advanced users wanted to be able to drill down into details and have easy access to a far broader range of options and granularity. The majority of all users wanted:

- Podcasts from climatologists
- The ability to tailor the information to their unique needs
- A zoom or 'Google Maps' type facility
- The ability to change the time frame and easily access past seasonal information
- Simplified language and improved text layout
- Ease of navigation.

Creating new design solutions

The initial 40 alternate SCO design concepts were developed through a series of creative design workshops. Participants were given a pile of coloured markers and blank A3 paper; they were asked to refrain from criticizing any new idea and given a variety of prompts such as 'design it so that a 12-year-old could understand it at first glance.' Designs were placed on large display boards in the workplace with sticky notes provided for other staff and visitors to provide comments. To harness the benefits of reflection or 'slow thinking', staff and stakeholders were encouraged to continue to submit ideas over the duration of the project. This creative design activity was highly valuable as it achieved the breakthrough of producing many new ideas and fresh approaches, which could then be tested with users.

The final alternate SCO design included:

- An Overview Map, which presents the key highlights of temperature, rainfall and tropical cyclone outlooks. It only depicts information where there is a significant deviation from the median
- A 3-5 minute podcast, no longer than the weather report on the TV news
- A revised confidence map, enhanced with educational features and simplified language and more readily accessible via 'tab' navigation from the outlook maps
- Tailor My Outlook — the new outlook maps were provided in two versions: 'simple' and 'advanced.' Both allowed users to configure the information to suit
- Text solutions — 'talking headings' which can be expanded to provide more information; text laid out in dot-points rather than sentences and the use of plain language.

Results of user testing

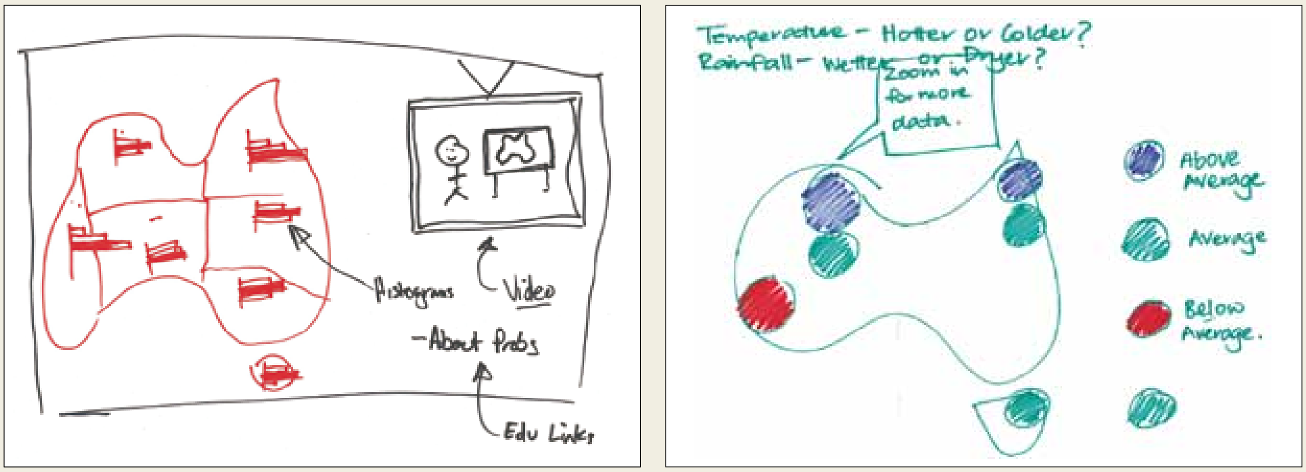
The alternate design concepts were well received. When reviewing the Overview Map (Figure 2), users made comments such as: "Impressed. Looks like a powerful tool" or "Clarity is good, broad scale approach is good". Some commented that the icons were a little confusing, ("fire icon not immediately obvious as representing fires" or "a legend would be helpful"). The podcast idea was very popular: "video gets a big tick"; "video is excellent"; "climate expert is good". However, several cautioned that it needed to be in "everyday English" and questioned whether it would be workable for those with limited Internet bandwidth. When considering the Tailor My Outlook map (Figure 3), users commented: "less waste of time", "concise information delivered in a faster way" and "good to have choice, if you can click straight on what you want it is better".

In their report, marketing consultants ORC International wrote: "The new designs are heading very much in the right direction. It will be impossible to achieve 100 per cent endorsement from end users as their needs (and comprehension levels) vary greatly. Nevertheless, the current designs are attempting to allow end users to locate and even tailor information that suits their needs, while providing information that is easy to understand and digest." At the end of the process, the existing SCO was tested alongside several new designs. It was ranked least liked by users.

Goals for the future

A new SCO Rebuild Project that commenced in July 2012 will see the realization of these design concepts. This is expected to be an 18-month project, culminating in early 2014. The Rebuild Project will involve the development of detailed prototypes; technical and user testing and a relaunch supported by communications specialists. In the longer term, the Bureau will consider incorporation of other climate and weather variables such as tropical cyclones into the SCO website and user-specific indica-

Workshop participants sketched new designs to enhance climate resources for users



Source: National Climate Centre

tors (for example, bushfire, flood, sheep chill risk). The frequency of seasonal updates will not change, only their appearance.

Expansion and knowledge transfer

The results of this project had value to other areas of the Bureau that also face the challenge of communicating complex, multilayered probabilistic information to a wide user group, such as those working in disaster mitigation, extreme weather and flood forecasting. More broadly, the results provided insights about users' general preferences for web-based products. This information was shared through presentation of two internal seminars, which were filmed, the development of a project website,[4] and a project brochure.

Aside from improving understanding on how best to depict probabilistic information, the project was also regarded as being a highly successful pilot of a new user-centred design process for product redesign. Accordingly, the lessons from this project's success also relate to the use of an interdisciplinary project team. The employment of a generalist (rather than technical specialist) project manager, with expertise in managing multidisciplinary teams, was important. This allowed seamless integration of advice from scientists, designers and communications experts, and the creation of a synergistic and positive team environment. Particularly valuable was the use of a neutral external market research agency with genuine expertise in properly understanding and synthesizing disparate user responses, while the Communication and Adoption Team Manager provided valuable 'on call' advice. Finally, the active involvement of the science product manager was crucial. He had an extensive network of contacts with key stakeholder groups and the project was able to leverage this to gain extensive, deeply considered and detailed user feedback. His involvement and that of other scientists from the climate prediction section ensured the design concepts remained grounded in scientific realism.

Challenges to moving forward

The design concepts produced in this project remain only 'abstract' design notions created by a graphic designer; they are yet to be tested with real data. The production of working prototypes that also achieve aesthetic and communication objectives will be a challenge. There are also several practical issues to consider. Significant staff and information technology resources will be required to develop and test the new prototypes, and effort must be maintained in the area of ongoing user consultation. A coordination challenge will be the need to strive for a similar 'look and feel' across the Bureau's entire web product range.

Finally, in this consultation project, users told the Bureau that they wanted more visual representation of the data. This raises some scientific and technical issues about how data is accurately 'cartoonised' so as to appear neat and clear yet also scientifically accurate. For example, should all areas of high probability of above median rainfall be depicted, even if they are 'pin prick' size, or should climatologists be able to manipulate the cartoon graphics to simply indicate the main general trends?

Honouring the principles of the Global Framework for Climate Services

Principle 8 of the Global Framework for Climate Services emphasizes the importance of user-provider partnerships. This project has demonstrated the strength of ongoing user consultation at a wide range of levels. Achieving broad consultation between those with a sophisticated level of scientific knowledge and those from a non-scientific background, or between inhabitants of tropical zones and of alpine areas, requires a multilayered, deep and wide consultation process. Using several consultation methods (interviews, focus groups and online surveys) helps to capture and amalgamate the variety of viewpoints. The use of market research specialists to manage the information gathering process and also analyse the disparate results is a highly defensible and robust way to ensure user needs are carefully identified and expertly addressed.

Acknowledgement must be given to the expertise provided by other project team members (not already listed as authors): Grant Beard, Agata Imielska, Michael Shaw, Jenny Hunter and Robyn Duell. Critical input was also received from Neil Plummer, David Jones and Rob Morton.

Multinational efforts to produce regional climate prediction for informed decision-making

Jin Ho Yoo and Nina Horstmann, Asia-Pacific Economic Cooperation Climate Center, Korea

Changes in the Earth's climate and its variability, in combination with the ongoing evolution of society (for example increasing populations in coastal regions), have increased human vulnerability to environmental conditions. As evidence of climate change mounts and the issue gains prominence in public discourse, largely prompted by the Intergovernmental Panel on Climate Change Fourth Assessment Report, the demand for skilful and accessible climate information for use across different sectors grows. Such sectors include public health, environmental protection, natural resource management, coastal zone management, urban and regional planning, insurance, water management, the energy industry and beyond.

Among the wide range of climate information products, forecasts for the upcoming season have become part of the operational product portfolios of many national hydrometeorological services (NHMSs), as they are now considered to have great potential to create social benefits, based on scientific evaluations and several experimental applications conducted around the world. Seasonal climate prediction information and its use in society are a good testbed for evaluating our ability to harness the full spectrum of climate information and respond to climate-related global change.

Sharing seasonal climate forecasts

It is clear that the integrated effort of the global community will be required to solve the problems related to climate variability and change, as these climate anomalies are global phenomena and their societal impacts will transcend national borders due to the globalized economy. As the regional organization that accounts for the largest share of the Earth's land mass and population, the Asia-Pacific Economic Cooperation (APEC) and its member economies recognized the need for to establish a global network to minimize natural disasters and their negative economic impacts through international collaboration on science, technology and innovation and setting up a proper sharing mechanism for available climate information. In 1999, the APEC Climate Network (APCN) was initiated with the aim of creating a channel for the exchange of seasonal climate information and prediction technology in order to reduce the impacts of climate disasters and to enhance the socioeconomic wellbeing of the region through the utilization of climate information. The successful implementation of APCN led to the establishment of the APEC Climate Center (APCC) in 2005, with the endorsement of all 21 member economies. As a regional hub for sharing climate information, APCC collects seasonal climate forecasts from 17 operational and research groups in the Asia Pacific region and combines them to produce the optimized Multi Model Ensemble (MME) seasonal climate forecast, which is disseminated to the APEC member economies and the global community. Recently, the seasonal forecast from the UK Met Office was added to the MME pool. APCC currently operates the MME with the world's most extensive dataset of seasonal prediction forecasts. In addition to this, APCC also undertakes various research programmes and activities that aim to improve the quality of the climate information, such as MME methods, strengthening technical cooperation, and capacity building and training on climate prediction and its use.

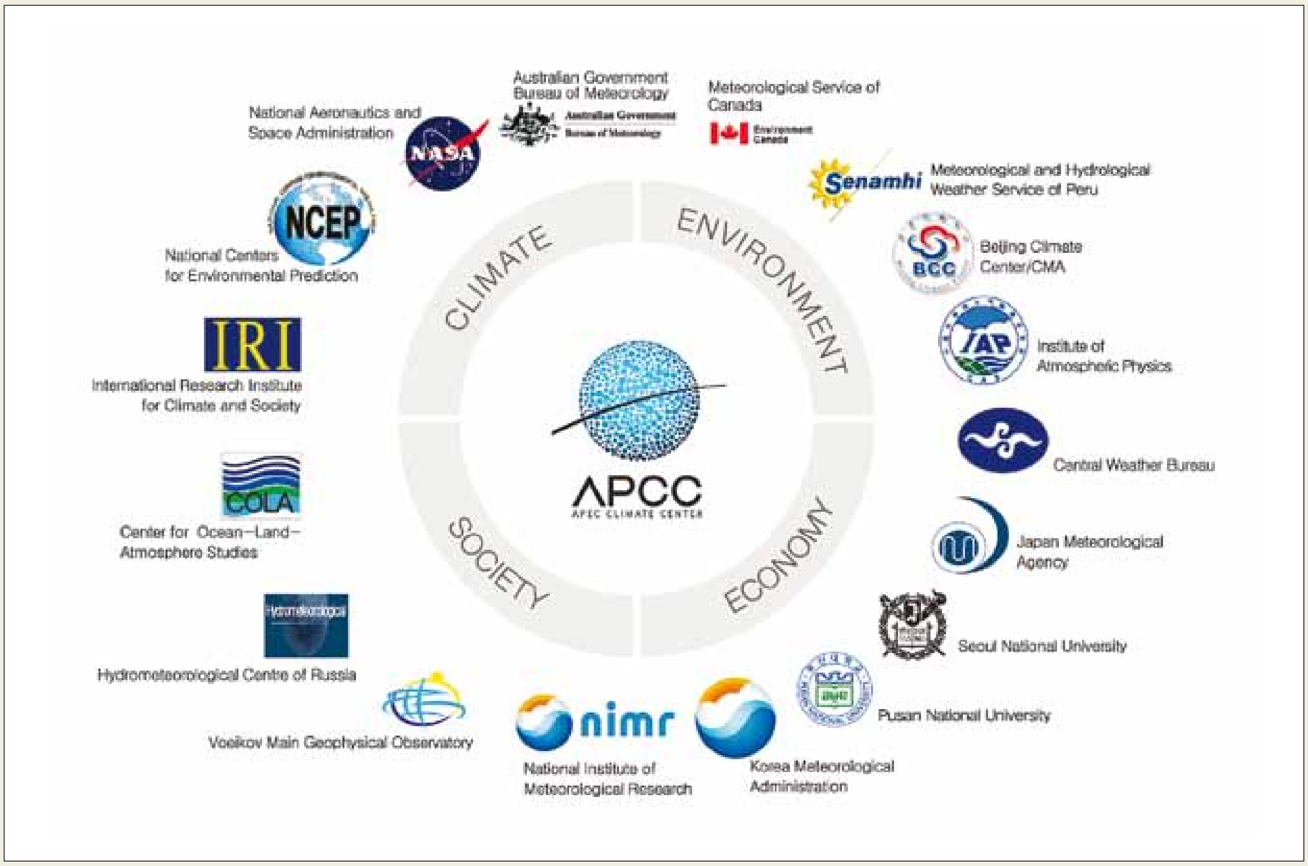
Currently, APCC provides a three-month MME forecast of global temperature and precipitation on the 25th of each month and a six-month MME forecast at the start of each season in the form of graphical and digital data. Furthermore, several monitoring products such as global hydrological extremes and sea surface temperature conditions are provided on the APCC website.[1] The format and variables of the MME forecasts are in accordance with the meteorological community standard for seasonal forecast products, as the NHMSs represent the primary user group of APCC products.

User interactions and lessons learned

However, scientific literature has commonly observed that real applications of climate forecasts in decision-making have been quite limited because of the large gap between forecast providers and users.[2] The formats, timing and accuracy of climate forecasts are often not suitable for the conditions under which potential users make decisions. Moreover, user groups have difficulties in accessing appropriate climate information. It has also been emphasized that an interdisciplinary approach is essential to resolve this problem. Therefore, the successful application of climate forecast information will require:

- Improvements in climate information products to suit user needs
- Enhanced accessibility and visibility of climate information
- Greater collaboration and communication between users and providers.

In addition to scientific research to improve the quality of climate forecasts, APCC is striving to enhance the socioeconomic value of the information it currently provides in line with the above-mentioned concerns.



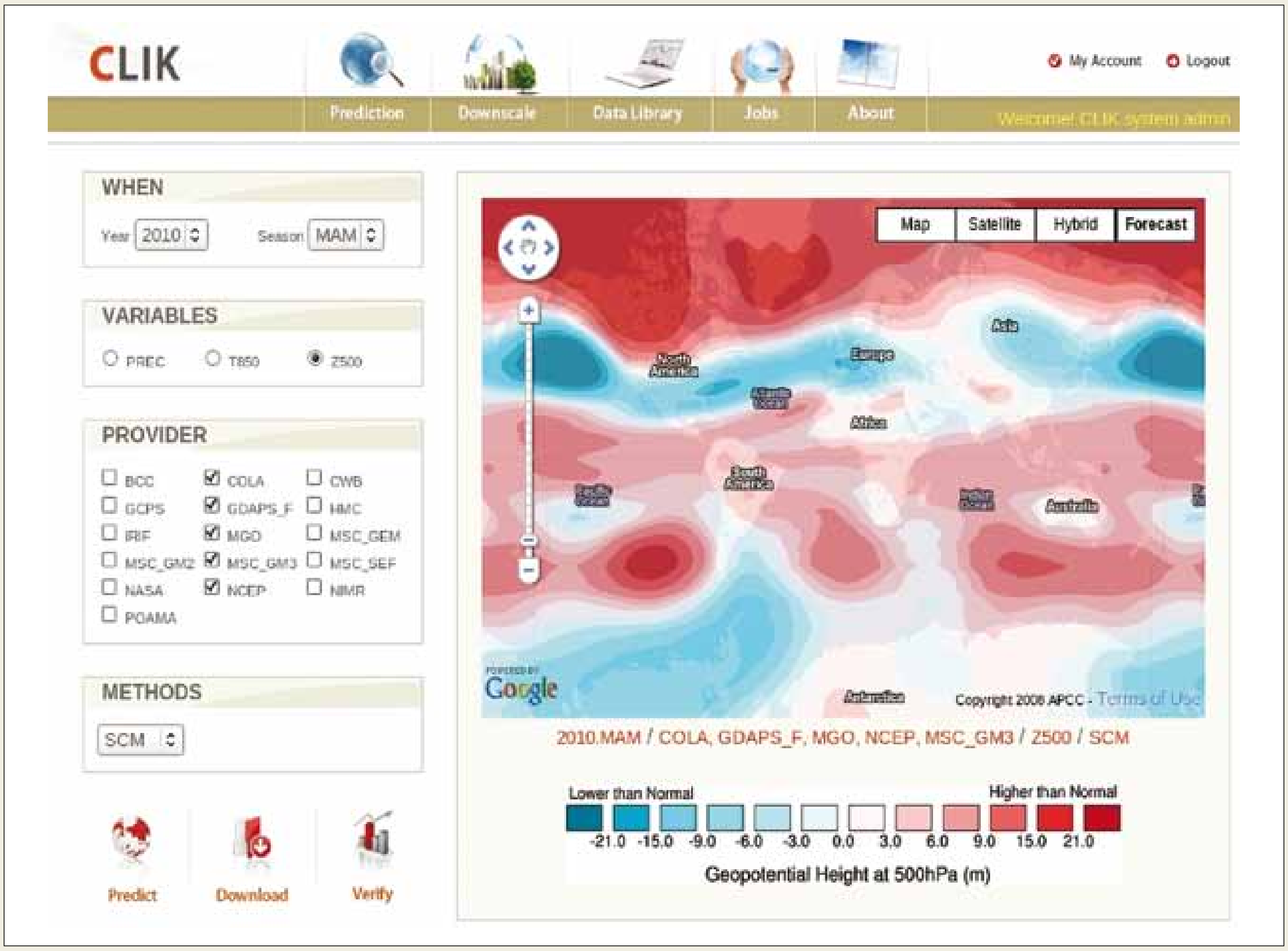
Multinational contributors to APCC MME seasonal forecasts

Source: APCC

Seasonal forecast information is formally disseminated through the APCC webpage and a basic climate outlook is distributed by email. In addition to the formal dissemination of its seasonal prediction products, APCC has developed a web-based tool, the Climate Information Tool Kit (CLIK).[3] CLIK is an online interface with some user functionality which allows users to access and customize the APCC MME seasonal forecast. It also provides the capability to statistically downscale the seasonal forecast to the region of interest. As an online tool, CLIK does not require any additional program installations or data except for a basic web browser, unless the user chooses to downscale the seasonal forecast with respect to their own station data. Since its launch in 2009, usage and recognition of the tool have continually increased.

The goal of CLIK is to enhance the accessibility of seasonal forecast information with low requirements in terms of prior knowledge or tools. APCC has hosted several series of training and workshops on CLIK for a variety of users (representatives from NHMSs, as well as experts from sectors such as hydrology, agriculture and environmental sciences) and the importance of tools that lower barriers to the access and use of climate information has been clearly recognized. The participants and stakeholders have been overwhelmingly appreciative about the ease of use and the fact that CLIK requires little advance training or tools. After a workshop with the Association of Southeast Asian Nations, the enthusiasm over CLIK resulted in a proposal to initiate a regional operational seasonal forecast by collecting downscaled forecasts to the local stations. This reflects the strong potential of existing regional organizations to strengthen the value chain of climate information. Such trainings and workshops also provide the opportunity to get feedback from users for further improvement of CLIK, which is kept under continuous revision.

APCC interacts with users and publicizes its products and services through various international outreach activities. Since its inception, APCC has organized the annual APEC Climate Symposium (APCS). The APCS is a venue for stakeholders and scientists from around the Asia-Pacific region to gather together and exchange information and best practices. In this forum, interactions take place between information providers (climate scientists or dynamical seasonal forecast providers) and between providers and customers (NHMSs from developing countries and experts from different sectors). In the early years of the APCS, the dialogue revolved primarily around information exchange among climate scientists. However, as the importance of user interaction has become more widely recognized, the focus of the APCS has shifted towards the practical application of climate



The CLIK interface for MME forecasts

Source: APCC

information and the number of participants from user groups has increased. In 2011, more than 100 scientists and experts participated in the APCS, which was themed on 'Harnessing and using climate information in decision-making: agriculture, water and energy efficiency'. Both climate information providers and users agreed that the symposium was meaningful and productive and called for its continuation to share deeper knowledge and experiences in the various climate application sectors. As a progression of the 2011 event, APCS 2012 will focus on climate applications to the agricultural sector.

Apart from international conferences and events, continuous institutional collaborations with other disciplines are also under active exploration. Although user groups' recognition of the risks associated with climate change and variability and the need for adaptation is growing, many users do not have proper decision mechanisms in place, even if accurate climate forecast information, which is probabilistic by nature, is available. In 2012 APCC, together with scientists and experts in the US, Japan, Indonesia, Malaysia, the Philippines and Singapore, launched an international collaborative project to develop an early warning system for fire and haze for Southeast Asia based on seasonal forecasts. The key problems will be providing accurate drought condition forecasts for the region of interest and developing effective fire management strategies that incorporate forecast information at the seasonal time-scale. For the successful implementation of this project, close collaboration at various levels covering both science and policy will be required, emphasizing the importance of a multidisciplinary approach.

Numerous multinational efforts for the better use of climate information in the Asia Pacific region have been made by the APCC. To maximize the social value of climate information, APCC is performing research to improve the quality of its MME forecast, as well as to tailor its climate information products to formats appropriate for end users. In addition, with the understanding that better distribution mechanisms are also a key concern, APCC provides an easy online tool to enhance the accessibility of climate information. Through the provision of reliable seasonal climate information, an emphasis on user interaction and multinational research collaborations, APCC strives to amplify the use of climate information for problem solving in the Asia Pacific region.

Building a scientific basis for climate change adaptation — the Research Program on Climate Change Adaptation

Professor Nobuo Mimura, Research Program on Climate Change Adaptation (RECCA) Programme Director, Ibaraki University; Professor Satoshi Takewaka, RECCA Programme Officer, University of Tsukuba; Dr Shunji Ohta, RECCA Programme Officer, Waseda University and Masatoshi Kamei, RECCA Secretariat, Remote Sensing Technology Center of Japan

The effects of climate change have been occurring across the world, and it is a major concern that future changes will significantly affect the water cycle, extreme weather events, urban environment, agriculture, forestry and fisheries. As climate change effects vary regionally, climate change adaptation should be planned and implemented on a national, sub-national or even local basis. Scientific information on projections of climate change and its impacts is vital to develop adaptation policies. The Research Program on Climate Change Adaptation (RECCA) began in 2010 as a five-year programme by the Ministry of Education, Culture, Sports, Science and Technology in Japan. Its aims are to enhance the research level for climate change adaptation dynamically, provide scientific knowledge to evaluate the adaptations, and contribute to achieving a society that is resilient to the effects of climate change.

Led by Programme Director Professor Nobuo Mimura of Ibaraki University, RECCA focuses on adaptation at the regional level. Twelve sub-programmes were selected to work together with local (prefecture or city) governments. RECCA categorized the sub-programmes into three fields:

- Water
- Urban-area
- Agriculture, forestry and fisheries.

The water field addresses the impacts of climate change on water, such as torrential rains, long-term droughts, reduction in snow accumulation and changes in snow-melt time. The urban-area field addresses low-carbon society and the impacts of climate change on urban areas, such as concentrated downpour, abnormally high temperatures and heat islands. These two fields are led by a Programme Officer, Professor Satoshi Takewaka of University of Tsukuba. The agriculture, forestry and fisheries field is led by another Programme Officer, Dr Shunji Ohta of Waseda University. It addresses technologies for stable agricultural production and securing living aquatic resources amid changes in meteorological and oceanic conditions.

Although RECCA emphasizes adaptation policies, strategies and actions at the regional level, the spatial resolution of the current climate change projection is not sensitive enough for the local scale. Improvement of temporal and spatial resolution, reduction of uncertainty and advanced adaptation simulation technologies are important for decision-makers at regional level. Therefore, RECCA's research sub-programmes are developing three kinds of method/technology:

- Advanced data downscaling methods – including dynamic and statistical downscaling methods, and new forward-thinking techniques. The goal is to take advantage of the global climate change projection model to create a local-scale one and enable impact assessments
- Data assimilation technology for observation data – to reduce the uncertainty of the simulation model. The model supplies scientific knowledge to review regional climate change impact assessment and adaptation
- Simulation technology for climate change adaptation – for regional climate change impact assessments and planning adaptation measures.

Through this RECCA framework, 12 principal researchers are conducting 12 research sub-programmes respectively.

Research sub-programmes – water

Professor Toshio Koike of the University of Tokyo is developing a mitigation technique for flood disasters caused by climate change. This targets the Tokyo metropolitan area and its neighbours that have insufficient provisions against long-lasting drought in terms of river improvement measures. Moreover, the areas are very vulnerable to massive flood disaster led by typhoons and torrents in the rainy season, and to urban-specific water damage by local downpour.

Professor Fujio Kimura of the Japan Agency for Marine-Earth Science and Technology (JAMSTEC) is developing advanced and dynamical downscaling methods with the high-resolution regional climate model which is locally available. He also aims to develop a translation and transmission method for planning and reviewing adaptations. These are targeted at the Sea of

Ground monitoring by Prof. Ninomiya's sub-programme to validate the accuracy of their models

Japan side areas in Toyama Prefecture, which has experienced significant warming impacts.

Dr Tomohito Yamada of Hokkaido University aims to develop downscaling methods for flood control and water utilization, and to develop software to refer hydrological and weather information obtained through the project for climate change adaptation measures. His subject area is the northernmost prefecture in Japan, Hokkaido, where water resource may be drastically changed, such as a decrease in snowfall or of the melting season.

Dr Motoki Nishimori of the National Institute for Agro-Environmental Sciences integrally implements statistical downscaling and developments of simulation technologies for climate change adaptations. These are essential for planning strategic adaptation estimations for climate change and environmental policies in his subject area, Kochi Prefecture, which has complex topography and various land use.

Research sub-programmes – urban area

Dr Koji Dairaku of the National Research Institute for Earth Science and Disaster Prevention focuses on research and development of a simulation technique which provides scientific knowledge for local adaptation planning and reviewing. The target is the Tokyo metropolitan area, and the goal is to enable adaptation to low-carbon society and climate change. Dr Dairaku digitalized the Regional Planning Atlas, which covered the most of his target area since 1888, and developed a data set from floods damage statistics (1961-2008) for flood risk assessment. This enabled him to quantify deforestation and urban area expansion and calculate flood information in the Tokyo metropolitan area.

Dr Keiko Takahashi of JAMSTEC is developing a detailed model which duplicates and predicts the effects of heat islands, local downpour in urban areas and inland floods in her subject areas, the Tokyo metropolitan area and Kawasaki city. The model is for disaster adaptations addressing global warming and climate change impacts. Presenting scenarios based on quantitative simulation assessments contributes to adaptation measures for the heat island phenomenon and the downpours.

Dr. Satoru Iizuka of Nagoya University is developing a new sophisticated downscaling model that is capable of analysing weather and climate from regional/urban scales to building scale. He performs sensitivity analyses, impact evaluations and future projections of urban heat islands, extremely hot days and downpours using this model. He examines how to plan adaptation to these environmental problems in his subject areas, Nagoya city and Tajimi city.

Professor Seigo Nasu of the Kochi University of Technology aims to develop an integrated simulation model for natural and social phenomena such as the water cycle, use and environment, which considers the effects of climate change. The target is to offer quantitative information which contributes to adaptation measures for changing water resource management in Shikoku region, which includes four prefectures and the Yoshino River. Having discussed the project with hundreds of ordinary citizens and the other local stakeholders, he has already accomplished a 'civic-conscious structure logic model' which can assess climate change impacts on the socio-economy and civic-consciousness, and improved the model by integrating the other economic impact assessment model.

Professor Teruyuki Nakajima of the University of Tokyo is developing a system to estimate the source and generation of carbon dioxide and air pollutants. It is implemented over the next-generation global atmos-

Image: RECCA

Dr Iizuka's sub-programme conducted a survey on thermal environment and human health in Tajimi city (near Nagoya)

Image: Advanced Simulation and Technology Development Program, Earth Simulator Center Japan Agency for Marine and Earth Science and Technology (JAMSTEC)

Ultra high resolution urban climate model developed by Dr Takahashi's sub-programme

pheric model to assimilate both carbon dioxide (a greenhouse effect gas) and the pollutants. The system is expected to be used for planning adaptation measures for the changing environment with complicated factors of warming, air pollution and urbanization in his subject area, Kanto region which includes Tokyo and the other six prefectures.

Research sub-programmes – agriculture, forestry and fisheries

Professor Toshiki Iwasaki of Tohoku University is improving experimental computational techniques in physical process and developing data assimilation methods, to enable global warming impact assessment and accuracy improvements in near- to mid-term prediction for Yamase or winter monsoon in the Tohoku region, the northern portion of Japan's main island, particularly the Pacific side of the Aomori Prefecture, Iwate Prefecture and Miyagi Prefecture. Additionally, he is developing a high-degree downscaling application for climate prediction and agro-meteorological data.

Professor Seishi Ninomiya of the University of Tokyo is developing a decision support system for optimal agricultural production, to enable robust and stable activities and management. The goal is to minimize climate change impacts for product quality, to optimize cultivation and water resource management, and to consider stable farm management, even with severe climate conditions or long-term warming trends in his subject areas Toyama Prefecture, Ishikawa Prefecture and Fukui Prefecture.

Professor Toshiyuki Awaji of JAMSTEC aims to develop both the new integrated atmosphere-ocean-marine ecosystem data assimilation system and the downscaling approach towards better understanding and prediction of the linkage between ocean/climate variations and biogeochemical and fishery environments under global warming. This will be aimed at the level of practical use for optimal fishery stock management and adaptive fishing operations with low cost and low carbon dioxide emission, leading to sustainable fishery activity in his subject area, the North Pacific Ocean offshore of Aomori prefecture.

Even in the middle of the project, some local governments have already used RECCA's developed technology and knowledge. For example, the distributed hydrological model developed by Professor Koike was arranged and applied in the development plan of cities in Tokyo, Hokkaido, and even the Pakistan Government is trying to apply it. Nagano prefecture relied on a future snow cover change projection derived by Professor Kimura to compile a report on impacts on the tourism industry in the prefecture; even Nagano was out of his target area. Professor Awaji has provided fishing ground forecast information for fishermen, particularly those who suffered serious damage by the great East Japan earthquake in 2011. The information enables them to save fuel for fishing vessels and effective fishing. In order to expand and facilitate such various applications of outcomes and contribute to achieving a robust society in climate change impacts, RECCA emphasizes dialogues with local governments, stakeholders and citizens. As part of this principle, RECCA held symposiums and workshops in the local areas as well as in Tokyo, and made efforts to maximize the benefits from its outcomes. Towards the completion of the programme in March 2015, RECCA is preparing to share its experience, knowledge and technology, not only with the target areas, but also with other regions wherever they are.

For more information, visit the RECCA website at www.mext-isacc.jp/eng

Climate variability and change: perceptions, experiences and realities

K.P.C. Rao and A. Oyoo, International Crops Research Institute for the Semi-Arid Tropics; and W.G. Ndegwa, Kenya Meteorological Department

Farming in the semi-arid tropics, where climatic conditions are marginal and highly variable, is a risky enterprise. The main source of this risk is the variability in rainfall that occurs at many different timescales, ranging from seasons to years to decades and beyond. Farmers operating under these conditions make decisions based on their perceptions and experiences gained from several years of keen observation and practice in the field. However, perceptions are influenced by many factors, both real and subjective. For agriculture, factors like farm productivity, crop, market and local preferences, capacity to invest, willingness to take risks and soil quality play an important role. While the role and significance of some of these factors on productivity and profitability can be perceived more easily due to their relative predictability, extreme variability in climate and the random nature of that variability makes it difficult for farmers to accurately perceive trends in climate. In the absence of detailed measurements, perceptions can be biased and unreliable. Climate information can play an important role in helping farmers better understand this variability and its associated risks, and enhancing their decision-making for effective risk management.

Inter- and intra-seasonal variability in rainfall have been the key climatic elements that determine the productive efficiency of rainfed agriculture. While the amount and distribution of rainfall have a direct impact on the productivity of agriculture, its variability contributes to the uncertainty in the expected benefits from investments made, and to the rates of return that farmers receive from these investments. Farmers, operating under these highly variable climatic conditions must have a good understanding of the risks and opportunities such conditions create for them to make best use of available resources. With a good understanding of the historical and current climatic conditions including climate forecasts, it is possible to tailor the management of agricultural systems in a way that capitalizes on opportunities and minimizes risks. While farmers have developed a good understanding about the climate variability at their locations through keen observation, experimentation and practice, there are problems in their perceptions that arise from the complex nature of agriculture and an inherent problem in separating climate impacts from other drivers that also affect agricultural production. Since farmers take decisions based on their perceptions it is extremely important that, while assisting farmers to adapt to climate variability and change, the perceptions, experiences and actuality of changes in climate are placed in the context of the impacts of various drivers on the performance of agriculture. Our work with farmers in Eastern Africa – mainly in Kenya – on managing risks associated with variable climatic conditions, has identified three common perceptions that can be effectively addressed through provision of more accurate climate information to extension officers and farmers. These studies were conducted in the Machakos, Makueni, Kitui, Mwingi and Mutomo districts in semi-arid Eastern Kenya, where the average annual rain fall varies from 500 mm in the lowlands to over 1,050 mm in the hilltops. The annual rainfall is distributed almost equally over two rainy seasons that fall during the periods of March-May (also referred to as ‘long rains’) and October-December (‘short rains’). The studies involved structured surveys, group discussions and interpreting and presenting seasonal climate forecast information in the form of agro-advisories.

Perception 1: the climate has already changed

Farmers across the study locations strongly believe that the climate in their area has changed for the worse. This response is consistent with results reported from surveys conducted elsewhere in Africa. In all these studies, most farmers identified declining rainfall, increased variability in the distribution of rainfall within and across the seasons, and shifts or even disappearance of seasons as the major changes observed. However, the changes that farmers have identified are not obvious from the available rainfall records. Detailed analyses of long-term daily and monthly records from five sites in Kenya where these interviews were conducted indicate no major detectable change in the rainfall during the last four or five decades. For example, at Machakos, Kenya, the longest dry period that the region has ever experienced was between 1966 and 1975, during which the annual and seasonal rainfall was below the long-term average in at least seven out of 10 years. This strong belief among farmers that the climate has changed for the worse despite lack of evidence in the climatic data to support this, is prompted by the declining yields in the area which are more likely due to diminishing soil fertility, low levels of use of inputs, and the expansion of agriculture into marginal lands as the population

A farmer group in Mwala, Machakos, Kenya doing an exercise aimed at understanding variability in rainfall and evaluating the reliability of seasonal climate forecasts

has grown. The implication of this unsupported perception is that farmers do not pay adequate attention to the actual yield-limiting factors such as soil fertility since they strongly believe that climate change is the main driver for low productivity and that not much can be done to manage it.

Perception 2: climate is too risky

Farmers are well aware of the season-to-season variability in their climates. They generally classified the seasons as good, not so good or average, and very dry or poor based on criteria that included factors such as crop yields, early and late onset of the rainy season, and the amount and distribution of rainfall. Most farmers were able to recollect how the season that preceded the survey was, with 49 per cent able to recall the conditions that existed during the previous 10 seasons over five years (there are two seasons per year in Kenya). In general, there is a good consensus between the farmers' rating and the observed conditions for seasons that are either good or poor, except for one or two seasons out of the 10. However, their ability to estimate the frequency distribution of different events and discern long-term trends is more subjective. Farmers tend to attach greater significance to negative events or impacts, which leads to a biased estimation of the frequency of occurrence of negative events. This has important implications in their assessment of risk and in subsequent decision-making. Their perception of higher risk results in a preference for techniques that require low levels of cash and labour investment, and acts as a major deterrent in optimizing input use and taking advantage of improved technologies. We consider this as one of the primary reasons for low levels of adoption of improved technologies in the drier areas.

Perception 3: climate forecasts are unreliable

In general, both farmers and the general public view climate forecasts with a lot of scepticism. Much of this is due to the misunderstanding and misinterpretation of the forecasts that come with different time steps, different levels of prediction skill and different spatial resolutions. Often users cannot generally distinguish between short-range weather forecasts and long-range climate forecasts and their potential applications. Seasonal climate forecasts can form a basis for farmers to plan and manage their farms better, since many management decisions such as crops and the varieties to be planted, proportions of land to be allocated to various crops and the level of investment on inputs need to be taken well before the season starts. Despite their value and usefulness of forecast information, its use by smallholder farmers remains very low because of perceived poor reliability, lack of awareness of the potential applica-

A woman farmer in Ethiopia explaining rainfall records that she has been recording on her farm

tions and non-availability of timely information in a user-friendly format. Fortunately, Eastern Africa is a region where climate is relatively more predictable due to the strong correlation with El Niño/La Niña episodes. In a study conducted to evaluate the potential benefits of seasonal climate forecasts, we asked farmers to evaluate the skill in forecasts and assess their usefulness in planning and managing their farms. We used hindcasts provided by the International Research Institute for Climate and Society for 43 short rain seasons (October-December) starting from 1961, for Katumani in the Machakos district.

Farmers rated the forecasts, comparing the predicted with the observed seasonal conditions by grouping the seasons into two categories – below normal and above normal for maize growing. According to the farmers' assessment, 35 of the 43 predictions were extremely good and use of these forecasts for farm management could result in substantial productivity gains during wet years and in minimizing losses during dry years. Of the eight misses, farmers considered the four seasons in which below-normal rainfall was predicted but above-normal rainfall was received to be less of a problem, since they represent a lost opportunity but involve no loss on investment. The real problem is with the four seasons that were predicted to be above normal but turned out to be below normal. These are the seasons in which investments guided by forecasts could potentially lead to a loss. However, the observed prediction skills are above the farmer acceptable level of 80 per cent, which is four out of five seasons.

Evidence from our studies clearly establishes that significant benefits can be derived from the use of climate information if it is interpreted and presented in a way that can easily be understood by the end users. Farmers were able to appreciate the value of forecast information when this was interpreted in terms of its agricultural significance and presented in the form of an advisory that summarizes key potentials and risks associated with the type of season predicted. When the usefulness of the advisory service was evaluated after three seasons, most farmers considered the advisories to be extremely useful in planning farm operations, an observation well supported by the willingness of 87 per cent of the farmers interviewed to pay for the service if required.

Given the general complexity and extreme variability associated with climate, it is not only difficult to perceive the trends but also difficult to measure, analyse and explain them accurately. However, the trends derived from longer-term observations and predictions at seasonal scale, which are fairly reliable, have the potential to make significant contributions to addressing the misperceptions and gaps in understanding that have come to light through these studies.

X
Capacity Development

Making climate change information available online

Juha A. Karhu and Reija Ruuhela, Climate Service Centre, Finnish Meteorological Institute

The Climateguide.fi site provides scientific background information on climate change as well as the tangible means for mitigation and adaptation. Available in three languages, the material has been prepared by Finland's leading climate researchers and experts. The Finnish Meteorological Institute (FMI), the Finnish Environment Institute (SYKE) and Aalto University share responsibility for the contents and updating of the Climateguide.fi website. The contents will be supplemented and developed gradually.

The Climateguide.fi site aims to:
- Raise awareness about global climate change and its implications for Finland
- Communicate scientific information in an understandable way to the general public on climate change, its impacts and options for adaptation and mitigation response at the community level
- Offer guidance to local decision makers, especially at the municipal and regional level, on integrating climate change information into their planning and decision-making processes
- Assist the Finnish municipalities and regions in meeting their national and European Union responsibilities for sustainable development, including targets to reduce greenhouse gas emissions
- Improve the adaptive capacity of Finland's environment and society to avoid the adverse effects of climate change and to make use of its potential benefits
- Enhance the networking of key national institutions working to disseminate climate change information and to raise awareness
- Create a common platform for different institutions to deliver climate change information in an integrated manner to various target groups and the general public.

Home page of the Climateguide.fi portal

Source: Finnish Meteorological Institute

Meeting the need for quality information

There is a large and growing body of information about climate change available on the Internet. However, the quality of this information is highly variable, with reliable, peer-reviewed research results to be found alongside other material that is less rigorous and in some cases highly misleading.

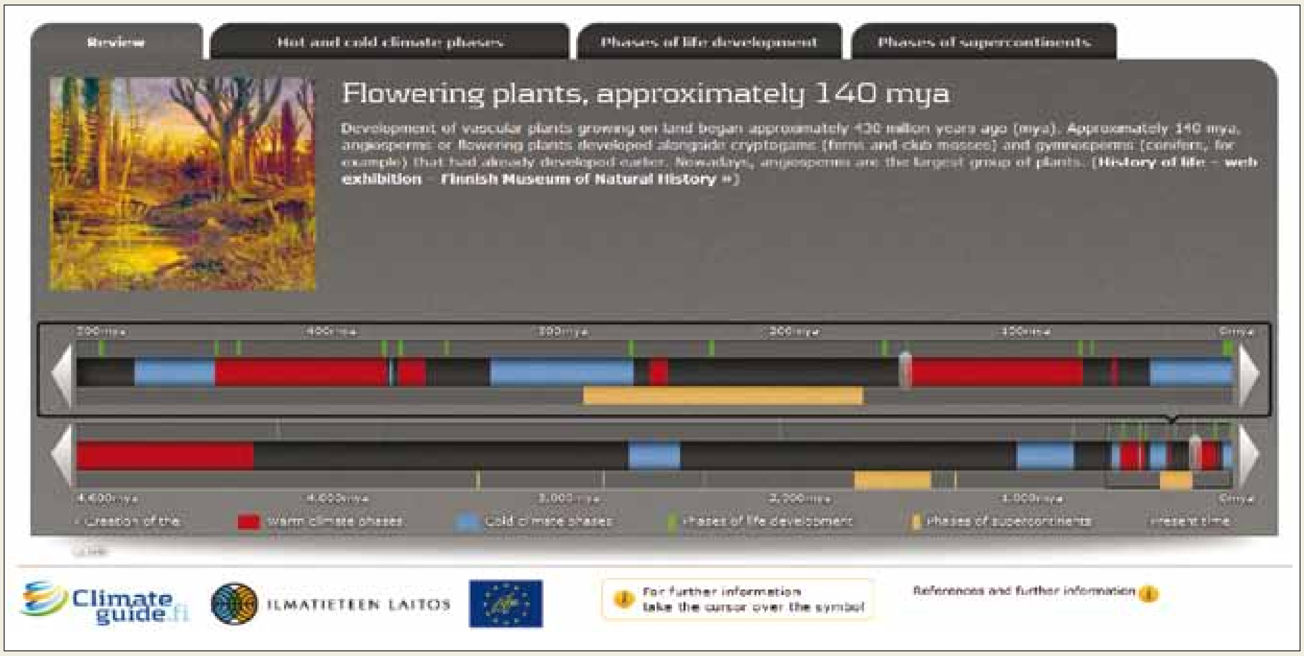
The problem is that for the layperson without scientific training, including many decision makers, it can often be very difficult to access reliable and relevant information. Moreover, even the reliable sources are often widely dispersed and may be too scientifically orientated to be applied in practical planning and decision-making.

Many important decisions and practical mitigation and adaptation measures are carried out at the local level. In Finland there are nearly 400 municipalities and it is difficult to reach all their decision makers for face-to-face discussions or consultation. Therefore, tailored climate services via effective media are needed.

Various types of climate information

Climateguide.fi addresses these problems by offering a common, one-stop national website for Finland where citizens and decision makers can easily find reliable and up-to-date climate change information (left). It also serves as a platform through which key national research institutions and projects can disseminate their information in a user-friendly way.

The concept of the portal is unique. It is the first to provide information equally on all aspects of climate



One of eight learning modules available at Climateguide.fi portal in 2012 is a climate history of the world

Source: Finnish Meteorological Institute

change: the phenomena leading to climate change, the impacts of climate change, opportunities for mitigation of climate change and challenges in adaptation to climate change.

Climatguide.fi features approximately 250 web articles on climate change issues, checklists, adaptation and mitigation solutions, learning modules, observational and modelled data and interfaces for data visualization.

The three main components of Climateguide.fi are:

- Climate Change Explained
- Maps, Graphs and Data
- Community Response Wizard.

Climate Change Explained provides research-based information on physical climate science focusing especially on climatic changes in Finland as well as impacts, mitigation and adaptation measures in Finland. This section consists of mainly web articles produced in a standard format providing references, internal and external links to further information. In addition, eight learning modules and visualizations on selected subject have been produced for the benefit of the users (above).

Maps, graphs and the data component conveniently provide users with insight into observed and anticipated climate change and its impacts through maps and graphs. With the help of the easy-to-use interface, citizens and decision makers can learn from the past and look to the future.

Community Response Wizard offers support and options for both adaptation and mitigation for local scale planning and decision-making in municipalities. It helps the user to quickly grasp the main impacts of climate change in each sector of the municipal sphere of authority (Land Use and Construction, Technical Services, Education and Culture, Social and Health, Environmental Protection), understand the possibilities for adaptation and mitigation in municipalities, find the most suitable set of actions and find case studies and best practices. Municipalities themselves can also add their own solutions to the site.

As an additional component, a Facebook page of the portal is being used as an interactive communication tool.[1] Use of the information is free of charge and is permitted for non-commercial purposes, provided that the source is mentioned whenever information is used.

A comprehensive service

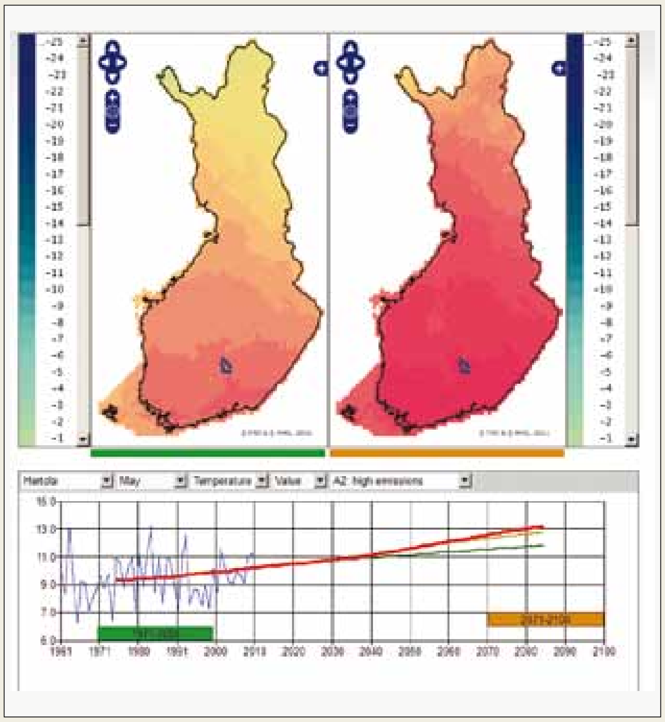
Information regarding socioeconomic factors is included in the service. The sources are various research projects and scientific articles, many of which originate from the Finadapt research project (2004-2006).

The socioeconomic information can be accessed through various articles on the portal. It is also included in the checklist tables of the sectoral articles of the Community Response Wizard component of the portal, covering aspects such as climate change mitigation in social services through energy saving and energy efficiency.

Mitigation and adaptation case studies/solutions are presented to illustrate socioeconomic factors; for example, there is a description of how the City of Tampere assessed the costs of implementing planned emission reduction measures.

User-specific information

The information in the Climate Change Explained component of the portal is generic and aimed at all citi-



The map on the left shows the average monthly values in the present climate of Finland (normal period of 1971–2000) and the map on the right the corresponding projected future values. The graph below the maps shows observed (blue curve) and simulated (red, yellow, green) values for selected municipality for three scenarios.

Source: Finnish Meteorological Institute

zens and decision makers. Impacts, mitigation and adaptation are also dealt with from the sector-specific point of view.

The Community Response Wizard is the first tailored section of the Climateguide.fi portal. The next tailored section will be available to senior secondary education level users.

With the Observed and Projected Climate map and graph tool, climate observations and projections can be visualized and in the future will also be available for download on the basis of geographic location. The Climate Impacts map tool shows modelled impacts for various sectors.

Tailored information is provided by the expert organizations responsible for the portal. Users are encouraged to suggest adaptation and mitigation case studies and in these cases, information is provided by a joint team of the user, the science editor of the portal and an expert.

When users need more tailored information than the Climateguide.fi portal can provide, they are guided further to make contact with expert services from the content producers of the portal. In case the information cannot be found within these services, the users are helped to locate a service producer that can assist in the specific problem.

The stakeholders of Climateguide.fi are:

- Users (citizens, decision makers, actors at municipal level)
- Climate change information providers (research institutions, universities, ministries, public authorities)
- Policy makers and funding organizations.

How stakeholders were identified and involved

The stakeholders were identified by FMI, SYKE and Aalto University early on in the service development. The need for a national service that focuses on serving decision makers and planners at local level was identified. Stakeholders were involved throughout the development process, serving in workshops and as members of the steering group of the project. Surveys on user requirements were conducted, and concepts of the portal were tested with a stakeholder pilot group.

In operational terms, the first level is the content of the web service and the various tools within it. At the second level, a user contacts Climateguide.fi personnel for further questions, comments, suggestions for improvements or requests for data. The personnel either answer the needs of the user themselves or facilitate the connection between the user and the service provider that can deliver the service in question. User feedback is utilized to improve the service of Climateguide.fi.

In the case of local solutions in the municipalities, the information flow can go in different directions. A user can describe a mitigation or adaptation solution at his/her municipality and send it to Climateguide.fi via a solution form.[2] After the information is received, the editor reviews it and contacts the sender of the solution for further clarification and additional information. Following any necessary revisions, the solution is published as a part of the sectoral article in Community Response Wizard.

The service entered its launch (Beta) phase at the end of 2011.

Funding mechanisms

The Climateguide.fi website was produced in cooperation by FMI, SYKE and Aalto University. The undertaking was part of a three-year EU Life+ project (2009-2011). The content providers will maintain and develop the website but new providers are also welcome to join the portal. Operations in 2012 have been supported by the Ministry of the Environment, the Ministry of Transport and Communications, and the Finnish Innovation Fund, Sitra.

There are great possibilities to upscale the project in terms of special user groups addressed, such as municipal actors and senior secondary education groups. Several sectors, such as forest owners, farmers and the tourism industry, would benefit from a tailored version of Climateguide.fi.

Scaling up of the service in terms of broadening the pool of information and content providers of the site is another very plausible path of development. The research institutions for forestry, game and agriculture in Finland have been identified as the next partners for service production under the umbrella of the Climateguide.fi network.

Management of the project

In order to consolidate the portal and develop the services, a Steering Group has been formed. It consists

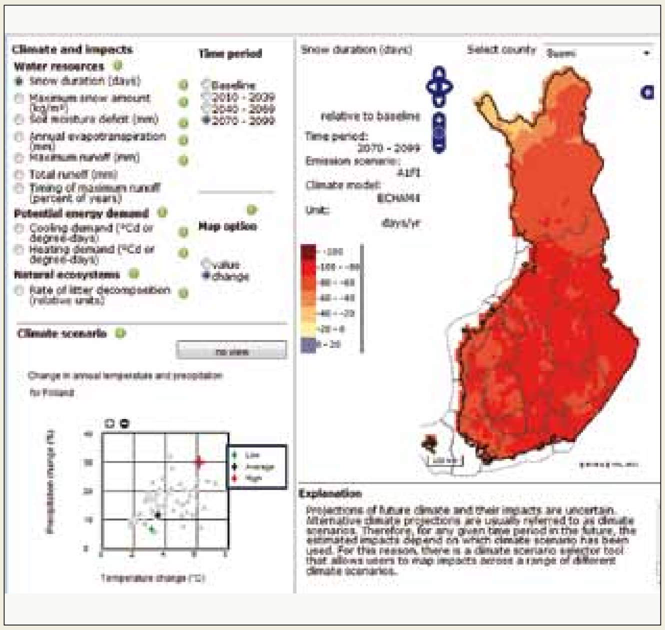


Figure 4: Example view of the Climate Impacts map tool, showing modelled snow duration for the future period 2070-2099. The scenario view also shows the climate scenario selector tool.

Source: Finnish Environment Institute

of representatives of the partner organizations and the funding organizations. Stakeholders of Climateguide.fi comprise the users, potential content producers and potential funding organizations such as ministries and the Academy of Finland. A stakeholder meeting is organized once or twice a year.

Operational decisions and implementation of the maintenance and development tasks are the responsibility of the operational team, which consists of the project coordinator, science editor, representative of the communication departments of both SYKE and FMI, and the head of the Climate Service Centre of FMI.

The portal development project was evaluated using feedback from user seminars and the Internet (including Facebook and the feedback form on the site), Google Analytics and the Steering Group. These will remain the principal means for evaluation in the future.

A partnership approach

It was necessary to form a consortium of partners to develop Climateguide.fi portal. None of the partners institutions could have produced the output by themselves or without other partners. The Climateguide.fi website involved almost 100 experts for varying periods of time during the three year development phase of the portal; a few experts were employed full time. Programmers, GIS experts, graphic designers and concept planners were employed with the external funding provided by the Life+ programme.

Developing and designing the mode of information presentation and how data is made available for visualization was a laborious process involving climate science experts as well as graphic and concept designers.

The texts, which have been written by experts and reviewed by peers, avoid scientific terminology, aiming for clarity and ease of understanding for the lay reader. Interested readers are guided towards advanced information sources and portal users can give feedback on articles. This has proven useful, as a few articles have been further defined according to user feedback.

The users of the service are mostly not climate information experts. With the help of the background and guidance material in the portal, they are able to research the issue from their own perspectives, regions and sectors. Yet further information and external support for interpretation of the information may be needed – for example, when long-term investments are made.

Innovations to meet needs

The concept of Climateguide.fi itself is an innovation. It provides a multi-organizational national platform for climate change information and data dissemination, where all aspects of climate change are covered.

There are various other highlights, including:

- Several innovations to the structure of the portal — for example, the sector-specific pages of Community Response Wizard are divided into Mitigation, Adaptation and Solutions
- The climate scenario selector tool in the Climate Impacts map tool of the Maps, Graphs and Data component helps users visualize uncertainty[3]
- Visualizations[4] facilitate easy updates to the information and data. They are also designed to be easily transferable to other platforms and in different languages
- The history of the Earth's climate has been displayed in a novel interactive visualization.[5]

What next?

One goal for Climateguide.fi is to become an established starting point for citizens in their search for climate change information in Finland. Another goal is for all major climate change information producers — research institutions, universities, ministries and public authorities — to become content producers of Climateguide.fi. The website can also be scaled up by developing new tailored sections for various users on the portal. However, providing permanent resources to guarantee steady development of the portal, in addition to the specific development projects, remains a challenge for the future.

The concept for the portal can set a good example for climate services in other countries. Exchange of experiences from the development phase, user feedback from the operational phase and potentially also exchange of modules between climate portals could be beneficial forms of collaboration between climate services and could strengthen and broaden climate change communication.

How the Met Office (UK) is building capacity and supporting adaptation in some of the world's most vulnerable regions

Professor Julia Slingo, Chief Scientist, Met Office (UK)

A recent World Bank policy research paper observes: "Global warming is expected to heavily impact agriculture, the dominant source of livelihood for the world's poor. Yet, little is known about the distributional implications of climate change at the sub-national level."

It's likely that the strongest impact of climate change will be felt by the world's least developed countries. But without detailed climate change understanding at a local level, governments and regional authorities will be unable to plan adequately for the future.

With few developing countries having the capacity to perform all the necessary climate research on their own, there's an increasing need for world-leading climate change institutions to assist. Met Office Hadley Centre (UK) already works in this way with many countries – helping to build capacity for predicting the effects of weather and climate change through high-resolution regional modelling and to develop adaptation strategies.

Among these endeavours are a major climate change project launched in Maharashtra, India in 2011, climate-related capacity building programmes in Bangladesh and Singapore, and work to enhance national meteorological capabilities in Rwanda.

Image: www.istockphoto.com/ferrantraite

Global warming is expected to heavily impact agriculture, the dominant source of livelihood for the world's poor

The climate change threat to Maharashtra

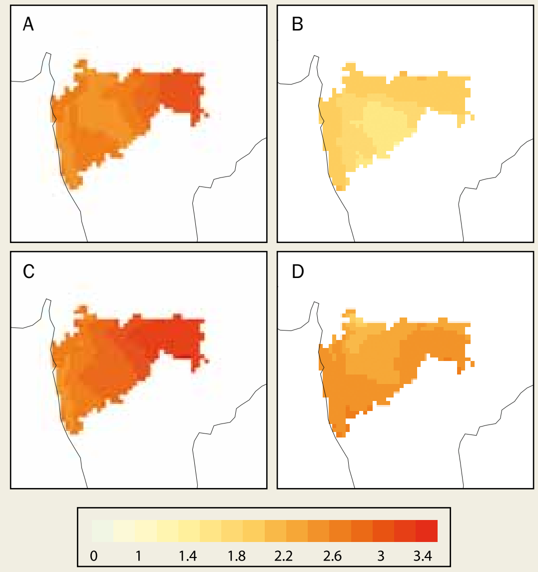
The World Bank notes that "In the state of Maharashtra, a single drought (2003) and flood (2005) absorbed more of the budget than the entire planned expenditure on irrigation, agriculture and rural development from 2002–2007. Climate change is expected to increase the frequency of extreme events."[1]

Covering an area of almost 308,000 square kilometres, Maharashtra is India's third-largest state and is home to the commercial hub of Mumbai. Its population of almost 97 million is the country's second-largest. Yet despite extensive industrialization, the majority of its population (64 per cent) works in agriculture and some 47 per cent are living below the poverty line. The state's high dependency on the land, combined with a vulnerable 840 km coastline, leaves it particularly susceptible to changing weather patterns. Key climate changes and possible impacts include:

- Increased temperatures and altered seasonal precipitation patterns affecting hydrological systems and agricultural productivity
- Increased risk of severe weather events having a devastating effect on agriculture, water resources, forestry and the wellbeing of the population
- Coastal communities facing a serious threat from rising sea levels — a 1 metre rise would put more than 1.3 million people at risk.

The associated costs of climate change-related damages in Mumbai alone could exceed US$30 billion if no action is taken.

Projections for 2070–2099: temperature



Each of the four models used (A, B, C and D) projected temperature increases of between 1.5° C and 3° C for the Maharashtra region during the monsoon season

Source: Met Office (UK)

Project strategy and key objectives

"Allowing for a range of plausible changes in local climate, rather than using a single projection, when assesing impacts of climate change leads to more robust development planning and policymaking," says Dr Bhaski Bhaskaran, Climate Services Manager of the Met Office Hadley Centre.

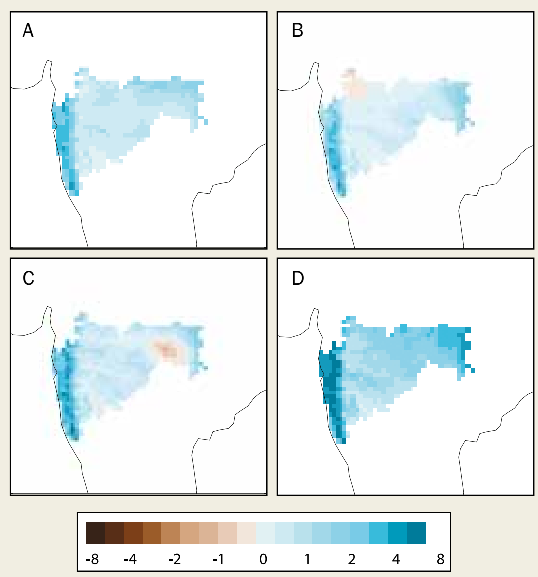
In 2011, working in close collaboration with The Energy and Resources Institute (TERI) of India and key funding partner the Government of Maharashtra, the Met Office began a project called 'Assessing climate change vulnerabilities and adaptation strategies for Maharashtra'. It aims to:

- Establish how climate change may affect the state
- Alleviate impact on the economy, society and people's lives
- Share lessons learned with other similar initiatives worldwide.

The strategy focuses primarily on water resources, agriculture, coastal areas and livelihoods. Starting with a review of secondary data and relevant past work, it involves collating best possible regional climate change information from a range of projections at 25 km spatial grid, a first for the region.

Four future climate projections which characterised the range of a larger ensemble of Met Office climate models were selected for use. Met Office partners then analysed datasets covering the 2030s, 2050s and 2070s using various methodologies developed by TERI to identify impacts and vulnerability and to inform policy and decision-making.

Projections for 2070–2099: rainfall



All four model projections suggest an increase in monsoon rainfall, particularly along Maharashtra's coastlines and the Western Ghats, with only slight decreases in rainfall seen further inland in projections B and C

Source: Met Office (UK)

Key roles

Each of the three project partners has a key role to play. The Met Office Hadley Centre focuses on model validation and climate changes. Validation compares the results for key climate variables to observational datasets covering the Maharashtra region, with particular emphasis on the monsoon season. This information guides the interpretation and application of the projections.

A range of plausible future climate outcomes were produced by the Met Office Hadley Centre, using a perturbed physics ensemble approach[2] which involves building a number of global climate models consistent with current knowledge of how to represent the climate system. Results from these global climate models were downscaled using the Met Office's regional climate modelling system PRECIS at 25 km resolution. The high resolution PRECIS data provide a level of detail relevant for exploring many impact and vulnerability issues.[3]

TERI focuses on impact modelling, vulnerability assessment and case studies, and capacity building. The high-resolution climate projections from regional climate models provided by the Met Office have been used for impact modelling in selected sectors, and cross-sectoral linkages were also investigated.

As climate vulnerability is highly site-specific, TERI will select six case-study sites to conduct detailed vulnerability assessments and propose appropriate adaptation strategies. The project is expected to draw linkages from the case-specific findings to regional/state level adaptation strategies, addressing the key sectors and leading to a State Adaptation Action Plan for the Government of Maharashtra.

Advised by both the Met Office and TERI, the Government of Maharashtra will use results from the climate projections and impact assessments in its policy and decision-making process to agree state-wide adaptation techniques. Through stakeholder and partner workshops, the Met Office will play a key role in ensuring accurate interpretation of climate projection results.

Research highlights

Maharashtra's monsoon season is from June to September and the study focused solely on these months as they account for roughly 70-80 per cent of the region's rainfall. It's a highly important season for agricultural productivity and crop yields, water resources, and the health and wellbeing of Maharashtra's citizens.

Rising carbon dioxide concentrations mean that globally averaged temperatures are continuing to increase. For Maharashtra, studies consistently projected a temperature increase over the entire region for the monsoon season of between 1 .5° C and 3° C for the four models used. Such increased temperatures could lead to severe drought, water scarcity, and reduced crop yield – all of which could have a devastating impact on people.

In addition to increasing temperatures, we expect climate change to alter many aspects of global and regional precipitation patterns. For Maharashtra, all four model projections suggest an increase in monsoon rainfall, particularly along the state's coastlines and the Western Ghats, with only slight decreases in rainfall seen further inland. Strong rainfall increases, such as those seen along the Maharashtra coast, could result in extreme flooding – drastically reducing the state's agricultural productivity and promoting water-borne diseases such as cholera.

While the amount of monsoon rainfall is a key factor affecting future adaptation strategies, any changes in the duration or intensity of this season could have strong impacts on Maharashtra's vulnerability to future climate change. Although we expect the monsoon season to remain relatively unchanged, all four models project an increase in the intensity of monsoon rainfall.

We project that intense rainfall events will extend further into the final months of the season. While the present day monsoon period produces maximum rainfall during July, our projections widen this maximum rainfall period to both July and August. With the heaviest monsoon rainfall lasting longer into the monsoon season, the threat of localized and severe flooding events is further intensified in a warmer future climate.

Daily extremes

We looked at the projected changes in the frequency of extreme occurrences in both high temperatures

Image: Met Office (UK)

Training at the Bangladesh University of Engineering and Technology

A country with limited resources, infrastructure and a dependence on subsistence agriculture, Bangladesh is also highly vulnerable to climate change. In fact, recent studies found that even the most aggressive emissions reduction policies will still result in two thirds of the expected twenty-first century sea level increase.

In 2010, the Met Office Hadley Centre ran a project called 'Capacity Building in Climate Modelling in Bangladesh' working with UKaid and the Climate Change Cell at the Bangladesh University of Engineering and Technology (BUET). It aimed to apply regional climate change models, interpret their outputs and provide policymakers with the high quality, high resolution data they need to plan for climate change.

The project funded a modern, dedicated climate change computer lab. This was set up within the Institute for Water and Flood Management at BUET and includes everything needed to run the Met Office Hadley Centre's regional climate modelling system PRECIS and other programs.

The facility also enabled training workshops run by Met Office Hadley Centre scientists, and other climate change modelling activities. It will continue to be used for modelling in the future.

The Met Office Hadley Centre and BUET partnership has resulted in a range of new initiatives including:

- An online discussion forum for climate modellers in Bangladesh
- A new website for news and sharing information
- A division of responsibility for conducting the high-resolution model runs between different institutes in Bangladesh
- The establishment of monthly meetings of all Bangladeshi participants to discuss progress, share results and agree next steps.

Singapore: enhancing national climate science capability

South East Asia is highly vulnerable to climate variability and climate change – for example through flooding from tropical thunderstorms and storm surges, coastal land loss from sea level rise, heat stress, and the resurgence of diseases such as dengue.

In May 2011, the UK Met Office and the Meteorological Service Singapore (MSS) started a three-year programme to enhance Singapore's climate science capability involving an exchange of scientists to and from the UK. Met Office scientists are using their expertise to help MSS and other national weather services across South East Asia analyse the wealth of extreme weather data accumulated over the years. Led by MSS, this project will establish a database that will be used to determine the level of risk each country faces and assess the reliability of climate models in the region.

An additional aim of the Met Office-MSS partnership is to produce joint scientific papers relevant to the upcoming Intergovernmental Panel on Climate Change (IPCC) Assessment Report in 2013/4, covering fundamental issues of climate change and its impacts on the South East Asia region. By integrating MSS into IPCC processes in this way, the Met Office is not only helping to enhance the scientific capability of Singapore but strengthening IPCC's process with a broader and more comprehensive evidence base.

and intense rainfall. During the monsoon season, all four models projected an increase in the percentage of days with temperatures above 35 °C over the entire Maharashtra region, with a large reduction in the percentage of days recording less than 25 °C.

Looking at three sub-regions of western, eastern and central Maharashtra, there is a clear increase in the number of extremely warm days consistent with an increase of approximately 1.5° C to 3° C.

The number of days with 'high' or 'very high' rainfall (greater than 25 millimetres per day) is projected to increase over the Maharashtra region across all four projections, while the number of days with 'low' to 'moderate' rainfall is expected to reduce. This suggests an increase in the region's monsoon rainfall in a warmer future climate, and is consistent with the other results. An increase in the frequency of extremely high rainfall events will further threaten Maharashtra with the risk of severe and widespread floods.

In summary, all four projections for the Maharashtra region suggest a warmer, wetter monsoon season with more frequent days of extremely high temperatures and intense rainfall events lasting longer into August.

Future uses

The climate projections generated by the Met Office will be used by TERI to provide impact assessments for various sectors, such as water (availability and affects of more rain in the monsoon season), agriculture (millet and sugarcane) and health (heat stress, malaria).

As also seen in Bangladesh and Singapore, the high-resolution regional climate model implemented for this region can easily be employed in any part of the world to provide regional climate change information for impact assessments to inform climate policymaking.

Currently, efforts are underway at the Met Office to develop the next generation of climate models that will take into account various Earth system elements to provide integrated impact assessments (as opposed to one-way or offline assessments).

The next version of the regional climate model will be able to provide climate change information at a resolution of around 10 km. Such information is highly valuable for city level adaptation planning for cities like Mumbai.

Consulting on observations network in Rwanda

Image: Met Office (UK)

Although the Met Office's work in Rwanda focuses on rebuilding the national meteorological service following war, it further highlights the importance of a high quality weather service for strengthening the economy – particularly agriculture.

A Met Office consultant has just spent a year in Rwanda working with the Rwanda Meteorological Service through the World Meteorological Organization's Voluntary Cooperation Programme:

- Developing a new severe weather warning system
- Modernizing observational data processes
- Modernizing national TV weather bulletins
- Producing forecasts for radio and newspapers
- Refreshing the service's website.

Building resilience to climate-related hazards

Pilot Program for Climate Resilience in Nepal and Yemen

The World Bank is helping the Governments of Nepal (GoN) and Yemen (GoY) to increase their resilience to climate change. In Nepal, the national hydrometeorological service (NMS) is the Ministry of Environment, Science and Technology's Department of Hydrology and Meteorology (DHM); In Yemen, the NMS is the Civil Aviation Meteorology Authority/Yemen Meteorological Service (CAMA/YMS). Aided by the World Bank, these institutions are being strengthened to improve essential weather, water and climate services. The following account outlines the GoN and GoY projects, along with details of further hydromet and climate information services projects in Central Asia and Jamaica.

As in many of the least developed countries, Nepal's DHM struggles to maintain adequate staffing and cope with an extensive network of manual observations, and cannot maintain 24/7 operations. Lacking extensive real-time data and upper air observations, it has virtually no capacity to detect and issue weather-related hazard warnings or identify climate-related threats. As a result, there is relatively little engagement with users, no explicit service delivery function, and no baseline from which to measure service improvement.

In Yemen, the situation is slightly better. CAMA/YMS focuses on 24/7 aviation weather services which are provided on a cost recovery basis, and it provides basic weather forecasts for the public and a variety of users. The emphasis in Yemen is on extending the meteorological and hydrological observing network and improving hazardous weather warnings and climate forecasts. This

Image: Stephan Bachenheimer

The high altitude meteorological station operated by the Department of Hydrology and Meteorology in Nepal is being done in partnership other organizations responsible for observation, collection and use of weather and climate data and information, especially the Environmental Protection Authority (EPA), Ministry of Agriculture and Irrigation (MAI), Agricultural Research and Extension Authority (AREA), and National Water Resources Authority (NWRA).

Building resilience in Nepal and Yemen

The Pilot Program for Climate Resilience (PPCR) Building Resilience to Climate-Related Hazards projects aim to strengthen infrastructure, modernize observing and forecasting systems and strengthen public weather, climate and hydrological services. The new systems and services will target – and be measured by their impact on – activities that affect the most vulnerable in the population: farming, disaster risk management (civil protection), water resource management, energy production, population health, and the transportation sector.

Social and economic assessments are a key component of the projects. In Nepal, the Finnish Meteorological Institute has conducted preliminary assessments which indicate the potential benefits to agriculture, electric power supply, public health and safety, civil aviation and tourism, and road transport. Estimated benefits of several hundred million Nepali rupees (more than US$10m) can be achieved in agriculture by improving forecasts for food staples such as rice and cereals, cash crops and livestock. Efficient hydropower generation requires better forecasting, accruing benefits of tens of millions of rupees annually and more if hydropower generation expands. Forecasts and warnings of extreme weather events and related health impacts such as vector- and water-borne disease can, if managed, reduce loss of life and livelihoods and economic disruption. The actual financial benefit has not been quantified, but will be hundreds of millions of rupees per year, given the frequency of extreme events. Better forecasting will improve aviation safety and increase opportunities for tourism with initial benefits of tens of millions rupees per year, and much larger benefits as the industry expands. More detailed assessments are required to quantify the benefits as a part of the development of a National Framework for Climate Services (NFCS) within the Global Framework for Climate Services (GFCS), which will be piloted during each of the PPCR projects.

In Yemen, floods and droughts are frequent hazards. Recent estimates from the Global Facility for Disaster Reduction and Recovery (GFDRR) at the World Bank indicate that losses from flooding can be as high as 2.6 per cent of gross domestic product. In 2008, for example, floods caused US$1.6 billion in losses in three days. Rainfall is the major source of water in Yemen, and is accessible from wadis, springs, shallow wells and rainfall harvesting. Renewable water resources are well below the critical water scarcity level of 130 m3 per person per year. New working relations are required and will take advantage of an NFCS to increase exchange of data and introduce new climate services, including better flood forecasts, agriculture management and water resources, and sand and dust storm forecasting. While there is extensive knowledge of the current social and economic impact of climate related hazards on Yemen, more detailed assessments are required to quantify the benefits as a part of the development of an NFCS.

The template for conducting future studies in Nepal and Yemen is similar to the World Bank and PPCR economic assessments in Central Asia, which were part of the modernization of hydrometeorological services in that region. Based on estimated losses, the likely benefit will be high and in line with estimates from similar countries (cost-benefit on the order of 1:10). Communicating climate information in an understandable form is a priority. In preparatory workshops for the NFCSs, national and local government and civil society participants in Nepal and Yemen's EPA, MAI and NWRA have all emphasized the need to focus on translating climate information into knowledge that informs local communities, especially farmers.

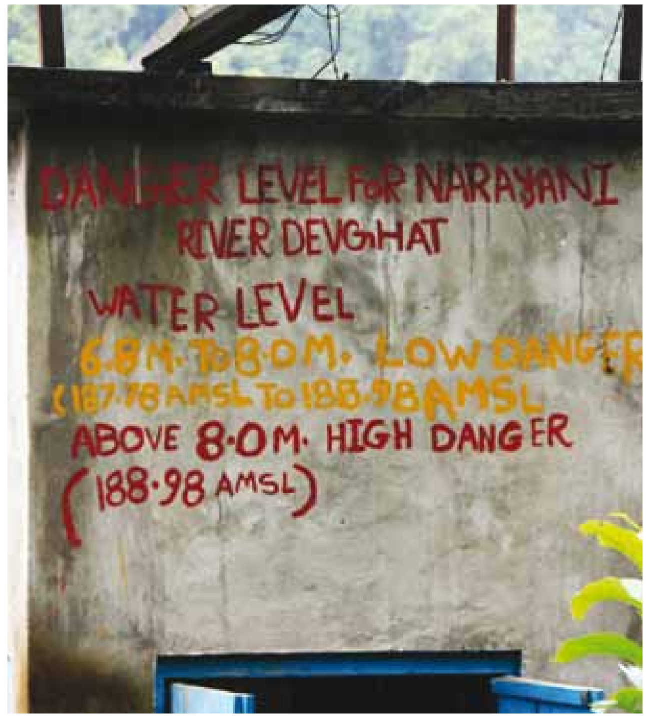
PPCR investment programme

Nepal is considered the world's fourth, and Yemen one of the top ten, most vulnerable countries to climate and extreme events. The GoN, supported by the World Bank, International Finance Corporation and Asian Development Bank PPCR teams, undertook an extensive consultation process involving over 850 people at the national, district and local levels to identify a five-project Strategic Programme for Climate Resilience (SPCR). They identified, among other things, the urgent need to strengthen hydrometeorological services to build the country's resilience to climate change and weather extremes. In a similar process, the GoY established an Inter-Ministerial Committee on Climate Change, developed a National Adaptation Program of Action (NAPA) and appointed the EPA to manage the Government's actions on climate change and to lead the PPCR effort. A four-project SPCR was developed, which also identified strengthening hydrometeorological services to improve climate information systems as a critical component.

In each country, to address these priorities, the bank's teams agreed to develop the Building Resilience to Climate Related Hazards projects as a component of each the SPCR. The bank's PPCR teams then requested assistance and support from the GFDRR Hydromet team assess the capabilities of the NMSs of Nepal and Yemen and help develop the technical design for the projects.

Both projects are currently in development. For Yemen, the team is in the process of developing a Concept Note for a US$19 million five-year project, which will move to the pre-appraisal phase following World Bank approval. Nepal is at this later pre-appraisal stage. Building on the interactions of the earlier SPCR activities, two large stakeholder consultations were conducted in Nepal involving non- governmental organizations, government ministries, development partners, the private sector, academicians and civil society organizations involved in water management, disaster reduction, early warning and climate resilience. Separate field trips were also conducted, during which a number of stakeholders were consulted to review the preliminary design of the project.

The Nepal project will be funded by the PPCR with a total estimated budget of US$31 million. An agricultural services component will be implemented by the



Images: David Rogers

Left: typical image of Nepal, showing a river, terraces and erosion. In heavy rains landslides are common, in addition to river flooding. Right: shows flood levels on the side of a hydrological gauging station. These stations are permanently manned by an observer who takes care of the measurements and issues local alerts based on the river level and the instructions on the side of the building

Ministry of Agriculture Development (MoAD), focusing on the development of an Agricultural Management Information System (AMIS), which will use both historical and current weather and climate data from the DHM. Each modernization effort has three critical components:

- Institutional strengthening
- Updating the observing networks and forecast production infrastructure
- Developing effective service delivery that meets users' expectations.

Experience has shown that all three must be tackled if a modernization programme is to succeed.

Depending on the capacity of the NMS, expert assistance may be needed for the entire five years of project implementation. In Nepal, training and other capacity improvement efforts will increase the abilities of DHM staff, and implementation support will be provided by contracting a 'systems integrator' (an expert consortium familiar with NMSs, observing networks, forecasting and service delivery), to help define the overall requirements for the procurement of equipment and the design of the overall system.

While the systems integrator can provide the internal support needed to build the system, it is essential that the NMS is connected to the global meteorological community through the World Meteorological Organization (WMO) and, in particular, can take advantage of opportunities to pair with more advanced NMSs, such as the neighbouring Indian Meteorological Department and China Meteorological Administration in the case of Nepal. Such twinning or pairing arrangements should include forecasting and warning support and weather, climate and water services delivery. Twinning would provide operational support so that the NMS could rely on its partners to help it interpret hazardous situations. It would also provide donors and investors with a viable risk reduction strategy. Government investment would show an immediate return while national expertise is built, by leveraging the expertise of partners. Since expertise is likely to be needed from several different NMSs, the favoured approach is to use WMO Regional Specialized Meteorological Centres and Regional Climate Centres.

The agricultural component of the programme will build an AMIS to provide weather and climate information for agriculture. This kind of dedicated user-oriented service, built with the ministry responsible for agriculture, demonstrates how services in general could be developed. Lessons learned from this effort will be generally applicable to other weather- and climate-sensitive sectors, enabling comparable sector-specific services to be developed.

Ensuring positive results

The World Bank requires a strong results framework for all its projects. The PPCR will be evaluated through several factors including the measurement of weather and climate product improvements. Continuous assessment of the delivery of services to the public will consider the programme's impact on various groups of stakeholders, including gender and minority groups. Targeted sector-specific weather- and climate-sensitive groups will be solicited through an independent evaluation process.

In both Nepal and Yemen, there is extensive need for skills building and for climate and warning information to manage weather extremes for vulnerable populations, within many government agencies (such as disaster management, health and water resources) and weather- and climate-sensitive sectors (agriculture and hydropower). None of the potential users of climate information is fully supported at the moment.

The projects will be conducted over five years. In Nepal, the next step will be for the World Bank and GoN to appraise and negotiate the project followed by implementation of the programme of work.

The projects are scaled to meet many of the GoN's and GoY's basic needs to improve their resilience to climate change. In both cases the projects focus on agriculture and flood warnings for civil protection as the principal beneficiary of the new services in the first instance. Further investment will enable this experience to be included more explicitly in other climate-sensitive sectors, such as health.

Further projects

There is a growing need for better quality weather, water and climate information particularly to enable early warning, to support disaster-reduction strategies and to improve operations in climate-sensitive sectors. The improvement of hydrometeorological service delivery in participating countries will focus on providing technical assistance and equipment to help build the capacity to deliver these services to end users.

Central Asia

The Central Asia Hydrometeorology Modernization Project will strengthen regional coordination and information sharing between participating NMSs (to be implemented by the Executive Committee of the International Fund for Saving the Aral Sea), and hydromet services in the Kyrgyz Republic (to be implemented by Kyrgyzhydromet) and the Republic of Tajikistan (to be implemented by Tajikhydromet). The project will provide much needed equipment and capacity-building to NMSs in Central Asian countries. Most importantly, emphasis will be placed on improving service delivery through institutional strengthening and building partnerships with key stakeholders. New business models will be developed, tested and implemented to help partly recover costs for sustainable development.

Benefits will include reduced human vulnerability to natural hazards, reduced risk of damage to property and the potential for overall reduction of economic losses as a result of natural disasters. Coordination and information exchange among the NMSs will be improved, as will regional cooperation in support of climate adaption, through the generation of more reliable data that better responds to clients' needs.

The project is still in its early phases: the regional coordination and Republic of Tajikistan components have recently begun and the Kyrgyz Republic component is yet to start. As such, the initial start-up is slow and the project management units are not yet fully functional. It will take four to five years to put the results on the ground and to achieve the desired impact.

Jamaica

In Jamaica, a project is underway to improve quality climate information for effective planning and action at local and national levels. The project entails upgrading the data collection, processing and forecasting system of the meteorological services, replacing the current, almost obsolete radar and upgrading the data acquisition network with automatic recording systems that can transmit real-time data. Business processes and the technical expertise of key personnel will be reviewed and updated, and strategies formulated to ensure greater sustainability and more effective customer services. The project will also determine the feasibility of developing climate goods and services for private sector clients.

Climate change scenarios specific to Jamaica will be developed, including high-resolution scenarios at the national and sectoral levels, to enable effective planning and design of adaptation initiatives. This will also entail building sector-specific methodologies for climate-resilient planning and design, to improve the capacity of professionals to apply the scenarios in development planning.

A vulnerability assessment and risk information platform will be developed to improve the understanding of how climate change affects other risks and vulnerabilities within the sectors, such as the relationship between future rainfall changes and rain-fed agriculture. Specialized vulnerability assessments will be carried out using climate scenarios to assess the expected consequences of climate change for each priority sector. These assessments will enable the convergence of socioeconomic data and climate data to more meaningfully devise adaptation strategies. There will also be a detailed vulnerability assessment of the health sector, and a costed plan of action will be developed outlining the actions necessary to make the key health facilities climate-resilient. Low-cost but critical actions will be implemented to enhance resilience in pilot facilities.

A further component is to develop a climate change risk information platform based on intensive assessments of end-user needs and updated climate scenarios. This will give Jamaicans a common medium for sharing information and learning in order to facilitate better adaptation to climate change risks. Climate change awareness and education activities will be implemented, including demonstration projects such as a rain water harvesting project at a school located in a community with demonstrated water deficit. This component will also scale up the 'Voices for Climate Change' awareness and education project, which was successfully implemented in selected communities across the island.

The platform is intended to improve the knowledge, attitudes and practices of the Jamaican public towards climate change by 50 per cent. It will provide guidance for decision makers and planners, and serve as a tool for awareness building and decision-making at national, sectoral and local levels.

These projects illustrate the work being done to enable better gathering, analysis and sharing of hydrometeorological services, so that PPCR countries that are currently highly vulnerable to the impacts of climate variability and change can build the solid hydromet and climate information services that they need to support decision-making and enhance resilience.

The Climate Change - Mitigation and Adaptation international training programme — a Swedish initiative

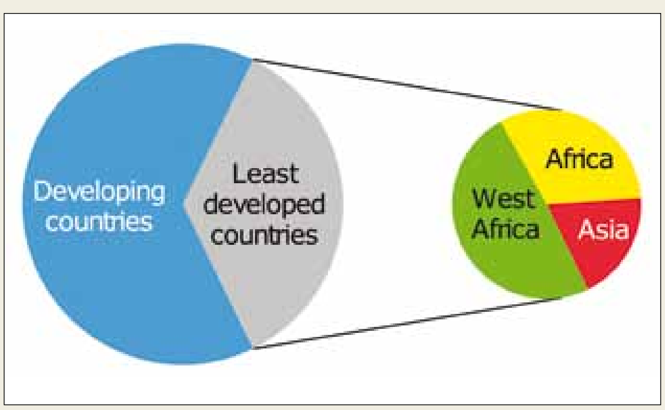
Daniel Holmstedt and Bo Holst, Swedish Meteorological and Hydrological Institute

Climate Change – Mitigation and Adaptation is an advanced international training programme for capacity building in developing countries, funded by the Swedish International Development Cooperation Agency (Sida). The overall objective is to increase, and transfer knowledge and capacity related to climate change and its consequences. Experiences from the programme have been very positive and it is obvious that this type of training programme fulfils a need for many organizations. It is also clear that it contributes to the improvement of climate services by promoting information exchange and dialogue between climate experts and community planners. The programme organizer is the Swedish Meteorological and Hydrological Institute (SMHI) along with its partners Sweco and the Stockholm Environment Institute.

The programme is designed for individuals who have key positions in organizations related to national, regional or local community planning. In other words, those who are active in reform processes of strategic importance at various levels. Participants are expected to be well acquainted with climate change issues from an adaptation perspective and to have a university degree in technical, natural or social sciences. The programme aims to provide methods for the identification of vulnerable sectors in society. Mitigation and adaptation to future climate conditions and the development of action plans are other important aspects. The intention is that the programme will contribute to capacity building and strengthening of institutions in the participants' home countries. Participants are recruited from:

- Ministries
- Authorities (local, regional or national)
- Environmental institutes and research organizations
- Non-governmental organizations
- Consulting firms
- Industries.

Distribution of participants from the training programme



Out of the total 450 participants, 160 come from LDCs (Asia, Africa and French speaking West Africa).

Source: Elin Sjökvist, SMHI

The main target group for the training programme is decision-makers rather than, for example, staff at national meteorological and hydrological services (NMHS) who are already knowledgeable in climatology and climate change. Therefore the number of participants from NMHSs amounts only to about 10 from least developed countries (LDCs). However, out of the total 160 participants from LDCs, about 80 are recruited from organizations that are immediate users of climate services from the respective national hydrometeorological agencies and institutes. Most of them come from governmental or regional organizations in direct need of climate information for their planning and decision-making processes. Examples are ministries of environment, water, energy, forestry, agriculture and fishing, and health, as well as national disaster management committees and specific development councils, commissions and projects are represented.

Programme outline

The programme has four main components:

- Preparation
- Training in Sweden (four weeks)
- Project work in the home country (six to eight months)
- A follow-up regional seminar.

The preparation phase includes the selection of participants by the programme organizer. This is based on a formal application which contains a brief presentation by the applicant, including an outline of their role in the home country and a description of the individual project work, which is an important part of the programme.

Image: Åsa Johnsen, SMHI

An excursion in Wadi Rum — close to Aqaba — during the regional seminar in Jordan, May 2011

Image: Åsa Johnsen, SMHI

Participants during a lecture at SMHI in Sweden, March 2012

The training programme is mainly based on lectures, exercises and field visits. To cover the broad scope of objectives, external international experts as well as staff from SMHI are used as lecturers. The content is built up around the following blocks:

- The greenhouse effect and impacts of climate change
- Impacts on water resources and coastal zones
- Impacts on agriculture and forestry and the need for preventive action
- Strategic planning to counteract the causes of climate change
- Community planning, vulnerable sectors, interdisciplinary planning and cost-benefit analysis
- Strategic planning pertaining to potential positive consequences of climate change
- Information, education and public participation.

One essential aspect of the programme is that it provides a forum for discussions and exchange of experience between participants, lecturers and specialists. Much of the time is dedicated to group exercises, which helps bringing the individuals of different nationalities and backgrounds closer together. The training programme ends with a one-week follow-up seminar in one of the regions relevant to the specific course. At these regional seminars the results of the individual projects are presented and discussed, and there is also input from regional organizations.

Long-term engagement

For six to eight months after their visit to Sweden, participants work with their individual projects according to the plan elaborated during their stay. A written report is produced and a presentation is prepared for the regional seminar. In this work it is essential that the participants are supported by superiors and colleagues in their home organization. Ideally the project work should be in line with their ongoing work and contribute to the development of knowledge and efforts to improve methods and procedures. This demands long-term engagement by the participants and commitments from their home organizations.

The programme started in 2007 and since then we have witnessed a great variety of individual projects. The majority of the studies have been oriented towards water resources, agriculture and education/communication. One example is from Mali in West Africa. This project discusses the existing management strategies for water and land resources and how they have been weakened by ongoing climate change. The author concludes that the situation leads to structural poverty and difficulties in accessing necessary resources. However, there is still hope based on some successful examples in the Diorila region and the author recommends further international cooperation on these issues. Another example from the West African region discusses the climate impact on surface water resource in the Niger watershed in Burkina Faso. The project report highlights the climate-related water stresses that affect the already daunting hunger and poverty. The author recommends large-scale studies to further understand the climate impacts on surface water resources.

Two further examples come from Tanzania and Zambia. The project work from Tanzania points out climate variability as a big challenge to farmers, particularly those who solely depend on rainfall to grow their crops. For various reasons there is widespread lack of use of weather and climate information as well as predictions in farm management. The author believes that the application of climate forecasts can significantly improve the farmers' decision-making and adaptation to the changing climate. The example from Zambia discusses the need for communication networks for disseminating climate change information and raising awareness in rural communities. The results show that rural communities are aware that the climate is changing but they know little about the causes. The project achieved the goal of disseminating climate change information in three communities and raising awareness on climate change among them. This in the end enabled the communities to identify climate hazards affecting their area and coping strategies.

The examples given above are all from project works accomplished by staff of NMHSs. They are encouraging as they show that NMHS personnel are prepared to

Image: APCCC

The official opening of the APCCC office in Bukoba, Tanzania in 2012

go beyond their core expertise, widening their studies to assess the impact of a varying and changing climate on society. Furthermore, many of the participants are users of information about climate change, and therefore need to approach the NMHS to discuss what data is available for their respective study. Most certainly this also paves the way for the development of better, easily accessible and comprehensible climate services for the benefit of society in developing countries.

Many of the individual projects completed during the training programme have focused on the important aspect of long-term and continuous interaction between climate change specialists, decision-makers and stakeholders. In a complex decision-making processes, especially when basic data are uncertain, there is a need to identify adaptation options that function over a wide range of climatic conditions now and in the future. Consequently the dialogue may need to continue over several years. Consultation should also take into account new research findings, the use of climate scenario ensembles and innovative approaches to mitigation.

Evaluation shows encouraging results

Until now, a total of 450 participants have undergone the training. The funding agency Sida has an overall objective to fight poverty, which leads to an orientation towards specific countries and regions. French-speaking West Africa is one such prioritized region, which explains the large number of attendants from this region. Sida sets a high priority on the evaluation of both immediate and long-term results of the training programme. Approximately 50 per cent of all participants have been asked to respond to an evaluation questionnaire 12 month after the regional seminar. The purpose of the evaluation is to find out whether the programme has encouraged further work on climate change. For the remaining 225 participants this survey is still due.

Results from the survey show there is a strong belief that the knowledge acquired through the programme has been beneficial for participants' organizations. As many as 95 per cent answered that it had been beneficial to a large or very large extent. Most respondents say that they are still using the knowledge and tools they received throughout the programme.

The majority of the participants who have answered the survey have joined an existing network. This opens opportunities for further cooperation and exchange of information and experience between the participants. More than 10 per cent have been involved in starting up new climate change networks. One example is from Bukoba in Tanzania where a former participant, from the 2007 programme, has started a network called the Africa Partnership on Climate Change Coalition (APCCC). The organization is growing day by day and currently tries to implement low-carbon growth activities in the Kagera region.

Many of the participants believe that their participation in the programme has led to an increased awareness among the public and decision-makers. Over 80 per cent answered that the programme had led to greater influence to a large or very large extent. A single participant cannot change anything unless the rest of the community understands the importance of the problem and therefore this is an important step towards real change.

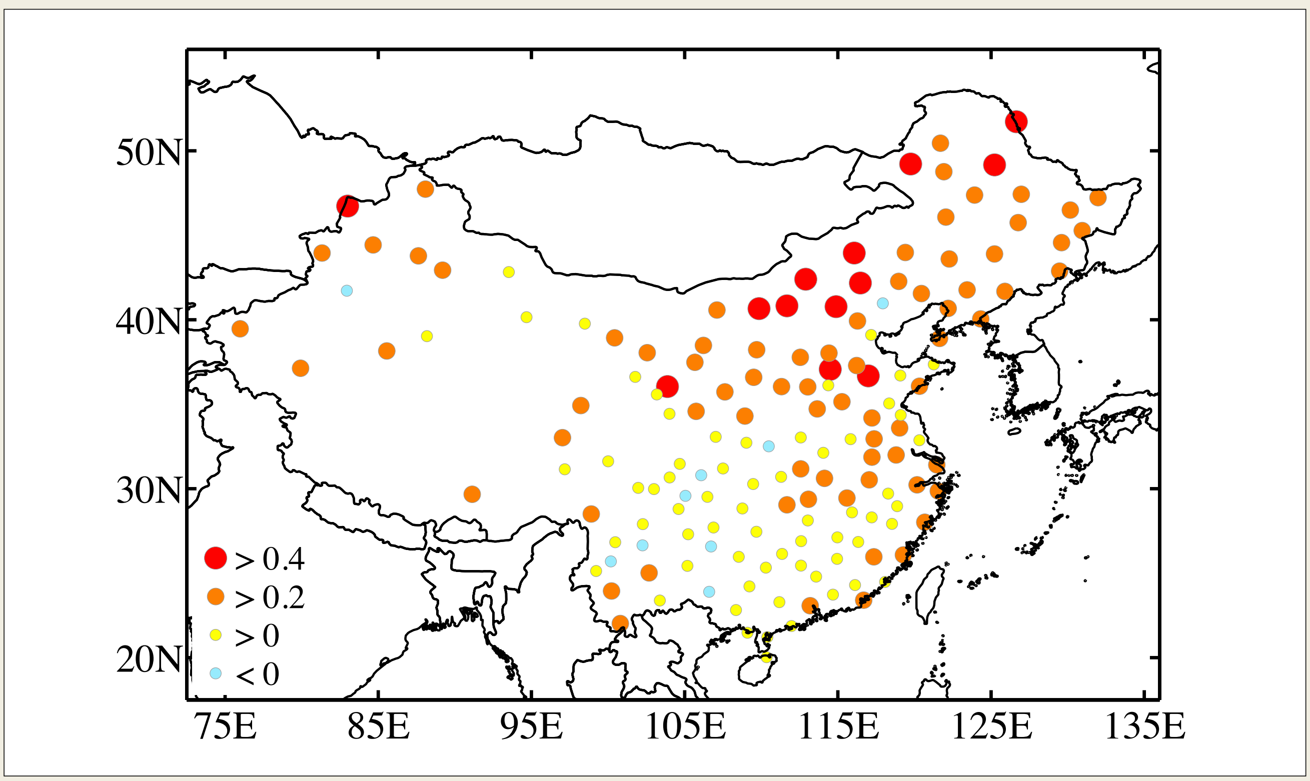
Climate-related services in China

Huijun Wang and Dabang Jiang, Institute of Atmospheric Physics, Chinese Academy of Sciences

China is situated in East Asia, bordered on its east by the western North Pacific. The national climate is modulated mainly by the East Asian monsoon circulation, the western North Pacific subtropical high, surface conditions on the Qinghai-Tibetan Plateau, the South Asian high pressure system in the upper troposphere, atmospheric circulation in the middle and high latitudes of the Eurasian continent, and remote factors through atmospheric teleconnection. Spatial and temporal climate conditions are quite complicated in the country, with warm-wet climates in summer and cold-dry climates in winter. The national natural environment, highly influenced by geographic location and topographic and geomorphic features, is generally poor, and most regions are susceptible and vulnerable to climate change. A considerable effort has been made by meteorologists and climatologists to investigate the facts and mechanisms of climate change over a wide range of timescales and to evaluate its influence. At the moment, climate service products generally consist of climate detection and diagnosis, climate prediction and projection, climate resource development, climate risk management and so on. Climate services are provided for agriculture, hydrology, traffic, disease prevention and atmospheric environment control among other uses.

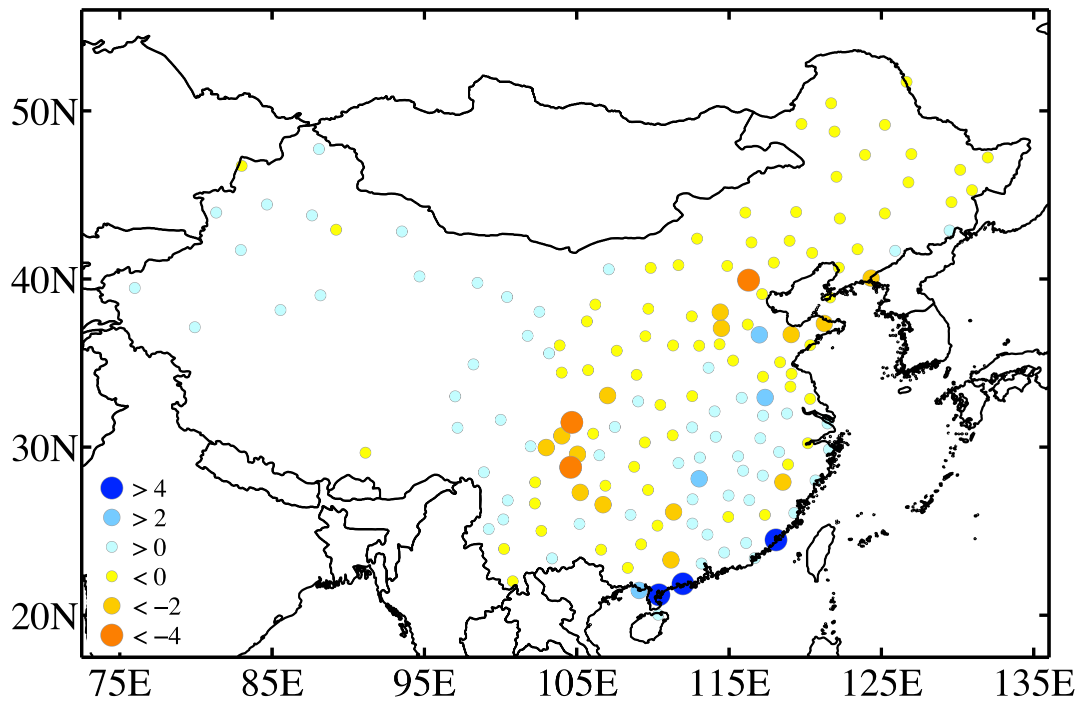
Climate change-related services

Meteorological stations have increased in China since the 1950s. The network of automatic meteorological stations currently includes more than 2,000 sites across the country. In addition, there are satellite data and marine observations as well as observation stations for wind and solar energy. Based on these continuous and quality-controlled observations, it has been found that China's climate has undergone



Spatial distribution of linear trends of annual mean temperature with 160 stations in China from 1951-2010. Units: °C/decade

Source: IAP China



Spatial distribution of linear trends of annual mean precipitation with 160 stations in China from 1951-2010. Units: mm/yr

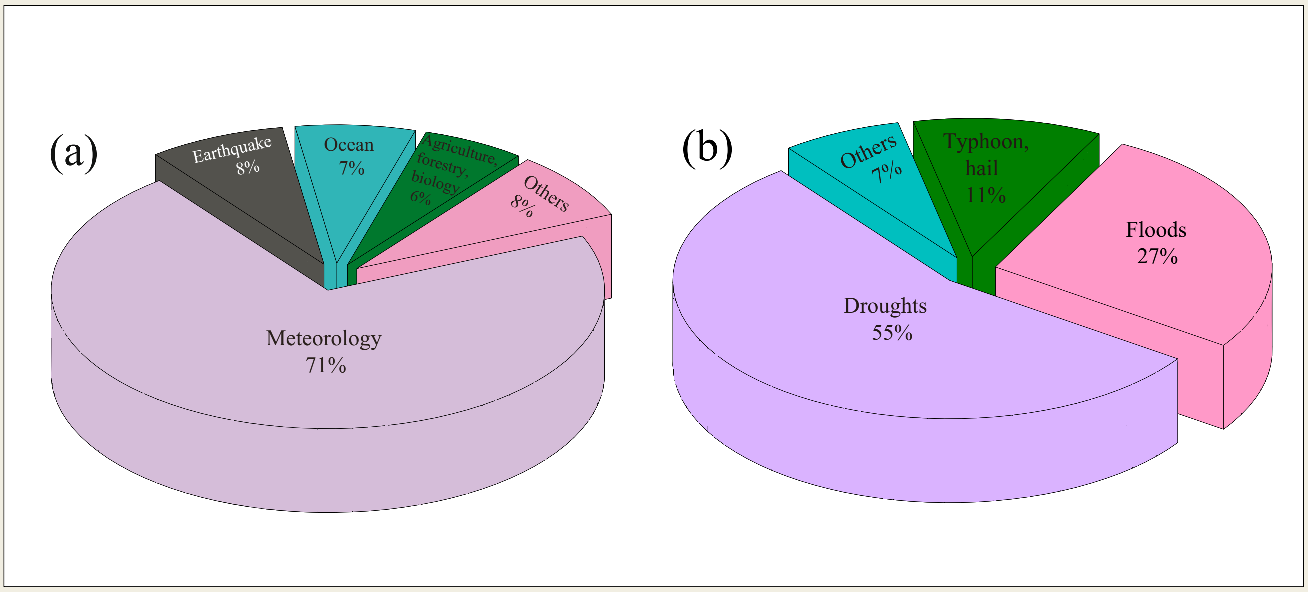
Source: IAP China

significant warming during the twentieth century and the beginning of the twenty-first century. The country-averaged annual mean surface air temperature has increased by 0.5–0.8 K during the period 1905-2001 and by 1.1 K during 1951-2001. Both of these figures are slightly higher than the global temperature increase for the same periods.[1] The warming is not uniform over time and space. There are generally two warming episodes: the 1920s-1940s and the 1980s to the present. The Qinghai-Tibetan Plateau and northern parts of China have experienced larger increases in temperature than the rest of the country. By contrast, a cooling trend occurs in southwestern China. Seasonal mean temperature for all seasons has shown an upward trend between 1951 and 2001, while the strongest warming appears in winter and the weakest in summer. Because of a warming shift of the whole seasonal cycle, the 24 solar terms have changed through recent decades. Meanwhile, the number of frost days has displayed a significant downward trend, suggesting that the frost-free seasons in China have been lengthened. These results have provided a scientific base for climate change adaptation, especially for agricultural planning and energy-saving management throughout the year.

Observations show that no significant long-term trend in nationwide precipitation occurs for the period 1905-2001. At the regional scale, however, decadal variability and obvious trends are detectable during 1956-2002. In particular, annual precipitation has increased obviously in northwestern China and the middle and lower reaches of the Yangtze River Valley, while the opposite situation is true for the Yellow River Basin and the North China Plain. This so-called southern flood and northern drought pattern in eastern China has been widely believed to be closely associated with the changes of the East Asian summer monsoon. To cope with this inter-decadal change, the country has been implementing a huge project to divert water from southern China to northern China through a man-made canal. In this way, fresh water resource will be added for the sustainable development of the economy in northern East China. All the above insights have also provided a scientific base for making national policies on climate change adaptation and mitigation.

Climate prediction-related services

At present, most of the population lives in East China, particularly in and around the middle and lower reaches of the Yangtze River and Yellow River valleys. Agricultural and industrial production in those areas plays an essential role in the domestic economy. In recent decades, anomalous climate events, particularly for severe floods and droughts in summertime, have occurred frequently in East China and have impacted many aspects of environment, economy, society and people's daily life. For example, a severe summertime flood event occurred in the middle and lower reaches of the Yangtze River Valley in 1998 and lost over 2,000 human lives, which led to a direct loss of



(a) Mean percentage of economy losses caused by different disasters, and (b) mean percentage of economy losses caused by different meteorology disasters in China in recent decades

Source: Huang, 1999[3]

around CNY145 billion. In this situation, it is important to perform seasonal climate prediction to meet the needs of defence against meteorological disasters. Accordingly, seasonal climate prediction is always emphasized in the field of climate change. In that area, both statistical and dynamical approaches have been applied in seasonal precipitation prediction by the Chinese Meteorological Administration. A statistical approach, such as the year-to-year increment approach, is based on a comprehensive study of the relationship between regional precipitation and the preceding climate conditions such as snow cover on the Eurasian continent, the El Niño–Southern Oscillation, soil moisture, Arctic Oscillation and Antarctic Oscillation, after which a regression equation for prediction is established. The dynamical approach is based on numerical experiments of climate models. For the two-tiered method, global sea surface temperatures are first predicted by an oceanic or atmosphere-ocean general circulation model, and then used to force an atmospheric general circulation model to forecast atmospheric elements. For the one-tier method, the seasonal prediction system is generally composed of an atmosphere-ocean general circulation model and a data assimilation system. Since China and East Asia are areas with low prediction skill on seasonal precipitation, statistical downscaling and dynamical downscaling have also been used to perform seasonal prediction. In addition, error correction schemes have also been applied in practice.

The aforementioned effort has improved China's regional climate prediction skills on the seasonal scale. The related climate prediction product has also served society. For example, seasonal precipitation prediction has been carried out by several research centres and universities, and their results are collected by the National Climate Center. All experts in that field are organized together to discuss the forthcoming climate change at regional and national scales. The final prediction products for key climatic variables will be publicly issued by the Chinese Meteorological Administration. In that way, the end user and policy-maker can make effective use of climate information.

Perspective

The warming climate is accompanied by changes in the mean and extreme climates, and both have large impacts on the society and economy of China.[2] Statistically, annual meteorological disasters account for 3-6 per cent of China's gross domestic product during the 1990s, with a larger percentage in the years featuring significant climate anomalies. In recent years, those disasters tend to intensify and lead to more severe losses to the national economy, human life and property, resulting in a variety of key social and environmental problems. In particular, to a great extent, meteorological disasters are directly caused by extreme climates. For example, the freezing rain in southern China in January 2008 caused economic losses of about CNY151 billion and the death of 129 people, and the torrential rain and landslide in Zhouqu County of Northwest China in 2010 resulted in the death of 1,501 people. Climate change studies and their services are at a preliminary stage. In future works, there is an urgent need to further examine the nature and cause of climate change over a wide range of time and spatial scales in China. Understanding the observed changes in various kinds of mean and extreme climates, improving the ability of climate models in reproducing observed changes, and improving the techniques of projecting future changes in both dynamical and statistical approaches are equally important tasks. Finally, climate products such as seasonal and decadal predictions and long-term climate change projections can better serve Chinese society.

China's climate prediction services

Beijing Climate Center, China Meteorological Administration, China

China has a large territory with diverse landforms, and it is exposed to the impacts of various meteorological disasters including heavy rain-induced flash floods and geological disasters, droughts, typhoons, frosts, cold temperature, wind, hailstones, heavy fog, and sand and dust storms. In the context of global warming, the higher frequency and greater intensity of extreme events has caused mounting losses from meteorological hazards and secondary disasters as China faces increasingly higher disaster risks. In 2010 and 2011, the economic losses caused by meteorological disasters were more than CNY500 and CNY300 billion respectively, and both were higher than normal.

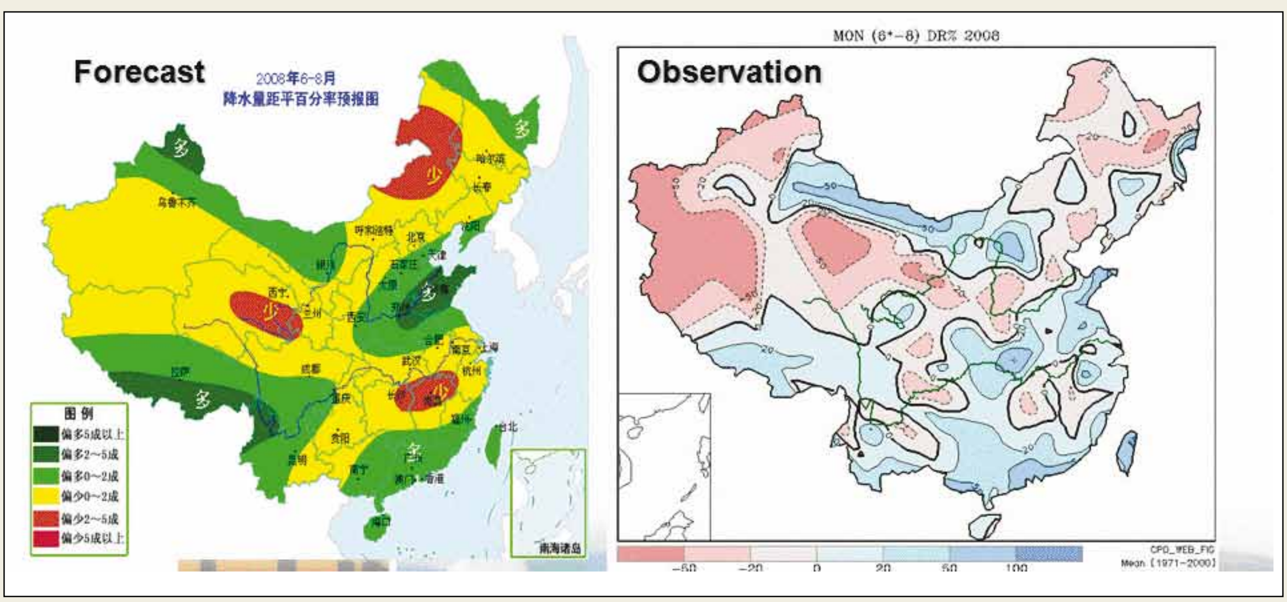
China is located in the East Asia monsoon zone. Being subject to the impacts of the monsoon, the winter in China is relatively dry and its summer has abundant precipitation as the main rainy season in the year. Abnormal precipitation may lead to frequent meteorological hazards and secondary disasters. As the main rainfall areas can vary largely from year to year, droughts and floods can have different impacts on different regions. Bearing this in mind, it is particularly necessary to make precipitation predictions for the flood-prone season each year, which serve as important information in support of disaster prevention, preparedness and mitigation. On the other hand, China's agriculture is an important foundation of its national economy, and climate predictions are closely related to agricultural services. This linkage also determines the necessity for making climate predictions in China.

Climate prediction services

Climate prediction services involve almost all aspects of meteorological hazards, and most prominently floods and droughts. During a flood-prone season, the first question to be addressed is whether or not severe floods are likely to occur in China's major river basins, and this is the focus of the flood predictions. The major customers of these specific basin-wide flood predictions are water resource and hydropower authorities. These predictions allow them to prepare for potential floods, and provide science-based information that will enable them to schedule their water- and electricity-related activities.

China's climate prediction services pay close attention to agriculture, with predictions closely linked to the processes of spring sowing, summer planting, autumn sowing and frost prevention. In summer, drought prediction mainly addresses questions of whether or not significant droughts are likely to occur in China's major grain producing areas. As the occurrence of low temperature episodes or persistent cold

The summer rainfall anomaly percentage in 2008: forecast (left) and observations (right)



Source: BCC

events in Northeast China in early summer may have a significant impact on agriculture, this is another priority for seasonal prediction service delivery.

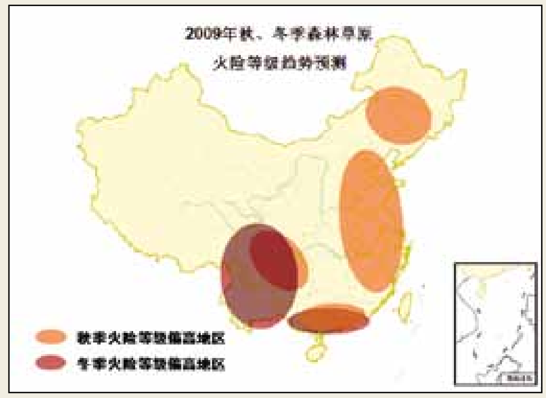
Government decision-makers are major recipients of climate prediction services in China. Among different types of prediction, they mostly focus on predictions for the flood-prone season, which provide scientific information in support of major decision-making for disaster prevention, preparedness and management, agricultural production planning and economic activities.

Information and products

The Beijing Climate Center (BCC), an operational climate prediction unit in China, mainly provides tailored products in its climate prediction and services for the flood-prone season such as Flood-prone Season Climate Trends; Special Bulletin on Significant Meteorological Events; and Climate Prediction Review among others. These products are accessible through the BCC website.[1] They include the changing precipitation and temperature trends; the frequency of tropical cyclones over the Northwest Pacific and the South China Sea throughout the year (which may be numbered for tracking or may land on China); the East Asian summer monsoon, South China Sea monsoon, the South China pre-flood season, plum rain in Yangtze-Huai River basin, and the North China rainy season. The products are generated by BCC in collaboration with other China Meteorological Administration (CMA) facilities and in partnership with external organizations, such as the Institute of Atmospheric Physics (CAS), Water Information Centre, National Marine Environmental Forecasting Centre, General Staff Meteorology, Hydrology and Space Weather Center, Shanghai Typhoon Institute, Peking University, and Nanjing University of Information Science and Technology.

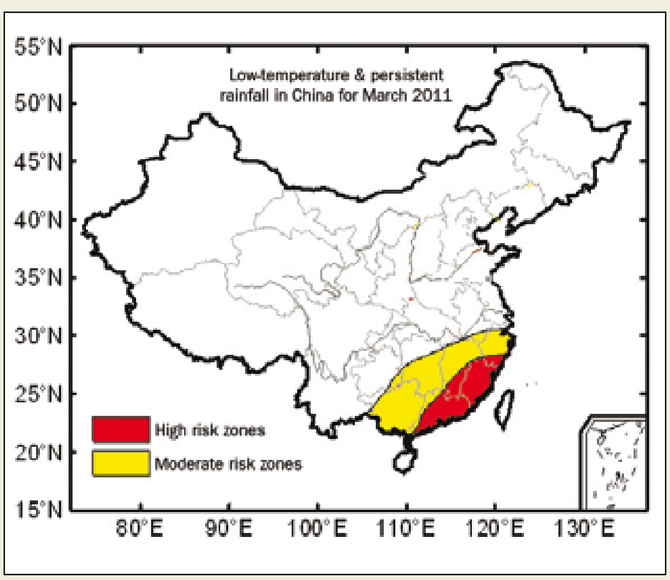
Apart from general climate prediction services, BCC also delivers specialized climate services for different sectors, such as sand and dust storm trend prediction and forest fire risk forecasts and warnings in association with the State Forestry Administration (SFA). Since the spring of 1999, it has provided the SFA Fire Office with meteorological forest fire products including the current weather and climate conditions, weather and climate forecasts, and climate trend prediction in relation to forest fire risk during a forest fire prone period. The meteorological service for forest fires is developing at a quicker pace with its operational capacities being continuously improved, due to its contribution to nationwide forest fire prevention and widely-recognized socioeconomic benefits. BCC develops, among others, methodologies used for climate trend-related forest fire risk predictions, and for meteorological forest fire risk grade forecasts, as well as operational climatic forest fire risk grade prediction systems. The relevant services and products can be accessed from the BCC website, with relevant bulletins or tailored service links.

Forest and grassland fire risk grade predictions for autumn and winter 2009



Source: BCC

A pre-assessment of climatic conditions showing low temperature and persistent rainfall for China in March 2011



Source: BCC

Benefits for decision-making and application services

Flood-prone season climate prediction provides an important scientific basis for governments in their flood control work, and accurate flood-prone season prediction has played a significant role in disaster prevention, preparedness and reduction. For example, the prediction that above-normal precipitation would occur in the Yangtze River basin in 1998 played a decisive role in the flood prevention actions taken that year, and a similar prediction for the Huaihe River Basin in 2008 also proved to be useful for flood prevention work in the same year.

In addition, the products of climate pre-assessment on such sectors as agriculture, water resources and meteorological drought, based on climate predictions, have provided strong scientific support to those sectors. The specific applications of climate predictions in pre-assessment for the agricultural sector are:

• Pre-assessment on agro-meteorological disaster risks – based on the characteristics of agro-meteorological disasters being monitored in combination with the climate predictions, BCC makes a pre-assessment of potential agro-meteorological disaster risks for the next month by the end of current month, and produces the Express Bulletin of Climate Impact Assessment on Agriculture, which is delivered to the Ministry of Agriculture Department of Crop Production.

- Pre-assessment and estimation of climatic conditions for critical farming seasons – BCC conducts the impact pre-assessment based on climate prediction information including spring seeding conditions in South China and south of Yangtze River, initial frost date, cold dew wind in the south, low temperature in the north-east in summer, and the forest and grassland forest danger index. In December every year, BCC produces an Annual Outlook on Agro-meteorology based on the annual climate prediction and analysis.

Work process and mechanisms

CMA is a competent government agency responsible for providing various climate services. CMA provides not only basic data and prediction services, but also information for the public, government and special users in support of their decision-making. It focuses primarily on addressing climate risks, response to meteorological disasters, and the use of climate resources. For last 10 years, CMA has established this mechanism for climate service delivery in combination of government leadership, multi-sectoral synergy and social participation.

So far, CMA has effectively cooperated with the Ministry of Agriculture, Ministry of Water Resources, Ministry of Land and Resources, State Forestry Administration and the Ministry of Health. The products and information generated through collaborations have played an active role in socioeconomic activities, disaster prevention and preparedness.

Consultation process

The national experts in the field of climate prediction gather to address the issues related to the flood-prone season predictions from different perspectives. After different units independently complete their individual forecasts, the National Climate Center will take the lead in organizing a national consultation meeting to achieve a consensus-based prediction for the flood-prone season, inviting the main research institutes, universities, provincial climate operational units and related service centres engaged in climate prediction. Through the consultation, they will elaborate and discuss the national climate trends of the upcoming flood season in the current year, and reach a consensus by considering comments from the different units. The National Climate Center will submit the final result to CMA for official release.

Prediction methodology

Climate trend prediction for the flood-prone season in China began in the 1950s, and it has gone through several stages since then. Early on, CMA mainly used statistical correlations and an analysis approach to make flood-prone season forecasts, and established a number of objective statistical methods for quantitative prediction later on. With the ocean-atmosphere coupled model developed by the National Climate Center being put into operation in 2005, the dynamic model — and prediction methods combining statistics with dynamics — have played a more important role in preparing predictions for a flood-prone season.

Image: BCC

Climate Prediction Consultation Meeting for Summer Season

Image: BCC

The Eighth Forum on Regional Climate Monitoring, Assessment and Prediction for Asia (FOCRAII)

With the advent of dynamic models, flood-prone season predictions not only focus on climate trend in China, but can also be used to make climate predictions for Asia and even for the world.

Participating institutions

The consultation is organized through government involvement and inter-institution synergy. The participating institutions mainly include: BCC; the National Meteorological Center; the National Satellite Meteorological Center; the Chinese Academy of Meteorological Sciences; provincial operational climate services; CAS; the Water Information Center of the Ministry of Water Resources; hydrological centres for various river basins under the Ministry of Water Resources; the National Marine Environmental Forecasting Center; the Shanghai Typhoon Institute of CMA; Peking University; Nanjing University of Information Science and Technology and so on. These institutions individually put forward their own predictions including:

- Precipitation and temperature trends in the flood-prone season
- Onset of the South China Sea monsoon
- Occurrence and duration of Meiyu period
- Intensity of rainy season in the North China region.

Different institutions consider various impact factors using diverse methods. They provide a wide range of information from broader perspectives to facilitate their understanding of previous abnormality and predictions for flood-prone seasons during the consultation.

FOCRAII

In order to provide high-quality climate applications and services, under the auspices of the World Meteorological Organization (WMO), BCC has hosted the annual Forum on Regional Climate Monitoring, Assessment and Prediction for Asia (FOCRAII) on regular basis since 2005. The forum mainly focuses on such topics as seasonal and inter-annual climate predictions, Asian monsoon activities, climate monitoring and impact assessment, climate system modelling and regional climate cooperation. It provides a platform for WMO members, particularly those in RA II, for mutual learning and exchanges on seasonal prediction experiences, enabling them to benefit from an enhanced network of climate experts and the production of consensus-based predictions for the region.

Follow-up plan

Future objectives are to provide high-quality, accurate predictions and improved information services for the Government, to offer the general public the information they are interested in, and to deliver special and refined predictions and relevant information for various sectors (agricultural production, major projects, environmental construction and energy reserves etc).

In the context of global warming, the factors affecting China's flood-prone season and its correlations with climate in the region have changed. This is not fully understood, leading to unsatisfactory predictions and services for the flood-prone season in some years. The National Climate Center is required to better understand and reconsider some climate behaviours from a perspective that can incorporate these changes, and apply them in predictions and services for the flood-prone season.

Currently, our climate prediction in flood season cannot meet the demand of the rapidly growing economy. Particularly, predictions for seasonal turning-point events and critical weather processes still leave much to be desired; we lack effective means for extreme event prediction, and the regional and basin-wide predictions are not detailed enough. All these inadequacies prevent us from providing refined and tailored services. As a regional prediction centre of RAII, BCC will extend its prediction services to other parts of Asia. However, it still faces huge challenges in the availability of actual climate data and effective means for making regional climate prediction, which in return hinders BCC in further developing an integrated regional prediction system for Asia that combines dynamics with statistics.

Data rescue: a necessary look at climate

Philippe Dandin, Patrick Aressy, Nathalie Deaux, Brigitte Dubuisson, Gérard Fleuter, Anne-Laure Gibelin, Sylvie Jourdain, Laurence Laval, Sylvia Menassere, Emeline Roucaute, Anne-Marie Wieczorek, Météo-France, Direction de la Climatologie

The implementation and provision of climate services implies the enhancement of climate information. The latter is, of course, a crucial step to achieve the former. From that point of view, it is increasingly widely recognized that data rescue is of vital importance. Data rescue helps climatologists to strengthen their judgement in terms of time, space, parameters, distributions and extremes, or to improve the quality of the existing assessments. Thanks to the results of data rescue efforts, which deliver enriched data series and enable a better qualification process by homogenization, climate scientists can describe, understand and address issues that suffer from a lack of observation.

A seldom mentioned benefit of data rescue is that it is a real climate service. But how does the improvement and inclusion of historic information lead to — or hold the potential for — improved climate services? Old documents tell us a story that all stakeholders more or less know or have heard about. From that point of view, data rescue is critical for risk management and climate adaptation. Notably, data rescue creates links with other communities and other ways of analysing the world, understanding its complexity and predicting its possible futures.

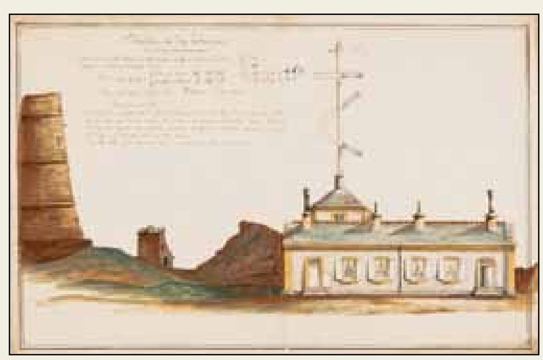
National meteorological and hydrological services (NMHSs) have a critical role to play in data rescue. They have a long history, and have routinely produced large sets of observations. Their archives are rich — being kept 'in-house' or by specialized agencies — and full of information, if sometimes undervalued. Moreover, NMHSs reach out every day to users, dealing with natural disasters and being able to locate such events in a historical context; this is where they can shed light on historical resources, temporally merged with present hazards and confronted by possible futures. Old documents tell us a story we can understand. They speak of us, as human beings, facing a global change. Data rescue is much more than getting access to data and metadata. It is a way into citizens' perceptions of climate.

Risk, adaptation and education

Among climate services, the education of users is one of the most significant requests. This can cover a wide range of aspects, from being uncomfortable with scenarios and the management of uncertainty to using series without accessing quality or even knowing about traceability. Data rescue efforts not only contribute to improving background knowledge; they also help scientists to make users aware of such aspects. Data rescue helps citizens or decision makers to grasp a little of what scientists try to explain, to figure out and foresee possible futures by diving back into our common history, into our memories. Delivering scenarios in a fancy way is not enough. Users' feedback asks mainly for support, explanation and education. Users need to understand and to see. Brains need to be stimulated and fed.

This is a real climate service to educate us about best practices. In France, typically, it took time before many affected communities realized how critical the memory of their activities could be for addressing the future. As a benefit of that, on the side of the meteorological service's efforts regarding data rescue and homogenization, hydrologists started their own effort in that direction, being aware that they could not carry on impact studies and imagine adaptation measures without a correct representation of the past. Long homogenized series delivered by the meteorological service were used for detection and impact studies on hydrological extremes.

We believe it would be an abuse, and a mistake, to think that climate scenarios alone, albeit with statistical corrections, could be enough. There is a crucial need for high-quality past data and awareness must be raised on this issue. Data rescue is a strategic need. Advocating for it is a vital necessity. Resolute action and support must come from governmental agencies and can also, as in France, benefit from private sponsorships.



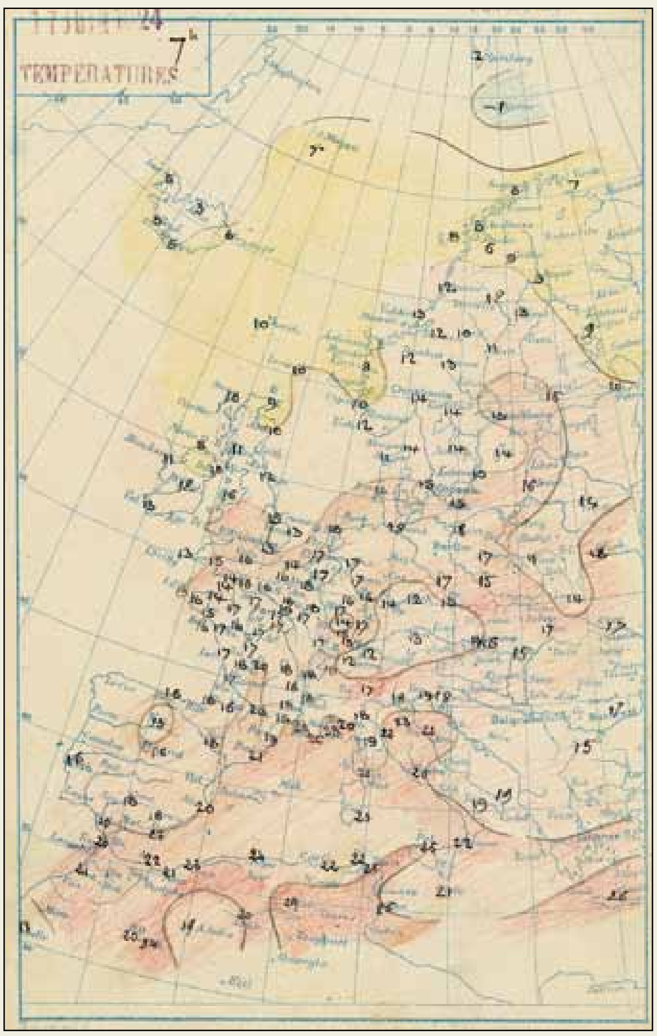
A drawing of the 'sémaphore'coastal station of Cap de La Hougue; one of many documents extracted from an asbestos-polluted box in a joint effort between Archives Nationales and Météo-France, sponsored by Fondation BNP Paribas

Source: Météo-France and Archives Nationales

Data rescue at Météo-France

Advocating for data rescue and convincing a wide range of actors is a necessary step to ensure that all stakeholders bring resources and work together, beginning with the recognition that old documents are a major community asset and a rich source of knowledge for coping with climate change effects. Data rescue at Météo-France is no longer a research activity. Météo-France's climatologists put a special emphasis on archives, aiming to preserve old documents still kept in-house in good condition. It is now necessary to look again at these documents, as climatologists who had typically worked at monthly timescales a few years ago must now reprocess daily or sub-daily data as they focus on extreme events. There is also a need to search in various archiving agencies for unknown documents and retained information.

Climatologists first of all want to retrieve observations from old documents. Enriching the data banks is not the sole goal. They definitely dream of raw data but also of the compulsory metadata, explaining the measurements' conditions and thus enabling a higher quality of existing series and derived diagnostics. A primary goal for Météo-France is to improve the quality and length, but also the spatial and parameter coverage of the existing series, used for detection and attribution of climate change. Data rescue feeds analysis and reanalysis. Preservation and recovery are the first steps, followed by a stringent homogenization procedure. Homogenization is a geostatistical evaluation of the series: it detects shifts due to the evolution of measurement conditions. While the tradition was a day-to-day quality control of the observation, climatologists now check the quality of the entire series. They shed light on the vital need for metadata related to the measures. For example, which instruments were used? When was such a new model put in place? Did the surrounding conditions evolve?



A chart of temperatures for 07:00 on 17 June 1924 – The values on such charts can help today's climatologists to understand rapidly changing climate events

Source: Météo-France and Archives Nationales

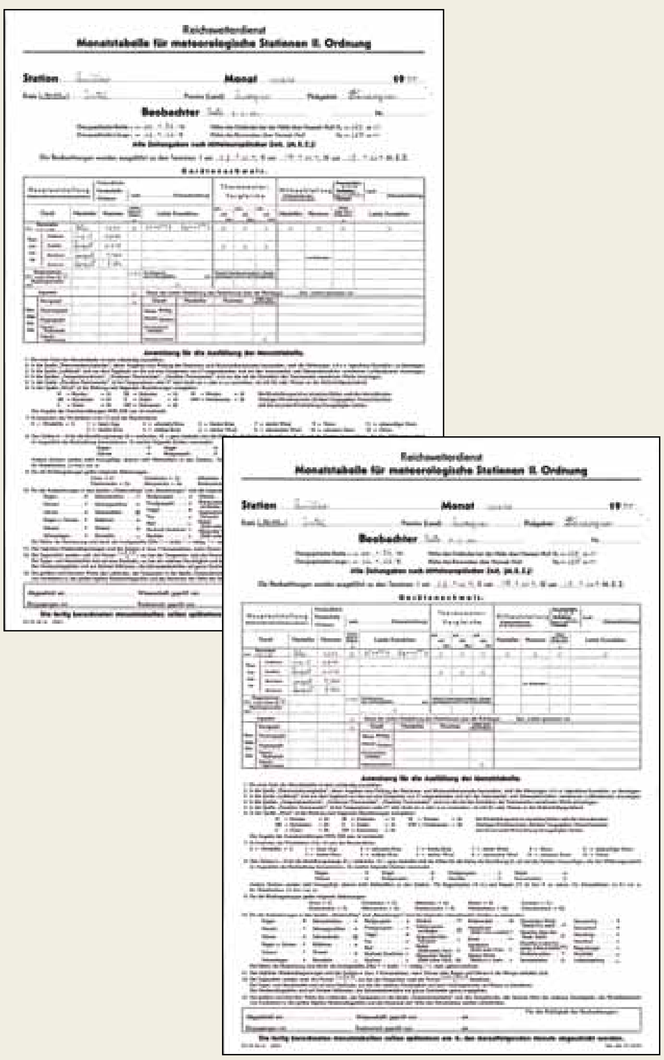
Various other aims motivate data rescue. One should first of all mention political motivation: society must be sure that climatologists have made all possible efforts to improve the quality of the delivered diagnosis, and exploited all potentially available information gathered by the meteorological services. Facts can be criticized and they need to be as strong as possible. Secondly, and not least, our duty is to provide climate research with all elements that would help scientists to better understand the Earth's climate system: long series, facts and figures, especially on extremes or gaps, such as wars, ex-colonies or upper-air, all being targeted as primary goals for global reanalysis projects.

The originality of the current effort at Météo-France lies in the transfer of such activities from a research mode to operations. Meteorologists in every local service, including in overseas territories, are committed to these tasks. Homogenization, which requires skills and was originally a research effort, is becoming a more widely spread skill for climatologists. This opens their horizons to climate science, and they gradually move from data control to climate analysis, trends and extremes, enabling them to fruitfully interact with climate scientists and enriching their dialogue for mutual benefit. Data rescue and homogenization is therefore also a strategy for improving skills and widening horizons. This is true in the meteorological service and it appears to be true outside. Climate services are not so far away when it comes to educating partners in impact communities.

Cross-cutting partnerships

Data rescue actions are carried on in our offices, where a lot of archives are kept. The organization of the preservation and archive automatically opened the meteorological community to partners, mainly archivists. This partnership is critical. Not only does it bring knowledge on archiving, but it also opens connections with partners from communities like historians or heritage specialists who enrich climate knowledge. Documents are also searched for in various archive agencies and libraries, having national, local or thematic duties. Documents are located, identified and, the value of information being assessed, the priorities are established and documents are scanned for data keying or further consultation. Research projects and Government budget support these efforts. Research projects impose strong scientific drivers that bring together scientists and climatologists, with a common goal.

Many actions are carried on in parallel — urgent matters make it compulsory to increase momentum in various directions — and brilliant results have been obtained or are foreseen. We could mention the identification of the Société Royale de Médecine, which asked its correspondents in the late eighteenth century to record meteorological parameters. A French historian located this rich source of information at the French Medicine Academy, which is now online thanks to the National Research Agency and Météo-France.[1] This retrieval was carried on in the Climate, Health and Environment: Data Rescue and modelling (CHEDAR) research project, which looked at the impacts of Icelandic volcanic eruptions, namely the Laki, on health in the late eighteenth century (the project was built and launched before the eruption of the Eyjafjöll).


Reichswetterdienst

Monatstabelle für meteorologische Stationen II. Ordnung

Station Monat

Beobachter

Documents, recently found by DWD, the meteorological service in Germany and transferred to Météo-France, help to fill gaps in the data series and provide information about the observing system during the occupation, when French observers had to report to German authorities

Source: Météo-France

Many good examples showing that data rescue is an international effort could be mentioned. Let us point out two or three highly valuable examples that show, first of all, that the connection between meteorological services and academic communities is bringing value, and secondly that climate is a subject for a united humanity. The strongest floods ever recorded in the French Alps are the Isère and Drac floods that caused huge damage in Grenoble and the areas surrounding these mountain rivers in 1859. Climatologists were able to recompose the meteorological sequence that drove these rivers' responses, thanks to data rescue — together with archivists and historians on both side of the border between Italy and France, which have successively ruled the surrounding regions in the nineteenth and twentieth centuries; and hydrologists were successful in reproducing the peaks of the flood for the first time ever. Another example is one of the most beautiful things meteorologists, who share every day across borders, could dream of: the transfer of old documents by the German meteorological service back to Météo-France, containing observations made before or during the Second World War. That is to say that starting from the identification of a gap, and logically analysing the possible sources of information, French and German colleagues easily agreed that a search in German archives could be fruitful. Lastly, the collaboration efforts with the former colonies of France must be mentioned. Meteorological information was collected in these areas, which is now critically needed by local meteorological and climatological services as well as by various international programmes aiming to run numerical reanalysis. For example, in Algeria, the definition of adaptation strategies for the Wilaya of Algiers is underway now, and in parallel, Algerian and French colleagues rescue data and study extreme events and indices together to create past and future scenarios. Data rescue is a real part of climate services.

Big challenge, imaginative solutions

Dust is not the only obstacle to data rescue; there is also asbestos among many other plagues. The major effort currently underway in France is a partnership between the French national archives agency, Archives Nationales, and Météo-France. Because of asbestos, the French meteorological archives — 2 km of raw data, 6,300 big boxes — could not be accessed by scientists. A twofold action has been carried out:

- The state agencies have committed themselves to act and the ministry in charge of sustainable development agreed that giving access to this unique fund was a critical measure, endorsed in the French National Plan for Adaptation to Climate Change
- Climatologists and archivists have answered a research call from a private sponsor willing to support research on climate change through its foundation.

The Fondation BNP Paribas international jury decided that this action should be one of the supported projects, allowing a very significant fee. This was not only a huge financial support, but also an authoritative message that data rescue is a critical contribution to climate sciences and to culture — and also to adaptation. This action is now underway. The rich potential is already confirmed as decontamination operations begin.

Beyond meteorology and climate science

Météo-France is acting with few scientists at the forefront on these matters in France, spreading the message of the importance of data rescue. The example is being followed by many communities which are used to closely interacting with meteorologists — for example, hydrologists. Of course, in the past a lot of scientists have carried on such efforts — but the message now is that data rescue has to be considered as a systematic eneterprise, run with all the necessary priority and support: climate change imposes a higher momentum where, traditionally, only a few isolated scientists were trying to act.

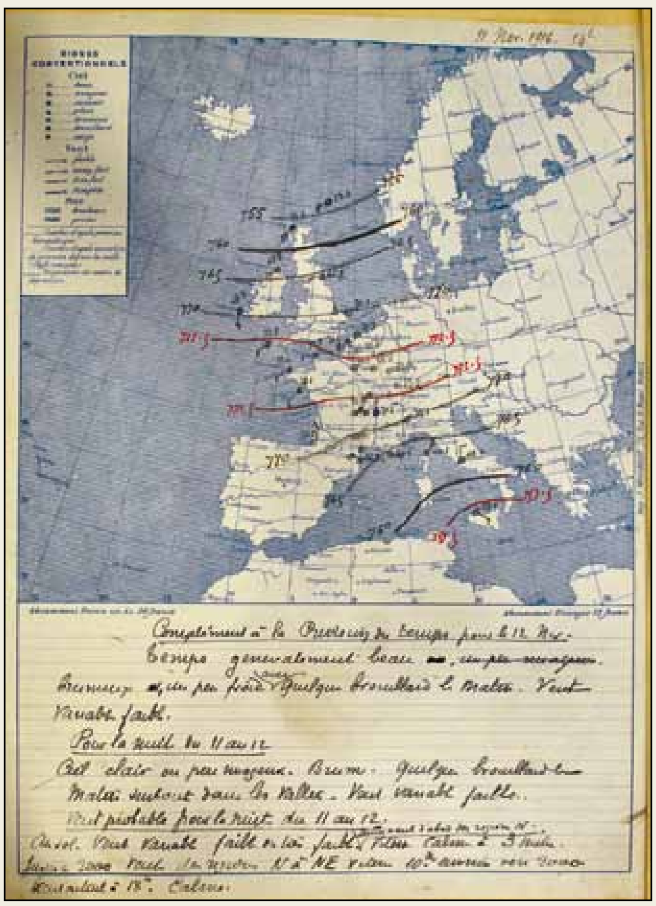
Data rescue must be considered as a real climate service. Indeed, it is a long chain of actions. At each step, close partnerships have to be established with various actors: priorities are given by climate scientists, while opportunities and clues are permitted by historians or archivists. Searching and identifying sources is a quest. Mobilizing resources and funds demands energy and best practices must be shared.

Date rescue must be encouraged for other reasons, namely because it contributes to making various communities work together towards a single goal: developing awareness and educating about risk, in the framework of climate change.

A final word

It is a critical obligation to advocate for, and support, data rescue. A strong voice has to come from the Global Framework for Climate Services. Resources are critical, of course, but our example aims at showing that this can be dealt with. Research projects are gradually bringing onboard data rescue work packages. It is important to keep in mind that data rescue is not an aim; it is a tool, the input to homogenization and reanalysis; it feeds climate science. NMHSs have to be heavily involved, since they inherit from a long history. Similarly, data rescue is an effort that needs collaboration with academic, climate, history and archive scientists. The construction of a research project, enabling targeted data rescue, is valuable, as are systematic enterprises. Of particular note is the original public-private partnership in our example with the support of the foundation of a major French and international bank, BNP Paribas.

We have challenges ahead, due to resources. But we would like also to emphasize that data rescue tells us that we have to think now for the future. We know that we have to recover a memory of the past: this must remind us that we have a duty to observe current data that will help future generations of climatologists to answer the questions they will be asked. These scientists will appreciate that our generation, today, has enabled them to work and deliver to societies a few decades from now. We know data rescue is critical; let us not forget that data seeding is also vital.



A map from November 1916 found in the French archives and currently undergoing asbestos decontamination in a joint effort between the Archives Nationales and Météo-France, sponsored by Fondation BNP Paribas

Source: Météo-France and Archives Nationales

Following after the destruction of the allied fleet in the Black Sea by a storm, during the Crimean war, a weather service was established in France; this chart was drawn soon after, in 1857, and shows a French network but also connections with other European countries

Source: Météo-France and Archives Nationales

The Climate Science Research Partnership

Professor Stephen Belcher, Head of the Met Office Hadley Centre, UK;
and Dr Yvan Biot, Department for International Development (DFID)

Climate variability and change have huge impacts on food security, water availability, human health and social and economic infrastructures. This is particularly relevant in Africa where people are especially vulnerable to hazardous weather and climate change. Substantial sustainable poverty reduction can be achieved in Africa through improved predictions of climate variability and change. Among other things, this needs improved understanding and modelling of the African climate.

The Climate Science Research Partnership (CSRP) is working with African stakeholders to improve the understanding and practical prediction of African climate to help alleviate poverty. The CSRP is a partnership between the Department for International Development (DFID) of the UK Government and the Met Office Hadley Centre. It is working to advance the scientific understanding of African climate now and in the future, and bring new science into use.

Challenges and strategy

With climate change, referring to historical data is becoming a less reliable way of estimating the risk of climate extremes. Seasonal forecasts now provide the best basis to predict climate risk up to six months ahead and they can take into account both climate variability and change. Seasonal forecasting systems can also form the basis for early warning systems to enable better planning of relief activities. Improvements to the understanding and modelling of climate over Africa can be incorporated into seasonal forecasting systems and improve the usefulness of these forecasts.

On longer, decadal time scales, climate change and variability signals are typically of the same magnitude. A starting point in adaptation planning is to build resilience to current climate variability, while recognizing that current climate conditions will significantly change in future. Decadal prediction systems enable both current variability and future climate change to be systematically accounted for.

There is a growing tendency to attribute all climate-related local and regional changes to man-made increases in greenhouse gases, whereas other reasons such as natural climate variability and land use changes, for example deforestation, can be of more importance. Developing near-real-time systems that can attribute the causes of observed changes is a high priority to avoid inappropriate and potentially expensive adaptation measures.

Information about the future climate is needed on a scale that can be used directly by in-country stakeholders. This requires downscaling global climate information to the local level. The products currently available, such as seasonal forecasting products, are of limited use because they do not address key stakeholder requirements. Therefore, it is vital to establish the priority variables and regions of interest for long-range (monthly-to-decadal) forecast information, through discussions with relevant projects and institutions operating in Africa.

The CSRP is enhancing the professional development of African climate scientists by running training workshops to help develop and disseminate new products based on CSRP research. In addition, African graduate students have been engaged in study fellowships to research African climate issues as a way of strengthening the pool of in-country climate science researchers.

Work streams

CSRP has five different work streams, each led by a Met Office Hadley Centre scientist, designed to achieve a set of project objectives. These objectives have been refined through consultation with African stakeholders, with key aims to determine the variables and parameters for which improved prediction is most urgent and to identify priority requirements for capacity building.

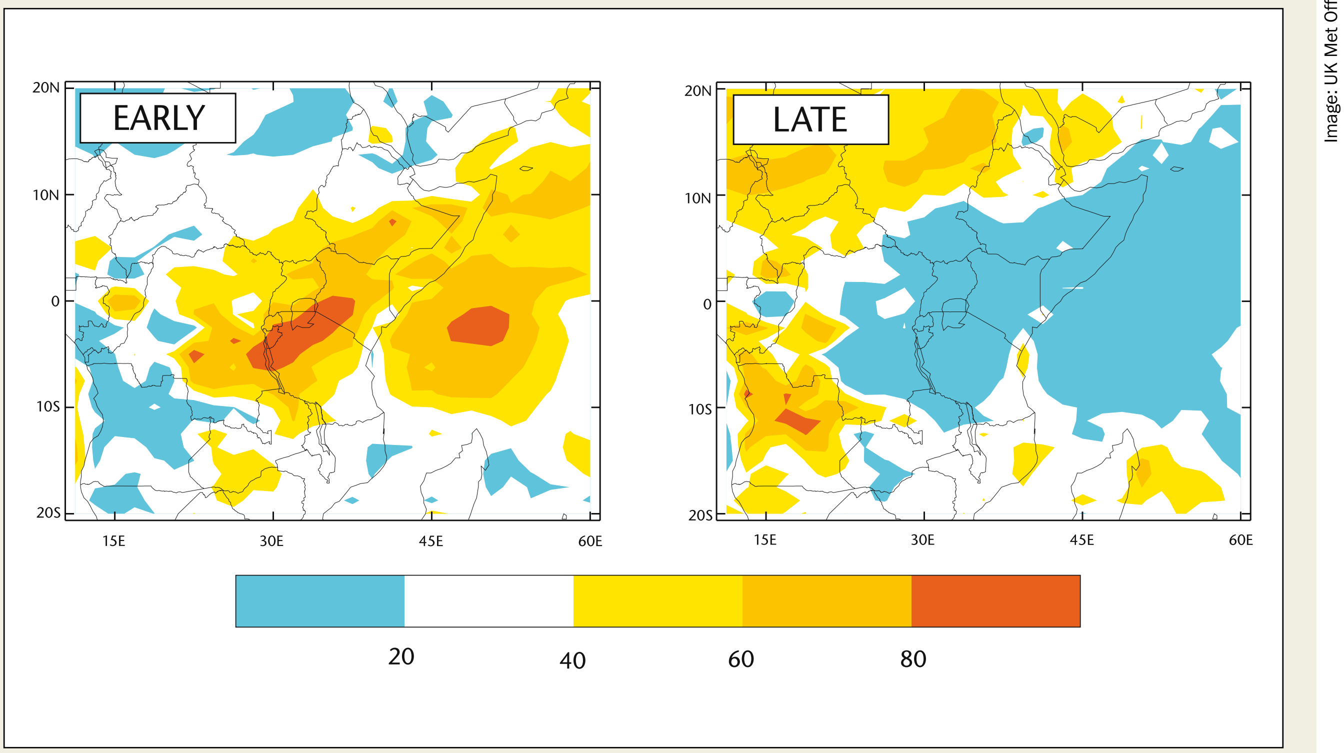
Consultation

The aim was to help identify research directions that would best contribute towards enhancing the range and quality of climate information available to users in Africa

A total of 52 interviews were held with a wide range of stakeholders in eight African countries. Stakeholders included the main regional climate organizations, national meteorological and hydrological services, universities, non-governmental organizations, government ministries and 'boundary organizations' acting on climate information to aid vulnerable communities.

The largest number of interviews (12) was held with African climate service providers and included regional climate organizations such as the Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC), the African Centre for Meteorological Applications for Development (ACMAD) and the Southern African Development Community Climate Services Centre (SADC-CSC). A technical questionnaire was fielded to nine African climate service providers to obtain insight into their ranking of research priorities.

The consultation focused on needs for monthly-to-decadal predictions, as these timescales are of most practical interest in developing resilience to climate variability and change.



Forecast probabilities for early (left) and late (right) onset of the 2011 short rains season over the Greater Horn of Africa. The predictions give a substantially raised probability (>60%) of an early onset over much of the eastern side of the Greater Horn of Africa and early onset was observed to occur (with definitions used here, early onset has a baseline chance of occurring of 33%).

Key results of the consultation were as follows:

- There was wide recognition of an urgent need to improve the understanding and modelling of African climate in order to provide reliable climate early warning systems and information for adaptation
- Improvement of seasonal-range predictions (to six months ahead) was seen as a higher priority than multi-annual to decadal-range predictions, though the need for decadal-range information for adaptation was seen as urgent
- There was a very strong signal that development of capability to predict temporal distributions of rainfall (such as season onset, duration and dry spell frequency) was the highest priority need.

The consultation also addressed training needs and possible ways to respond. The results of both the research and training prioritization exercises were then used to make adjustments to the project's science and training components.

CSRP outputs

Improved understanding and modelling of African climate and its drivers

The first output is advancing understanding of African climate processes in order to improve their representation in climate models. Work is focusing on the new Met Office Hadley Centre climate model, HadGEM3. Key results include improved representations of rainfall in all important sub-Saharan rainy seasons, enhanced understanding of the drivers of variability in the West African Monsoon and a comprehensive assessment of the ability of present-day climate models to represent the important influences of the global oceans on African rainfall.

Improving the application of science and climate models for early warning systems and adaptation planning

The CSRP is developing new, experimental, real-time climate forecasts for users in Africa. Products have been designed to meet the needs expressed in the initial consultation of user needs and are currently being tested with African regional organisations and National Meteorological Services. The timing of the onset of rains is crucial to agricultural production and food security. If planting is done too early, seeds rot in the ground; if too late, the early growing season is missed. Experimental seasonal forecasts of onset timing have been developed, using the Met Office's seasonal forecasting system, and evaluated over past seasons. The performance is encouraging – in particular, good guidance for the early onset of the 2011 short rains season over the Greater Horn of Africa was achieved (above). The forecasts are currently being trialled by climate organisations in west, east and southern Africa and at Regional Climate Outlook Forums (above right). These dynamical forecasts of onset are the first of their kind and are additional tools to help African regional centres and NMHSs improve their predictions of onset and thereby increase agricultural output and food security.

A new monthly-to-decadal prediction system has been developed based on the new HadGEM3 climate model and has improved our abilities to predict multi-annual (next five years) rainfall and temperature averages over Africa. The key impact of this is enhanced potential to provide

Image: UK Met Office

Participants at the 32nd Greater Horn of Africa Climate Outlook Forum 29-31 August 2012, Zanzibar Beach Resort Hotel, Zanzibar, Tanzania

'long-lead' early warning (eg for drought or successive drought) and adaptation advice.

In addition, CSRP has developed methodology to investigate the attribution of extreme climate events over Africa. Work has focused on the Greater Horn of Africa severe drought of 2010/11 in which both the 'short' (October-December) and 'long' (March-May) rainy seasons failed. First results indicate that man-made climate change has had little impact on rainfall in the short rains season, but may have increased the risk of drier than average conditions in the long rains season. Science-based information on the role of man-made climate change in driving extreme events over Africa is essential to inform adaptation decisions and will help avoid potentially expensive inappropriate adaptation.

Increasing geographical detail in climate predictions

In the CSRP consultation the need for higher spatial detail in forecasts was given high priority. To provide higher spatial detail, predictions from global climate models need to be post-processed using a technique known as 'downscaling'. Regional Climate Models (RCMs) or high-resolution limited area climate models, are widely used for downscaling predictions from global models. They use information from the global model to provide the large-scale context and then add high-resolution details. By limiting their focus to specific regions, RCMs are able to provide much finer geographical detail without prohibitive increases in computing costs. CSRP is developing the science of RCM downscaling, with a focus on downscaling seasonal forecasts.

Significant improvements to the simulation of African rainfall achieved in the global version of HadGEM3 are also found in the regional model. In addition, the higher resolution of the regional model has brought additional performance benefits. The new RCM has been installed at ICPAC and tested for downscaling seasonal forecasts for the Greater Horn of Africa. To support this activity, a research workshop has been held with climate scientists in the region to develop strategies for interpreting and using downscaled information for preparation of consensus seasonal forecasts. The improved performance of the RCM for Africa will also enhance the quality of our contribution to the CORDEX dataset and our service to developing countries through the PRECIS system.

Strengthening climate science in Africa

A key part of the collaboration with the African climate scientists is the CSRP climate fellowship scheme. Eleven fellows have been appointed and each is working on a CSRP research topic within one of the three science output areas. This approach helps advance the project's objectives, while also strengthening the professional development of the fellows. Fellows have been appointed from across Africa: four in West Africa; four in East Africa, one in central Africa and two in southern Africa – providing a wide range of regional perspectives. Four CSRP fellows presented results of their work at the 4th International AMMA conference in Toulouse, France, 2-6 July 2012.

Developing research products that target demand and are accessible to users

A key objective of CSRP is to bring results of the programme's research into practical use in Africa. This is being achieved in three main ways:

- Climate science workshops held in collaboration with African centres
- Participation in Africa's Regional Climate Outlook Forums
- Participation in policy forums for climate and development.

Climate science workshops

The theme of the first CSRP climate science workshop was 'appreciation and use of dynamical seasonal forecasts for the Greater Horn of Africa'. This two-week workshop was delivered in collaboration with ICPAC Nairobi and included development of the first ever consensus prediction for the July to September season – an important rainy season in the north of the Greater Horn – and a forum with users of climate products.

Key outcomes from the workshop include the successful trial of spreadsheet-based interactive training tools for familiarizing with and verifying dynamical seasonal forecasts, as well as strategies for improved use of dynamical forecasts in the preparation of regional and national seasonal outlooks. The second climate science workshop was on RCM downscaling of seasonal forecasts for the Greater Horn of Africa (see previous section).

More information about CSRP is available at www.metoffice.gov.uk/csrp

Strengthening hydromet services in Mozambique

Louise Croneborg, Water Resources Management Specialist, World Bank

In Africa, Mozambique is ranked third country most at risk to extreme weather- and water-related events.[1] Some 48 per cent of the country's 24 million people are estimated to be negatively affected by reoccurring floods and droughts.[2] At the same time, Mozambique's climate and water resources present potential for economic growth and agricultural productivity as key to human development and poverty reduction.

The Government of Mozambique acknowledges the importance of hydromet information in preventing disasters from floods and droughts or improving productivity in sectors such as agriculture and hydropower. In addition, because climate change is expected to exacerbate the uncertainties and magnitude of extreme events, the Government's responsibility to provide hydromet information becomes even more relevant. Hydromet information is important not only for understanding climate processes, but also for everyday decision-making and planning for the public and private sectors.

Mozambique's hydromet services are provided by:

- The National Directorate of Water (DNA) at policy and planning level
- The five regional water authorities (ARAs) which undertake hydrological monitoring and modelling
- The National Institute for Meteorology (INAM) which observes and forecasts weather conditions.

Through various laws and policies,[3] these agencies have the political mandate to monitor and collect raw data on water and weather across the country, use data to forecast future conditions (at different time- and space-resolutions), and disseminate and communicate their data and predictions to relevant users.

Mozambique's hydromet services are weakened by a number of deep-set challenges. The institutional mandate to deliver hydromet services is fragmented across different government agencies (DNA, the ARAs and INAM). In addition, other government agencies such as the Ministry for Agriculture are also collecting data. These agencies are are not able to coordinate and share information effectively because of practical obstacles such as Internet connectivity or institutional impediments from hydro-met services being spread across multiple line-ministries. The networks and equipment for monitoring hydromet, as well as the IT solutions for data management and processing, are in significant need of technological upgrade and rehabilitation. Retaining sufficient numbers of qualified staff, and fluctuating core financing, put additional dent in the services' sustainability and consistency.

The World Bank started working with the relevant institutions in Mozambique in the late 1990s, particularly the water sector. Work on comprehensively supporting the improvement of its hydromet services, in collaboration with related domestic institutions, began in November 2011. Since then, it has been undertaking a detailed needs assessment to inform the future interventions. Although the project will be implemented on a standalone basis funded by the Pilot Program for Climate Resilience (PPCR)[4] (US$10 million), it is closely interlinked with a broader programme of support from the World Bank. During 2012, the project is in its planning stages and the components and activities continue to evolve. The proposed Project Development Objective is to strengthen hydrological and meteorological information services to deliver reliable and timely information that increases climate resilience, which in turn will lower the water- and weather-related risks to local communities and economic development.

The World Bank is particularly concerned with enabling the government institutions mandated to deliver hydromet services to develop improved raw data monitoring and forecasting capacity, and to improve their inter-agency coordination. Furthermore, the project will focus on the ways in which information can be tailored to suit a range of users, including governmental actors and those in the private and public spheres.

Improved hydromet services have the potential to benefit important social, economic and environmental issues. In addition to accurate and timely information for disaster management (especially due to reoccurring tropical cyclones, floods and droughts), and for the productivity of agricultural and hydropower industries, hydromet can also serve the interests of sectors such as fisheries, aviation and transport, all of which currently have limited access to hydromet services.

Financial sustainability is also a critical issue affecting hydromet services in Mozambique. At present, there is no fixed business model to support the country's hydromet services. This can partly be explained by the fact that hydrology and meteorology information services are split between the multiple agencies DNA, ARAs and INAM, which have different government budget allocations and different levels of international donor support.

Mozambique's climate needs

Over half of Mozambique's population lives and works in low-lying coastal areas where they experience recur-

Image: © World Bank/John Hogg

80 per cent of the population depend on small-scale farming

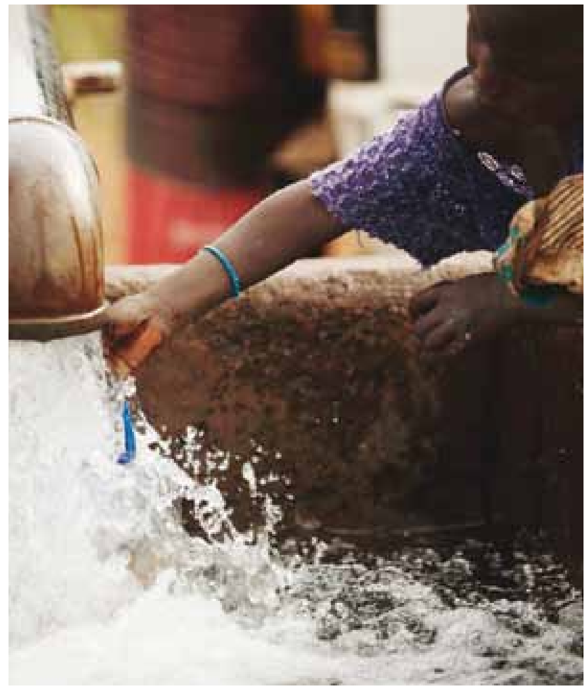


Image: © World Bank/John Hogg

Local water supply

ring floods that are often associated with the paths of tropical cyclones. Drought conditions are also commonplace — particularly in the southern region where the greater Maputo metropolitan area is located and in the central provinces along the Zambezi River where roughly 20 per cent of Mozambicans live and over half the country's mean annual run-off is.

Since the catastrophic floods of 2000 and 2001, the social and economic impacts of extreme events have been researched in detail. For example, cyclone Eline in 2000 was estimated to have caused losses, damages and reconstruction costs equivalent to 20 per cent of country's gross domestic product in addition to loss of human lives and livelihoods.

In 2010, the World Bank estimated that merely four per cent of the potential 2.7 million hectares in Mozambique were developed with equipped irrigation. Because almost 80 per cent of Mozambicans depend on small-scale farming for food security and income, and the area they farm represents almost 97 per cent of total cultivated land, harnessing water and planning for weather events is essential for crop production — especially considering that 60-80 per cent of rain falls between December and March during the rainy season. Equal to the potential for agriculture, Mozambique's rivers could provide some 13,000 megawatts in hydropower capacity. Yet infrastructure development is low and the vast majority of the country lacks access to electricity. In the Southern African Development Community, Mozambique has some of the lowest level of development in both irrigation and hydropower. It is also uniquely positioned regionally as the downstream riparian of nine of its 13 large rivers. The fact that more than 50 per cent of the total mean annual run-off is generated outside Mozambique's boundaries further elevates the importance of having a sound understanding of water flows and weather patterns.

Furthermore, the climate change scenarios of the Intergovernmental Panel on Climate Change predict significant implications for Mozambique. Global circulation models indicate:

- Varying rainfall patterns across the country (31 per cent reduction to 16 per cent increase)
- Shorter rainy seasons and prolonged periods of drought, especially in the central regions of the Zambezi River Valley
- Temperature increases on average of one to two degrees Celsius by 2050
- Rising sea levels.

With growing uncertainties, hydromet information becomes increasingly important for understanding, preparing and managing the implications of climate change.

Improving hydromet services

The type, source and accessibility of hydromet information vary between the DNA, ARAs and INAM. For hydromet service agencies, strengthening their relations with and understanding of end-user needs tends to improve the quality of information in countries with advanced levels of services. Although this is not the sole solution to improving services, the proposed support for Mozambique will give due attention to the user-relations of DNA, the ARAs and INAM.

For general use, the format of hydromet information products are ususally 'bulletins' where the scale of monitoring or forecasting is either basin (such as for the ARAs and DNA) or provincial (such as for INAM). In certain cases, the information may be tailored to the user's needs. This is the case for the aviation sector (eg monitoring and forecasting at airports) or providing data in excel on rainfall and run-off for dam operators.

With the proposed project, attention will be given to how DNA, the ARAs and INAM can tailor the hydromet information products. The goal is that with better monitoring and forecasting capacity, the actual content of the products would be more accurate and relevant to the user. Equally, the communication format and channel with which this information is conveyed is important. Advances can be made by introducing new technological solutions (such as regular access to precipitation predictions from global remote sensing sources), opening data access and refining products to user needs. The project would also include opportunities to pilot new solutions to serve particular needs. These pilots can include improvements to ongoing early warning systems for rural communities or providing weather forecasts to farmers and so on. Because it is beyond the scope and resources of the project to serve all user groups across the entire country, these pilots can become useful tools in trialling new solutions that can be refined and scaled up, and build on existing mechanisms for communication between government and different users without duplicating existing early warning systems, for example.

With respect to dissemination of hydromet information, the institutions in Mozambique use email, fax and Internet to share their information products with the stakeholder government agencies. There is a well established system where the hydromet agencies send information to the National Institute for Disaster Management (INGC) which acts as a hub for further dissemination to agencies, media organizations and private companies. Bulletins are also sent on a daily basis to the media as well as other government agencies.

Mozambique is often heralded in southern Africa as a successful example where emergency response functions well and has sound political backing that enables inter-agency cooperation.

Implementation and evaluation

The World Bank is mandated to administer the support from the PPCR for the Mozambique Government for this project (the International Finance Corporation and the African Development Bank also administer the PPCR support for Mozambique). As the primary institution managing the process for the needs assessment, the World Bank is working in close collaboration with the named implementation agencies. Staff within these agencies are providing the bulk of information and analysis, and are working with the World Bank in a continuous process that includes meetings, field visits, extensive communication and workshops. Ultimately, the responsibility to implement the project will be with these main institutions and the bank will play a supportive role during this period.

Capacities

All capacity building and training for staff on topics such as quality control, calibration and data standardization will be rolled out together with efforts to improve inter-agency cooperation. As clarified, the hydromet services are delivered by a number of agencies –DNA, the ARAs and INAM — whose operations are not guided by one national shared action plan, strategy or vision. This means that responsibilities have gradually become more fragmented, sharing of data between the agencies is cumbersome and technically challenged, and enforcing World Meteorological Organization (WMO) quality standards across all stations in all the agencies' networks is problematic. For example, the ARAs have a vast number of rain gauges but INAM does not have the staff capacity or full mandate to check or certify these stations in meeting WMO standards. There is a memorandum of understanding between the hydromet agencies on sharing information, but this has been difficult to enforce due to the lack of practical solutions for data sharing and more clearly defined roles and responsibilities. The proposed project therefore works actively on bringing the staff of the agencies together in the design and implementation of the project to identify joint solutions. Simultaneously, bringing the issues to the attention of political decision-makers at ministerial level is equally important.

Capacities will be built in the following areas:

- Strengthening and optimizing the hydrological and meteorological monitoring networks
- Improving forecasting capacities (modelling, data management and other ICT interventions)
- Improving quality control and enforcement of standards
- Product development (with improved monitoring and forecasting, review and update of the package of information products used to communicate among agencies and users)
- Skills, capacities and training
- Securing financial sustainability using management tools to improve and secure revenue flows for long-term sustainability.

Looking ahead

Lessons from previous support to hydromet services in Mozambique can be applied to this project. An understanding of the wider context in which the intervention will take place is critical in ensuring the success and sustainability of the project. Such contextual information includes an understanding of the in-depth details on availability of trained staff to run equipment; facilities for calibration and standardization; sufficient, stable energy supply; Internet connection and so on.

There are a number of examples where previous support for hydromet services has not been as successful as expected. Learning from these, the project design will try to address some underlying causes for failure. These include financial sustainability, institutional collaboration, and ensuring that both 'soft' and 'hard' resources are in place to maintain technically advanced equipment (for example, telemetric stations often need secure and steady electricity supply to function as well as a paid guard to protect the station from theft). Another lesson is to capitalize on other initiatives in associated beneficiary sectors in an integrative manner. One such example is piloting distribution of weather information that can be integrated into existing projects to improve farmers' access to information. Capitalizing on regional hydromet initiatives is also important so that more consistency and harmonization of different systems at different levels can be achieved.

It is increasingly important that lessons are shared among donors who may finance separate interventions. Any lessons learned during this project can be transferred through ongoing and future projects at national, regional and basin level.

Drias, the futures of climate: a service for the benefit of adaptation

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The climate is changing, and France is facing a rapid change too. Many effects of global climate change are visible while others remain unclear. In any case, research must be boosted and applications eased. Various communities are tackling the challenge and working hard to improve the diagnosis of past evolution, reduce the uncertainties of projections and assess the impacts, taking advantage of the scenarios provided by climate modelling groups. In parallel, adaptation is underway. The French Ministry for Sustainable Development has elaborated a strategy for adaptation and, more recently, a national plan has been proposed covering a wide range of actions, starting with the monitoring and research of the Earth system and going to the local actors who have to cope with adaptation.

The adaptation concept has been introduced in a new French law[1] with regional implementation starting in 2011. The law makes it compulsory to consider climate change issues in the managing process of any administrative entity with more than 50,000 inhabitants.

Climate services are still in their definition stages. They should result from crossing products and services enabling individuals and groups to assess their vulnerability and take appropriate adaptive and preventive measures. In this approach, 'Drias, les futurs du climat'[2] aims to basically evaluate all information available from national climate modelling laboratories, process it, and make it accessible for complementary and additional studies. Drias serves a wide range of interests and appears to be a critical milestone for the French climate adaptation strategy.

The Drias service and the 'reference scenarios' initiative, a set of assessment reports for France, came from such considerations. Drias stands for 'Deliver Regional climate scenarios for Impacts and Adaptation of our environment and Society'. The project was built with the basic idea that a facility was now needed for climate information delivery. The resulting portal offers easy access to data and products, including a quick-look discovery, as well as the associated expertise to facilitate impact and adaptation studies:

- Several greenhouse gas emission scenarios, using different regional climate models and downscaling methods, because it is critical that users work with the idea that climate projections have to be addressed in a probabilistic mode
- Standard formats, easy access, quick looks and simple products for a wide range of users, baring in mind that many communities do not share the technical skills of climate modellers
- Expertise and guidance, especially addressing the various sources of uncertainty, and promoting best practices and know-how — one of the first requirements of users, as shown in every user needs survey.

Drias integrates existing and widely distributes components from partners. It brings together their knowledge, tools and expericences. It facilitates the transfer and delivery of relevant information to stakeholders, promotes good practices and raises awareness regarding uncertainties attached to climate change. For these reasons, it is critical that the service receives continuous guidance from the research community.

The Drias web portal comprises three main areas: Delivery, Support, and Discovery. The Discovery area contains general information for a wide range of people, allowing them to grasp climate scenarios and visualize outputs. It also positions Drias to fulfil the INSPIRE European directive. In the Support area, a range of documents is offered to help users make the best use of available climate information (glossary, description of methods and climate models, frequently asked questions). The user finds information on scenarios, on climate change and on past experiences, with links to existing educational and information sites. This part of the site is more specific about products to be delivered, explaining how they were created and guiding users' choices. A hotline mechanism involving experts is also implemented at this level. The Delivery area enables users to order, in digitized format, data and products they have identified in the Discovery area.

The partners have brought their assets to the initiative. They also heavily took advantage of Météo-France's production engines. The result is an efficient and user-


Image: © Météo-France/Pascal Taburet

Heat wave in Paris, France, July 2012

friendly system, delivering products taking various forms, adapted to climate projections - e.g. recalling users that climate change information is not just a deterministic short range weather forecast and that various scenarios have to be considered. Drias was funded by the Management and Impact of Climate Change programme of the French Ministry for Sustainable Development. It focuses on existing French regional climate projections obtained from national modelling groups: IPSL, CERFACS, and CNRM. It delivers all kinds of climate information from numerical data to tailored climate products and guidance to promote best practices and know-how.

While the project is coordinated by the Department of Climatology at Météo-France, which is in charge of climatological operations and services, a multidisciplinary group of users and stakeholders concerned by climate change issues was also involved. Three categories of user have been identified, each with their own needs in terms of climate change information and guidance:

- Scientists such as environmentalists, agronomists, hydrologists, geographers, economists and sociologists, dealing with impacts or adaptation strategies. Some have established linkages between meteorology and climatology (such as agronomists, hydrologists), and have already initiated contact with climate groups. Others need stonger advice and closer guidance.
- Intermediate users are, for example, consulting companies involved in environment and policy management and planning, or outfits supporting adaptation for private companies or administrative entities. They also need appropriate information and support and will act as intermediate users for climate scenarios and products. In some cases, they still need to raise awareness of local impacts from global changes.
- Climate scientists have been identified as partners of the project. The added pressure on scientific teams is increasing, bringing some scientists away from theoretical science to applied science. There is a need to deliver climate scenarios operationally and to allow scientists to focus on the challenges populations will face.

A user committee was created at the beginning of the project, to help define effective and strategic needs, evaluate prototypes using beta testers, validate the choices made by the project team, and ensure that Drias will continue to meet users expectations.

Drias is positioned at the interface between actors. A layer of intermediate users — or translators — is gradually appearing in the form of engineers from the meteorological service, or from private companies already deploying activities in the field of environment, or climate experts hired by local organizations. Drias is serving these users, who were highly involved in the development of the portal and will continue to contribute to the evolution of the service.

Drias must primarily be seen as a facility. It is an answer to a growing need for information, tools and methodology to address adaptation. On closer inspection, it can be seen as the emerged part of a more fundamental trend moving the entire climate community, a first step toward 'services'. Drias contributes to assist and support impact studies, providing data through a web portal to allow different communities to respond to requests for climate change information. Drias will undoubtedly foster a new era for the transfer of climate information between users and the multi-disciplinary community of climate modelling, making it compulsory to:

- Enhance assistance to users and create a new generation of actors
- Gradually broaden the spectrum of climate information (and services) to respond to as many people as possible in an understandable and usable way
- Keep delivering with the principle that scenarios must be considered while facing the futures of climate, leading to several hypotheses of emission, several models and several downscaling methods.

Reference scenarios for France

Drias is the result of an association between climatologists and climate scientists, joining forces to improve the service to the country. Established in line with a reference scenarios initiative that aims to deliver a set of common inputs for public and private adaptation policies, it paves the way for further services. The climate information comes from the regionalized simulations elaborated over France, covering the recent past (from 1950) and the future (until 2100). Data are corrected according to Météo-France's analysis of the past climate. The reference scenarios were published following a request from the ministry to Jean Jouzel, vice-president of the Intergovernmental Panel on Climate Change (IPCC), after this point had been raised during the elaboration of the National Plan for Adaptation. They are disseminated on the French National Observatory of Climate Effects website, an entity of the Energy and Climate Directorate of the Ministry for Sustainable Development.

Two assessment reports have been published on reference climate indices for the future, as well as a comprehensive synthesis on the state of knowledge regarding sea level change for France. The climate indices reports make full use of the concerted projections elaborated by the French community, corrected with the analysis provided by Météo-France. The first report shows two GES scenarios and two models (resolutions less than 60 km) for three 20-year periods covering the twenty-first century. The second report presents two 30-year periods, three other regional models (resolutions between 12 and 20 km) and three scenarios. Indices are given with confidence intervals, corresponding to averages and extremes values for temperature and precipitation, and extreme winds. They are computed for metropolitan France and five sub-regions. For the overseas territories and other variables such as river flows, a synthesis is established relying on IPCC reports and other relevant research. The climate projections used for the most recent report (February 2012) are also accessible through the Drias portal, where users can retrieve data and indices.

The portal and the scientific assessment are made as fully compatible as possible, illustrating the wish of the scientific community to deliver a coherent service to users. Research activity is also defined by user requirements, and interaction with users will now orientate part of the future evolution of the service.

The challenge ahead

Users' feedback has been enthusiastic on these initiatives. The portal and the facilities offered are highly appreciated. For the first time, there is access to products that until recently were only for scientists with the tools and skills to manipulate them. From a technical point of view, the construction of the portal has been a challenge for teams who were used to elaborating and delivering climatological standard products, but had very little competency with climate models outputs. The synergy with the scientists has proven very fruitful, increasing the level of the operational team while feeding the climate modellers with requirements and advisories regarding data, output specifications or the voluntary effort necessary for further harmonization of the various climate model outputs and metadata.

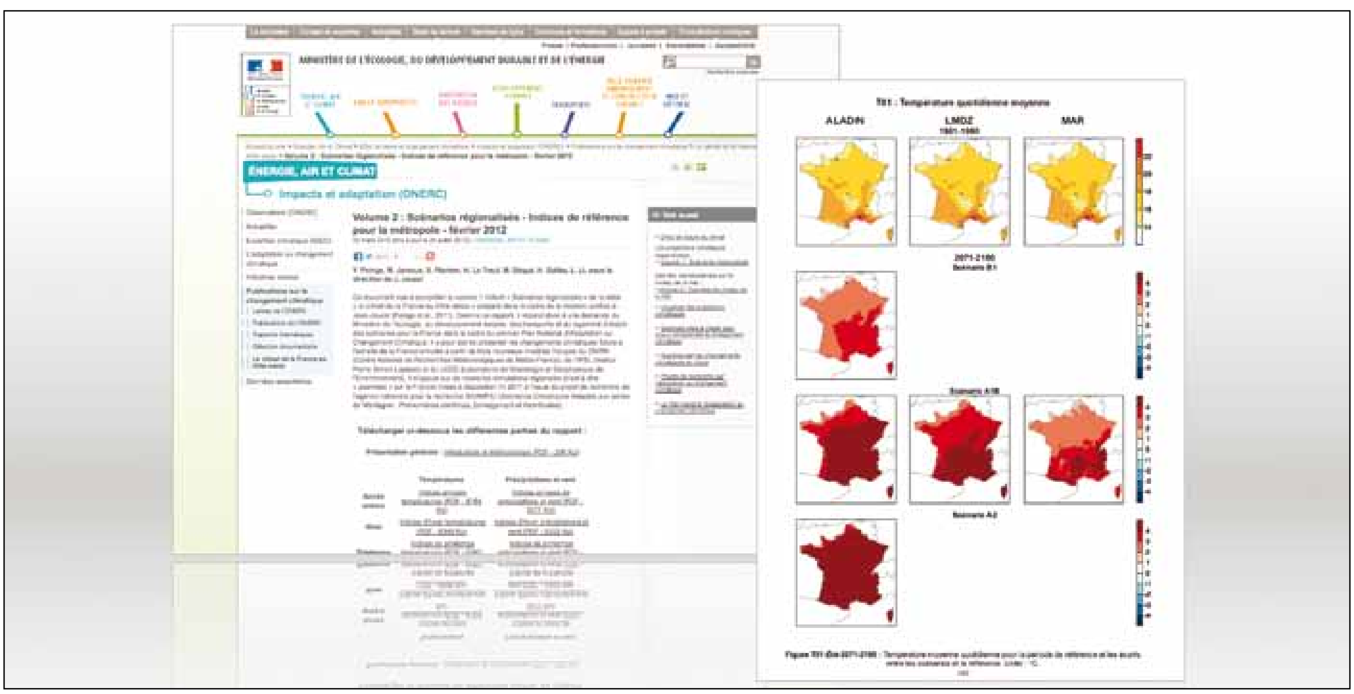
An imperceptible change has also occurred because of the opening of Drias. From now on, science is heavily connected not only with the society, but also with end users. This is the fundamental spirit of 'services', a word that must be considered and weights a lot in 'climate services'. Climate modelling and climate science are no longer purely science driven: users and societal needs require a stepwise delivery of information, accompanied by explanation, best practice examples and guidance on how to face the decision making process. Drias acts as a channel for this. For this reason too, the portal was

Home page for the Discovery area of the Drias portal – visitors are offered two different ways to discover the scenarios based on their level of competency built on a strong infrastructure, inherited from the meteorological one. The next evolutions of the portal, both in terms of content and functionality will be easy to put in place.

A great challenge will be to boost the service around the portal, and interact with scientists and intermediate translators, so that the service will meet everyone's requirements and expectations. Another challenge will be to define the appropriate governance for this service, with three types of players. The main developments in the coming months will be to extend coverage of the service to overseas territories. Refined scenarios are currently being produced and will be integrated into the portal. New indices will be introduced too, namely those delivered by current research efforts led by academic laboratories together with industrials or other scientific communities. Similarly, information from the past will be made available through the portal. Some users have already asked for the introduction of impact studies, and works of general interest could be considered such as impact studies on water resources. Efforts will still be made to explore various ways of representing uncertainties and expected projections – such as developing analogous approaches. Representations of past, present and future climate, of uncertainties, and of their impacts are undoubtedly critical for conveying the message to citizens and decision-makers. The reports on the reference scenario for France are a first attempt to address such issues by presenting a variety of results, scenarios and confidence intervals instead of the single scenario originally requested — this would have been an abuse, of course. Education remains one of our key challenges.

The partnerships around Drias must also be highlighted. Nothing could be done without the research groups or the meteorological service. A strong tribute must be paid to the governing bodies that have supported the initiative, and have placed it high on the agenda at the ministerial level, making Drias one of the most prominent actions of the French National Plan for Adaptation. The scientific and political coherence was very high. This is a condition for the success of such initiatives, starting with a project, which will be maintained in the long term by a national agency, namely Météo-France. Close association of all stakeholders will be ensured as a critical condition for a long-term achievement. One can bet that the rate of enrichment of the Drias portal, as well as the publication of the synthesis reports for reference scenarios, will be carefully chosen, so that it will represent a good compromise between abundant scientific production and the progress it carries out, as well as the need for users to fully use the information delivered. The next report should take into account the results of the newest regionalized scenarios for France, based on the 'Representative Concentration Pathways', and will soon be made available through Drias.

Are we on the right track? Will our co-citizens be more convinced because such synthesis reports and facilities are now in place? Undoubtedly there are many aspects of the human conscience that must be activated in order to reach the appropriate level of commitment regarding climate change. The real challenge for climate services may also appear in the training and education arena, and definitely has to deal with a wide range of human and political sciences. There is a vital need to develop the level of understanding; the capability to translate and spread the scientific results to a larger audience and help the end user to understand, accept and cope with the options we have as we face the climate challenge. Making information available to a wider public is a safe bet. The challenge, and the urgency, motivated all the actors of Drias to ease and speed up the process. But other paths will have to be explored too.



Example of the multi-model representation that can be seen in the Discovery area of the "Drias, les futurs du climat" portal

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Acknowledgement
We wish to thank NASA GES DISC and NOAA OceanWatch Central Pacific for the Chlorophyll-a and SST data. Chlorophyll-a and SST data used in this paper were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC and Ocean Watch Central Pacific respectively.

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Climate implications of atmospheric warming due to aerosol black carbon over the Indian region

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Acknowledgements

In this study, Acclimatise (UK) worked with WorleyParsons (UK), University of Oxford (UK), Synergy (UK), EXOCOL (Colombia), and Universidad Nacional de Colombia. The full study results are freely available on this page: www.ifc.org/climaterisks

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Better localised CO_2 measurement as a component of accurate climate forecasting

Acknowledgements
The CO_2 sonde and FES-C were supported by JST. The peat and forest fires measurement campaign in Central Kalimantan, Indonesia, was performed as part of an MRV feasibility study for a peat forests restoration project by the Sumitomo Corp. Environmental Solution Business Dept. and METI, which used bilateral credit in Central Kalimantan.

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New Zealand's climate change and urban impacts toolbox

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IX. Communities

Making climate science useful: cross-regional learning from Kenya and Senegal

1. Climate scientists in the UK participating in the exchange come from the universities of Liverpool, London, Oxford and Sussex as well as the UK Met Office.
2. International humanitarian organization partners in the exchange include CAFOD, Christian Aid, Senegal Red Cross and Oxfam GB.
3. This was subsequently extended to November 2012 to support provision of climate services over the 2012 rainy season in Senegal, and allow for follow-up evaluation and synthesis of cross-exchange learning.
4. Richard Ewbank, Christian Aid (2012). Review of the Sustainable Agricultural Livelihoods Innovation (SALI) Project - Strengthening Access to Climate Information.
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6. A webspace for pooling evolving learning on approaches which support dialogue between the providers and users of science is being established within a current two-year Knowledge Exchange Fellowship, supported by the UK Natural Environment Research Council and hosted at HFP. This webspace was launched in late May 2012, housed at the Enhanced Learning and Research for Humanitarian Action.
7. 2008, Kaffrine local government website. Available from http://www.kaffrine.org/LaVille/Geographie/tabid/327/Default.aspx
8. Development of the Early Warning > Early Action (EW>EA) game was supported by the PetLab/Red Cross Red Crescent Climate Center collaboration. Readers can access game cards and rules of the EW>EA game at: http://petlab.parsons.edu/redCrossSite/gamesBTS.html

A user-centred design approach to the Seasonal Climate Outlook

1. www.bom.gov.au/climate/enso
2. House of Representatives Standing Committee on Industry, Science and Innovation, November 2009, Seasonal forecasting in Australia, Forward, paragraph 1.
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X. Capacity Development

Making climate change information available online

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3. http://ilmasto-opas.fi/en/datat/vaikutukset#SykeDataPlace:vaikutukset
4. http://ilmasto-opas.fi/en/lisamateriaalit
5. http://ilmasto-opas.fi/oppimismoduulit/ilmastohistoria/?lang=en

How the Met Office (UK) is building capacity and supporting adaptation in some of the world's most vulnerable regions

1. World Bank Report No. 43946-IN, Climate Change Impacts in Drought and Flood Affected Areas: Case Studies in India (2008)
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Climate-related services in China

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1. See http://meteo.academie-medecine.fr for reports covering France and other locations in the world.

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1. Global Assessment Report on Disaster Risk Reduction (2011).
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3. The 1991 Water Law, 2007 Water Policy and 2006 Decree for Meteorology.
4. The PPCR is one of the strategic funds under the Climate Investment Funds http://www.climateinvestmentfunds.org/cif/ and have helped channel more than US$143 million to hydromet investments.

Drias, the futures of climate: a service for the benefit of adaptation

1. The so-called 'Grenelle II' law: http://www.developpement-durable.gouv.fr/-L-adaptation-au-changement-.html
2. 'The futures of climate', to recall that various options (scenarios) are available, but only one climate as a result of our choices.

ISBN 978-0-9568561-3-5

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