Norwegian support for the Global Framework for Climate Services

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Funding the Global Framework for Climate Services: Challenges and Opportunities

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What do we mean by Climate Services?

by Arame Tall - CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

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Clim-Health Africa
In this issue

In 2009 when world leaders from 155 countries agreed to establish a Global Framework for Climate Services (GFCS), a challenge was launched to both the scientific community and the users of climate services to galvanize collaborative efforts to develop effective climate services in support of decision-making.

A High Level Taskforce of eminent personalities from scientific and political spheres produced a blue print to provide guidance on the focus of the Framework. With this the GFCS entered in motion. An Implementation Plan containing Annexes, detailing the essential elements needed for its operation, and Exemplars, providing details on what needs to be done to enable better application of climate services in the four initial priority areas (agriculture and food security, disaster risk reduction, health and water resources management), was developed and approved by the World Meteorological Congress Extraordinary Session 2012.

In this issue, “What do we mean by Climate Services?” discusses the practical aspects of GFCS implementation while “Reconciling Post-Positivist and Post-Modern Worldviews in Climate Research and Services” provides a philosophical discussion of the implementation. However, capacity development – essential to effectively support the initial GFCS priority areas – is inspiring all the work being undertaken. GFCS implementation involves extensive consultations with various stakeholders and communities of define good practices. Pilot projects have been initiated in order to identify the critical steps to be taken into consideration as implementation moves forward. “Localizing Climate Information Services for Agriculture” highlights some the lessons learnt through capacity development by the Food and Agriculture Organization of the United Nations (FAO).

The good practices presented in that article and others are helping in the development of guidelines that Members can use to facilitate the establishment of appropriate mechanisms to promote cooperation and collaboration among key stakeholders, particularly at the national level. The GFCS calls for countries to establish their own national frameworks in order to identify and coordinate activities relating to the development and provision of climate information, products and services to meet national needs. “From global to regional to national: building operational climate services” introduces the work of the WMO GFCS Office and its partners to launch national processes in several regions. The experience of the United Kingdom in developing its national framework – Climate Service UK – is highlighted in “The Application of Climate Science to Benefit Society.” While “Climate Effects of China Three Gorges Project” presents an exemplary case of climate information services in the water sector.

Early collaborative actions with partner agencies in the UN system are providing concrete results of the type of benefits that society can derive from implementation of the GFCS. The Atlas of Health and Climate, showing the geographical spread and magnitude of health issues related to climate and providing various examples on the production and application of climate services to mitigate health risks, is a good example. “Clim-Health Africa,” goes one step further. The WHO-led Climate and Health Consortium for Africa (Clim-Health Africa), in which WMO plays a leading role, will address climate change in general and its health impacts in particular in order to strengthen the resilience of African countries and communities by improving management of the effects on public health of climate variability and change.

WMO is also planning the release of a second atlas in November 2013, this time with the Centre for Research on the Epidemiology of Disasters (CRED) at the Université Catholique de Louvain. The “Atlas of Mortality and Economic Losses from Weather, Water and Climate
Extremes (1970 - 2009),” will provide some perspective of the toll of disasters related to meteorological, hydrological and climate hazards disasters around the world. The WMO centerfold presents some of the early results of analysis of CRED EM-DAT.

With climate changes comes a risk of more intense and frequent weather, climate and water related disasters. “Weather and Climate Resilience” highlights the key findings of a World Bank study on how to build preparedness through National Meteorological and Hydrological Services (NMHS).

The above articles and partnership demonstrate that implementation of the GFCS is now well underway, but will require full support, including investment/funding for institutional, procedural, infrastructural and human capacity development. “Funding the Global Framework for Climate Services” looks into the challenges and opportunities for GFCS, while “Norwegian Support for the Global Framework for Climate Services” discusses motivations from a donor country’s perspective.

**IBCS**

The Intergovernmental Board on Climate Services (IBCS) represents an important milestone as it will set the direction and provide guidance on the implementation of the GFCS in the years to come. It will pave the way for improved decision-making in climate sensitive sectors and support adaptation to climate variability and change.

The challenge ahead of us is enormous but there are many benefits to be accrued through the implementation of the GFCS. By working together we will enhance decision-making in disaster risk reduction, water resources management, health, agriculture and food security. These are the priorities of the GFCS.
Funding the Global Framework for Climate Services: Challenges and Opportunities

The implementation of the Global Framework for Climate Services (GFCS) is now well underway, but will require full support, including investment/funding for institutional, procedural, infrastructural and human capacity development.

The main sources of GFCS funding thus far are Member contributions to the GFCS Trust Fund or to project specific trust funds, through bilateral and multi-lateral investments for projects in selected countries or regions. In addition, various actors can support projects contained in a compendium of GFCS projects or designate their activities as contributing to the GFCS by fulfilling criteria to be approved by the Intergovernmental Board on Climate Services. As of June 2013, contributions and pledges total some CHF 29 millions, mainly from Australia, Canada, China, Finland, France, Greece, Hong Kong China, India, Ireland, Japan, South Korea, Norway, Switzerland and the UK.

To attract the full financial backing it needs, the GFCS must instill confidence and trust that it will deliver the expected benefits. It has already taken steps to do so, including

- The launch of pilot projects in target countries – Burkina Faso, Niger, Mali, and Chad – with other projects under preparation in Botswana, Nepal and Spain;

- The organization of workshops to initiate regional engagement in South Asia, the Pacific and the Caribbean with more to come in Africa and other parts of Asia;

- The launch of national frameworks in countries, such as the United Kingdom, as part of their contribution to GFCS implementation;

- The embedding of regional structures, such as AMCOMET, which adopted an Integrated African Strategy for Meteorology (Weather and Climate Services), into the GFCS; and

- The preparation of a GFCS project compendium as part of the Implementation Plan.

To ensure sustainable implementation of the GFCS, it is critical that a wide range of financing mechanisms and development partners be engaged in the process. The GCFS Implementation Plan strongly emphasizes the importance of building on existing international, regional and national development mechanisms. This includes national budgeting processes, United Nations system initiatives, overseas development assistance programmes, development banks and agencies’ financing windows, in-country budgets of overseas missions and embassies, climate financing resources (e.g. Climate Investment Funds, Adaptation Fund, Global Environment Facility, Green Climate Fund) and private sector resources.

Robust climate science and related information services are becoming more visible and are in greater demand, bringing attention to the GFCS. Thus, various global, regional and national initiatives have demonstrated growing interest in the GFCS. This bodes well for building momentum to ensure that climate services are embedded into development policy and practice and offers an opportunity for the GFCS to leverage funding and actions for its implementation as well as to build solid partnerships.
Norwegian support for the Global Framework for Climate Services

The Ministry of Foreign Affairs of the Government of Norway has maintained an international development programme for many years. In fact, it started in the post-1945 period when the United Nations system was being established, following World War II. Norway started channelling development through the UN system towards the end of the 1940s, and its bilateral engagement started in 1952. International development cooperation is an integral part of Norway’s social development, cultural history and foreign policy. In 2012, Norway’s aid budget exceeded NOK 30 billion (US$ 5.1 billion), double its 2004 budget. Norway’s official development assistance (ODA) is second only to Sweden when measured as a proportion of gross national income.

On average, 50 per cent of Norway’s international aid is bilateral, directly state-to-state. The other half is distributed through international organizations, multi-lateral aid, and non-governmental organisations. Voluntary organizations have become increasingly important channels for aid, and development aid has also been channelled through Norwegian businesses operating in developing countries.

The main goal of Norway’s ODA is poverty reduction, through an equitable distribution of social and economic goods and sustainable development. The strong interdependence between environment and development has been emphasised by the Government, thus the budget for climate change adaptation and mitigation has increased strongly over recent years. The main priorities for Norwegian Climate Finance are reducing emissions from deforestation and forest degradation and promotion of renewable energy and energy conservation/efficiency. Adaptation to climate change is another priority, with particular focus on food security, disaster risk reduction and climate services. In addition, efforts are being made to integrate climate change concerns into all development efforts. Africa receives the largest share of the adaptation support, about 40 per cent of the total adaptation budget in 2012. In the country level, Haiti, Mozambique and India received the highest amount of funding for climate change adaptation in 2012.

Motivation

Norway has an expressed interest in the issue of societal adaptation to climate variability and change. All countries and regions of the world are interconnected in many ways, this is especially true when it comes to weather, climate and oceans. Many complex factors drive and influence these elements, but Norway, positioned on the edge of Europe facing the vast North Atlantic Ocean, has an important role to play.

Norway’s historic contribution to global exploration also spurs its interest in this area. The famous Norwegian seafarer Leif Eriksson, the Viking who made it to the North American landmass 500 years before Christopher Colombus, had acquired advanced understanding of the elements before he steered ship west toward the unknown. Roald Amundsen, who discovered the Northwest Passage between Greenland and Northern Canada on his 1903-1906 voyage, led the first expedition to reach the geographic South Pole (on 14 December 1911).

Interestingly, modern meteorology started in Norway – in Bergen – where conceptual models were first developed to help early weather forecasters to better understand the atmosphere and its movements. The Bergen School of Meteorology produced the basis for much of modern weather forecasting. Founded by Prof. Vilhelm Bjerknes in 1917, the Bergen School attempted to define the motion of the atmosphere using the mathematics of hydro- and thermodynamics.
The Global Framework for Climate Services is high on the agenda for Norwegian priorities. Norway believes it is essential to help the world to adapt to climate change and prevent weather related disasters. The GFCS will enable better management of the risks of climate variability and change and adaptation to climate change, through the development and incorporation of science-based climate information and prediction into planning, policy and practice on the global, regional and national scale. Experience from earlier extreme events and disasters shows that thousands of lives may be saved if countries are prepared, early warning systems are in place and people in vulnerable areas receive preparedness training in combination with other adaptive and preventive measures. Norway has lead the international push to direct investment in the building of in-country meteorological capacity that is a necessary to provide data or content for climate information as well as financially supporting the building of the framework itself. Norway is keen to encourage other governments to follow its example.

**Nature of the Support**

Norway’s support, in the first instance, was in participating in the High-Level Task Force that established the GFCS. It then contributed to the development of the GFCS Office and developing African based GFCS programmes. More recently, discussions have been around encouraging cross-agency cooperation within the UN system itself as well as with world-leading institutions in order to merge natural and social sciences to inform the development of climate services.

This support is central to Norway’s international development aid programme and in accord with its long-standing tradition for multi-lateral cooperation.

**National Level Frameworks for Climate Services**

The creation of national level frameworks for climate services, mimicking the interdisciplinary relationships that are occurring at the global level, is essential for successful implementation of the GFCS. A number of countries have initiated the process to hone the delivery of climate services to their citizens, several through WMO national or regional level pilot projects.

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<tr>
<th>Country/Region</th>
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<th>Date</th>
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<tbody>
<tr>
<td>Nigeria</td>
<td>Framework Launch</td>
<td>April 2013</td>
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<tr>
<td>UK</td>
<td>Framework Launch</td>
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<tr>
<td>Burkina Faso</td>
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<td>Niger</td>
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<td>Mali</td>
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<td>Chad</td>
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<td>Germany</td>
<td>National stakeholder meeting</td>
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<td>South Africa</td>
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<td>Spain</td>
<td>National stakeholder meeting</td>
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<tr>
<td>LDCs in South East Asia</td>
<td>Regional stakeholder meeting</td>
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<td>SIDS in the Caribbean</td>
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<td>May 2013</td>
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In April, Nigeria launched its national framework for climate services, and the United Kingdom’s launch followed in June. Other countries have formulated roadmaps, Burkina Faso, Niger, Mali and Chad have recently completed theirs, having benefited from WMO GFCS pilot projects that were initiated in 2012. Germany, South Africa and Spain are planning national stakeholder meetings to assess the status of climate services capacities and needs. WMO GFCS Office has also coordinated regional stakeholder meetings in South East Asia and the Caribbean with the support of other UN Agencies and donors.

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What do we mean by Climate Services?

“Climate is what you expect and weather is what you get”

Arame Tall

Climate services are essential for adaptation to climate variability and change. The endorsement of the Global Framework for Climate Services (GFCS), whose intent is “to strengthen the production, availability, delivery and application of science-based climate prediction and services,” by 155 nations at the 2009 World Climate Conference-III attests to this. The Global Framework aims to bridge the gap between the climate information being developed by scientists and service providers and the practical needs of end-users.¹

The GFCS implementation plan targets gaps in climate services in support of four initial climate-sensitive sectors – agriculture, health, disaster reduction and water – especially for those most vulnerable. This will be achieved through the development and incorporation of science-based climate information and predictions into planning, policy and practical decision-making. Effective climate services will facilitate climate-smart decisions that will, for example, mitigate the impacts of climate-related disasters, improve food security and health outcomes, enhance water resources management, and bring better outcomes in disaster risk reduction.

As climate services continue to rise in prominence on national, regional and global agendas for climate adaptation and mitigation, it is important to re-examine what is meant by climate services and to look at the more difficult challenge.

What are climate services?

A climate service is a decision aide derived from climate information that assists individuals and organizations in society to make improved ex-ante decision-making. A climate service requires appropriate and iterative engagement to produce a timely advisory that end-users can comprehend and which can aid their decision-making and enable early action and preparedness. Climate services need to be provided to users in a seamless manner and, most of all, need to respond to user requirements.²

As indicated by the well-known adage “climate is what you expect and weather is what you get” used to distinguish between the climate and weather, climate information prepares the users for the weather they

An example from the agriculture and food security sector - early actions that a farmer can take based on the type of climate services received, from the seasonal down to the mid and short-range timescales. (Adapted from Red Cross Climate Centre Early Warning > Early Action model)

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actually experience. For most users climate and weather are mutually interchangeable. It is, therefore, imperative for climate and weather services to operate in close tandem, so as to be seamless to the end-user. The seamless delivery of services from the long- to short-term time scales is critical to ensure effective and consistent use of information for various real-world decision-making contexts. Timescales are key in understanding climate services.

Who are the end-users?

The end-users perspective is a key in the tailoring of climate services. The “end-users” are in fact a heterogeneous mix of stakeholders from the national, sub-national and community levels. Each user can derive a benefit – potential or actual – in using climate services.

However, not all users are end-users. Some recipients of climate information, such as trend projections and forecasts of various climate and weather parameters, interpret, analyze and process it in light of sector-specific knowledge in order to produce a useable, tailored and integrated climate service that can be communicated to end-users. For example, agricultural experts employed by departments of agriculture may receive 10-day rainfall forecast bulletins (climate information) to which they overlay information based on their knowledge of the growing season for farmers in a given region of the country, such as stage of planting, plant phenology, etc (sector-specific knowledge), in order to produce a tailored rural advisories (climate services).

These “intermediary users” are the partners of National Meteorological and Hydrological Services (NMHSs) in producing climate services. They work hand-in-hand with forecasters to transform climate information into a climate service. They are, in practice, the national stakeholders in charge of processing climate information (input) to produce sector-tailored climate services (output).

Intermediary users or service co-producers are different from the final end-users of climate services who often do not need climate information/data, but a finished useable climate advisory service or product that they can input into their decision-making. The latter category encompasses farmers, fishermen, vulnerable communities, etc., as well as national decision-makers and planners who need finished climate information products at longer timescales (climate projections).

This distinction is important when mapping the user community in a given country and setting out to produce tailored climate services to meet decision-making needs. An ideal climate service delivery chain includes end-users both at the beginning and at the end of the service production and delivery process. Production of climate services begins with a thorough identification of the needs of each set of end-user then builds and grows through feedback and re-assessment of end-user needs.

Delivering climate services for end-users

Delivering tailored climate services that can effectively inform the decision-making is a multi-front challenge. It requires multi-disciplinary and cross-sector collaboration, and an agreed upon framework within which such collaboration can take place. Based on good practice evidence from climate service pilot projects implemented recent years by WMO and its partners in implementing the GFCS at regional and national levels, five steps have been identified to achieve this.

Step 1: Understand the demand side

What appears as an intuitive step, asking end-users what they need, is often overlooked in the design phase of initiatives aiming to deliver salient information services in support of local/national climate risk management efforts. However, end-user participation in the assessment of their climate service needs is a pre-requisite to the success of any national program aiming to build resilience to climate variability and change.

Climate service needs are minutely context specific, varying from one village to the next. Examples from the Indo-Gangetic plains of India, and Kaffrine, Senegal, targeting women farmers in the design and delivery of climate services, show how one can effectively conduct an ex-ante assessment of farmer climate service needs, using tailored participatory action research tools to gauge end-user needs ahead of project design.

A mapping of farmer adaptation and climate service needs in every target region or sector is required.

Identifying end-user needs also means valuing local sources of information. The community should be asked to identify the information gaps and needs that they

3 WMO pilots National Workshops in Burkina Faso, Chad, Mali, Niger to support establishment of Frameworks for Climate Services at the National Level. More at: www.wmo.int/pages/gfcs/office/Dialogue_SE1.php

4 See: “Identifying farmer’s information needs to manage production risk in the Indo Gangetic Plains of India” and “Communicating climate services to three target communities in Kaffrine (Sénégal)”. For more info: iri.scalingup.columbia.edu.
have observed. Climate service projects in northern Tanzania and western Kenya offer promising examples of ways to integrate traditional indicators with scientific techniques for seasonal forecasting.

Following identification of the context-specific climate service needs of end-users, their continuous involvement in the production, delivery and evaluation of climate services is key to ensure adherence of delivered climate services to identified needs. This is the role of the User Interface Platform, one of the most critical components of the GFCS.

**Step 2: Bridging the gap between climate forecasters and sector expertise**

This is the most challenging component of climate service delivery to overcome. The lack of interaction between NMHSSs and their essential partners from national technical departments – agriculture, disaster management, public health planning, etc. – hinders efforts to tailor climate information.

Various participatory processes have mediated two-way dialogues and brokered effective partnership between NMHSSs and technical sector experts, based on complementary expertise. Always centered on the needs of end-users, these dialogues have brought forecasters face-to-face with expert planners and managers in climate-vulnerable sectors to identify how they can work together. As a result, multi-disciplinary working groups and national frameworks for the co-production of climate services were established. However, their numbers are limited, a lot more is needed.

The Early Warning > Early Action workshops conducted across Africa from 2009-2012 (see Tall et al., forthcoming) provide a good example of a participatory approach. They brought together vulnerable communities, technical departments from climate-sensitive sectors, communication intermediaries and forecasters in national dialogues that identified needs and co-designed response services. Using participatory or scenario games, the workshops encourage communities and experts to work together to identify possible solutions and means of supporting end-users in managing climate risk. Facilitated discussions generated an environment of openness and trust to ensure that all participants were comfortable and felt secure enough to share and explore each other’s experiences.

These games are also used to train intermediaries who can continue employing them in vulnerable communities to facilitate the translation of complex, often technical climate information into a format that can be easily understood. This is particularly important as intermediaries often work in communities where socio-cultural constructs can pose a significant challenge (see May and Tall, 2013). This trusting relationship is critical to achieve effective climate services.

The GFCS Office initiated a series of four pilot projects in West Africa in 2012 aimed at identifying the critical elements for the establishment of national frameworks for climate services for the most vulnerable users. Thus, the meteorological offices of Burkina Faso, Chad, Mali and Niger carried out stakeholder mapping at the national level and reached out to key stakeholders and potential users across all climate-sensitive sectors in their individual country. National Workshops on Climate Services followed, launching dialogue between the providers and users of climate services on the appropriate institutional mechanisms for establishing a perennial framework for climate services. The interaction created a national communication chain for climate services, linking climate science and early warning information.

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6 See “Promoting Integration of Indigenous Knowledge and Scientific weather and climate forecasting for risk management under a changing climate in Lushoto District, Tanzania” and “Integrating Indigenous Knowledge in Climate Risk Management in support of Community Based Adaptation in Nyangi, Western Kenya”. For more info: iri.scalingup.columbia.edu.

7 Sumiko May and Arame Tall, 2013. “Developing a methodology for the communication of climate services at scale through intermediaries in Africa and South Asia: White paper for the CCAFS Expert Workshop on Climate Services, 12-14 June 2013, Nairobi, Kenya”. Available online at ccafs.cgiar.org.
with the technical services in climate-sensitive sectors to produce targeted climate service which, in turn, linked with local end-users and the most vulnerable communities. The chain has built-in channels for feedback from end-users in order to continuously refine climate service development. It is hoped that these national frameworks will overcome the obstacles to climate information access and use. The GFCS Office aims to replicate the West Africa pilots in other regions.

The above experiences underscore the necessity of face-to-face dialogue to bridge the gap between forecasters and other sector specific staff. However, the process has to be mediated and pro-actively inserted into efforts to develop climate services for end-users. For the interaction to be sustainable, all major players in the chain of climate services will have to discuss and agree on clearly delineate roles and responsibilities for the production, communication and delivery of climate services for end-users.

Step 3: Co-producing climate services to address end-user climate service needs

The next essential step is the production of climate forecasts and advisory services that respond to end-user needs. In the food security sector, for example, the successful development of tailored agro-climate advisories that respond to farmers’ decision-making needs requires the following critical steps:

- downscaling existing climate information to achieve local detail and bridge geographical scales;
- adding value to climate information by complementing it with agricultural knowledge on, for example, which farm-level and agro-pastoral practices ought to be adopted to thwart predicted impacts of climate-related anomalies⁹; and
- developing suites of advisory products tailored to needs within the established integrated frameworks for climate service production (e.g.: multi-disciplinary teams of climate, agricultural, soil, pest, water, seed and extension experts).

For examples, readers are invited to read the FAO article “Localizing Climate Information Products and Services for Agriculture” that present a series of case studies in the agriculture sector.

Step 4: Communicate to reach ‘the last mile’

It is vital to ensure that the final advisory product is efficiently and effectively communicated. Assessments of delivery channels are necessary to ensure that vulnerable communities and national planners receive the climate support services destined to them. There are many options: rural radio, SMS, voice recorded messages, “agro-met bulletin boards” posted across strategic locations, etc. The format should be suited to local needs. For example, radio alert for farmers should be sent when they are available to hear them, in the local language and timed to inform ongoing farm operations.

⁹ An example of value-addition in practice can be found in the good practice case: “Testing the Design and Communication of Downscaled Probabilistic Seasonal Forecast & Evaluating their Impacts at Wote (eastern Kenya)”. More information on this case: at iri.scalingup.columbia.edu.
Two important channels through which remote rural communities can be accessed and their inputs fed back to providers:

- Information and Communications Technology platforms such as SMS or voice messaging; and
- through partnerships with other intermediaries – media communication professionals, non-governmental organizations, community based organizations, women’s associations – to serve the “missing link” between communities at risk and forecasters.

**Step 5: Assess and re-assess**

Finally and most important, one needs to keep assessing adherence of provided services to local needs throughout the life span of the climate services program.

Participatory Action Research tools have proven instrumental for enabling, for example, farmer’s learning and innovation to steer the continued tailoring of available climate and agricultural information to meet their needs. Farmers in the Kaffrine project, for instance, suggested new more effective channels to reach women farmers – SMS on their children’s cell phones in the local Wolof language or by spreading the word at the water boreholes, where they gather each morning to fetch water. Similarly, farmers surveyed in the India’s Integrated Agro-meteorological Advisory Service (IAAS), the largest of its kind in the world, suggested that agro-meteorological bulletin boards in local language be posted at strategic outposts across their villages where they can be read as the farmers go about their daily activities.

As such, re-assessments of climate service needs provide a pretext to open spaces for iterative triple loops of learning feeding into product design, and enabling social learning for more effective co-design and tailoring of services to meet the critical information needs of end-users10.

**Keeping focus on the needs of the most vulnerable**

One cross-cutting issue in the five steps is to keep focus on the needs of the most vulnerable. It is relatively easy to scale up climate services for millions of farmers in a country, but it is quite another to reach the most vulnerable who tend to be resource poor, female and marginalized groups, constrained by the invisible boundaries of their community’s socio-cultural norms. Therefore, it is important to target specifically these sub-groups in the various steps of the design and deliver of the national climate services programs.

The end-to-end approach outlined herein offers a way forward to achieving targeted climate service delivery. Together the five good practice components map out an innovative, achievable blueprint to establish an integrated framework for the production, communication and evaluation of climate services.

It is a multi-front challenge and will require concerted work across disciplines in order to be successful in equipping communities at risk with climate information and advisory services that enable them to make improved decisions under a variable and changing climate. The most difficult step will be to bridge the gap between climate forecasters and sector-specific expertise in order to move from climate information to a useable climate service. To this end, the GFCS West African pilots offer a model for future initiatives.

Supporting countries to establish such frameworks for climate services is an urgent priority. Regardless of the model adopted, climate information will need to be tailored and packaged appropriately to serve the needs of end-users in all climate sensitive sectors. In a world where exacerbated climate variability and uncertainty is projected as significant consequences of climate change, equipping policy-planners and the most vulnerable communities with early climate/weather information and advisories to anticipate climate-related shocks and changes is an urgent priority.

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10 See CGIAR Climate Change, Agriculture and Food Security (CCAFS) Climate Change and Social Learning Strategy, April 2013. Available online at ccafs.cgiar.org.
Localized climate information products and services in agriculture aim to provide a full range of advice regarding climate, its impacts on crops, livestock, fisheries and management practices to be followed to prevent, reduce and/or manage risks. This tailored information assists farmers in making management decisions to reduce the risks and benefit from the opportunities of our variable and changing climate. Thus, it needs to contain details and inputs from agricultural support services/institutions, suppliers, local cooperatives or community-based organizations in order to help farmers to make practical, feasible and relevant decisions.

Localized climate information services must consider community perceptions, local knowledge, livelihood patterns, vulnerability, gender and reliable communication channels. Such a service motivates community participation and enhances two-way feedback. Enabling of User Interface Platforms (UIPs) at local level is crucial to ensure collection and synthesis of data on local weather, climate, crops and market price of crops and inputs; use of weather and climate forecasts; analysis and development of impact outlooks and management practices; and communication to end-users.

FAO has acquired much experience in this area thanks to the technical assistance it lends to its members in order to improve localized climate information products. Much of this experience is pertinent to FAO partners in the Global Framework for Climate Services. The case studies below each highlight different aspects.

**Needs assessment to define user-driven climate information services**

Viet Nam’s Ministry of Agriculture and Rural Development and Hydrometeorological Service partnered with FAO to assess the needs of various user agencies in three provinces – Loa Cai, Yen Bai and Phu Tho – in the mountainous region in the county’s north. Some 200 staff, working at provincial, district and community level, were asked to respond to structured questionnaires in order to assess their perceived need and current gaps. Site surveys and focus group meetings were also organized at the community level to better understand the needs of end-users.

The results show that 84 per cent of the respondents at the institutional level actively seek weather and climate products and services to develop risk information for decision-making. Over 80 per cent of the respondents need sector specific impact outlooks and location specific value added forecast products and services. However, the primary purposes vary – 67 per cent to add value to advisories for end-users, 33 per cent to enhance institutional preparedness for pro-active risk management. The majority of provincial level staff seek climate information for enhancing institutional preparedness while those at the district and community levels seek additional details for preparing advisories for end-users. Some 46 per cent of the respondents felt that climate information was highly technical and 35 per cent did not respond mainly because of a lack of knowledge on the products and services. Over a third felt that the
lead times of forecasts were insufficient for meaningful
decision-making, and 91 per cent wanted to have simpler,
user friendly products.

Capacity development

The above assessment shows that there is a definite
need for capacity development and training in provincial,
district and communal level institutions and that capacity
development for intermediate users should be designed
based on needs. Climate services are not used adequately
by farmers as technical expertise to prepare impact
outlooks and response options, and to communicate to
the farmers is lacking at the intermediary user institutions
level. Thus, FAO capacity development includes training
of provincial and district level authorities.

For example, FAO, the South African Government,
the University of the Free State (UFS) and the South
African Weather Services partnered to conduct staff
training at the Provincial Departments of Agriculture
to improve agro-meteorological advisories in two
provinces, KwaZulu Natal and Mpumalanga. The aim
was to produce location specific advisories for the
communities’ emerging farmers, who have recently
become involved in agriculture.

Participatory learning and decision-making

Women group participating in a Farmer Field School (FFS) on
climate in Arghakanchi, Nepal

Wider, effective use of climate services depends on
improving communication from providers to users and
on lateral seepage of information among end-users. The
FAO Farmer Field Schools (FFS) provide an effective
interface mechanism to promote farmer-to-farmer learn-
ing. A multi-disciplinary team, participating in an FAO
facilitated dialogue in Nepal between the Department
of Hydrology and Meteorology (DHM) and the District
Agriculture Department Office (DADO) to assess local
climate service needs, concluded that a primary target
would be to improve understanding of local climatic
conditions; however, the first priority should be to
strengthen agro-meteorological networks and to make
better use of historical climate data. Such historical data,
when integrated into FFS sessions, facilitates end-user
understanding, and discussions on, climate products
and services.

During FFS sessions in Nepal’s Arghakanchi district,
value added information on climate-crop interactions,
based on historical records and superimposed with local
context, stimulated discussions between farmers on the
likely impacts of prevailing weather and preparedness
measures. This permitted farmers to gain knowledge
on climate variability and change and its effects on
their livelihoods. The FFS allowed DHM and DADO
to reach out to local farmers and promoted learning
among peers. The sharing of weekly weather and crop
situations was discussed. This close interaction helped
DADO to understand the training needs of end-users
and to re-structure subsequent FFS sessions.

Building partnership

Many anticipate that it is up to climate information
providers to customize and add value to their products
and services to match sector and location specific
needs. The reality is that climate information providers
often do not have sufficient human resources and
technical capacity to do this. Experience from an FAO
project in the Philippines show that strong, decentralized
partnerships between the meteorological services,
departments of agriculture, research institutes and
provincial, municipality and village authorities are crucial
to deliver end-to-end climate information products
and services. Value additions must take place at the
intermediary user institution level in close partnership
with the meteorological services.

The project brought the Southern Luzon Philippines
Atmospheric, Geophysical and Astronomical Services
Administration (PAGASA) Regional Services Division
and the Department of Agriculture (DA) together to
discuss roles and responsibilities in the “user-interface
mechanisms” at the sub-national level. A multi-
agency memorandum of understanding enhanced the
commitment and better understanding of the roles
and responsibilities of different institutions. The new
User Interface Platform (UIP) led to several positive
outcomes, including:
• the PAGASA regional services division has more frequent and improved climate outlooks as it now better understands the profile and needs of the users;

• the regional department of agriculture is committed and trained to interpret, prepare and issue agricultural advisories every month;

• the provincial and municipal level agricultural extension staff have the role of communicating the advisories to the village level authorities and end users; and

• Barangay “captains” are responsible for monitoring and observing weather from newly installed weather stations and for communicating this information to the PAGASA regional services division.

This result came after a lot assessment, much continued dialogue and targeted capacity development. The frequent weather and climate related events that impact agriculture, the active role that information providers and users can play in a decentralized model, and the identification of champions in each of the agencies to advance tasks justified the effort.

Collaboration between the department level institutions and the National Meteorology and Hydrology Service (SENAMHI), facilitated by FAO, led to implementation and strengthening of Early Warning Systems (Sistema de Alerta Temprana - SAT) that generates and disseminates hydrometeorological risk information and warning levels to focal points at departmental, municipal and community levels. SENAMHI now maintains software, which automatically transmits processed climate information to pre-assigned addresses of risk management units. The database contains the cell phone numbers of key department and municipal officials. Messages are first sent to the department level SAT interface mechanisms and to the risk management units at the municipal level for speedy preparedness. The risk management units communicate the information to the local communities. The communication to the end-users is mostly via radio by community level health posts/centres.

The system operates well to provide alerts of extreme weather events and is a significant development for local communities. However, the communication of detailed value added climate information, such as the available alternatives relevant to climate risk management of livestock and crop, requires further efforts. The probability of the early warnings that are issued is not currently provided to the communities, but will be soon. Currently, the focus is on reducing the loss of lives. Future proposals include effective use of this communication channel and interface mechanism for long-lead climate outlooks to guide protection of livelihoods.

### Considering livelihood perspectives

Localized climate information products and services should contribute to decision-making on community livelihood strategies. With its Agricultural Disaster Risk Management Plan (ADRMP) now in place, Jamaica is focusing on developing its livelihood baseline data and agro-meteorology programme. The Rural Agricultural Development Authority (RADA), with technical guidance from the Jamaica Meteorological Services (JMS) and assistance from FAO, has acquired and installed automated weather stations in all major production areas of the country. The equipment records parameters that influence crop growth – rainfall, temperature, wind speed, relative humidity and solar radiation. It also calculates derived parameters such as evapo-transpiration and dewpoint, and has capabilities for the addition of more sensors, e.g. soil temperature, leaf wetness.

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*Experts from the Department of Agriculture and Southern Luzon PAGASA Regional Services Division discuss localized climate services for agriculture sector during a training workshop.*

**Ensuring equitable access to information**

Equitable access to climate information for the most vulnerable populations is a pre-requisite in the agriculture sector. For example, in the small communities in Potosi (in the high altitude of the Bolivian Andes) and Beni (low-lying area in the north), regions highly vulnerable to climate risks, climate information is crucial to implement risk reduction plans that protect the livelihood activities of these farmers. However, the interface mechanisms to facilitate two-way communication for the delivery of such services were not functional.
The objectives of the RADA/JMS agro-meteorology programme are manyfold:

- guide development of agro-meteorology forecasts/advisories,
- enable farmers to better determine and time operations that are weather/climate-dependent, for example planting, irrigation, fertilizer application, pest management,
- provide farmers with agro-meteorological information for efficient and competitive agricultural production; and
- enable better assessments and estimates of crop productivity/production levels.

RADA’s comprehensive national agro-meteorological database is also able to support a parametric disaster risk insurance scheme. Similarly, the livelihood baseline database that contains details of location specific livelihood activities, livelihood assets and vulnerabilities can provide additional information needed for localizing climate information services.

The value added services will include area-specific weather forecasting along with lunar phases, forecasting crop yield and production levels, scheduling of crop planting and irrigation dates, estimation of crop irrigation needs, development of pest and disease management programmes including early warning systems, determination of crop (and livestock) zone production potential, agricultural drought management advisories and timing of interventions, wind monitoring for parametric agricultural risk insurance and development of a database for future historical and trend analyses. RADA is planning to expand the programme to facilitate crop assessment, natural resource management and improved services to most vulnerable communities in the mountains and coastal areas.

Promoting commitment and budget provision

The sustainability of localized weather and climate information services also depends having the commitment of local authorities and budget provision to maintain the observation networks, communication facilities, local alert systems and capacity development activities. In a project with SENAMHI Peru, risk management laboratories, managed by local authorities, were set up in the Andean communities of Cusco-Canchis, Canas and Punolampa, which interface between climate service users and providers. Meteorological stations were installed in the communities in order to monitor and record local data for input into targeted climate services for farmers. Training was provided to those given responsibility for observation and two-way communication, via email, with SENAMHI in Lima on the one hand and with farmers on the other. The frequency of these exchanges will need to be enhanced to allow sufficient time for the farmers to use the information for decision-making.

The community risk management team prepared village level vulnerability maps for the agriculture sector that specify main livelihood activities. These are the basis for customization of weather and climate services. The community also developed a risk management plan to reduce the impacts of frost, hailstorm and drought on major crops. A communication mechanism is in place to disseminate this information to members of the community, however, capacity will have to be improved in order to rapidly reach all.

But the key to sustainability in this project is that the communal authorities negotiated with the local authority (council) for a budget line to cover the operation and maintenance of the User Interface Platform and the risk management laboratories. The agreement between the municipality and the community ensures the sustainability of the risk management laboratories.

Further lessons to be learnt

As the Global Framework for Climate Services is implemented and more partners join the initiative, there will be more to be learnt from their experiences in improving and localizing climate services and products for the needs of end-users. The aim is to build on the knowledge each has acquired in order to mitigate risks and benefit society in a variable and changing climate.
Weather and Climate Resilience
Effective preparedness through National Meteorological and Hydrological Services

by David Rogers and Vladimir Tsirkunov of the World Bank

Faced with a growing risk of weather and climate related disasters that can set back economic and social development for years, the global community needs to act quickly to strengthen National Meteorological and Hydrological Services (NMHSs). This strengthening should be done in a way that transforms weak agencies – especially in the developing world – into robust professional agencies capable of delivering the right information to the right people at the right time. Although the price tag of modernizing and sustaining NMHSs will be considerable, the rewards for the country and its citizens will be much higher. The World Bank, working closely with WMO and other development partners, can help countries navigate this complex task in a timely, efficient manner.

The need to serve more elaborate societal needs, minimize growing economic losses from natural hazards and help countries adapt to climate change is increasing the importance of weather, climate and water information. Weather, climate and water affect societies and economies through extreme events, such as tropical cyclones, floods, high winds, storm surges and prolonged droughts, and through high impact weather and climate events that affect demand for electricity and production capacity, planting and harvesting dates, managing construction, transportation networks and inventories, and human health.

Costs of modernizing NMHSs

The key players are the NMHSs, which are the backbone of the global weather and climate enterprise. They are the authoritative source of weather, climate and water information, providing timely input to emergency managers, national and local administrations, the public and critical economic sectors.

NMHSs are a small but important public sector agencies – with budgets of usually about 0.01 to 0.05 per cent of national gross domestic product and total annual public funding globally of more than US$ 15 billion. The problem is that their capacity has become so degraded in many regions over the past 15 to 20 years – primarily owing to underfunding, low visibility, economic reforms and in some instances military conflict – that they are now inadequate. As a result, globally, NMHSs in more than 100 countries – over half of which are in Africa – need to be modernized.

How much will modernization cost? A conservative estimate of high-priority modernization investment needs in developing countries exceeds US$ 1.5 billion to US$ 2.0 billion. In addition, a minimum of US$ 400 million to US$ 500 million per year will be needed to support operations of the modernized systems (staff costs plus operating and maintenance costs). These recurrent costs should be covered by national governments, but few have been able to do so. Moreover, the amount of international support for the NMHSs is significantly below what is needed just for the high-priority items.

Complicating matters is that internationally supported NMHSs modernization efforts in the developing world have achieved only limited success so far, owing to:

- Insufficient communication directed at governments and agencies with many competing priorities and limited budgets in order for them to gain a full appreciation of the value of the NMHSs;

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1 This article is based on the forthcoming book Weather and Climate Resilience: Effective Preparedness through National Meteorological and Hydrological Services. 2013 International Bank for Reconstruction and Development / The World Bank.
• A preoccupation with project time-scale installation of hardware without adequate provision for training, ongoing maintenance, consumables, and other continuing technical support;

• A multiplicity of uncoordinated projects from different donors, each with its own assistance policies, objectives, and equipment suppliers, without sufficient regard to the individual NMHSs’ needs, circumstances, and priorities; and

• The technical complexity of the projects.

What can be done to improve the track record of modernization efforts and help policy-makers realize the urgent need to overhaul NMHSs? To help answer this question, studies – several by WMO in the build up to the World Climate Conference-3 – analyzed the overall global meteorological and hydrological system, its importance for the effectiveness of NMHSs, the obstacles to modernization, and possible desirable operating models. One study by the World Bank combined desktop analyses based on existing documentation with expert opinion and the experience of several leading NMHSs – the UK Met Office, MeteoSwiss and the China Meteorological Administration. It synthesized recent experiences of the World Bank and Global Facility for Disaster Reduction and Recovery (GFDRR), WMO and other development partners. It also builds on key recent World Bank strategic documents on economic growth and environmental sustainability.

The World Bank study – like the WMO studies – underscored the urgent need to strengthen NMHSs,
especially those in developing countries, and provides cost-benefit estimates of the return that countries can hope to achieve. It recommended an approach that has been tested and implemented in Europe, Central and South Asia and other regions. It also underscores the significance of international collaboration to access data, knowledge, and know-how of the large-scale atmospheric and oceanic conditions that drive the global weather patterns that affect individual countries.

Another study (Hallegratte 2012) conservatively estimated that upgrading all hydrometeorological information production and early-warning capacity in developing countries would save an average of 23 000 lives annually and would provide between US$ 3 billion and US$ 30 billion per year in additional economic benefits related to disaster reduction.

Why are NMHSs important?

Weather, climate, and water hazards

In recent years – thanks largely to advances in weather forecasting and risk assessments – people have been better prepared for natural disasters. Despite an increase in the number of disasters and people affected since 1980, the number of people killed has not risen significantly. However, there is a huge concern that the number of people affected and the number of disasters will continue to rise and will in turn increase the number of people killed if governments and other stakeholders do not intervene. The reasons are many:

- An increasing number of people and assets are located in areas of high risk;
- Developing countries will continue to be exposed to frequent and extreme weather, water and climate events as climate change exacerbates these extremes;
- The world’s population continues to explode;
- The urbanization trend continues, with more people living in cities than ever before; and
- Weather- and climate-sensitive diseases claim more than 1 million lives each year; most are children under five years of age in developing countries.

Between 1970 and 2010, natural hazards killed about 3.3 million people (World Bank 2010). They also took a huge financial toll on human well-being. In 2011, about 206 million people were victims of natural disasters, and the economic impact was US$ 366 billion. During a longer period, between 1980 and 2011, the total estimated financial cost from floods, droughts, and storms was more than US$ 3.5 trillion.

Weather, climate, and water forecasts

The NMHSs make a significant contribution to safety, security and economic well-being by observing, forecasting and warning of pending weather, climate and water threats. However, this contribution is rarely quantified, which often results in an undervaluing of the vital role that NMHSs play in a country’s capacity to cope with meteorological and hydrological hazards. Also severely undervalued are the economic benefits of accurate weather, climate and water information to increase productivity and avoid losses.

Accurate forecasting depends on a network of global, regional and national remote and in situ observations of the atmosphere, oceans and land that are conducted by NMHSs and their partners. These observations are assimilated by a network of global and regional forecast centres, which have differentiated responsibilities for the production of global, regional and national products. This system ensures that large-scale numerical predictions – which are needed for a good national forecast but require enormous computing power – are created cost-effectively by a few NMHSs and supporting organizations on behalf of all Members of the WMO.

Alone, no nation would be able to provide the meteorological and hydrological services necessary to meet the essential needs of its citizens. But as WMO Members, countries agree on data-sharing arrangements, establish operational guidelines, implement best practices, and develop and use training opportunities. This international cooperation, however, depends on the continued investment of advanced countries in developing and supporting meteorological satellites, major computing facilities, and research and development. It also depends on regional investment in adapting global products for regional and national application. And it depends on national investment in maintaining NMHSs’ observation networks and tailoring services to the needs of the population and specific economic sectors.

What are the obstacles to better NMHSs?

Lack of capacity

Despite their importance, many NMHSs in developing countries lack the capacity to provide even a basic level of services. The massive underfunding of NMHSs has led to (a) a deterioration of meteorological and hydrological observation networks and outdated technology, (b) a
lack of modern equipment and forecasting methods, (c) poor quality of services, (d) insufficient support for research and development, and (e) an erosion of the workforce (resulting in a lack of trained specialists). As a result, substantial human and financial losses have occurred, which could have been avoided if weather and water agencies were more developed. Climate-resilient development requires stronger institutions and a higher level of observation, forecasting, and service delivery capacity. In addition, successful adaptation to the existing and future weather and climate variability is impossible without reliable and well-functioning NMHSs. The WMO Severe Weather Forecasting Demonstration Project has highlighted the importance of the regional, specialized and global centres in helping countries reach a high level of service. But there too investment is limited, often hampering the capacity of these centres to provide on-demand guidance. Although a national focus is primary, the benefit of international cooperation and collaboration must also be considered. Synergy between the different levels ensures that national data are available to improve model output at regional and global centres. The high value-added segment of the production chain with regard to numerical weather prediction and space-based observations is at the global level. At present, it is assumed that developed economies will continue to support this segment. But this assumption is becoming increasingly uncertain.

**Public financing of NMHSs**

Nearly all NMHSs started as public service institutions that were funded exclusively by government. But at the end of the 20th century, a series of economic policy shifts occurred in both developed and developing countries, resulting in public policies less supportive of this concept. There has been a growing expectation among many governments that the public sector should raise revenue from the sale of services to other government departments and to the public. This view presents serious threats to the continued free and unrestricted exchange of information that WMO has always pursued.

In response, institutional frameworks have been adjusted to give NMHSs more flexibility to generate revenue and to use that revenue to expand and improve services. As claims on limited tax revenue have increased, greater emphasis has been put on applying the principle that the user should pay for government services. This commercial approach does not take into account the natural monopoly component of this type of information – which requires large fixed investments with a quasi-zero marginal distribution cost, thus should be available for free. Without the large fixed public (NMHSs) investments, it is impossible to sustain the observation networks, except for geographically constrained and specialized applications. Without these observations, basic forecasts are limited and value-added services to end-users are not possible. This situation undermines civil protection, food security, water resource management, energy and emergency management, and economic development.

**Key principles for modernizing NMHSs**

In response to the growing risk of meteorological and hydrological hazards, the study has identified six principles for improving NMHSs in developing countries:

**Principle 1: Modernizing NMHSs in developing countries is a high-value investment**

Although the challenges in modernizing NMHSs are great, so too are the potential benefits to societies coping with meteorological and hydrological hazards and the risks posed by climate change. Globally, our capabilities are the best that they have ever been. Scientific and technological advances continue to improve numerical weather and climate prediction. We now have the scientific skills to provide reliable warnings of extreme events and day-to-day weather forecasts that are more accurate, specific, and timely than ever before – and these skills continue to improve. However, they are often limited to developed countries, because NMHSs in developing countries lack the infrastructure to transfer and use these technologies.

Unfortunately, many governments have not gained a full understanding of the societal value of the information and services that NMHSs should provide as a public service. One way to enhance government and broaden public understanding of what is at stake is to conduct socioeconomic studies that quantify the value of the public services resulting from NMHSs’ strengthening. Such studies can also identify gaps in the current system and help prioritize elements of a modernization program. This process should be iterative so that stakeholders’
expectations are realistic. Engaging all stakeholders, both internal and external to the NMHSs, is critical to the success of a modernization program – as emphasized by the WMO-led Global Framework for Climate Services. In Switzerland and the United States, studies show high economic returns from better NMHSs – with cost-benefit ratios of 1:4 to 1:6. And a recent World Bank study in Europe and Central Asia suggests cost-benefit ratios of 1:2 to 1:10.

**Principle 2: The financing and scope of modernization must be sufficient to be transformative**

Financing and scope of modernization must be enough to change NMHSs with poor infrastructure, declining observation networks and weak forecasting capability into public service organizations capable of delivering timely and useful information to mitigate weather, climate and water risks to the public and sensitive economic sectors. New capabilities incur additional operating and maintenance costs, which governments must consider up front to ensure the sustainability of the modernization effort beyond the initial work program.

The appropriate operating models need to be recognized explicitly to ensure that the NMHSs meet their public service and international obligations. Governments need to recognize and support their NMHSs to protect lives, livelihoods, and property as a critical, publicly funded mission. Policies that may restrict the free and open exchange of meteorological and hydrological data should be avoided, and the public sector responsibilities of the NMHSs should be emphasized. Selecting an operating model goes hand in hand with establishing appropriate legislation to institutionalize the agreed mission.

**Principle 3: Clear legal and regulatory frameworks for providing weather, climate and water services increase effectiveness**

Broad engagement across government departments, agencies, and other institutions is essential for success. To achieve success, countries need legal and regulatory frameworks for providing meteorological and hydrological warnings, as well as for delivering other weather, climate, and water services. Such frameworks will enable all stakeholders to understand their respective roles and responsibilities and to act accordingly. Coordination across government agencies is difficult, if not impossible, without it.

Modernized observing, forecasting and delivery systems provide countries with the capability to cope effectively with hydrometeorological hazards.
Principle 4: Large-scale modernization programs should specifically include three components:

- Institutional strengthening, capacity building and implementation support. Strengthening NMHSs’ legal and regulatory frameworks, improving their institutional performance as the main provider of weather, climate and hydrological information for the country, building the capacity of personnel and management, ensuring operability of future networks and supporting project implementation are all necessary to a large-scale modernization program.

- Modernization of observation infrastructure and forecasting. This component includes modernizing the NMHSs’ observation networks and communication and ICT systems, improving the meteorological and hydrological forecasting systems, and refurbishing offices and facilities.

- Enhancement of the service delivery system. Such enhancement involves creating or strengthening the public weather services, climate services, and hydrological services and developing new information and value-added products for vulnerable communities and the main meteorological and hydrological dependent sectors. This component should include developing national frameworks for climate services as outlined in the Implementation Plan of the Global Framework for Climate Services.

The World Bank’s experience suggests that NMHSs need help to transform their operations. They need expert guidance throughout the modernization process. Pairing advanced NMHSs with less advanced NMHSs helps sustain staff training and provides operational guidance.

Principle 5: Modernization of NMHSs should be considered within the wider regional and global context

It is important to understand which parts of the public meteorological infrastructure are best funded and operated at the local, national, regional, and global levels and to make investments accordingly. There is room for more efficient distribution of responsibilities among these levels. Technological developments make it possible to generate more useful products at regional and global levels, which can underpin the services that NMHSs provide at the country level.

WMO regional centres and specialized centres are an integral part of the information system. They provide NMHSs with operational guidance based on the products created by the global modeling centres. Strong regional and specialized centres can help sustain national modernization programs by supporting continuous technology infusion, thereby ensuring that the NMHSs are up to date. However, new financing mechanisms are needed to support the regional and global elements of the meteorological and hydrological system.
Principle 6: The World Bank, WMO and development partners have a vital role

The reason is simple: weather, climate and water services are a key public good, and better resilience to climate variability and change is a key element of a broader sustainable development and green growth agenda.

Scaling up support

The World Bank is beginning to scale up support through investment and development policy operations. For example, hydrometeorology forms a key pillar of all of the programs developed under the Pilot Program for Climate Resilience of the Climate Investment Funds. And countries are increasingly recognizing the importance of integrating better weather and climate service delivery into broader strategic development agendas.

Hydrometeorological programs are technically complex, but the World Bank has gained practical knowledge in modernizing NMHSs in middle-income and now low-income countries – although so far it has limited experience in the least developed countries. In 2012, new hydrometeorological modernization projects are being developed and implemented for Mexico, Mozambique, Nepal, the Russian Federation, Vietnam, the Republic of Yemen, Zambia, and other countries. In Nepal, the approach is one of the few examples of end-to-end modernization, focusing on institutional strengthening, modernization of the observation and forecasting systems, and service delivery. In addition, a dedicated assessment of the current capacity of hydrological services will be the focus of a separate study that the World Bank is planning to undertake jointly with the WMO. The hope is that the World Bank’s growing modernization experience can help improve the design of future programs and underpin the place of hydromet strengthening in broader sustainable development agendas.

The World Bank believes that this initiative to modernize the global NMHS infrastructure is a prerequisite to fulfilling the promise of the Global Framework for Climate Services.

References


3 Nepal’s hydromet modernization program is called Building Resilience to Climate-Related Hazards and is funded by the Pilot Program for Climate Resilience.
Reducing and managing risks of disasters in a changing climate

Disaster risk reduction (DRR) is a core priority of WMO and one of the four priorities areas to be addressed by the Global Framework for Climate Services. An analysis of 1970-2009 EM-DAT data reveals 7870, reported disasters from climate, hydro and meteorological hazards, leading to the loss of 1.86 million lives and causing economic damages amounting to US$ 1.954 trillion (adjusted to 2011 US$ prices). Disasters set back socio-economic development by years if not decades, particularly, in the less developed countries. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) highlights that the frequency and severity of hydrometeorological hazards are on the rise, posing challenges to sustainable development and to building resilience in both developing and developed nations.

WMO DRR priorities (2012-2015)

Risk assessment – Information on the characteristics of weather and climate hazards needs to be complemented with exposure and vulnerability information to develop a complete picture of risks. The latest scientific advancements in climate modeling and forecasting provide unprecedented opportunities for analyzing and providing predictions of the changing patterns of hazard characteristics and longer lead-times for risk assessment. Individuals, communities, organizations, businesses and governments, armed with evidence concerning weather and climate risks, can make decisions to reduce them.

Early warning systems – Effective early warning systems include risk knowledge, monitoring and warning services, dissemination and communication, and response capacity. Climate services are critical for decisions on investing and strengthening early warning systems and for the development of emergency preparedness plans. Early warnings of hazards are critical for activating emergency plans on the ground.

Risk reduction in climate-sensitive sectors – Multi-sectoral planning to reduce disaster risk and to adapt to changing patterns of hazards due to climate variability and change require information on historical, current and forward-looking risk analysis. Relevant multi-sectoral planning and investment decisions include areas such as financial planning, land zoning, infrastructure and urban development, agricultural practices and food security measures, water management, health service provision, education planning and many others.

Risk financing and transfer – This involves the structured sharing of the potential financial impacts of disasters caused by natural hazards, often, but not strictly, through insurance mechanisms. A suite of risk financing and risk transfer approaches can be used at different levels to guarantee the availability of immediate post-disaster and longer-term recovery funds for which climate information on historical and forward-looking hazard characteristics are critical underpinning information.

Atlas of Mortality and Economic Losses

WMO and the Centre for Research on the Epidemiology of Disasters (CRED) at the Université Catholique de Louvain, will release an Atlas of Mortality and Economic Losses from Weather, Water and Climate Extremes (1970 – 2009) in November 2013. The publication will offer a bird’s eye view of weather, water and climate related disaster worldwide and their human and economic impacts. The next few pages, excerpt from the Atlas, offer a global picture then focus in on three WMO regions (Africa – Region 1, Asia – Region 2, and North America, Central America and the Caribbean – Region 4) for inter comparisons.
From 1970 to 2009, 7,870 hydrometeorological related disasters were reported globally, causing the loss of 1.9 million lives and economic damages of US$ 1.9 trillion. In that period, the top ten disasters in terms of human lives lost represented only 0.1 per cent of the total number of events, but accounted for 70 per cent (1.3 million) of the total lives lost. The ten costliest disasters accounted for 19 per cent (US$ 377 billion) of the overall economic losses.

Storms and floods accounted for 79 per cent of the total number of events, but accounted for 70 per cent of the total lives lost. The ten costliest disasters accounted for 19 per cent (US$ 377 billion) of the total lives lost. The ten costliest disasters accounted for 19 per cent (US$ 377 billion) of the overall economic losses.

The figures show that reported economic losses are increasing, while the number of lives lost reveals a slight decreasing trend. Droughts, tropical cyclones and floods are the major causes of loss of life and economic damage.

### Ranking disasters according to deaths (top) and economic losses (bottom) Top 10 costliest global disasters (1970-2009)

<table>
<thead>
<tr>
<th>Disaster Type</th>
<th>Year</th>
<th>Country</th>
<th>Number of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm (Bhola)</td>
<td>1970</td>
<td>Bangladesh</td>
<td>300,000</td>
</tr>
<tr>
<td>Drought</td>
<td>1983</td>
<td>Ethiopia</td>
<td>300,000</td>
</tr>
<tr>
<td>Drought</td>
<td>1984</td>
<td>Sudan</td>
<td>150,000</td>
</tr>
<tr>
<td>Storm (Gorky)</td>
<td>1991</td>
<td>Bangladesh</td>
<td>138,866</td>
</tr>
<tr>
<td>Storm (Nargis)</td>
<td>2008</td>
<td>Myanmar</td>
<td>138,366</td>
</tr>
<tr>
<td>Drought</td>
<td>1975</td>
<td>Ethiopia</td>
<td>100,000</td>
</tr>
<tr>
<td>Drought</td>
<td>1983</td>
<td>Mozambique</td>
<td>100,000</td>
</tr>
<tr>
<td>Flood</td>
<td>1999</td>
<td>Venezuela</td>
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<td>Extreme temperature</td>
<td>2003</td>
<td>Italy</td>
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<table>
<thead>
<tr>
<th>Disaster Type</th>
<th>Year</th>
<th>Country</th>
<th>Economic Losses (in US$ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm (Katrina)</td>
<td>2005</td>
<td>United States</td>
<td>141.56</td>
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<tr>
<td>Storm (Andrew)</td>
<td>1992</td>
<td>United States</td>
<td>41.80</td>
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<tr>
<td>Flood</td>
<td>1998</td>
<td>China</td>
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<td>2008</td>
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<tr>
<td>Flood</td>
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<td>2004</td>
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<tr>
<td>Drought</td>
<td>1994</td>
<td>China</td>
<td>20.53</td>
</tr>
<tr>
<td>Storm (Charley)</td>
<td>2004</td>
<td>United States</td>
<td>18.74</td>
</tr>
<tr>
<td>Flood</td>
<td>1993</td>
<td>United States</td>
<td>18.38</td>
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</tbody>
</table>

Map of disasters
United States

East Africa
Droughts in 1975 (Ethiopia, Somalia) and 1983/1984 (Mozambique, Ethiopia and Sudan) caused more than 600,000 deaths

Bangladesh
Cyclones Bhola (1970) and Gorky (1991) caused nearly 450,000 deaths

The 2003 summer heat wave was reported in 15 countries and caused 70,000 deaths

Myanmar
Cyclone Nargis (2008) : 140,000 deaths

Venezuela
1999 /flash/lood: 30,000 deaths and cost (US$ 4.2 billion)

South Africa
Drought in 1991 cost US$ 1.6 billion

Madagascar
Tropical cyclone Emilie in 1977 cost US$ 1.3 billion and killed 10 people

Morocco
Drought in 2000 cost US$ 1.2 billion

Iran Islam Rep
Economic losses mainly related to floods, notably those of 1992 (US$ 5 billion)

Philippines and Indonesia
Storms lead to important human losses, especially storm Thelma (1991, 6,000 deaths)

Australia
Drought in 1981 (US$ 15 billion) and storms Tracy and Alby (US$ 3.5 billion) were the costliest events

Europe
Floods and storms are the costliest disasters

**Source: CRED EM-DAT.**

**All amounts have been adjusted to 2011 US$ prices.**

**The designations employed and the presentation of material on maps in this or any WMO publication does not imply the expression of any opinion whatsoever on the part of the WMO concerning the legal status of any country, territory, city or any area or of its authorities, or concerning the delimitation of its frontiers or boundaries.**
WMO Region I

In Africa from 1970 to 2009, 1 137 reported disasters caused the loss of 695 163 lives and economic damages of US$ 22.2 billion. Although floods were the most prevalent cause of disasters (59 per cent), droughts led to the highest number of deaths – some 97 per cent of all lives lost to weather, water and climate-related disasters in the region. The severe droughts in Ethiopia in 1975 and in Mozambique and Sudan in 1983–1984, respectively, caused the majority of the losses of lives. In contrast, the reports show that storms and floods caused the highest economic losses (75 per cent).

The top ten disasters in terms of human lives accounted for 97 per cent (674 000) of the total lives lost, while the top ten events in terms of economic losses accounted for 44 per cent (US$ 9.9 billion) of all losses.

The number of reported disasters is shown to be increasing while the number of lives lost – with the exception of the 1980–1989 anomaly associated with the severe droughts – reveals a slight decreasing trend. There was no discernable trend in the economic losses reported.

<table>
<thead>
<tr>
<th>Disaster Type</th>
<th>Year</th>
<th>Country</th>
<th>Number of Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought</td>
<td>1983</td>
<td>Ethiopia</td>
<td>300 000</td>
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<tr>
<td>Drought</td>
<td>1984</td>
<td>Sudan</td>
<td>150 000</td>
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<tr>
<td>Drought</td>
<td>1975</td>
<td>Ethiopia</td>
<td>100 000</td>
</tr>
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<td>Drought</td>
<td>1983</td>
<td>Mozambique</td>
<td>100 000</td>
</tr>
<tr>
<td>Drought</td>
<td>1975</td>
<td>Somalia</td>
<td>19 000</td>
</tr>
<tr>
<td>Flood</td>
<td>1997</td>
<td>Somalia</td>
<td>2 311</td>
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<tr>
<td>Flood</td>
<td>2001</td>
<td>Algeria</td>
<td>921</td>
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<td>Flood</td>
<td>2000</td>
<td>Mozambique</td>
<td>800</td>
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<tr>
<td>Flood</td>
<td>1995</td>
<td>Morocco</td>
<td>730</td>
</tr>
<tr>
<td>Flood</td>
<td>1994</td>
<td>Egypt</td>
<td>600</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Disaster Type</th>
<th>Year</th>
<th>Country</th>
<th>Economic Losses (in US$ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought</td>
<td>1991</td>
<td>South Africa</td>
<td>1.62</td>
</tr>
<tr>
<td>Flood</td>
<td>1987</td>
<td>South Africa</td>
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</tr>
<tr>
<td>Storm (Emilie)</td>
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<td>Madagascar</td>
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</tr>
<tr>
<td>Drought</td>
<td>2000</td>
<td>Morocco</td>
<td>1.16</td>
</tr>
<tr>
<td>Drought</td>
<td>1977</td>
<td>Senegal</td>
<td>1.09</td>
</tr>
<tr>
<td>Storm (Gervaise)</td>
<td>1975</td>
<td>Mauritius</td>
<td>0.82</td>
</tr>
<tr>
<td>Storm</td>
<td>1990</td>
<td>South Africa</td>
<td>0.66</td>
</tr>
<tr>
<td>Storm</td>
<td>1990</td>
<td>Madagascar</td>
<td>0.61</td>
</tr>
<tr>
<td>Storm (Benedicte)</td>
<td>1981</td>
<td>Madagascar</td>
<td>0.57</td>
</tr>
<tr>
<td>Storm</td>
<td>1982</td>
<td>Canary Islands</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Ranking disasters according to deaths (top) and economic losses (bottom): Top 10 costliest disasters in Africa (1970-2009)
Total amount of economic losses (1970 - 2009)

- 0.0 - 0.1
- 0.1 - 0.6
- 0.6 - 1.2
- 1.2 - 2.0
- 2.0 - 5.3

(in US$ billion)

Morocco
- Storms in 1977, 1981 and 1990 caused a total of US$ 2.46 billion in damages
- Losses of US$ 1.2 billion related to a drought in 2000

Canary Islands
- Storms caused significant economic losses, notably the event of 1999 (US$ 0.6 billion)

Senegal
- A drought in 1997 caused more than US$ 1.09 billion

South Africa
- Drought in 1991 and flood in 1987 cost US$ 1.5 billion each, and US$ 0.7 billion were associated to a tornado in 1990

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Total number of deaths (1970 - 2009)

- 0 - 500
- 500 - 1 200
- 1 200 - 22 000
- 22 000 - 150 000
- 150 000 - 410 000

Morocco
- 730 deaths due to a flood in 1994

Algeria
- 39 floods reported, including the event of 2001 that caused more than 900 deaths

Egypt
- 500 deaths due to a flood in 1994

East Africa
- Droughts in 1975 (Ethiopia, Somalia) and 1983/1984 (Somalia) caused more than 600 000 deaths

Somalia
- A flood in fall 1997 caused over 2 300 deaths in the South of the country

Egypt
- 500 deaths due to a flood in 1994

East Africa
- Droughts in 1975 (Ethiopia, Somalia) and 1983/1984 (Somalia) caused more than 600 000 deaths

Somalia
- A flood in fall 1997 caused over 2 300 deaths in the South of the country

Madagascar, Mauritius, and La Réunion
- Tropical cyclones have caused the loss of many lives

Mozambique
- A flood in 2000 led to 800 deaths

Map of disasters and their related deaths in Africa (1970-2009)

Non-WMO member states are indicated in white.
WMO Region II

In Asia from 1970 to 2009, some 2 425 disasters were reported, causing the loss of 898 726 lives and economic damages of US$ 641 billion. The majority of the disasters were attributed to floods (45 per cent) and storms (36 per cent). Storms had the highest impact on life, causing 78 per cent of the lives lost, while floods caused the greatest economic damage (55 per cent). Three tropical cyclones, which struck Bangladesh and Myanmar leading to over 100 000 deaths, were the most significant events. Economic losses were mostly associated to disasters in China, most notably the 1998 floods.

<table>
<thead>
<tr>
<th>Disaster Type</th>
<th>Year</th>
<th>Country</th>
<th>Number of Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm (Bohla)</td>
<td>1970</td>
<td>Bangladesh</td>
<td>300 000</td>
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<tr>
<td>Storm (Gorky)</td>
<td>1991</td>
<td>Bangladesh</td>
<td>138 866</td>
</tr>
<tr>
<td>Storm (Nargis)</td>
<td>2008</td>
<td>Myanmar</td>
<td>138 366</td>
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<tr>
<td>Flood</td>
<td>1974</td>
<td>Bangladesh</td>
<td>28 700</td>
</tr>
<tr>
<td>Storm (TC)</td>
<td>1985</td>
<td>Bangladesh</td>
<td>15 000</td>
</tr>
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<td>Storm (TC)</td>
<td>1977</td>
<td>India</td>
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<td>1999</td>
<td>India</td>
<td>9 843</td>
</tr>
<tr>
<td>Storm (TC)</td>
<td>1971</td>
<td>India</td>
<td>9 658</td>
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<tr>
<td>Flood</td>
<td>1980</td>
<td>China</td>
<td>6 200</td>
</tr>
<tr>
<td>Storm (Sidr)</td>
<td>2007</td>
<td>Bangladesh</td>
<td>4 234</td>
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</table>

The top ten disasters account for 74 per cent (665 000) of the total lives lost and 29 per cent (183 billion) of economic losses.

With the increasing number of reported disasters, economic losses also increased, however, the curve for number of lives lost showed a slight decreasing trend.
Among the 10 costliest disasters, 6 were reported in China, mainly due to floods (notably in 1998, US$ 41 billion), but also to a cold wave in 2008 (US$ 22 billion) and a drought in 1994 (US$ 21 billion).

Democratic People's Republic of Korea
The flood in 1995 (US$ 22 billion) and a tropical cyclone in 2000 (US$ 7.7 billion) were the costliest disasters.

Japan
Storms Minelle (1991, US$ 16 billion) and Songda (2004, US$ 11 billion) were the costliest events reported in Japan.

India

In North America, Central America and the Caribbean from 1970 to 2009, there were 1458 reported disasters that caused the loss of 68 708 lives and economic damages of US$ 803.7 billion. The majority of hydrometeorological and climate related disasters in this region were attributed to storms (54 per cent) and floods (34 per cent). Storms were reported to be the greatest cause of lives lost (72 per cent) and of economic damage (80 per cent). The most significant events in terms of lives lost were Hurricane Mitch in 1998 (14 932 lives lost), which affected Honduras and Nicaragua, and Hurricane Fifi in 1974 (8 000 lives lost), which affected Honduras. However, in terms of economic losses, it was Hurricane Katrina in 2005, which caused US$ 142 billion in losses – the most costly disasters on record.

The top ten disasters in terms of human lives accounted for 58 per cent (40 000) of the total lives lost and in terms of economic losses 41 per cent (US$ 332 billion) of all losses.

The number of reported disasters and the amount of economic losses during the period are increasing significantly, while the number of lives lost shows no discernable trend.

<table>
<thead>
<tr>
<th>Disaster Type</th>
<th>Year</th>
<th>Country</th>
<th>Number of Deaths</th>
</tr>
</thead>
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<tr>
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<td>1998</td>
<td>Honduras</td>
<td>14 600</td>
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<td>Storm (Fifi)</td>
<td>1974</td>
<td>Honduras</td>
<td>8 000</td>
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<td>Storm (Mitch)</td>
<td>1998</td>
<td>Nicaragua</td>
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<td>Mass movement wet</td>
<td>1973</td>
<td>Honduras</td>
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<tr>
<td>Storm (Jeanne)</td>
<td>2004</td>
<td>Haiti</td>
<td>2 754</td>
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<tr>
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<td>2004</td>
<td>Haiti</td>
<td>2 665</td>
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<td>Storm (Katrina)</td>
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<td>United States</td>
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<td>Storm (Stan)</td>
<td>2005</td>
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<td>1979</td>
<td>Dominican Republic</td>
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<td>United States</td>
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<table>
<thead>
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<tr>
<td>Storm (Charley)</td>
<td>2004</td>
<td>United States</td>
<td>18.74</td>
</tr>
<tr>
<td>Flood</td>
<td>1993</td>
<td>United States</td>
<td>18.38</td>
</tr>
<tr>
<td>Storm (Rita)</td>
<td>2005</td>
<td>United States</td>
<td>18.12</td>
</tr>
<tr>
<td>Storm (Wilma)</td>
<td>2005</td>
<td>United States</td>
<td>16.19</td>
</tr>
<tr>
<td>Storm (Frances)</td>
<td>2004</td>
<td>United States</td>
<td>12.88</td>
</tr>
<tr>
<td>Storm (Hugo)</td>
<td>1989</td>
<td>United States</td>
<td>12.48</td>
</tr>
</tbody>
</table>

Distribution of (top) number of disasters, (middle) deaths and (bottom) total economic losses by hazard type reported in North America, Central America and the Caribbean (1970-2009)
Total amount of economic losses (1970 - 2009)
- 0.0 - 1.8
- 1.8 - 4.3
- 4.3 - 13.4
- 13.4 - 33.3
- 33.3 - 676.4
(in US$ billion)

Caribbean
The worst economic losses were reported in Cuba, Puerto Rico and Cayman Islands.

United States
A flood in 1993 caused losses of US$ 18.4 billion.

Hurricanes in the United States
Major hurricanes reported, such as Katrina (2005), Andrew (1992), Ivan (2004), and Ivan and Charley (2004), account for biggest economic losses of all time.

Nicaragua
Hurricane Mitch in 1998 (3 300 deaths) was the costliest event.

Guatemala
Hurricane Stan in 2005 (1 500 deaths) was the costliest event.

Canada
Droughts and forest fires account for 67% of total economic losses of the country (US$ 33.3 billion)

Total number of deaths (1970 - 2009)
- 0 - 260
- 260 - 1 500
- 1 500 - 6 000
- 6 000 - 14 000
- 14 000 - 27 000


In terms of human losses, hurricane Katrina (1 800 deaths) and a heat wave in 1980 (1 300 deaths) were the worst events.

Honduras
Hurricanes Mitch (1998, 15 800 deaths) and Fifi (1974, 8 000 deaths) were the 2 worst events in terms of human impact, followed by a landslide (1973, 2 800 deaths).

Guatemala
Hurricane Stan in 2005 (1 500 deaths) was the costliest event.

Nicaragua
Hurricane Mitch in 1998 (3 300 deaths) was the costliest event.

Haiti and the Dominican Republic reported the largest death rates.

Map of disasters and their related deaths in North America, Central America and the Caribbean (1970-2009)
The application of climate science to benefit society

by Chris Hewitt¹, Kirstine Dale² and Jonathan Stanford³

Climate Service UK will help decision-makers manage opportunities and risks arising from climate variability and change both in the UK and abroad.

Throughout history society has faced risks arising from natural variations in climate. Today, society faces additional challenges from human-induced climate change. However, we are now able to be more strategic in our response to climate-related risks and opportunities due to our expanding knowledge of climate science, ever-improving climate forecasts and growing understanding of how climate hazards impact society and the environment. The need for information and tools to enable both the United Kingdom and the wider world to cope is real and urgent.

Every year, there is ever growing evidence of society’s vulnerability to extreme weather. In 2012, for example, the UK began the year with a drought and a warm, dry first three months. This was abruptly followed by an exceptionally wet period for most of the country. 2012 eventually became the UK’s second wettest year on record since 1910. There were serious consequences, especially on farming and infrastructure. There are numerous examples beyond the UK: droughts across large parts of the United States, heatwaves and wildfires in Australia, flooding in Pakistan, heatwaves in Brazil and Russia – the list is long.

Recognizing that advice is needed worldwide to support decisions on managing exposure to climate variability and change, the WMO and other United Nations agencies have created the Global Framework for Climate Services (Global Framework) with strong engagement from users, donors and service providers worldwide. The Global Framework will ensure climate information is used effectively in decision-making at the global, regional and national levels.

National frameworks to empower decision-makers

The Global Framework calls for countries to establish their own national frameworks with their national meteorological services as they are likely to be well positioned to undertake a central role. The national framework needs to identify and coordinate activities

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² Met Office, kirstine.dale@metoffice.gov.uk
³ Met Office, jonathan.stanford@metoffice.gov.uk
relating to the development and provision of climate information, products and services to meet national needs. Engagement needs to take place between the users of climate information; the organizations that maintain the official climate record, develop operational climate products and provide climate science inputs to climate services; and the organizations that provide authoritative, credible, usable and dependable science-based climate information and advice. As WMO Secretary-General Michel Jarraud stated, “National frameworks for climate services are vital for empowering decision-makers to respond to the risks and opportunities of climate variability and change.”

In the UK, the Met Office is ideally placed to deliver to this remit. “We already have strong relationships in place both nationally and internationally which we can now build on to establish devoted climate services,” explained Kirstine Dale, Head of Climate Programmes for Government.

Chris Hewitt, Head of Climate Service Development at the Met Office, has been working with the WMO and other key UN Agencies since 2011 as part of the core team developing the Implementation Plan for the Global Framework. He is, therefore, well qualified to ensure that the activities of the Met Office and its partners align with, and support, international activities. Building on strengths

The UK has developed close interactions between research councils, universities, the Met Office, stakeholders and end users both at home and overseas. The UK has world-class capabilities that will allow it to take a leading role in developing and delivering climate services. The Met Office already provides services at the national scale (for the UK and for other nations) as well as regionally and globally based on strong collaborations. It will develop these further, particularly to draw on multidisciplinary expertise to support decision-makers.

The Met Office, particularly through the Met Office Hadley Centre, and other climate centres are constantly expanding the observations and monitoring of past and current climatic conditions, making advances in forecasting the regional climate and climatic extremes for the coming seasons, and improving the understanding of climate change. “The major developments we are seeing in the underpinning science are of course exciting,” explains Chris Hewitt, “and the really exciting developments for me are in applying this science to help decision-makers from across society.” Into the public eye

An event to showcase Climate Service UK 4 as the Met Office’s response to the Global Framework took place on 3 June at the Institute of Physics in London. Over 100 leading figures from UK government, academia and business attended the event. UK Secretary of State for Energy and Climate Change Edward Davey and WMO Deputy Secretary-General Jerry Lengoasa presented keynote speeches. The event was a great success, and placed Climate Service UK in the public eye. The Met Office is taking a lead in showing how science can be drawn on to deliver real value both nationally and internationally. “This is a fantastic opportunity to deliver the value of the government’s investment in climate science,” said Kirstine Dale.

4 www.metoffice.gov.uk/climate-service-uk

UK Secretary of State for Energy and Climate Change Edward Davey
Climate Service UK creates the necessary framework for providing support and advice for managing climate-related risks and opportunities. It will draw together the necessary expertise to meet the needs of society and its decision-makers, both in the UK and overseas. By working with users to understand their vulnerability to weather and climate, it will support timely, far-sighted and well-informed decisions to address the risks and opportunities posed by a changing climate. Through Climate Service UK, the Met Office will promote sustainable growth in the face of extreme weather and climate challenges, meet international capacity-development objectives, and provide a framework for ensuring that public investment in climate science can be used to maximum effect.

Climate Service UK is the next stage in ongoing developments at the Met Office and in the UK. The Met Office Hadley Centre Climate Programme, funded by the Department for Energy and Climate Change (DECC) and the Department for Environment, Food and Rural Affairs (Defra), was launched on 20 June 2012. It has enabled the Met Office to take a leading role in delivering the national climate capability. This is the core science used to help Government to make decisions to advance the UK toward becoming more resilient to climate variability and change. Just one year on, the launch of Climate Service UK shows how that science is being used to deliver real value.

Risk and opportunities

Secretary of State Davey is confident that Climate Service UK will make the most of world-leading climate knowledge here in the UK and further afield. “Climate Service UK builds on a foundation of world-leading science,” he said. “And I’m sure will become an essential framework for advising on the risks and opportunities of a changing climate.”

Those two words, “risks” and “opportunities,” demonstrate how wide-ranging the service is. Climate Service UK does not just provide advice about the risks that can arise from variations in the climate, it also enables opportunities for growth and development. A growing number of countries are utilizing the expertise at the Met Office to help them understand climate variability and change and assess their risks and opportunities. Climate Service UK, along with key collaborators and partners at the national, regional and global levels, will contribute to the successful implementation of the Global Framework.
Global climate change is now a reality. The Earth’s surface temperature has risen by more than 0.8°C in the past century and by approximately 0.6°C in the past three decades. This global change has led to extreme weather events such as floods, droughts and heavier and more frequent storms that have had negative public health impacts on vulnerable populations. In Africa, the health impacts of global warming include increased vulnerability to diseases borne by vectors, air and water as well as food insecurity. It has been demonstrated that the majority of African countries are ill-prepared to cope with the negative impacts of climate change. These countries lack solid evidence that links health to climate and the capacity to understand and apply climate and environmental information to decision-making and resource management. They conduct few risk assessments of the health impacts of climate change.

Climate-related public health impacts are especially pronounced in developing countries, which lack the protection of basic infrastructure and public health services. The poorest populations in Africa bear the heaviest burden of infectious diseases transmitted by insect vectors and through poor water and sanitation and unsafe food. The livelihoods and nutritional security of millions of people on the continent, especially women and children, are heavily dependent on rain-fed agriculture and seasonal water resources. The same populations are also particularly exposed to the harmful health effects of chemical pollutants, and other environmental factors, in the air, water, food and soil. All these health risks are highly sensitive to extreme weather events and climate variability. These risks tend to be exacerbated by climate change. An indirect public health impact of climate-induced changes will be observed in the distribution of productive ecosystems and availability of food, water and energy supplies. The distribution of infectious diseases, nutritional status, chemical exposure and patterns of human settlements will also be affected.

Climate services provide critical information for understanding the characteristics of hazards and their changing patterns. Forward-looking predictions and projections enable prevention and planning to increase resilience to the climate extremes that can result in disasters or epidemic outbreaks. However, the capacity to use climate information to reduce climate-related risks is limited by knowledge gaps on the linkage between climate and environmental health and by institutional challenges hindering effective response. The WHO-led Climate and Health Consortium for Africa (Clim-Health Africa), which responds to the political will of African governments to address climate change in general and its health impacts in particular, will address these challenges. Clim-Health Africa will support the Climate for Development in Africa2 (ClimDev-Africa) initiative by addressing its health aspects.

**Goals and expected outputs**

The goal of Clim-Health Africa is to strengthen the resilience of African countries and communities by

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* This article summarizes the “Building African capacity for early warning and response systems through forecasting, preventing and managing public health effects of climate variability and change” published by the World Health Organization (WHO). The full project brief is available at: www.afro.who.int/en/clusters-a-programmes/hpr/protection-of-the-human-environment.html

2 ClimDev-Africa is part of the effort to address climate change challenges in Africa. It is a joint initiative of the African Development Bank (“AfDB” or the “Bank”), the Commission of the African Union (“AUC”) and the United Nations Economic Commission for Africa (“UNECA”).
improving management of the effects on public health of climate variability and change and planning for resources to cope with climate-sensitive health outcomes, moving from the current reactive to a proactive mode. The five-year (2014–2018) Clim-Health Africa projects proposes to address the following specific objectives:

- Develop mechanisms and institutional capacities for implementation of climate-based public health early Warning and response systems in Africa;

- Develop operational public health early warning and response systems tools for planning and decision-making that address climate-sensitive health impacts;

- Utilize early warning and response systems to support timely response to climate-sensitive diseases and conditions;

- Develop and implement a communication strategy on climate change and health impacts; and

- Provide African countries at their request, especially the least developed countries and the small island developing states, priority support on urgent public health issues related to climate change.

Capacity building will be a key component in this project. There is a shortage of climate and health scientists in Africa to support the fast-moving climate change and health agenda. Therefore, efforts will be made to offer hands-on training courses to public health practitioners so that as early warning and response systems are developed and field-tested, there will be operational capacity in the countries to understand and use them effectively. One key strategy of this project is the development of a doctoral programme to breed a new generation of young African and non-African climate and health scientists.

The expected outputs of the project are:

- Databases - historical epidemiological data, community maps, and tested and validated models;

- Strengthened research capacity in Africa and elsewhere through specific research and training programmes at master’s and doctoral levels;

- Strengthened operational capacities of public health programmes for surveillance, early detection and response to climate-sensitive health conditions;

- Protocols, guidelines and operational systems integrated with existing planning processes;

- Evidence of improved timeliness of preparedness for cost-effective responses to the effects of extreme weather events;
Founding institutions of Clim-Health Africa

African Centre of Meteorological Applications for Development (ACMAD)
Biotechnology Centre, University of Yaoundé I, Cameroon
Kenya Medical Research Institute (KEMRI), Kenya
International Network for the Demographic Evaluation of Populations and Their Health (INDEPTH)
International Research Institute for Climate and Society (IRI), Columbia University, USA
Malaria Research and Training Centre (MRTC), University of Bamako, Mali
Medical Research Council (MRC), South Africa
National Institute for Medical Research (NIMR), Tanzania
Noguchi Memorial Institute for Medical Research, Accra, Ghana
National Aeronautics and Space Administration (NASA), USA
National Oceanic and Atmospheric Administration (NOAA), USA
United Nations Environment Programme (UNEP)
World Health Organization (WHO)
World Meteorological Organization (WMO)

Advances in climate sciences, computing and telecommunications now allow forecasts ranging from a few hours to many years and climate projections. In addition, country-led integration of observations and global products has provided a new opportunity for user communities to access high quality information at the national level. These new capabilities allow the production and delivery of services whose application offers great benefits for many socioeconomic sectors that are climate sensitive. In addition, new field-based epidemiological data-gathering tools, including SMS and rapid diagnostic kits, have dramatically improved the opportunity for increasing resilience of communities to weather and climate-related health emergencies if information is integrated and presented in an actionable manner to proactive decision-makers.

Integrating climate knowledge and information into epidemiological training: There are several training opportunities for integration of climate change. These include the field epidemiology and laboratory training
How climate affects health

Ecosystem services are indispensable for the well-being of all people in the world. Healthy, well-functioning ecosystems enhance natural resilience to the adverse impacts of climate change and reduce the vulnerability of people. Human health is likely to be affected indirectly by climate-induced changes in the distribution of productive ecosystems and availability of food, water and energy supplies. These changes will in turn affect the distribution of infectious diseases, nutritional status, chemical exposure and patterns of human settlement.

Climate and disease

Vector-borne infections, diarrhoeal diseases transmitted through water and food and airborne diseases are some of the most important health burdens of the poorest communities. The burden of infectious diseases is particularly heavy in Africa.

Epidemic forms of these diseases are particularly damaging to health and health services. For example, mortality rates are comparatively higher in malaria epidemics than in endemic situations, and other mosquito-borne epidemic diseases such as dengue and chikungunya can cause high mortality and disrupt control and treatment programmes. Among water- and food-borne diseases, cholera brings high mortality rates with overloading of public health systems. Meningococcal meningitis, associated with dry conditions, causes seasonal epidemics with both acute and long-term health impacts. There is strong evidence that both the spatial distribution and triggering of epidemics of each of these diseases is associated with meteorological conditions interacting with socioeconomic and public health determinants. For example, the meningitis belt in Africa is loosely defined by isohyets with the northern limit set at 300 mm rainfall per year and the southern limit at 1100 mm (Lapeyssonie 1968). The 2008–2009 rainy season in Zimbabwe triggered the worst outbreak of cholera in recent African history, causing more than 92 000 cases and 4 000 deaths from August 2008 to June 2009. Climate change is expected to alter, and in many cases exacerbate, the incidence and spatial and seasonal distribution of these and other infectious diseases such as leishmaniasis and tick-borne diseases.
Climate and environmental degradation are also linked with the transmission of diseases from animals to humans and emergence of new diseases. For example, the plague, which is transmitted by fleas that infect rodents such as the common rat, is associated with flooding, which forces the rodents to seek shelter and food from human dwellings (Ogen-Odoi et al. 2006), and with rainfall, an association that has been verified in Uganda (MacMillan et al. 2012), Madagascar and Namibia.

**Climate and nutrition**

Malnutrition remains an underlying cause of half of the approximately 10 million annual deaths in children under age five, as well as generating long-term effects on child development (World Bank 2008). This is partly due to a lack of calories, which leads directly to protein-energy malnutrition, but more importantly is due to the interactive effect of malnutrition, which causes increased susceptibility to infectious diseases such as diarrhoea and malaria.

Extreme weather events as well as seasonal flooding and drought affect crop production and thereby food availability, particularly for subsistence farmers and those who are vulnerable to increases in food prices. Over the long term, higher temperatures and reduced and more variable precipitation associated with climate change are projected to decrease crop production, particularly in Africa, and significantly increase food insecurity and malnutrition.

In addition to their effects on food security, weather and climate affect nutritional value and food safety. For example, outbreaks of mycotoxins, which contaminate food supplies and can cause high levels of morbidity and mortality, occur in unusually warm and humid years (Muthomi et al. 2009). Increasingly, noncommunicable diseases associated with environmental threats, including salination of water supplies through the rise of sea level, threaten the health of urban and coastal communities. For example, there is emerging evidence that increased salination of water supplies not only compromises agricultural production but also increases hypertension and miscarriage among pregnant women (Khan and Islam 2011).

**Climate and chemicals**

In 2004 WHO found that globally 4.9 million deaths (8.3 per cent of the total) and 86 million disability-adjusted life years (5.7 per cent of the total) were attributable to exposure to a group of selected chemicals for which data were available. Climate change may alter human chemical exposure through extreme precipitation, drought and increased temperatures. Changes in temperature may affect the transformation and breakdown of chemicals, in some cases contributing to reductions in the effectiveness of vector-control measures. Extreme precipitation affects water quality by increasing runoff of agricultural and industrial chemicals. Drought threatens water quality by increasing the concentration of nonvolatile chemicals and toxic metals. The effect on humans of chemical exposure will vary widely according to the properties of the specific chemicals, chemical combinations, soil and water conditions, wind patterns, topography, land use, level of development, and human population characteristics.
programmes, which are the most elaborate training programmes for developing competencies in field epidemiology, and the current International Health Regulations courses developed by WHO and partners, which support its Member States in their effort to strengthen their surveillance, alertness and response to public health events.

Integrated Disease Surveillance and Response: Countries in the WHO African Region are implementing the Integrated Disease Surveillance and Response (IDSR) strategy. IDSR focuses on a selected number of diseases including epidemic and climate-sensitive diseases such as malaria and cholera. IDSR data are being used to assess the impact of climate on meningitis epidemics in the Sahel (Perez et al. submitted) and malaria in Eritrea and Ethiopia (Graves et al. 2008, Thomson et al. 2012). So far limited attempts have been made to integrate environmental data with public health data generated by IDSR implementation for comprehensive and simultaneous action on both disease determinants and their outcomes. This has delayed epidemic detection and response. IDSR implementation is facing several challenges, one of which is the difficulty to provide timely data for immediate decision-making. The use of climate signals that precede disease outbreaks would vastly improve the decision-making process and that way improve the interventions.

Although these models have existed for several years, their wide application and use by national public health programmes to manage disease outbreaks and epidemics have remained very limited. One of the underlying issues is the applicability of the modelling systems in various ecosystems for diseases other than malaria. Applied research is required to adapt the existing models for application in different climate variability and change scenarios, taking into consideration other environmental factors that may prevail in these local ecosystems.

African countries more than other countries need to use early warning and early response systems to forecast, prevent and manage public health impacts of climate variability and change. However, currently only a limited number of institutions specialize in climate services, especially with a focus supporting such public health functions. Only a very few African scientists have worked to develop predictive models. In contrast many institutions in the United States and Europe have a longstanding history in the development of climate science, technology and weather services, including their application in public health.

References


From global to regional to national: building operational climate services

Building support for climate services at the national level

The Global Framework for Climate Services (GFCS) has already succeeded in building effective partnerships at the global level. Governments, with support from United Nations and other international organizations, are collaborating to advance the concept of climate services, attract funding and launch projects. The next step is to make the GFCS a reality at the national and local levels in order to bring it closer to the end-users of climate predictions, information and advice. This can best be achieved through country dialogues and frameworks that lead to operational climate services. The GFCS seeks to advance this process through a series of regional workshops on climate services at the national level.

Regional workshops allow experts to meet with their counterparts from neighbouring countries to debate shared problems and needs. By ensuring a critical mass of experts from such diverse sectors as meteorology, climate research, public health, disaster risk, water resource management and agriculture, they can produce highly enriching discussions. These discussions pave the way for the next critical step: national dialogues that lead directly to demand-driven operational services.

The first regional workshop on climate services at the national level was held in Bangkok in October 2012. This event focused on the least developed countries in Asia and was sponsored by WMO, the Asian Development Bank, the Food and Agriculture Organization (FAO) of the UN, and the Thai Meteorological Department. Over 50 experts from nine countries and from regional and global organizations participated.

The second regional workshop was held in Port of Spain, Trinidad & Tobago, in May 2013 and attracted some 70 participants from the provider and user communities in 20 countries. It was also organized by the WMO, this time in conjunction with the Caribbean Institute of Meteorology and Hydrology (CIMH) and the US National Oceanic and Atmospheric Administration (NOAA), with financial support from FAO, the State Meteorological Agency of Spain (AEMET) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). The next workshops will be organized for the Latin American and South Pacific regions.

Shared issues and concerns

The Bangkok and Port of Spain workshops highlighted a number of issues that are probably relevant to all regions. To start with, credible climate services must be underpinned by good science and research. Thanks to intensive scientific research, remarkable advances have been made in seasonal forecasting for many regions (particularly the tropics), and there is growing confidence in long-term climate change predictions.

To advance seasonal forecasting and build regional capacity, WMO is promoting the establishment of Regional Climate Outlook Forums (RCOFs). Given the limited resources of developing countries, the forums focus mostly on applied research. RCOFs serve two main purposes: they strengthen networking amongst regional climate experts as well as the users of climate forecasts (if the users cannot understand or apply the forecasts, they have little value), and over time they will improve the accuracy of regional seasonal forecasts. RCOFs have now been established in over 10 regions, including the Caribbean, south-eastern Europe and Southern Africa. They are a critical component of the GFCS and to the development of operational climate services.
Communicating GFCS and climate services

National Meteorological and Hydrological Services (NMHSs) communicate regularly about weather and extreme events; as a result, they have increased visibility and widespread public awareness of the value of weather services. Climate service providers will want to duplicate this success in the domain of climate variability and change. The challenges to achieving this are many: climate services are not as mature as weather services; climate is experienced less directly than weather; climate predictions are more complex than weather predictions; and climate tends to involve longer term strategic responses that can be more difficult to evaluate. Communications and outreach are therefore vital for raising climate literacy and convincing people of the many benefits provided by climate services.

The communications strategy for the Global Framework for Climate Services (GFCS) seeks to engage governments, UN agencies and other partners in building a cross-cutting, multidisciplinary framework. It also aims to inform the potential users of climate services about the impressive progress in climate science, the operational services and products made possible by this progress, and the benefits that communities and socio-economic sectors are already reaping from climate information, predictions and advice.

WMO and others actively promote the GFCS via the web, workshops, presentations, publications, articles, press outreach and social media. In October 2012 the Extraordinary Session of the World Meteorological Congress adopted the communications strategy, which can be found on the GFCS website.

The GFCS brand

Branding is a useful tool for ensuring a strategic and coherent approach to outreach. A brand can be defined as how people perceive or respond to a product, service or organization – they trust it, or they do not; they want to use it, or they do not. In the case of the GFCS, the brand, or identity, is the sum of all the Framework’s attributes. This includes the visual identity – the logo and the common look and feel of the GFCS website and publications.

More important is the perceived added value or attributes of the GFCS brand that differentiate it and make it unique from all others. The GFCS is a government driven, UN-wide, interdisciplinary partnership that provides access to state-of-the-art science and applications, responds to both climate variability and change, supports national priorities, assists governments to build national and regional climate services, and empowers users to apply climate services to solve real problems. These are the values that attract people to the GFCS brand.

Compelling stories and messages are essential for bringing the GFCS brand to life. The GFCS Office has already collected a number of case studies from governments and organizations and presented them in “Climate ExChange,” a 250-page book with over 100 authors, published by WMO and Tudor Rose in October 2012. As climate services mature it should be possible to tell better and better “human interest stories” about how specific services are helping particular people or communities to address urgent problems. Gathering and sharing stories that convey the human impact of climate and climate services is important for the entire GFCS community.

National outreach

While the outreach activities for the GFCS started with engaging governments and organizations at the international level, they must increasingly focus on reaching out at the regional and national levels. It is now vital to engage partners in national frameworks and to energize the end-users of climate services. The aim should be to promote climate literacy and a general understanding of climate services, including amongst politicians, high-level officials responsible for national budgets and development, and potential funders. In this way, NMHSs can open the door to dialogues for defining the specific service needs of users in priority sectors.
Plan ahead

To be effective, national outreach should not be treated as an add-on or an after-thought. Instead, communications should be integrated from the start into all activities that support climate services. Preparing a written plan in advance is a useful way to think through the brand, messages and stories that should be promoted. Priority audiences (such as private- and public-sector end users, the media, potential partners, funders) should be identified and multiple communications tools and channels (web, press, etc.) should be exploited.

Generic messages could include: climate science and prediction are now mature enough to support operational services; climate services provide actionable information and predictions; climate-smart decision-making will improve lives and livelihoods, etc. To the extent possible, messages at the national level should be more specific and targeted.

Other considerations for effective outreach include: recognize that many potential users may not be familiar with the basics of climate variability and change, let alone what is meant by “climate services;” messages and stories should be simple, positive, relevant to daily life and expressed in non-technical language; and climate services should be linked when possible to other government priorities and campaigns and to current events (storms, droughts, launches of the IPCC assessment reports, etc.).

As these brief suggestions demonstrate, outreach is rather simple – even if it is not always easy. A key challenge is having the capacity, staff skills, time and funding to pursue effective outreach. While an upfront investment is clearly required, the pay-off in terms of attracting political and financial support and educating users ensures that outreach will more than pay for itself.

Research depends on data, and concerns about the quantity and quality of data are universal. Obtaining, managing and disseminating data can be expensive. It may be necessary to identify useful datasets that need to be rescued from loss and decay. Data issues can be usefully discussed at the regional level.

The question of how to maximize limited resources may also lend itself to regional solutions. Centres of excellence, for example, may be more easily supported at the regional level than at the national level. Regional coordination could also be useful for ensuring that the GFCS is aligned with the many other global frameworks and structures that the UN and others have established to support sustainable development.

Regional workshops allow participants to explore gaps, capacity development and strategies for engaging stakeholders. They offer the opportunity to share good practices and success stories for providing and using climate services. They can explore how National Meteorological and Hydrological Services (NMHSs) and other climate service providers can best communicate highly technical information to experts in fields that are equally technical and have their own highly specialized vocabularies. Workshop participants can also exchange ideas on how to engage high-level government officials, potential funders, the press and other audiences with compelling messages and stories that raise awareness about how climate services can contribute to sustainable development (see box).

Climate-smart health services in the Caribbean

Regional workshops can also explore sector-specific climate services in greater detail. Participants can complete a survey of currently available and used climate services and make a list of the additional ones that are needed. They can identify specific gaps, capacity development needs, institutional arrangements, priorities, and next steps.

For example, at the Caribbean workshop climate and health experts brainstormed about issues that many said they had never before addressed. They identified dengue as a common regional concern. Dengue is prevalent throughout the Caribbean in the rainy season. Effective early warning systems are needed to advise vulnerable populations about the behaviour they should adopt to minimize the risks of a pending outbreak. The health authorities need climate services that combine seasonal rainfall, temperature and humidity forecasts in order to predict a dengue outbreak. This information
A road map for national action

The Asian and Caribbean regional dialogues have already proven their value. The next step towards national frameworks for operational climate services will be to organize national dialogues that bring together experts from climate-sensitive sectors.

These dialogues will develop national coordination mechanisms for nurturing partnerships and networks of climate service users and providers. The resulting climate services should be designed to address each country’s specific challenges and user needs. They should be action oriented and should solve real problems. The national dialogues will help users to define their needs so that service providers can respond to them. National consultations will also enable the participating institutions and partners to agree on their respective roles and mandates. Effective governance mechanisms for the national frameworks will ensure that all partners work towards shared goals and avoid unwanted overlaps and gaps. They will also make it possible to identify capacity development needs and a common approach to international funders.

In addition to involving experts from relevant sectors, these national dialogues can start to engage the high-level political officials who make decisions on resources and budgets. To do this, the promoters of climate services may need to translate climate impacts into financial and development impacts – to speak the language of development planners. They must convince the politicians that ignoring climate risks will damage key economic sectors, such as tourism, agriculture or coastal development, and thus the overall national economy. A sign of their success in creating this new paradigm will be the day when the Finance Ministry reviews the Water Ministry’s strategic plan and without prompting asks: how does your plan address climate risks?

needs to be communicated well in advance so that health officials can roll out an appropriate outreach campaign.

Other Caribbean priorities areas for climate services to support public health are respiratory tract infections, diarrhea and gastroenteritis, and injuries from natural disasters. In addition to the three climate parameters already cited, these three areas will require, respectively, the provision of information on dust transported from the Sahara Desert; climate change information, for example, on ocean warming; and data and forecasts on extreme events. Continued research is vital to a better understanding of the link between climate and these various public health concerns. Long-term historical meteorological and climate data from the NMHSs – preferably computerized, in a format that health experts can understand, and transmitted in a timely manner – are also vital for mapping health risks.

To achieve all this, a regular dialogue between health ministries and NMHSs is essential. Even with the best will in the world, initiating and sustaining such a dialogue can be a challenge. People are absorbed by their day-to-day work and have limited resources. Ideally, a person or organization will be tasked with facilitating the dialogue and coordinating the sharing of data and information between national agencies. (The intervention of policymakers may sometimes be required to improve data sharing.) Other issues that could be addressed through a national framework could include the translation of research papers and data products from other languages used in the region. The end result of the dialogue should be the mainstreaming of climate services into operational health services.

Participants at the second regional workshop was held in Port of Spain, Trinidad & Tobago, in May 2013
Reconciling post-positivist and post-modern worldviews in climate research and services

by Inez Ponce de Leon¹ and C. Kendra Gotangco²

Climate change has evolved into an almost all-encompassing issue of this generation. What had begun in the realm of the physical sciences has now proved more complex than initially anticipated, and to be inherently tied to human lifestyles and decision-making. Thus, a holistic approach to climate science requires rigorous interdisciplinary and trans-disciplinary research and practice toward implementing responsive actions on the ground.

Post-modernism has emerged in the last few years as a potential interdisciplinary research paradigm for issues such as climate change because of its inclusiveness. However, it has been criticized by researchers in general because of its apparent relativism, as well as its lack of concrete metrics for evaluating the validity of findings. Scientists still mainly appeal to the traditional post-positivist approach in which there is one “truth” that is objective and can be known through careful experimentation. Post-positivism holds scientific knowledge and reputation in high regard, while often dismissing the views of non-scientists as being uninformed or lacking in depth of technical understanding.

However, the complexity of the climate change issue cannot be contested; and the diversity of stakeholder voices make an already complex issue more challenging to comprehend, much less address. A variety of terms such as “resilience,” “risk,” “safety,” and “vulnerability” are used with no clear consensus about what these terms mean. Because these terms are tied to societal values, different contexts result in different meanings and, hence, implications for adaptation goals.

These issues become all the more crucial given the current initiatives toward conceptualizing, developing, and implementing frameworks and infrastructures for the delivery of climate services, that is climate information tailored for the use of stakeholders in vulnerability, impact and adaptation assessments, and subsequent decision-making on policies and interventions. Our understanding of the climate problem drives our definition of goals, our formulation and implementation of sound policies, and our articulation and measurement of progress indicators. The diversity of stakeholders means a potential diversity in the understanding of what needs to be done in face of climate change and in defining the indicators to monitor the actual progress and success of implementation.

How then, do we move forward given the limitations in both current post-positivistic and post-modern approaches, and the difficulty in reconciling the two? Can we integrate the strengths of these worldviews in order to conduct rigorous research toward delivering relevant and effective services? Can the discourse be broadened to introduce both philosophical and sociological perspectives in order to navigating the nexus between science and society? We argue herein for a reconciliation, which we hope will contribute to building the foundations of interdisciplinary and transdisciplinary methodologies in climate change research and response.

A review of worldviews

A worldview is a lens through which a person might view, study, and attempt to understand the world. It consists of several elements, including assumptions about the nature of knowledge (epistemology); the nature of reality (ontology); the nature of valid ways of

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knowing and understanding the world (methodology); and the relationship of the world to its component parts.

Post-positivism asserts that there is an objective reality but claims that such reality can be measured and understood only approximately. This is due to a limited ability to be completely objective, and due to human errors and limits in instrumentation. In post-positivism, objectivity is distributed among scientists; that is, results are validated by triangulation of findings by many different scientists. Reflective of this tradition are the processes of peer review and consensus-building in the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports.

Post-modernism is a radical departure from post-positivism. It is often set aside alongside the modern world’s growing skepticism of science as well as the acknowledgment that our problems are far more complex than previously anticipated. Post-modernism makes no claims about the nature of reality. In post-modernism, a person’s context (e.g. as defined by their culture, upbringing, religion, society and other external factors) creates a unique limited lens through which the person perceives the world. Hence, no person can be objectively described. There are no facts or grand narratives, only interpretations of facts which will vary across individuals, but which should be recognized and regarded equally. No person is better or worse than another, so “expertise” must be redefined.

Now, the differences in approaches to research between the two worldviews become clearer: Post-positivism is strong in terms of setting rules for valid research methodology. However, it also assumes that knowledge is limited to certain groups (e.g. the scientists). This assumption is inconsistent with the field of policy, which considers the perspectives of various stakeholders. It is also inadequate given the broad cross-sectoral scope of the climate problem. Post-modernism is strong in considering the needs and perspectives of multiple stakeholders. However, it lacks rigor in terms of systematic research that can produce the generalities needed by fields such as policy and communication.

This clash in worldviews has implications that reach beyond the philosophy classroom. Researchers have explored this clash in interdisciplinary research groups and have found differing epistemological beliefs to be at the root of many research group quarrels. Research has also found that misinterpretations of the epistemological and methodological assumptions of scientific research can muddle environmental controversies further. The participation of lay experts in research groups has also been questioned, even if they sometimes have the knowledge and experience of real-world situations that the designated experts might not (but should) have.

Given the multi-dimensionality of the challenges posed by climate change in our daily lives, reductionist science has clearly become inadequate to deal with complex multi-dimensional issues such as climate change but post-modern approaches, by themselves, are not yet up to the task either. Therefore, both worldviews merit re-examination with a view toward a potential reconciliation to produce a more responsive and efficient approach to the challenges posed by climate change research and the delivery of climate services. Such reconciliation of the two worldviews might combine the systematic approach of post-positivism with the inclusiveness of post-modernism.

Reconciliation and recommendations

A reconciliation between post-positivism and post-modernism is attainable not merely as an abstraction, if the current trend in research and practice is any indication. Recent global initiatives show steps in the direction of closer collaboration between climate research producers and users (it is important to note that these groups are in no way mutually exclusive), so as to develop services that are relevant and tailor-fit to the many different realities that we face.

The Global Framework for Climate Services (GFCS), for example, is founded on pillars that include not just “Research, Modeling and Prediction” and “Observations and Monitoring,” which are traditionally considered within the purview of physical/natural science research programs, but also a “User Interface Platform,” “Climate Services Information System” and “Capacity-building.” These latter three will require more input from the social sciences and humanities and, more importantly, will require more involvement of the stakeholders themselves. Furthermore, the framework for interaction among the pillars allows for stakeholder feedback into the research and observation components. Another new international and cross-cutting program in environmental change is the Future Earth: Research for Global Sustainability Initiative, which is transitioning from the Earth System Sciences Partnership (ESSP). The Future Earth draft research framework explicitly espouses co-design and co-production between researchers and diverse stakeholders.

The Global Framework for Climate Services is designed for capacity building occurring within and between all its components.

Such initiatives are promising in that they demonstrate how to integrate the post-modern recognition of the heterogeneity of actors and contexts with the rigorous research standards of post-positivism. Nevertheless, there are challenges from both practical and theoretical standpoints. Of grave concern is a possible “crisis by analysis”, where researchers are hampered from moving forward because of the questions and quandaries posed by post-modern thought. It can be a challenge to provide climate services without second guessing whether the service fits within the theoretical framework of post-modernism.

As such, we propose a reconciled worldview, which unites post-positivism and post-modernism. This worldview can be used as a guide by climate change researchers and practitioners, whether they are studying the decision-making behavior of various stakeholders or conducting physical science research for the purpose of informing actions on the ground. This worldview can then guide the choice of conceptual and theoretical frameworks that will set the boundaries of future research, so that all research is internally consistent and therefore externally valid.

In this reconciled worldview, we propose the ontology of an objective reality, over which any person has limited control, and which can only be approximately measured. While some post-modernist schools might balk at such a proposition, it should also be remembered that there are some environmental indicators that cannot be judged as “relative.” For instance, our store of fossil fuels will indeed run out at some point, and a new reservoir cannot simply be imagined into being by stakeholders invested in a fossil fuel-based reality. Hence, the task of developing renewable sources can be said to have an objective basis.

We also propose an epistemology that is limited by one’s expertise. Post-positivism limits valid knowledge claims to those that have undergone training as specialists, while post-modernism sets no limits and considers all perceptions as valid. In either case, research can be hampered, especially with as cross-sectoral an issue as climate change. Post-positivism can reduce the climate change issue, such that studies represent only a specific group’s experience of the problem and become divorced from the diverse interactions on the ground. On the other hand, post-modernism might fail to distinguish informed perception from opinion in the caucus of stakeholder voices, and therefore lead to actions built on less-than-robust premises. One’s perception about an issue can be rooted in one’s expertise, and it is this understanding that is of value to future research. On the other hand, a personal opinion might not be rooted in expertise, and can simply be indicative of the effects of external factors such as the mass media. Practically, what this means for climate change research is inclusiveness and respect for different transdisciplinary actors, but also careful articulation of the roles of these actors, as appropriate to their given specialization and experience.

We also propose that a valid methodology is one that considers researchers as both participants and instruments of research. Researchers should be aware that while there is an objective reality, their training, personal bias, and even the language that they use (1) prevent them from measuring or perceiving the world with complete objectivity and (2) can also make them change the world that they measure, particularly if the study involves human dimensions. Consequently, researchers cannot be considered isolated from the communities they study.

Furthermore, the role of the community should not be limited to providing information about the study area at the beginning, then receiving the finished research product at the end, with neither substantial interaction with researchers in between nor long-term improvements after. Community-members can be both active users of climate information as well as active producers of knowledge of their own sectors that may prove relevant to climate research and services. They should therefore be involved in meaningful partnerships from the research design stage and throughout the implementation process. Given that different data and information have different meanings and uses across contexts, the determination of research outcomes and climate services has to be rooted in the context these will be applied in in order to translate to sustainable actions on the ground.
Therefore, research that is targeted toward providing climate services must consider the unique environments and cultures to which different groups belong. Researchers should agree that a global assessment of climate change effects and implications is valuable, but the global study may not be as relevant on the ground as regional-level, non-governmental assessments developed to suit local, cultural conditions. This regional-level assessment needs the cooperation of the sciences, social sciences, and humanities, all of which must meet as equals. In such a set-up, science does not simply hand over knowledge to the humanities for translation; this post-positivist throwback cannot exist in a complex, multi-cultural, multi-disciplinary world, where science is not the only source of knowledge. No single field has a monopoly on valid knowledge, and disciplinary boundaries are crossed constantly in acknowledgement of the diversity and complexity of the climate problems that we all face.

Research, therefore, should consider both quantitative and qualitative data to address the complexity of climate change issues; however, research should not always seek to derive grand narratives. While this may be possible in some cases, it could be equally if not more useful to embrace the diversity amongst stakeholder groups, understand what climate means for a particular group, and carry out analysis in a systematic, rigorous, and thorough manner in that context, regardless of whether the data comprises numbers or words. Moreover, research should consider non-laboratory, “non-scholarly” sources of knowledge. This might include local and indigenous knowledge on fish harvests, weather patterns, wildlife, and agriculture. The decentralization of expertise should be recognized and respected.

Furthermore, the traditional model of science repacking knowledge for an ignorant lay public should be replaced with a model that does not assume that provision of scientific information equals behavioral change, or that a lack of change indicates “stubbornness” and “irrationality.” Stakeholders will perhaps have equally valid criteria outside of the technical input on which to base decision-making.

The rationale behind providing climate services is to create impact on the ground; but because each “ground” is culturally and socially different, there should be no single template for designing and delivering climate services in a manner that will complement other factors influencing policy. Even the language used cannot be taken for granted. There are no universal definitions for terms like “resilient,” “vulnerable” or “safe,” and there are no uniform thresholds for coping and adaptation. Rather, definitions and meanings are developed, discussed, and negotiated within each context and application. In general, there is no one formula for designing the process of scientist-user dialogue and engagement. Our perception of and discourse on climate are shaped by both culture and nature.

A new look at climate science today

Science is a powerful tool, which is all the more reason to articulate the foundational principles for how we conduct scientific research. However, there should be more and stronger partnerships among science, other disciplines, and actors. The climate problem cannot be addressed effectively if science alone, or even if technology or social values alone, is put in control.

Future research should explore the climate science and society nexus, with the aim of developing a climate science that is both externally and internally consistent. With a reconciled worldview, future research can include all relevant stakeholder perceptions without losing itself in a mire of analysis and opinions. Climate science should practice this inclusiveness in all its activities, from the bench to the social sciences; and in all stages of its activities, from the initial scoping and research design, to results dissemination and capacity-building. This organized inclusiveness can perhaps allow some stakeholders to lose their indifference to environmental problems, which might then lead to stronger policy and cooperation within and amongst nations regarding the issue of climate change. Acknowledging the diversity of experience and decentralization of expertise will not only serve to enrich climate research and services, but also enable us to more completely and effectively address the issue of climate change where it matters the most: on the ground, in communities.

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Addressing the potential climate effects of China’s Three Gorges Project

The China Three Gorges Project has generated extensive concerns both domestically and abroad. People have been arguing the pros and cons of building such a large-scale dam and debating its possible impacts on the local environment. There have been frequent reports of extreme events, including both droughts and floods, throughout the region since the Three Gorges Reservoir started to raise its water level.123 4567

At the same time, the Project has brought important social and economic benefits in flood control, power generation, shipping and water resources redistribution. Most remarkable is the huge amount of clean electric power that it generates, which helps to slow down the depletion of non-renewable natural resources. Therefore, in the current social context, a comprehensive assessment of the dam’s climate effects is paramount for ensuring its smooth operation and providing the public with a sound scientific analysis of whether the extreme events observed in the last few years can be attributed to the Project.

Is the climatic pattern of the reservoir area, the neighboring localities, and even the entire Yangtze River Basin, changing? Can a scientific, objective and quantitative climatic assessment be made to determine whether the severe weather events in recent years are linked to the project’s construction and operation? If so, then what is the magnitude of the project’s impact?

To answer these questions, the Beijing Climate Center of the China Meteorological Administration (CMA) initiated a systematic study of the climate effects of the reservoir with the participation of renowned scientists. The study yielded a range of objective, scientific conclusions on the climate effects of the project that can be used to develop climate services for informing future decision-making.

The project

The Three Gorges Water Control Project includes a river-blocking dam, a water reservoir, power generators, navigation structures, and more. It is one of the largest water conservancy projects in the world, running across the canyons and mountains of central Hubei Province

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1 China Meteorological Administration (CMA)
2 National Climate Center, CMA, Beijing Climate Center
3 Changjiang Water Resources Commission, Ministry of Water Resources (MWR), China
4 Meteorological Service of Hubei Province, CMA.
5 The Institute of Atmospheric Physics (IAP), the Chinese Academy of Sciences (CAS).
6 National Satellite Meteorological Center (NSMC), CMA
7 The full text of this report, which includes an analysis of the “Future climate variation projection for the Reservoir and neighboring areas,” methodology and a complete list of reference is available in the online version of the Bulletin.
and the hilly areas in the eastern part of Sichuan. The Three Gorges Dam controls a drainage area of 1 million square kilometers – 55.6 per cent of the total drainage area of the Yangtze River Basin.

When the Dam’s water level is raised to the desired capacity of 175 m, the 632 km² of land flooded in the Three Gorges Reservoir form a man-made lake 600 km long and 1-2 km wide, with a total area up to 1,084 km². It is able to retain 39.3 billion m³ of water, with a flood control capacity up to 22.15 billion m³. The reservoir feeds the Three Gorges Hydropower Station, which has 34 generator units with an installed capacity of 22.5 million kw and an annual generating capacity of 88.2 billion kwh.

Assessing the climate effects

The CMA study included assessments of the climate effects of large water reservoirs or lakes in various regions of the world, including on Lake Volta, Ghana; Lake Nasser or the Aswan High Dam, Egypt; the Itaipu Dam on the border between Brazil and Paraguay; and the Longyang Gorge and Liujiangxiao Gorge Dams in China. The results show that in the summer, the lake and water surface temperatures in the different localities are lower than over their surrounding land surfaces. As a result, the waters absorb heat, and the exchange of energy from the neighboring areas to the waters is enhanced. In the winter, the process is reversed, and the lakes and reservoirs become heat sources. This enhances the exchange of energy from the reservoirs to the neighboring areas.

An enhanced energy exchange between the reservoir and the neighboring areas could make the atmospheric structure unstable, which could result in a changed precipitation pattern and a changed geographical distribution of precipitation. However, these studies of the climate effects of large reservoirs have concluded that the impoundment of a large reservoir does not significantly impact the climate of a large region.

Scientific issues

The study of the Reservoir’s climate effects would involve three scientific issues: microclimate, interaction between the reservoir and weather events at different scales and the Reservoir’s cumulative climate effects and associated risk assessment.

Basic climatic features of the Reservoir Area

The Three Gorges Reservoir area has a predominantly subtropical monsoon climate. The area is warmer than the eastern China, though at the same latitude, due to the terrain effects of Mount Qinling. It has mild winters, hot summers, rainy seasons with high temperature, and moderate rainfall. The area has an annual mean temperature ranging from 17°C to 19°C with a seasonal temperature variation similar to that of the Yangtze River Basin, but a smaller annual and diurnal range. Warm winters are a unique climatic feature of the area.

The annual rainfall is 1000-1300mm, in a wet-dry-wet distribution pattern from the west to the east. Under the influence of monsoon, the climate presents a distinctive seasonal variation, with rainfall mainly in April-October, and most rainy days in May and October, in a dual-peak pattern that is distinctively different from the single peak pattern that prevails in other parts of the Yangtze River Basin. The area has a sophisticated spatial distribution of climate, especially vertically. The river valley is warm in the winter, while the hilly areas experience cool summers but cool, foggy, wet microclimate in winter.

Climate evolution in the Reservoir Area and the Yangtze River Basin

In the past 50 years, the Reservoir Area has registered an ascending trend for annual mean temperature, with the largest increase in the last 10 years, though the increase is significantly lower compared with the increase of the Yangtze River Basin. In both the Reservoir Area and the Yangtze River Basin, annual precipitation does vary significantly, but inter-decadal figures do show significant variation. The Reservoir Area saw limited annual rainfall variations from the 1960s to the 1990s, though with significantly reduced rainfall in the last 10 years. Meanwhile, the Yangtze River Basin became abnormally wet in the 1990s, but abnormally dry in other years. In the past 50 years or so, both the Reservoir Area and the Yangtze River Basin witnessed a reduced numbers of rainy days, of annual mean wind speed, and of relative humidity, though the former is on the slower side compared with the latter.

In the past 50 years, the Reservoir Area reported a drought and flood variation trend that is basically consistent with the lower and middle streams of the Yangtze River. The Reservoir Area saw significantly reduced annual incidences of consecutive rainy processes, consecutive rainy days, and total rainfall from consecutive rainy processes, but significantly increased numbers of drought days, implying a worsening trend for droughts and an unclear trend for floods. The entire Yangtze River Basin
registered an insignificant increase of high temperature days, while the Reservoir Area had a significant increase of high temperature days. Both the Reservoir Area and Yangtze River Basin claimed significantly reduced annual numbers of thunderstorm and foggy days.

The Yangtze River Basin has seen an ascending trend of annual mean temperature over the past 100 years (1883-2011). However, the upper stream of the Yangtze River and the Three Gorges Reservoir Area reported a cooling trend. Both the Three Gorges Reservoir Area and the Yangtze River Basin have registered a significant warm-cold-warm variation pattern. However, the Reservoir Area’s warming trend slowed noticeably in the 1990s, compared with the other parts of the country. The Reservoir Area has a drought and flood variation trend that is similar to that of the Yangtze River Basin, though significantly correlated to the upper stream.

Also became noticeably stronger, with more snow cover on the highlands and abnormal wetness in the summer, especially in the lower and middle streams of the Yangtze River from the mid-1980s to the 1990s. Then the southern Asia high became abnormally weak from the 1990s, resulting in a significantly reduced snow cover on the highlands that still lasts. In the eastern part of China, rain bands started to make a northward decadal shift, noticeably reducing precipitation over the Yangtze River Basin as of 2000.

In addition, the East Asian summer monsoon saw a significantly weakened inter-decadal variation in the late 1970s. As a result, the Reservoir Area and the Yangtze River Basin experienced an inter-decadal increase of rainfall in the summer, though the Yangtze River Basin became abnormally dry after 2000, under the influence of steadily enhanced East Asian summer monsoon.

Sea surface temperature, another important external forcing factor, would also affect drought and flood variations mainly by changing the position and intensity of the western Pacific subtropical high.

**Reservoir Area climate after impoundment**

The Three Gorges Reservoir started to raise its water level from 69 m to 135 m in June 2003. The water level hit the mark of 156 m in October 2006. During 2008 – 2009, one-month trial runs at 172 meters were staged. When the water level was raised to the highest level, 175 m, on 25 October 2010, the Reservoir entered another trial run phase, during which the water level sat at 175 m in the non-flood season (October-April) then dropped to its lowest level, 145 m, before the onset of flood season (usually in June).

**Variation of basic meteorological elements**

After the impoundment (2004-2011), most parts of the Three Gorges Reservoir Area reported a temperature rise when compared before the operation (1996-2003), with an annual mean temperature around 17.9°C – 18.9°C, or a 0.2°C increase of temperature. The most significant temperature rise occurred in the center of the Reservoir Area, or Qianjiang (0.47°C) in the south of the Reservoir Area, followed by Laifeng (0.39°C). However, the temperature rise apparently failed to pass the 95 per cent statistical confidence. More specifically, the winter and spring months had a mean temperature rise from 0.3°C to 1.1°C, and the summer months from 0.1°C to 0.4°C. The Reservoir Area reported a large inter-annual fluctuation of both extreme maximum and minimum temperatures, though the two temperatures showed a general ascending trend of 0.3°C and 0.6°C, respectively.
The coastal sites along the Reservoir had a smaller temperature rise, compared with other sites in the Reservoir Area. The sites near the Three Gorges Dam area appear to experience a cooling trend. A comparison between the near and distant sites in the Reservoir Area shows that after the impoundment, the sites near the Reservoir Area reported some temperature changes due to the expanded water surface, along with warming winters and slightly cooling summers.

Analysis of MODIS satellite data indicates that the surface temperature near the Reservoir Area has sustained a descending trend since 2001, especially in the Dam area and the upper and middle streams. Taking into account the temperature rise trend across the Reservoir Area in the past 50 years, this is consistent with the temperature variation trends of the southwestern part of China and the Yangtze River Basin. Thus, one can conclude that the impoundment has not significantly impacted temperature variations in the Reservoir Area.

After the impoundment, most parts of the Reservoir Area claimed a declined annual precipitation, though to different extents, mostly between 3 per cent and 4 per cent. The eastern section of the Reservoir Area reported significantly declined precipitation, though there is no obvious change of precipitation distribution in the entire Reservoir Area. Analysis of TRMM satellite data shows that the southern section of Mount Qinling and areas near the Dam experienced a noticeable increase in rainfall, while the downstream area and the southeastern part of the Reservoir Area experience a decline in rainfall (Fig. 10). A wide area analysis suggests that the Reservoir Area is positioned at a transitional section that connects a relatively wet to a relatively dry south. In this context, the Reservoir Area’s precipitation variation bears the regional mark of climate change over a wider area.

After the impoundment, the Reservoir Area registered an annual mean relative humidity between 74 per cent to 78 per cent with a limited inter-annual variability, a 2.4 per cent decline. The decrease was 1 per cent to 3 per cent in the summer and less than 1 per cent in the winter. Absolute humidity increased slightly. The Reservoir Area registered a declined trend for annual mean wind speed at 0.4-2.1 m/s. The wind speeds measured at sites near or distant from the water body showed limited variation, implying that the Reservoir had little effect.

**Changed occurrences of major climatic events**

After the impoundment, the Reservoir Area registered a 32 per cent increase of high-temperature days and 21 per cent decrease of low temperature days, both passed the 95 per cent confidence check. However, the annual number of drought days reported was slightly reduced, though drought days increased slightly in the late summer. The rainstorm days also came diminished, but at the expense of an increased intensity. Consecutive rainy process and lightning weather tended to decline in occurrence. Hazy days started to attract attention for their increased occurrences.

**Numerical modeling of climate effects**

Regional climate modeling shows that the Reservoir would produce some impact on the neighboring areas’ climate, but not beyond a 20 km radius. The Reservoir would noticeably bring down the air temperature above the water surface, by 1°C in the winter, and 1.5°C in the summer, with only 0.1°C for the land surface close to the water. The water body’s evaporative cooling effect would cause the air to sink, and as a result there would be less precipitation. However, the decline in precipitation would be small in winter, a 1 to 2 per cent drop within a 10km radius, and higher in summer, a 10 per cent drop. That 10 per cent would weaken to 3 per cent at 10 per cent drop and 1 per cent at 20 km radius.

Numerical modeling results show that the Reservoir may affect temperature, humidity and wind variations on a local scale - within 10 km – but to what point is undetermined. Whether impacts could be regional (within 100 km) remains controversial.

**Possible causes behind the extreme events**

The special environment, unique climatic conditions and human activities around the Reservoir Area also affect the weather. In recent years, the Reservoir Area saw reduced incidences of foggy days due to climate warming but, unfortunately, ever-increasing human activity exacerbates the problem, so there are more hazy days. The extreme climatic events observed in the region are also closely associated with the changed status of atmospheric circulations in East Asia, Arctic sea ice, tropical sea surface temperature and the Qinghai-Tibet Plateau’s thermal anomaly.

The major droughts and floods that occurred are mainly the results of the abnormal variations of large-scale climatic factors that run across the country. There have been a range such events across the country, including severe rainstorms and floods occurred in Chongqing in the summer of 2007, low temperatures caused disasters in the southern part of China in early 2008, and exceptional consecutive rainy days – a 1 in 50 years events – occurred upstream of the Reservoir Area in the autumn of 2008.
The extensive droughts in the lower and middle streams of the Yangtze River in the spring of 2011 and the sudden shift between droughts and floods in the summer were caused by the abnormal pattern of the tropical Pacific and Indian Ocean sea surface temperatures, the Qinghai-Tibet Plateau snow cover, and the Eurasian atmospheric circulations.

![Graphs showing temperature and precipitation changes](image)

The scope of the Three Gorges Reservoir’s impact on (a) temperature and (b) precipitation in the winter (blue line) and in the summer (red line) as one moves farther away from the Reservoir, simulated by RegCM3/NCC

**Anticipating climate change**

Further analysis of the possible future impacts of climate change on the Project revealed that:

- an increase in annual precipitation variability in the reservoir area may cause runoffs in the upper reaches to fluctuate, leading to greater variation in reservoir water levels, thus increasing instability and hindering safe operation;

- an increase in the frequency and intensity of extreme climate events may lead to exceptional floods, increasing the burden of flood control;

- an increase in the interannual variability of precipitation may result in more droughts, especially in the dry season, affecting the impoundment of the Three Gorges Reservoir and associated power generation, shipping and the water environment; and

- a temperature rise may aggravate the eutrophication of water bodies, thus increasing the vulnerability of natural ecosystems in the reservoir area.

To ease any negative impacts that climate change may have, an adaptation management system will be established and constantly improved at the micro-policy level to ensure the safe operation of the reservoir. At the macro-policy level, national and local government support will be secured for adaptation-related planning and policy-making. This will make climate change adaptation and disaster-risk management a part of the development planning for the reservoir area, allowing sustainable socioeconomic development.

Specific measures to be adopted could include:

- studying and defining the threshold values that may lead to the occurrence of meteorological disasters in the reservoir area;

- enhancing the weather observing network and constructing transport infrastructures in the locality;

- strengthening water pollution prevention and control activities in the reservoir area;

- optimizing the scheduling of the Three Gorges Project and strengthening coordination with the water conservancy projects in the upper stream;

- strengthening the development of innovative hydrologic forecasting techniques that can be applied to different forecast periods;

- optimizing the project’s drought resistance plan;

- taking positive industry adaptation measures; and

- strengthening the ecological environmental protection activities in the reservoir area.

**Towards climate services**

CMA’s study of climate in the reservoir area has led to a clearer understanding of the causes of the extreme events observed since impoundment and to the conclusion that the effects of the Project are minimal and within a 10 km radius. Further analysis of future impacts of climate change has revealed that there may be risks and/or benefits for the reservoir area. Climate services for the Three Gorges Water Control Project that build on CMA’s scientific study and the adaptation management system will be developed under China’s national framework for climate services in order to assist in decision-making to mitigate the risks and maximize the benefits.