

CLIMATE KNOWLEDGE FOR ACTION:

**A GLOBAL FRAMEWORK
FOR CLIMATE SERVICES—
EMPOWERING
THE MOST VULNERABLE**



**THE REPORT OF THE HIGH-LEVEL TASKFORCE
FOR THE GLOBAL FRAMEWORK
FOR CLIMATE SERVICES**

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PREFACE

BY THE SECRETARY-GENERAL OF THE WORLD METEOROLOGICAL ORGANIZATION

Over the last years, a strong spirit of multilateralism has prevailed in the concerted international response to a number of key global issues, such as the recent financial, health and food crises. Likewise, in September 2010 the international leadership gathered at the United Nations to assess progress in the achievement of the Millennium Development Goals and to plot the course for the period leading to the established 2015 deadline.

Partaking in this optimistic spirit we were especially honoured in 2007 when the World Meteorological Organization co-sponsored Intergovernmental Panel on Climate Change received the prestigious Nobel Peace Prize and we were stirred to action in 2009 as a result of the historic third World Climate Conference, which unanimously agreed to develop a Global Framework for Climate Services and called upon the World Meteorological Organization to convene, in urgency, an intergovernmental meeting to approve the terms of reference and to endorse the composition of a Taskforce of High-level independent advisors which, after wide consultations, would prepare within 12 months a report, including recommendations on proposed elements for this Framework and next steps, for consideration in May 2011 by the Sixteenth World Meteorological Congress.

In developing this Global Framework for Climate Services, it will be essential to build upon many of the capabilities and shared responsibilities which are already in place today, in particular those being provided 24 hours a day, 7 days a week, through the key contributions of the National Meteorological and Hydrological Services of the World Meteorological Organization's 189 Members and the programmes and activities which the World Meteorological Organization co-sponsors with partners, such as the Global Climate Observing System and World Climate Research Programme, for they will contribute significantly to the Global Framework for Climate Services observations and monitoring, as well as to its research, modeling and prediction components. However, from a wider perspective, Global Framework for Climate Services implementation will also be a critical cooperative task of the entire United Nations System Delivering as One on climate knowledge.

It should be stressed that several key Global Framework for Climate Services components in the developing world will require reinforcing, so I am especially pleased that the High-Level Taskforce has very clearly underscored the imperious need for capacity building, as a vital substrate to ensure the sustainability of all the Framework elements.

It has been a real privilege and a pleasure to interact with the High-Level Taskforce and to support its members as they addressed the World Climate Conference-3 expectations. All fourteen High Level Taskforce members contributed their unique and priceless perception on the way to optimally develop and to implement the Global Framework for Climate Services, as well as on various fundamental issues such as Framework governance, among others. I was indeed amazed by the remarkable harmony and collective wisdom which facilitated the consensus view manifestly reflected throughout their report.

I therefore wish to express my most sincere gratitude to the entire Taskforce for this key report, which will rapidly become an invaluable asset for all Members and sectors requiring climate services to fully exploit climate as a resource, as well as to the even wider global audience which, as we proceed into the twenty-first century, will increasingly need to manage the mounting risks and impacts of climate variability and change.

In 2009, the World Climate Conference-3 made a historic decision at the same level as the other two World Climate Conferences which the World Meteorological Organization organized with its scientific partners in 1979 and 1990. An inspired High-Level Taskforce has just completed its mission successfully and it will now be up to the Sixteenth World Meteorological Congress to adopt another historic decision, thereby enabling the Global Framework for Climate Services to advance from a vision to a tangible reality, for the benefit of all sectors and across all nations, but especially to meet the vital needs of the vulnerable developing world.

A handwritten signature in black ink, appearing to be 'M. Jarraud', written in a cursive style with a large, sweeping flourish at the end.

(M. Jarraud)

FOREWORD

BY THE MEMBERS OF THE HIGH LEVEL TASKFORCE

As a Taskforce, we present this report with a clear and striking appreciation of three basic facts. Firstly, we know that everyone is affected by climate – particularly its extremes, which cause loss of lives and livelihoods all over the world, but overwhelmingly in developing countries. Secondly, we know that – where they exist – needs-based climate services are extremely effective in helping communities, businesses, organizations and governments to manage the risks and take advantage of the opportunities associated with the climate. Thirdly, we know that there is a yawning gap between the needs for climate services and their current provision. Climate services are weakest in the places that need them most – climate-vulnerable developing countries.

We feel this situation is unacceptable and unjust, and we are unanimous in putting forward this proposal to address it. Our vision is for an end-to-end system for providing climate services and applying them in decision making at every level of society. Putting this system in place will require unprecedented collaboration across political, functional, and disciplinary boundaries and a global mobilisation of effort.

We believe the Global Framework for Climate Services is the right vehicle to guide and coordinate this effort. For a modest investment, and by building on existing systems and capacities, we believe it can achieve great benefits. Great benefits in terms of reduced disaster risks, increased food security, improved health, and more effective adaptation to climate change. Great benefits in terms of development and well being in all countries – but particularly for the poorest and most vulnerable.

In formulating our proposal, we have been reliant on the enormous expertise and enthusiasm for our work, across governments, international and non-governmental organizations, technical communities, climate service users and many other stakeholders and we would like to thank everyone who made a contribution to this Report. It is you that we will again rely on, this time to translate our ideas and strategy into practice and success.



Mahmoud Abu Zeid (Co-chair) – Egypt



Jan Egeland (Co-chair) – Norway



Joaquim Chissano – Mozambique



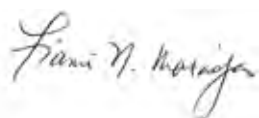
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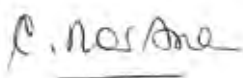
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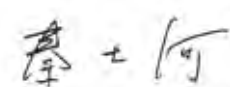
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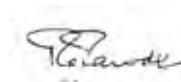
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Chiaki Mukai – Japan



Rajendra Singh Paroda – India



Emil Salim – Indonesia

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The Taskforce has benefited from valuable consultations and briefings in: Nairobi, Kenya, 12–16 April; Bali, Indonesia, 30 April–6 May; Geneva, Switzerland, 18 May, 25 May, 2 June, 9 June, 29 October and 17 December; Oslo, Norway, 8–12 June; Beijing, China, 17–18 June and 2–4 August; Delhi, India, 21 June; Mexico City, Mexico, 5–7 July; Belo Horizonte, Brazil, 1–4 July; Bogota, Colombia, 22–29 September; Bonn, Germany, 2–4 August; Marrakech, Morocco, 28 October–4 November; Cayman Islands, Caribbean, 9–10 November; Santiago, Chile, November 17–19; Windhoek, Namibia, 15–21 November; Washington, United States of America, 2–3 December; Cancun, Mexico, 29 November–10 December. We thank everyone who participated in these sessions and gave so freely of their time and knowledge.

The Taskforce is grateful to the governments and experts who provided comments on the draft report that was released in November 2010 and to the governments who contributed generously to the Trust Fund that supported this initiative.

Finally, the Taskforce would like to express its gratitude to the Secretariat of the World Meteorological Organization, which did a wonderful job of managing the Taskforce meetings and consultations and provided excellent support in the preparation of the Report. Without our hard-working, talented and service-oriented Secretariat and the expert drafting team under the able leadership of Geoffrey Love, to whom we are particularly grateful, we would not have been able to finish our substantive report on schedule and with consensus.

AN OPPORTUNITY FOR THE WORLD

Climate is a critical factor in the lives and livelihoods of all people and in development as a whole. This report proposes how a global system for the provision of climate services¹ can be set up over the next few years that will save lives and protect the jobs and homes of vulnerable people.

On the basis of its work and wide consultations, the High-Level Taskforce believes that the widespread, global use of improved climate services, provided through the Global Framework for Climate Services will provide substantial social and economic benefits. The Framework presents an important, cost effective opportunity to improve well being in all countries through contributions to development, disaster risk reduction and climate change adaptation. A global mobilisation of effort and an unprecedented collaboration among institutions across political, functional, and disciplinary boundaries is required and the Taskforce believes that the Global Framework for Climate Services can foster and guide this effort.

While all countries stand to gain from participation in the Framework, the Taskforce believes that it should give priority to climate vulnerable developing countries, particularly African countries, least developed countries, land-locked developing countries and small island developing states, where climate services are also often weakest.

FINDINGS OF THE HIGH LEVEL TASKFORCE

The Taskforce worked in consultation with all relevant actors to assess the current state of global climate service provision and identify opportunities for improvement, finding that:

- In countries that have effective climate services they greatly contribute to reduced risks and maximised opportunities associated with climate. However, there is a significant gap between the supply of climate services and the needs of users. Present capabilities to provide climate services do not exploit all that we know about climate, fall far short of meeting present and future needs, and are not delivering their full and potential benefits. This is particularly the case in developing and least developed countries, which are also the most vulnerable to the impacts of climate variability and change;
- To be useful climate information must be tailored to meet the needs of users. Existing climate services are not well focused on user needs and the level of interaction between providers and users of climate services is inadequate. Users need access to expert advice and support to help them select and properly apply climate information. Climate services often do not reach “the last mile”, to the people who need them most, particularly at the community level in developing and least developed countries;
- To support climate services, high quality observations are required across the entire climate system and of relevant socioeconomic variables. While existing capabilities for climate observation provide a reasonable basis for strengthening climate services, commitment to sustaining high quality observations is inadequate and enhancements to existing networks are required, particularly in developing countries. Further effort is also needed by governments and others to overcome the currently significant restrictions concerning sharing of, and access to climate and other relevant data;

¹ Climate services are climate information prepared and delivered to meet users’ needs.

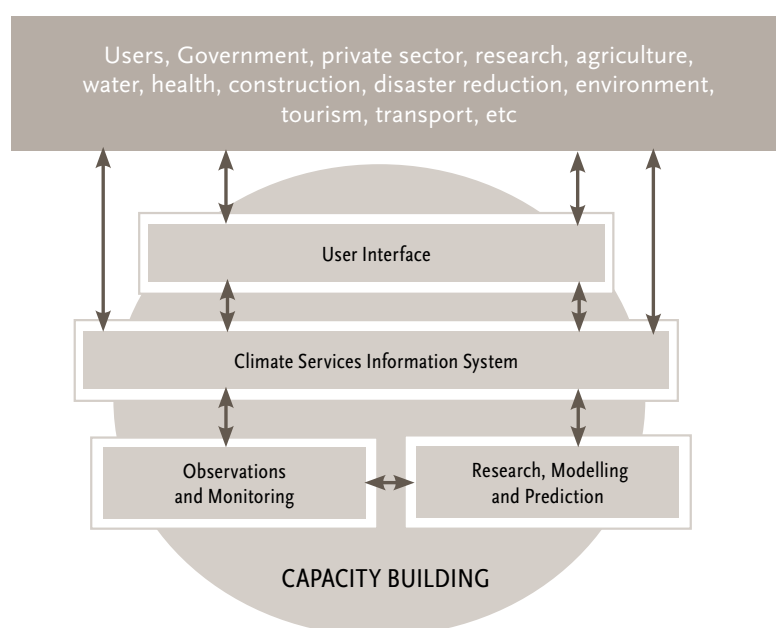
- Effective climate services will depend on maximising the potential of existing knowledge, new research developments and strong support from and strengthened collaboration between all relevant research communities. Understanding of the climate system is advancing quickly, but is not being effectively translated into services that can inform decision making. In particular, further effort is required to improve our ability to predict climate and help users incorporate its inherent uncertainty into their decision-making;
- Efforts to provide effective climate services globally will only be successful if capacity is systematically built to enable all countries to manage climate risk effectively. Current capacity building activities to support climate services need to be scaled up and better coordinated. A comprehensive capacity building initiative is needed to strengthen existing capabilities in the areas of governance, management, human resources development, leadership, partnership creation, science communication, service delivery and resource mobilisation.

COMPONENTS OF THE GLOBAL FRAMEWORK FOR CLIMATE SERVICES

The Taskforce broadly endorses the structure of the Framework, as proposed by the World Climate Conference-3, but with the addition of a capacity building component.

The proposed components of the Framework are as follows:

1. The User Interface Platform will provide a means for users, user representatives, climate researchers and climate service providers to interact, thereby maximising the usefulness of climate services and helping develop new and improved applications of climate information.
2. The Climate Services Information System is the system needed to protect and distribute climate data and information according to the needs of users and according to the procedures agreed by governments and other data providers.



A schematic of the components of the Global Framework for Climate Services with capacity building occurring within, and between all other components.

3. The Observations and Monitoring component will ensure that the climate observations necessary to meet the needs of climate services are generated.
4. The Research, Modelling and Prediction component will assess and promote the needs of climate services within research agendas.
5. The Capacity Building component will support systematic development of the necessary institutions, infrastructure and human resources to provide effective climate services.

Many of the foundational capabilities and infrastructure that make up these components already exist or are being established, but they require coordination and strengthened focus on user needs. The role of the Framework should therefore be to facilitate and strengthen, not to duplicate.

ROLES AND RESPONSIBILITIES AT GLOBAL, REGIONAL AND NATIONAL LEVELS

The Taskforce believes that providing operational climate services should be the focus of the Framework. It should operate at global, regional and national levels, in support of and in collaboration with global, regional and national stakeholders and efforts.

- At the global level, it will focus on producing global climate prediction products, coordinating and supporting data exchange, major capacity building initiatives, and establishing and maintaining standards and protocols;
- At the regional level, it will support multilateral efforts to address regional needs, for example through regional policy development, knowledge and data exchange, infrastructure development, research, training and the provision of services regionally to meet agreed regional requirements;
- At the national level, it will focus on ensuring access to data and knowledge products, tailoring information to user requirements, ensuring effective routine use of information in planning and management along with developing sustainable capacities in these respects.

Depending on their needs and capacities, users may obtain information from a range of available global, regional and national sources.

OVERALL IMPLEMENTATION OBJECTIVES OF THE FRAMEWORK

The Taskforce proposes that the five near-term implementation objectives for the Framework be as follows:

- Establishing mechanisms to strengthen the global cooperative system for collecting, processing and exchanging observations and for using climate-related information;
- Designing and implementing a set of projects that target the needs of developing countries, particularly those currently least able to provide climate services;

- Developing strategies for external communications, resource mobilisation and capacity building programmes;
- Establishing internal working methods, particularly for communications and for debating and deciding on implementation priorities, including for the observations, information systems, research and capacity building components;
- Setting targets and establishing procedures for monitoring and evaluating the performance of the Framework.

RESOURCING THE IMPLEMENTATION OF THE FRAMEWORK

The Taskforce unanimously recommends (Recommendation 1) that the international community makes the commitment to invest on the order of US\$ 75 million per year to put in place and sustain the Framework. This investment will build upon existing investments by governments in climate observation systems, research, and information management systems to return to the community benefits across all societal sectors but most importantly, and most immediately, in disaster risk reduction, improved water management, more productive and sustainable agriculture and better health outcomes in the most vulnerable communities in the developing world.

PRINCIPLES TO BE ADOPTED IN IMPLEMENTING THE FRAMEWORK

To ensure that the Global Framework for Climate Services provides the greatest benefit to those who are most in need of climate services, the Taskforce recommends (Recommendation 2) that the following eight principles be adhered to in its implementation:

Principle 1: All countries will benefit, but priority shall go to building the capacity of climate-vulnerable developing countries

Principle 2: The primary goal of the Framework will be to ensure greater availability of, access to, and use of climate services for all countries

Principle 3: Framework activities will address three geographic domains; global, regional and national

Principle 4: Operational climate services will be the core element of the Framework

Principle 5: Climate information is primarily an international public good provided by governments, which will have a central role in its management through the Framework

Principle 6: The Framework will promote the free and open exchange of climate-relevant observational data while respecting national and international data policies

Principle 7: The role of the Framework will be to facilitate and strengthen, not to duplicate

Principle 8: The Framework will be built through user – provider partnerships that include all stakeholders

IMMEDIATE IMPLEMENTATION PRIORITIES

CAPACITY BUILDING IN DEVELOPING COUNTRIES

The Taskforce believes that a strategy for building capacity in developing countries will be essential in successful implementation of the Framework. This will include a strong Management Committee for Capacity Building in both governance options proposed for the Framework. A principal near-term strategy for the implementation of the Framework should be designing and implementing a range of projects that target the needs of developing countries. Specifically, the Taskforce proposes the following capacity building projects, to be implemented as soon as possible:

- **Linking climate service users and providers.** The Taskforce is proposing that the Framework include a User Interface Platform to link climate service providers and users with a view to building the capacity of users to make better use of climate services, collecting user requirements, assisting in the monitoring and evaluation of the Framework and promoting a global understanding of the Framework;
- **Building national capacity in developing countries.** The Taskforce has found that about 70 countries do not have the necessary basic capabilities to provide sustainable access to climate services. It therefore recommends that a high profile programme of fast-track projects be established to build the necessary capacity of the countries, in accordance with their needs and priorities;
- **Strengthening regional climate capabilities.** Enhanced regional coordination and technical capabilities will be important to the functioning of the Framework. The Taskforce therefore recommends that a fully effective network of regional centres be established. This will require strengthening existing centres and creating a number of new centres. The roles and activities of regional climate centres will vary according to each region's specific interests and needs.

BUILDING CAPACITY TO IMPLEMENT THE USER INTERFACE PLATFORM IN THE DEVELOPING WORLD

A key to the long term success of the Framework will be its ability to interact with its user community to enable it to properly tailor climate services to meet community needs. The Taskforce urges that new efforts be made to develop the dialogue between providers and users and to focus on developing and implementing measures of the Framework's success in meeting needs, and using these monitoring results to continuously evaluate and improve the overall performance of the Framework.

IMPROVING CLIMATE OBSERVATIONS IN DATA SPARSE AREAS

Effective climate services rely on the availability of adequate, high quality climate data. The Taskforce proposes that a programme be put in place to address the problem of gaps in the two basic atmospheric global observation systems, the Global Surface Network and the Global Upper Air Network.

BUILDING THE CAPACITY OF THE CLIMATE RESEARCH SECTOR IN DEVELOPING COUNTRIES

To improve the rate at which research results flow to services, and to improve the quality and relevance of climate services, particularly in the developing world the Taskforce's proposal includes a programme of capacity building in the research sector of developing countries.

APPROACHES TO GLOBAL DATA POLICY

The Taskforce believes that barriers to accessing and using existing data sets are a major shortcoming in the provision of climate services. To overcome these barriers, the Taskforce proposes that existing international deliberative mechanisms, principally within the World Meteorological Organization System, be used to reach agreement on what essential climate data and products are needed to provide effective climate services and what can be shared in support of the protection of life and property and the well-being of all nations.

BUILDING A SUSTAINABLE LEADERSHIP AND MANAGEMENT CAPABILITY

Implementation of the Framework will require the establishment of a leadership team that has government ownership and support, as well as support from the United Nations System. This core of leadership and technical expertise that will drive the implementation of all aspects of the Framework in collaboration with existing national and regional capacities, should be supported by a small, United Nations-based secretariat.

DEVELOPING A DETAILED IMPLEMENTATION PLAN

This Report of the Taskforce provides a strategic level plan for the implementation of the Framework. After endorsement of this plan we recommend (Recommendation 3) that the United Nations System-establish, as a matter of urgency, an *ad-hoc* technical group to develop a detailed implementation plan for the Global Framework for Climate Services based upon the broad strategy outlined in this report, this plan to be endorsed by governments through an intergovernmental process prior to its implementation.

The detailed implementation plan should identify high priority projects to advance the Framework in areas where this would assist in reducing vulnerability to climate change and variability. In addition to the fast-track, capacity building projects, the implementation plan should describe a sustainable programme to underpin the coordination needed to maintain the operational capabilities of the Framework. The implementation plan should set targets to be achieved over the next ten years, further elaborate the roles and responsibilities of components of the Framework that contribute at the global, regional and national levels and of the secretariat that supports it, and include a risk assessment.

INDICATORS AND TIMELINES FOR IMPLEMENTING THE FRAMEWORK

The Taskforce proposes the following indicators and timelines for implementing the Framework:

- **By end 2011.** Develop a detailed implementation plan for the Framework that aligns with the decisions of the World Meteorological Organization Congress and incorporates the elements and principles proposed in this report. This plan to be considered at the inaugural, intergovernmental plenary meeting of the Framework's Board;
- **By end 2013.** Complete an organization building phase, including establishment of a secretariat to support the Framework and necessary management (technical) and executive committee structures. Establish programmes to undertake immediate implementation priorities;
- **By end 2017.** Facilitate access to improved climate services globally in four priority sectors (agriculture, disaster risk reduction, health and water). Establish active technical committees for each component and an active communications programme. Involve at least five United Nations entities and participate in at least US\$ 150 million of climate-related development projects. Completion of a mid-term review of the implementation of the Framework;
- **By end 2021.** Facilitated access to improved climate services globally across all climate-sensitive sectors. Involve at least eight United Nations entities and participate in at least US\$ 250 million of climate-related development projects.

RESOURCING THE CAPACITY BUILDING ELEMENTS OF THE FRAMEWORK'S IMPLEMENTATION

The Taskforce proposes the governments commit to supporting a modest secretariat requiring an investment of around US\$ 3 million per annum that will have the role of supporting the leadership and management structures of the Framework. As regards capacity building the Taskforce has proposed the implementation of a range of "fast track" projects aimed at building capacity in the developing world to create and deliver climate services requiring an investment of the order of US\$ 75 million per annum. The Taskforce strongly recommends (Recommendation 4) that governments and development assistance agencies give high priority to supporting national capacity building that will allow developing countries to participate in the Framework. Further analysis of national needs is required, but in the meantime we recommend a number of fast track projects as outlined in the Report. To ensure effective national access to global climate information by the largest number of countries, we recommend an initial strategy to strengthen rapidly or create the regional elements of the Framework. These regional elements should be led and hosted by countries of the region based upon regional agreements and should be tasked with supporting information flow and assisting national capacity building at national level.

GOVERNANCE OF THE FRAMEWORK

The Taskforce considered a number of options for governance of the Framework, taking into account the need to ensure the central role of governments, other needs based on the Taskforce's findings, and common principles, such as efficiency, transparency, accountability, flexibility, equitability and

participation. On the basis of these considerations, the Taskforce recommends (Recommendation 5) the following two governance options for the Framework be considered:

- **OPTION A – Create a new intergovernmental board within the United Nations System.** An Intergovernmental Board on Climate Services would be established to provide leadership and direction for the Framework. It would report to the World Meteorological Organization Congress. The Board would be open to membership of all countries and would meet in plenary session periodically, probably annually. It would develop formal mechanisms to engage the United Nations and other stakeholders in its work. It would elect a chair and a small executive committee to conduct the affairs of the board between sessions as well as designating a number of technical management committees to oversee and contribute to the Framework's implementation work. These technical committees would work intergovernmentally, and, where possible, would be based on relevant existing international committees;
- **OPTION B – Develop a joint board within the United Nations, hosted and convened by an existing Agency.** A joint board of relevant United Nations System entities (agencies, organizations, programmes, departments and independent funds) would be created to provide leadership and direction for the Framework. The United Nations System joint board would report regularly to the United Nations Chief Executives Board as well as to governments through the plenaries of the sponsoring United Nations agencies and programmes. The joint board would establish an executive committee and five technical management committees to implement and manage the Framework, of the technical committees working intergovernmentally. Mechanisms to engage non-United Nations stakeholders in the work of the Board would be developed through both the User Interface Programme and, up to the level desired by governments, through participation in national delegations.

The Taskforce recommends that Option A be adopted and that the Secretary-General of the World Meteorological Organization convene the first intergovernmental plenary meeting of the Global Framework for Climate Services by the end of 2011. The World Meteorological Organization should lead the process and put in place arrangements to ensure full participation of all interested United Nations agencies and programmes.

The Taskforce considers the main advantages of Option A are that the Framework would have a clear and independent realm of responsibility, direct accountability to governments, potentially strong involvement of national technical experts and the independence and high profile that would help secure good access to United Nations system entities and processes. The main advantages of Option B are that it can be implemented quickly and can immediately engage the mechanisms of the United Nations System and the financial requirements for governance and management are likely to be lower.

CLIMATE AND CLIMATE SERVICES

Every day individuals, organizations and governments in highly climate-sensitive sectors like disaster reduction, agriculture, health and water make decisions aimed at reducing the risks and taking advantage of the opportunities associated with climate. Society has always had to deal with climate variability, including extreme weather and climate events, but climate change presents new and greater challenges. Many normal activities and decision-making processes assume a continuation of past climatic conditions, but that assumption is no longer valid. To make better decisions that involve climate, households, communities, businesses and governments need to have access to climate information that is suited to their particular needs as well as practical guidance on how they can use it.

Climate services encompass a range of activities that deal with generating and providing information based on past, present and future climate and on its impacts on natural and human systems. Climate services include the use of simple information like historical climate data sets as well as more complex products such as predictions of weather elements on monthly, seasonal or decadal timescales, also making use of climate projections according to different greenhouse gas emission scenarios. Included as well are information and support that help the user choose the right product for the decision they need to make and that explain the uncertainty associated with the information offered while advising on how to best use it in the decision-making process.

Examples of the uses of climate services are as follows:

- Climate predictions can be used by farmers to help them decide, for example, which crops to plant or whether to reduce livestock numbers if a drought is forecast. Farmers making such decisions are likely to use climate outlooks of rainfall and temperature and take into account the uncertainty estimates provided with these products;
- Statistical assessments of the future frequency of extreme weather and climate events can be used by engineers to help them make decisions, including where to invest in disaster mitigation measures such as dams, where to locate buildings, which construction methods to use and how much heating and cooling is needed for critical infrastructure;
- Seasonal climate forecasts and monitoring of actual temperature and rainfall can be used to provide forecasts of when and where disease outbreaks are likely to occur. The impacts of predicted outbreaks can then be minimised by public awareness campaigns, stocking and shipping medical supplies and vector control programmes such as spraying;
- Climate change projections, which can indicate precipitation patterns in the 30-to-50-year timeframe, can be used to guide major investment decisions relating to long-term water management such as whether and where to build new reservoirs.

Providing effective, needs-based climate services globally requires: (1) mechanisms that allow for user needs to inform the development and provision of climate services and for promoting the demand for climate services where the needs are insufficiently recognised; (2) a physical means of communicating climate information; (3) accurate observations and monitoring of climate and relevant non-climatic variables; (4) an understanding of the climate system and its impacts and how they can be predicted; and (5) sufficient capacity in all parts of the process of climate service development, delivery, evaluation and use to ensure that the benefits of climate knowledge are maximised in all countries.

Box I.1. SOME BASIC CLIMATE DEFINITIONS

Climate: Climate is typically defined as the average weather over a period of time. The quantities measured are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense, on the other hand, is the state of the climate system, including its statistical description. For the purposes of this report we have used the term climate to cover time periods of months or longer.

Climate change: Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. The Intergovernmental Panel on Climate Change uses a relatively broad definition of climate change that is considered to mean an identifiable and statistical change in the state of the climate that persists for an extended period of time. This change may result from internal processes within the climate system or from external processes. These external processes (or forcing) could be natural, for example volcanoes, or caused by the activities of people, for example emissions of greenhouse gases or changes in land use. Other bodies, notably the United Nations Framework Convention on Climate Change, define climate change slightly differently. The United Nations Framework Convention on Climate Change makes a distinction between climate change that is directly attributable to human activities and climate

variability that is attributable to natural causes. For the purposes of this report, either definition may be suitable depending on the context.

Climate product: The end result of a process of synthesising climate science and data.

Climate service: Climate information prepared and delivered to meet a user's needs.

Climate variability: Climate variability refers to variations in the mean state and other statistics relating to the climate on all temporal and spatial scales beyond that of individual weather events. Climate can and does vary quite naturally, regardless of any human influence. Natural climate variability arises as a result of natural internal processes within the climate system or because of variations in natural external forcing such as solar activity.

Extreme weather and climate events: Extreme events refer to phenomena, such as floods, droughts and storms, that are at the extremes of (or even outside) the historical distribution.

Weather: The state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity and barometric pressure.

INTERNATIONAL EFFORTS TO STRENGTHEN CLIMATE SERVICES

Global decision makers are increasingly concerned by the adverse impacts of climate variability and change, and there is a growing demand for better climate services. In 2009 this movement came together at World Climate Conference-3, which assembled delegates from more than 150 countries, 34 United Nations organizations and 36 other governmental and non-governmental international organizations.

The Heads of States and Governments, Ministers and Heads of Delegations present at the Conference decided to establish a Global Framework for Climate Services to strengthen the production, availability, delivery and application of science-based climate prediction and services. They requested that a taskforce of high-level, independent advisors be appointed to consult widely with governments and relevant stakeholders and to prepare a proposal for implementing the Framework.

THE GLOBAL FRAMEWORK FOR CLIMATE SERVICES

The Global Framework for Climate Services is envisaged as a set of international arrangements that will coordinate global activities and build on existing efforts in order to provide climate services that are truly focused on meeting user needs, are available to those who need them and that provide the greatest benefits possible from knowledge about the climate. The Framework is intended to provide widespread social, economic and environmental benefits through more effective climate and disaster risk management. In particular it will support the implementation of climate change adaptation measures, many of which will require climate services that are not currently available. There will also be benefits for climate change mitigation in the form of information that can support the development of renewable energy infrastructure and other mitigation measures such as reforestation. The Framework is expected to bridge the gap between the climate information being developed by scientists and service providers and the practical needs of users. It would ensure that every country is better equipped to meet the challenges of climate variability and change.

THE HIGH LEVEL TASKFORCE: ITS APPROACH AND PROCESS

The High Level Taskforce for the Global Framework for Climate Services began work in January 2010. Its aim was to develop the components of the Framework and clearly illustrate how it would promote the integration of climate information into decision making at all levels and across all sectors of society. In particular, the Taskforce wanted to ensure that the Framework would take into account the special needs of Africa, Small Island Developing States, Least Developed Countries, and Landlocked Developing Countries and other vulnerable countries.

The Taskforce approached its task as follows: In order to understand better the needs of all users of climate information and the perspectives of providers, it undertook numerous consultations with governments, United Nations agencies, international and regional organizations and non-governmental organizations. It reviewed the current capabilities for providing climate services and assessed them against the needs of users. On the basis of this analysis the Taskforce identified gaps in the existing provision of climate services as well as opportunities for strengthening this provision. Lastly, the Taskforce developed its proposal for the Framework to ensure that the gap between the provision of climate services and the need for them was closed and that opportunities for strengthening services to meet existing and new demands would be fully exploited.

PURPOSE AND STRUCTURE OF THE REPORT

This report contains the findings of the High Level Taskforce along with its proposal for how the Framework should be implemented and governed. It provides overall direction in the development of the Framework and does not contain technical details. The report will be considered by Members of the World Meteorological Organization at their Congress in 2011, with a view to adopting and implementing the Framework. It is also intended to provide a basis for relevant organizations and expert communities to consider how they can contribute to the Framework's objectives as well as how the Taskforce's proposals might be translated into detailed work plans.

The structure of the report is based on the approach described above. Part I describes the current uses of climate information in decision making (Chapter 1). It looks at current capabilities and coordination mechanisms, highlighting important concepts in each of the three foundational components of climate service provision – observations (Chapter 2), research (Chapter 3) and capacity building (Chapter 4).

Part II assesses the demand for climate services. It describes how climate information is used in a number of socio-economic sectors and analyses their needs (Chapter 5). It looks at the needs for climate services to support international policy commitments such as the Millennium Development Goals (Chapter 6). A series of case studies are used to analyse the diverse needs of countries for climate services and to highlight the different levels and types of climate service development across countries (Chapter 7).

Part III presents the Taskforce's proposal for the Global Framework for Climate Services. It commences with Chapter 8 by drawing on the information in Chapters 1–7 to identify gaps in current capabilities. It then sets out details of how the Taskforce proposes that the Framework be implemented (Chapter 9) and options for the Framework's governance (Chapter 10). Chapters 9 and 10 close with a series of recommendations arising from our work and identify immediate next steps for establishing the Framework.

PART 1
CURRENT CAPABILITIES FOR
CLIMATE SERVICES

CHAPTER 1

CLIMATE INFORMATION AND PREDICTIONS

1.1 INTRODUCTION

In this chapter we describe the main categories of users of climate services and the ways they use and benefit from available climate information. We examine the nature of the climate system, the use that can be made of the climate record and how scientists can make predictions and projections of climate some seasons, years and decades ahead. We also assess the types of information that are currently available and of the organizational arrangements that countries have developed to meet the growing demand for climate services.

1.2 USE AND USERS OF CLIMATE INFORMATION

CLIMATE AND SOCIETY

The climate of a locality affects the daily life, economic activities and the social and cultural attributes found there. Rainfall provides water for agriculture and industry; warm conditions can accelerate plant growth and fruit setting; wind, rain and temperature dictate the design of houses, consistent strong winds in the upper atmosphere determine preferential flight paths for aircraft. Prolonged drought, torrential rains or unusually bitter winters affect livelihoods, bring insecurity and sometimes death and destruction.

The climate of places is thus of considerable interest to most people. Climate knowledge and data, from both scientific and traditional or indigenous sources, are widely used for a variety of purposes such as organising agricultural activities, preventing infectious disease outbreaks, designing water supply systems and drains and choosing tourist destinations.

The effects of climate are strongly linked to and superimposed on existing vulnerabilities, especially poverty. The poor have fewer financial and technical resources available to help them cope with climate risks and are often also heavily dependent on climate-sensitive resources. Other social, economic, cultural and political factors, such as social exclusion, inadequate social services and infrastructure, and lack of access to important resources, especially natural resources such as land and water, can exacerbate the vulnerability of certain groups. For example, women are often particularly vulnerable to the impacts of climate due to their responsibilities in the home and their limited access to information, resources and services. Other groups, such as pastoralists, the elderly, the disabled, and the geographically remote, may also be particularly vulnerable.

EVOLUTION IN THE USE OF CLIMATE KNOWLEDGE

Agriculturalists and traditional hunters and gatherers have been the pioneer users of climate knowledge since well before the days of thermometers and rain gauges. Crop calendars, crop diversification, methods of water collection and retention and wind shelters have been around for thousands of years and still, in modern forms, remain in common use.

With the development of science and its measurement capabilities from the 18th century onward, the basis for a new era of engineering and management was established. Quantitative data and methods were increasingly used for economic advantage, especially in agriculture, water supply, energy and transportation and in the detailed design of production systems and the construction of infrastructure. Long series of observations provided increasingly robust data on the probability of rare damaging conditions occurring, and this made developing formal risk management

approaches possible. These observations now form a primary source of evidence for assessing the rate and direction of climate change, and continue to form a fundamental input to modern climate services.

More recently the Earth and its climate are understood to be a complex system. Computers, observation and telecommunication systems, remote sensing, mathematical models and mapping software now provide tools that can help unravel the complexity of this system and answer important practical questions concerning future risks and management responses. Traditional uses of climate statistics are increasingly being complemented by innovative risk management approaches (Box 1.1 and 1.2). Through scientific development and high quality data sets the workings and impacts of the El Niño system have been revealed, and the implications of increasing concentrations of greenhouse gases are being realised.

USERS, DECISION MAKING AND ADDING VALUE

The principal categories of users are policymakers, managers, engineers, researchers, students and the public at large. The significance of climate information is best determined from the value it adds to their activities and decisions as seen through their own eyes.

Decision making is usually driven by imperatives – for example, the need to submit a building design by a specific date or to decide when to plant or harvest – and by a broad context of relevant economics, law, cultural expectations and individual preferences. These decisions will be made whether or not climate information is available, so for the potential user the question is simply one of whether adding climate information to the mix of factors involved is likely to improve the decision and promote the desired outcome, either, for example, by increasing efficiency or by reducing costs.

USES IN POLICY AND PLANNING

Policymakers and their advisers are concerned with broad public concerns such as efficient functioning of markets and industry, management and conservation of natural resources, regulation of land use, public health and well-being and protecting society from potential threats. Each of these is influenced by climate. At the global and regional levels there are a number of important intergovernmental conventions and agreements that require climate information, particularly, those concerned with development goals, climate change, environmental management and disaster risk reduction.

Good policy and planning depends on good evidence and information. Climate information is critical for major decisions concerning, for example, new water supply reservoirs, plans and infrastructure for expanding settlements and sectoral economic policy targeting climate-sensitive industries, e.g., tourism, renewable energy or aquaculture. Policymakers also acknowledge the need for publicly-available data and knowledge to support research, innovation and education. Increasingly they want better insight into, and preparedness for, an uncertain future in order to protect people against global threats such as climate change.

USES IN MANAGEMENT

Farmers, engineers and managers of public and private enterprises are key users of climate information. They use the information to plan, design and configure their enterprise properly for best returns over the lifetime of their investment and secondly to manage the operations of the enterprise efficiently and profitably. This inevitably involves dealing with climate variability in a risk framework as discussed in Box 1.1.

Box 1.1. CLIMATE INFORMATION AND RISK MANAGEMENT

Climate information plays a key role in managing risks in climate-sensitive industries but the way it is used is entirely dependent on the user's circumstances and the decisions and tradeoffs involved. For example, a soft drinks manufacturer that supplies a large mid-latitude city will likely react to a forecast of an increased chance of above-normal temperatures in summer quite differently to a similar forecast for winter. An

unusually hot summer is likely to result in a large increase in demand for soft drinks, whereas an unusually warm winter is unlikely to have much impact on demand. The soft drinks manufacturer is likely to consider temporarily expanding on its usual operations prior to expected heatwaves in summer in order to increase profits, but is less likely to adjust its usual operations in winter. This decision to expand operations in anticipation of increased summer demand will need to be weighed against the costs of hiring and training new staff, procuring extra supplies, and possibly requiring additional storage space in the event of demand failing to rise as much as anticipated. If the drinks are perishable the potential losses incurred through unsold products will also have to be assessed. The availability of an insurance policy significantly alters the assessment of the risks involved. While insurance companies are unlikely to protect against actual sales, they may offer a policy based on the average seasonal temperature over the summer, or the number of days in which the maximum temperature exceeds some predefined threshold (see Box 1.2).



Figure B1.1. Tropical fruit crops such as papaya are quite sensitive to the availability of adequate water.

Three important elements of risk management are the use of history as a guide, early warning systems and insurance tools. All are highly dependent on climate information. The historical climate record can tell us much about managing risk. For instance, if one in five years historically have experienced annual rainfall below 300 mm this may be too dry for a successful wheat crop. Such information can be used to plan a business operation as well as to assess its likely profitability. Early warning systems help in foreseeing and responding to future weather and climate variations and their warnings and predictions can be directly integrated into decision making processes, whether a manual process or a sophisticated process based on computer models. Insurance tools contribute by dealing with the more extreme climatic risks that individual enterprises cannot carry, ranging from micro-insurance for smallholders to major events risks for sovereign states. The insurance industry is just one of many in the private sector that make active and ongoing use of climate information (see Box 1.2).

Box 1.2. Insurance for Managing Climate-related Risks

Insurance and other risk transfer mechanisms have long been used to manage risks that are too large for individual people and businesses to bear on their own. For example, for a relatively small annual premium, a homeowner can be compensated in the relatively rare occasions when their house is damaged or destroyed by fire or natural hazards. Insurance also can be provided against an index that is strongly related to a risk, such as low rainfall is to crop failure. In this case a payment is made when the rainfall is below some agreed level.

By reducing the potential for great personal loss or bankruptcy, insurance has historically facilitated entrepreneurship and economic growth. By quantifying risk and putting a price on it, insurance helps promote awareness and efforts to reduce the factors that cause or exacerbate risk.

Global losses from climate-related hazards are rising and currently amount to about 100 billion dollars per year. Insurance covers 40 per cent of the losses in industrialised countries but only around three per cent of disaster losses in developing countries. With climate change, developing countries are likely to face both increased hazards and decreasing resilience. The Parties to the United Nations Framework Convention on Climate Change have identified risk transfer mechanisms including insurance as potential elements for adaptation action in future global climate agreements.

A number of innovative forms of insurance are being developed for climate-related risks. The Caribbean Catastrophe Risk Insurance Facility is a new index-based, multi-country catastrophe risk pooling facility designed to limit the financial impact of catastrophic hurricanes and earthquakes on Caribbean governments by quickly providing short term liquidity when a policy is triggered. On a completely different scale, index-based micro-insurance-type products have been piloted in agriculture in many developing countries including Bolivia, Ethiopia, India, Malawi, Mongolia, Sudan and Thailand.

Insurance requires a solid basis of weather and climate data and services in order to estimate reliably the risks involved, particularly the magnitudes of rare extreme conditions that result in the greatest damage. It also requires a close understanding of how risks are correlated across a region or a set of clients, for example as in the case of large-scale tropical cyclones where the total losses across several countries may be extremely high. Under climate change, insurance tools will need to be regularly updated to accommodate the scientific evidence on changes in hazardous events. Lastly, with climate index insurance, authoritative sources are needed for the real-time weather and climate data that are used to define whether the threshold for payments has been reached.

Uses by the Public and Research Community

The general public use climate information for numerous purposes such as planning building and maintenance, gardening, family events, holidays and recreational activities. They want to know how different places and countries compare, and they are interested to know how recent conditions relate to typical seasonal patterns and how extreme a particular climatic episode or event may have been relative to historical experience.

Researchers, in their quest to understand the functioning of natural systems and economically and socially important systems, make use of diverse and often extensive climate data sets alongside other types of data. Climate researchers in particular are heavily dependent on comprehensive global and national climate datasets. Ecologists, social scientists and sector applications scientists tend to use detailed site-specific information for particular communities or industries.

ESTIMATING THE BENEFITS

Many sectors including agriculture, water management, energy, transportation and disaster management make strong use of climate data, both for planning and for routine operations (see Chapter 5). Cost-benefit studies indicate that significant benefits are being generated from using climate information, both at enterprise level and on larger sectoral and public scales. This is underlined by the fact that some sectors and larger companies operate their own in-house services to monitor and predict climate-related impacts. It is also indicated by the growth of commercial services to meet demands for tailored products, particularly for the agriculture and energy sectors. At the same time there is worldwide recognition that the benefits derived from climate information depend on continued public investment in national data acquisition and archiving services and in knowledge development and research services as well as open exchange of information.

1.3 THE CLIMATE SYSTEM AND CLIMATE PREDICTION

UNDERSTANDING THE CLIMATE

The particular climates of different places can only be understood by recognising that they are all connected in what is called the “climate system”. From this viewpoint, climate is seen as a global and dynamic system involving the annual cycle of solar heating, the slowly moving oceans, the complex and fast-changing atmosphere and the effects of continents, mountains, ice caps and other land features (Figure 1.1). Atmospheric gases such as carbon dioxide counteract the loss of heat to space, leading to the well-known greenhouse effect that keeps the Earth much warmer than it otherwise would be. These elements act and react on each other in constant flux, creating continuously-changing global patterns of temperature, clouds, rain and wind, etc, and determining well-known climatic regimes such as deserts, hot moist tropics, cool mountain forests and many others.

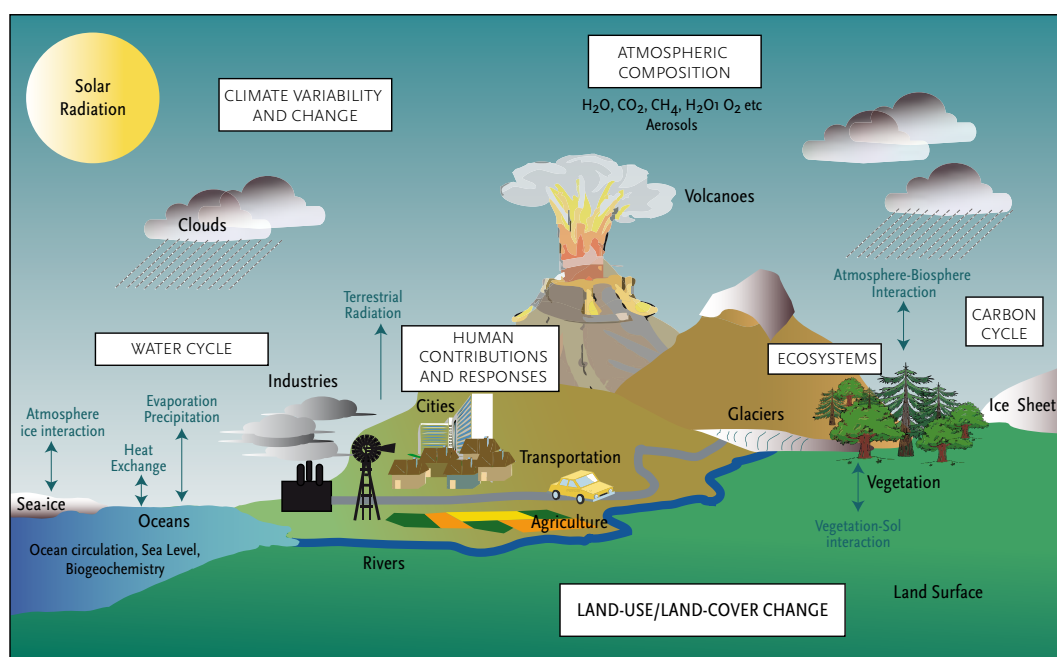


Figure 1.1. The global climate system

LOOKING AHEAD – FORECASTS, OUTLOOKS, PREDICTIONS AND PROJECTIONS

A significant requirement for climate information is concern with the future, i.e. with making decisions about what will or might happen soon, next month, or next season, year or century. The simplest way to estimate future climatic conditions is to assume that the patterns of the future will largely follow the patterns of the past, as recorded in climatological statistics, since the climate system is driven by the same processes every year. For example, we expect that the daily and annual cycles of temperature will continue and that winter months will continue to be colder than summer months.

In addition to these typical cycles and patterns, however, there are also ways to estimate what will happen in the future based on other characteristics of the climate system such as ocean temperature fluctuations and changing greenhouse gas levels. Global models have been developed to represent the complexities of the climate system and are the primary tool for making operational predictions of seasonal climate and for generating climate change projections many decades ahead. An overview of the research efforts leading to the development of climate models is given in Chapter 3.

These models belong to the same family of models that are used for weather forecasting, but weather forecasts and climate predictions are very different (see Box 1.3). However, both weather and climate models rely on an extensive set of global observation of the current state of the atmosphere, land surface and oceans for their initialization. These observations are collected and exchanged on a routine basis by national meteorological agencies and other centres worldwide as described in Chapter 2. The data are routinely processed under international collaborative arrangements established through the World Meteorological Organization.

SEASONAL TO INTER-ANNUAL PREDICTION

Model-based predictions on seasonal timescales, and sometimes on multi-year timescales, are being routinely generated by a number of National Meteorological Services and other operational centres. The demand for predictions is growing rapidly, as the seasonal time scale coincides with important planning horizons for many sectors.

Simpler empirical-statistical prediction methods are also used. These are based on statistically significant relationships that local rainfall or other climatic parameters may have with indices of global or regional components of the climate system. Commonly used indices include El Niño-Southern Oscillation indices such as the average ocean temperature in the eastern equatorial Pacific Ocean and temperature averages in other key areas of the oceans.

Empirical-statistical methods are simple to apply but are limited to broad brush representations of the type of patterns experienced in the past. Dynamical climate model-based methods, on the other hand, are able to represent directly the status and consequences of variations in ocean temperature and global atmospheric circulation as well as the influence of any longer-term changes in the climate system.

UNCERTAINTY IN SEASONAL PREDICTIONS

It should be noted that seasonal predictability varies considerably between geographical regions, different seasons and from year to year. Often there will be no useful predictability available and therefore no possibility of making a seasonal forecast. In this respect, seasonal predictions lack the universal applicability that we are so accustomed to having with daily weather forecasts.

Box 1.3. WHY WEATHER FORECASTS AND CLIMATE PREDICTIONS AND PROJECTIONS ARE DIFFERENT

How can scientists presume to say what the climate will be like months or years ahead when they are only able to forecast the weather a week or two ahead?

The reason for this seeming conundrum is the distinction between “weather” and “climate” – which are subtly different concepts. A simple definition of “weather” is that it is the state of the atmosphere as it is experienced at any one moment – wind, rain, sunshine, etc., whereas “climate” is the overall summary of weather conditions over many years, as represented by the patterns of averages and variability of the weather over the period. Each has a fundamentally different basis for prediction.

When scientists forecast the weather they need to know two things, firstly the state of the current weather conditions right now and secondly the physics of how weather conditions interact and evolve over time. Knowledge of the current state requires an extensive set of measurements and estimates of conditions both at the Earth’s surface and higher up in the atmosphere, while the physics is represented by thousands of equations in the global weather model. The problem for the forecaster is that the models and input measurements are never perfect and small inaccuracies grow naturally in the calculations, resulting in large errors in forecasts a few days hence. In general, weather forecasts are more accurate in the mid-latitudes than in the tropics because of better observation systems there, especially in the northern hemisphere, and because mid-latitude weather systems are easier to model. Weather forecasts are currently made out to approximately two weeks.

Beyond two weeks or so, scientists can draw on other aspects of the climate system that may offer a basis for prediction. For example, large-scale weather systems that form near the equator tend to persist and move slowly, and research scientists are now finding ways to predict roughly where they will be in about two or three weeks time. This does not enable weather predictions to be made that far ahead but it can provide some indication of whether a dry or wet, hot or cold, spell, onset or withdrawal of the monsoon, is on the way. Forecasts on a timescale of a

month or so are referred to as intraseasonal predictions.

Over longer periods ahead such as seasons, the oceans offer another basis for prediction. If the ocean surface is unusually hot or cold over large areas, the weather patterns above these areas are affected and since the ocean’s conditions change fairly slowly, the heating or cooling effect may last a few months. These effects are greater in the tropical oceans and so seasonal predictions are more accurate in the tropics than in the mid-latitudes. The best known example is the El Niño phenomenon, but large-scale changes in the tropical Atlantic and Indian Ocean can also provide useful sources of predictability owing to their influences on year-to-year variations in West and East African Monsoon rainfall, for example.

Seasonal predictions do not provide predictions of the weather. Instead they provide estimates of whether certain conditions are likely to be unusually frequent, persistent or intense. For example, scientists might predict that the coming period will be unusually wet without being able to predict when any storms may occur or how much rainfall they will produce.

Unusually hot or cold conditions at the sea surface usually fade over a few months but it is possible to stretch climate predictions beyond this period if changing sea-surface temperatures can be predicted using models of ocean behaviour. These models require information about ocean currents and ocean conditions at and beneath the surface as well as knowledge about how the atmosphere affects the ocean and vice versa. At least in the Pacific, the models have some success in the evolution of the El Niño phenomenon allowing for predictions up to about a year in advance. Recent deployment of thousands of small observing buoys is providing data that are expected to enable improvements in ocean-based prediction in other circumstances in the future.

Beyond a year or so, to make useful predictions for an individual season is not possible. But information about the current state of the oceans beneath the surface, or the effects of recent volcanic eruptions are anticipated to be valuable

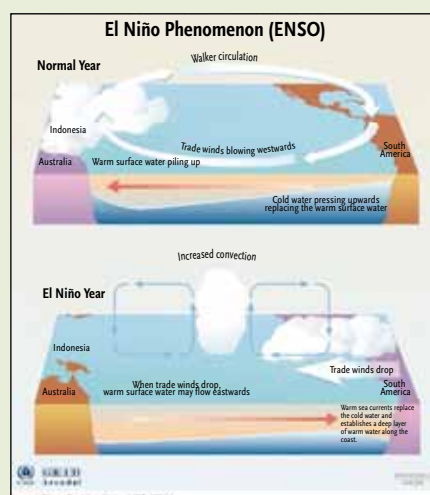


Figure B1.3. The El Niño-Southern Oscillation phenomenon. El Niño describes ‘the warm phase of a naturally occurring sea surface temperature oscillation in the tropical Pacific Ocean’, and Southern Oscillation refers to ‘a seesaw shift in surface air pressure at Darwin, Australia and the South Pacific Island of Tahiti’. This graphic explains the El Niño-Southern Oscillation Phenomenon, showing the differences between a normal year and an El Niño year. Sources: Climate Prediction Center (CPC), National Centers for Environmental Prediction (NCEP); National Oceanic and Atmospheric Administration (NOAA). Graphic: UNEP/GRID-Arendal.

in making longer term predictions about the general state of the climate over interannual to decadal timescales.

Finally, it is possible to use climate models to make projections of the effects of changing the composition of the atmosphere, whether from rising greenhouse gas emissions, air pollution or volcanic eruptions. These projections depend upon the extent to which societies reduce their emissions of greenhouse gases and other pollutants into the atmosphere. The aim is to estimate, according to different scenarios, how a changed atmosphere would differ from the current atmosphere and how the climate system might evolve over the decades ahead.

Projections even further into the future can be based on the slow changes in the atmosphere’s composition, the Earth’s surface and its orbit around the sun over the millennia. Climate model calculations for thousands of years ahead are important for testing simulations of past climates but are of little practical use in planning.

Seasonal predictability is generally greatest in the tropical and sub-tropical regions owing to strong connections there between the atmosphere and the oceans, but even then uncertainty is still high. Model-based predictions contain uncertainty because of the limitations of the global observing system (and hence of ascertaining the initial conditions); necessary approximations of the physics that are made in computer models; and the chaotic and sometimes inherently unpredictable nature of the Earth system itself. Uncertainty is therefore an intrinsic characteristic of all weather and climate predictions and model outputs and is an important consideration in their use. Verification information is therefore an essential accompaniment to forecasts to enable the user to quantify this uncertainty based on past model performance for a particular location or time of year.

Furthermore, it is not sensible to use current seasonal forecasting models to provide definitive, high-likelihood predictions such as “above average temperatures are expected next summer”. Instead, a more scientifically robust solution is to provide probabilistic outlooks on how seasonal conditions might differ from long-run average statistics. For example, in the long run the chance that summer temperatures will be above (or below) average is 50 per cent but a seasonal forecast may be able to predict that in the coming summer the odds have shifted to a 75 per cent chance of above average temperatures. This forecast certainly indicates the greater likelihood of a warmer summer but it still includes a 25 per cent possibility of cooler-than-average conditions. Box 1.4 provides an example of a seasonal outlook for Southern Africa.

CLIMATE CHANGE PROJECTIONS

Climate models can also be used to explore the effects of factors that are changing in the climate system over the long term, from decades to centuries hence. A key challenge is achieving the most accurate representation of “external” driving forces, especially future greenhouse gas concentrations, and accounting for complex feedbacks such as those associated with the effects of clouds, melting sea ice and changes in vegetation.

Projections of climatic conditions over the coming decades use scenarios of future emissions of greenhouse gases and start with average estimates of the current state of the climate. The results derived from different climate models, together with analyses of observational records, form the basis for assessments made by the Intergovernmental Panel on Climate Change.

While the projected amount of future global warming depends somewhat on both the model and the emission scenario assumed, the models are unanimous in predicting long-term global warming, with

Box 1.4. SEASONAL CLIMATE OUTLOOKS AND THEIR APPLICATIONS

Seasonal climate outlooks (Figure B1.4) are consensus products derived from analyses of historical and current observations as well as from outputs of statistical and dynamical seasonal forecasting systems made available by World Meteorological Organization members and other international climate institutes. Climate-sensitive sectors such as food security and water management are increasingly making use of climate outlooks to anticipate possible climate-related impacts on food and water security respectively and to develop strategies to mitigate these.

Seasonal climate outlooks are often presented as the per cent likelihood of precipitation falling within the below-normal, normal or above-normal categories for the coming season, as shown in Figure B1.4. Whilst probabilistic in nature and of relatively low precision they can still be informative. Often the challenge faced by the scientific community is that decision systems are not designed to handle probabilistic inputs. Rather, the user interprets the most likely category as the one that will actually occur. That is, the user assigns unrealistically high probability, confidence and reliability to a forecast that has a significant (and quantified) degree of uncertainty associated with it.

There have been many instances where outlooks providing relatively high probabilities for disastrous events have triggered effective mitigating actions. For example, in Ethiopia in

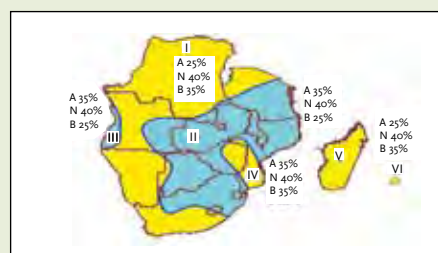


Figure B1.4. Seasonal forecasts Valid for January–February–March 2009 over southern Africa. Per cent likelihoods for above normal, normal and below normal rainfall are given in the upper, middle and lower boxes respectively. Source: Southern African Development Community Climate Services Centre, Gaborone, Botswana.

2002 forecasts of a high likelihood of drought triggered emergency team meetings and the identification of relevant actions leading to timely and effective donor commitments. Farmer surveys revealed gains in yields and income due to seasonal forecasts in some African countries, including Mali. More recently, in 2008, forecasts of very high likelihood of above-normal summer rainfall in West Africa prompted early response actions by the International Federation of Red Cross and Red Crescent Societies to lessen consequences and facilitate less costly recovery.

much faster warming over the land than over the ocean, particularly at higher latitudes. Large declines in sea ice and land ice, together with increasing global sea levels are also expected. Another key result is the projected acceleration of the global water cycle and hence an increase in global average rainfall, even though drier conditions in arid subtropical regions are expected. The intensification of the water cycle is also likely to increase the frequency of torrential rainfall events in many areas of the globe, with likely implications for increased flooding and erosion.

Climate models can also provide information on the risk of dangerous changes, where the changing climate exceeds a critical threshold. These include, for example, mass release of the active greenhouse gas methane due to permafrost melting, slowdown of the Atlantic Ocean currents that transport heat towards the poles from the tropics and species extinction due to ocean acidification.

PREDICTIONS AND PROJECTIONS FOR LOCAL SCALES

While global climate models have sufficient spatial resolution to represent global and continental scale phenomena successfully, they are less able to represent phenomena on the smaller national and sub-national scales that are often of greatest interest to decision makers, such as local patterns of temperature and precipitation extremes. Higher model resolution in space and time can potentially provide some improvement in resolving smaller scale features but comes at a high cost and so resolution is expected to improve only gradually.

In situations where the sources of predictability have an intrinsically large scale, such as continental-scale heating, it is possible to generate more detailed regional and sub-regional climate predictions by “downscaling”. A range of tools have been developed to downscale predictions and projections, all have the objective of providing more detailed results than are available from running global models alone.

1.4 OVERVIEW OF CLIMATE SERVICES PROVISION

THE NATURE OF CLIMATE SERVICES

The climate services sought by users include the provision of data, data summaries and statistical analyses and predictions as well as tailored information products, scientific studies and expert advice delivered with ongoing support and user engagement. A requirement may be as simple as providing the temperature for a particular place and date or as complicated as an assessment of environmental factors in constructing a billion-dollar infrastructure project. A service package may encompass past historical data, recent and current conditions and future predictions and projections.

Services may be provided directly in response to specific requests or in anticipation of the needs of particular groups. Services may be supplied free or at a price. Channels for delivery may include face-to-face advice, formal reports, periodic bulletins, news media releases, internet-based mechanisms, outlook forums and direct computer access. Climate services also include internal activities such as archive development, quality management and statistical analyses that benefit both current users and future generations.

The demand for climate-related information services is rising owing to a combination of factors such as greater awareness of climate issues and impacts and the need for an integrated approach to addressing environmental and other issues, pressures of competition, efficiency and accountability for businesses and public entities, greater capacity throughout society for computer-based accessing

and data manipulation, an developing capability to define and provide decision-relevant information and a growing scientific ability to analyse and predict climate variables. Climate change undoubtedly has brought a whole new perspective and suite of demands, often accompanied by unprecedented public and political interest.

SERVICE PROVISION ARRANGEMENTS

The organizational arrangements established in countries for supplying and meeting demand for climate services are varied, as discussed below, depending on national and sectoral circumstances. But in each case, and whether undertaken as a private or a public service, the core elements of service provision are the same – quality accessible data, climate expertise, dependable operational capability and skill in client relationships. The climate service provider starts with raw data sets and creates value for users through knowledge and skill in data management, statistical analysis, climate science and interdisciplinary research on impacts, and user decision processes (Box 1.5).

CLIMATE DATA RESOURCES

In most countries the networks established for weather forecasting purposes do double-service by contributing weather data to the national climate archive, particularly on temperature, rainfall, humidity, wind speed and pressure. Data collected for weather forecasting thus provides the major source of climate data, although the priorities for climate stations and weather stations sometimes differ. Climate information depends on long-term, stable records of data, but such criteria are not as critical to inform weather forecasting needs.

Dedicated national climate networks are becoming more common and usually cover additional parameters of climatic importance such as maximum and minimum temperature, soil temperature, sunshine, evaporation, solar radiation, daily wind run and frost occurrence. Other significant contributors of climate data include networks operated by sectoral agencies, particularly those for water resources, energy production, agriculture, forestry, fire management and marine affairs. Climate data is also collected by some research institutes and city and local governments.

Data sets originating outside the country may also be available, either through routine data exchange arrangements between countries, particularly under the Global Climate Observing System, or as global analysis products from global processing centres and research institutes.

There is considerable diversity among the various data sets. For example, a city may be interested mainly in air quality parameters, while a hydrology office may only measure rainfall amount and intensity, and different agencies may use different instrument types. There is a strong trend toward automated observation systems where instruments transmit observations as they are recorded or soon after, or accumulate their data in on-board data loggers for later extraction. Common standards of observation are therefore crucial to ensure that data from different instruments and places are comparable. This requires suitably frequent calibration of instruments against agreed standards and strong cooperation mechanisms. The increasing availability of remotely-sensed data from satellites, radars and other automatic systems brings special challenges for standardisation.

Climate stations that have operated for many decades without change are especially important as references and particularly as a means of detecting slow, long-term changes in climatic conditions. For all stations, and particularly for reference stations, it is important to collect “metadata”, i.e. information describing the history of the observing site, including details of the instrumentation used there over its lifetime, the dates and results of instrument calibration and other maintenance activities as well as periodic photographs of the observing site and its surroundings.

Box 1.5. DELIVERING CLIMATE SERVICES

A climate service is a process of developing and delivering climate information in such a way as to meet a user's need. The path and form that the information must take from the originator to the user can vary greatly depending upon the circumstances of both provider and user.

Possibly the most common climate service is provided to the first time traveller to some location who asks questions such as; how hot/cold will it be, will it be likely to rain, does the wind blow a lot there? Generally the National Meteorological Service responsible for the location in question will have 30-year averages of these parameters for the location, or for somewhere nearby. If it is a capital, or major city the averages will probably be on the web, if not then a call to the National Meteorological Service may be necessary, in which case the climate service will be delivered by way of a conversation with a climate information officer.

Not all climate services are as casual as this first example. Many farmers now make considerable use of seasonal forecasts in their planning, and just how they get these will depend on many factors including the country in which they farm. In China the Chinese Meteorological Agency makes routine climate assessments and provides decision-making advisory services to the State Council, Ministry of Water Resources, Ministry of Agriculture among other, and scientific guidance and services for relevant departments, sectors and the general public through television and other media.

In Australia the consensus outlook generated by a group of scientists from the Australian Bureau of Meteorology, the Commonwealth Scientific

and Industrial Research Organization, state governments, the university sector and user groups is made available through the Bureau's and other web sites. Farmers access this, compare it with other seasonal forecasts prepared by major climate centres overseas, and possibly seek advice on some sort of "grand consensus" in discussion with state government agricultural extension officers before making their decisions.

In Africa the regional climate outlook forum (Box 1.6), involving up to 200 to 300 scientists and users from many countries, meets to prepare a consensus forecast. This forecast reflects the integration of the individual country forecasts, those of Regional Climate Centres and vigorous discussion to bring these together. This forecast is then made available in each country involved through national arrangements. The National Meteorological Services of the countries involved publicise the forecast and officers from agricultural departments of many of these countries are then charged with ensuring that farmers are alerted to the contents of the forecast relevant to their decision making. Taking the consensus forecast down to a national or sub-national level requires a summarizing of its contents in ways that are relevant to the farmer and into the language spoken by the farmer. The consensus forecast, or information derived from it, may then be communicated by radio or through local briefings. Opportunities to discuss the forecast and to consider actions are provided through these local briefings.

The delivered service is only useful if the farmer can actually use the information it contains in his or her decision making.

Climate change introduces an interesting challenge regarding the applicability of the historical climate record for many planning activities – if climate is changing the historical records do not provide a very realistic indication of future conditions. Accordingly, there is increasing demand for climate projections data to supplement the historical climate record.

DATA MANAGEMENT SERVICES

Data management is a core value-adding activity for climate service organizations through the activities of archiving, documentation, quality management and providing means of access to users, whether of the observational record, or of predictions and projections. Collected data needs to be well organised and accessible in electronic databases. Careful, systematic and

well-documented quality control methods need to be applied at both the acceptance stage when data are admitted to the archive and thereafter through periodic comparisons and cross-checking of data sets in the archive.

Metadata also need to be properly managed. The climate database expert makes use of metadata to interpret data errors that may occur and to account for systematic differences between different data sets. Trees growing near an observation station may cause increasingly incorrect wind speed measurements for example. Consistency of data quality over time is important for monitoring of climate trends.

Providing ready access to users of the database (for both data and metadata) is critically important. This means not only that electronic access must be available, but also that desired data can be quickly located and selected, preferably using relational database software that allows the user to specify a particular requirement and draw upon multiple data sets within the database.

CLIMATE DATA, MONITORING AND ANALYSIS OF THE CLIMATE

Whilst access to the basic data is the requirement for many users, others require that some analysis of the data has been performed. Common analysis products are long-term averages at a location for the different months of the year, such as city climate data shown on many travel websites, annual summaries of the climate of a country for a particular year and maps of average patterns of climatic parameters across a country or district. Series of monthly average data over several decades are used for detecting and distinguishing short- and long-term climate trends. Statistics covering the extreme values in data sets are critical for estimating the likelihood of damaging conditions such as floods and droughts. Sophisticated statistics may be tailored for specific uses, such as joint probability tables for temperature and humidity relevant to designing air conditioning or probability tables of extreme wind gusts according to prevailing wind direction for airport operations or building design codes. Considerable expertise is required to generate reliable statistical products and summaries. This is a core capability of national climate centres.

APPLICATIONS SERVICES

To capitalise on data and databases another element is needed – knowledge and expertise on climate processes, climate variability and statistical analysis. It is this knowledge and expertise that helps extract the relevant meanings and avoid misinterpretations. For example, is a ten-year rainfall data set good enough to determine the chances of a flood at the site of a proposed new factory? How can sunshine in a remote valley be estimated if there are no observations in the valley? When the seasonal forecast shows an above-average chance of low rainfall, what difference would this make for actual rainfall?

A further important role of the climatologist is to oversee the production of authoritative interpreted products such as annual summaries, analyses of extreme values, variability maps of key parameters and seasonal outlooks. The climatologist will need to collaborate with the users to ensure that these products are useful.

TAILORED PRODUCTS AND SERVICES

Clients typically have needs that are specific to their circumstances and to the climate sensitivity of their sector. They seek climate advice and information that addresses their particular situation and are often willing to pay for tailored products and services if the benefits arising from their use are judged clearly to outweigh the purchase costs. Examples include the electricity company that requires

information to help establish a maintenance schedule for transmission pylons that will avoid the coldest and windiest periods; the agricultural ministry that needs to explore drought risks for a new rural development scheme; and the retail chain that wants advice on how improve the distribution and marketing of summer clothing.

In some cases the service may be unique to one client, while in others it may be a standard product for a particular sector or class of client. There are few rule books to guide these specialised tasks apart from the following general principles of client service: listen to the client and engage them in defining the problem and its solution; maintain high scientific and professional standards by monitoring and correction of product and service quality; and deliver what is promised and deliver it on time. As is the case with most service delivery operations, a critical operational challenge is managing fluctuating client demand despite largely fixed capacity in staff resources.

PUBLIC AND PRIVATE SERVICES

Historically, climate services were generally regarded as a necessary public service to support national objectives for the effective operation of agriculture, water supply, transportation and public safety. In most countries a climate service unit operated as a small part of the National Meteorological Service or within a university or research institute, often consisting of a handful of staff devoted to the basic work of checking and archiving data and preparing data summaries. Over time, many organizations have built up a staff of climatologists and client services staff to engage more actively in providing climate services.

Beginning in the 1980s, a wave of public sector reform spread around the world that transformed a number of public sector services into private sector entities, particularly in the telecommunications, energy, transport and construction sectors, and introduced cost-recovery policies and commercial modes of service delivery for the public sector services that remained. This was a challenging time for many weather and climate services as they endeavoured to develop their commercial capabilities and to meet imposed targets for recovering significant percentages of their operating costs. The period saw data networks and data archive operations shrink in some places. At the same time it also fostered a commercial market for climate services and the entry of private analysts and new services. Within the relevant public agencies, more responsive client relationship skills were developed along with tailored products and a clearer distinction was made between public and private services.

DATA ACCESS AND PRICING POLICIES

Policies covering access and pricing for climate data are established either by national law and practice or by the agencies that undertake the collection of data and own the resulting data archives. Conflicting objectives may be involved. On the one hand, motivations of protecting national security and economic advantage or of requiring users to contribute to the financial costs of data collection may lead to restrictive policies on data access and to charges for data sets. On the other hand, motivations of facilitating national economic and social development, including adaptation to a changing climate, and of supporting education and research favour open access to data and low or zero data charges. At present many countries charge for data, though often the charges are reduced or waived for researchers and educational users within the country. However, in other countries private and public users are treated the same way, with both groups paying only for the marginal additional costs of servicing the enquiry and not for the data itself. Where the data can be accessed directly by computer, there may be no charge to the user at all.

Many researchers have reported significant difficulties in trying to obtain data for their work. Charges based on per item rates can lead to prohibitively high costs for large data sets and it is known that

in order to avoid such costs researchers and industry consultants on occasion will make use of sub-optimal, out-of-date data sets or general summary information. In some cases an archive operator may not have the capacity or the permissions required to meet complex requests for data.

ARRANGEMENTS FOR THE EXCHANGE OF METEOROLOGICAL DATA

A similar situation occurs with respect to real time meteorological data needed for global weather modelling and prediction. After much debate, governments reached an agreement on the basis for international exchange of meteorological data in Resolution 40 of the Twelfth World Meteorological Congress. Resolution 40 distinguished “essential” data that should be provided on a free and unrestricted basis from “additional” data that might be exchanged subject to conditions imposed by the provider. The agreed “essential” data, principally data required for weather forecasting purposes, but also including a small amount of data relevant to climate monitoring, was listed in Annex I to the resolution. The later Resolution 25 Thirteenth World Meteorological Congress established a similar basis for exchanging hydrological data and products though it lacked a definition of which are the essential data that parties to the Resolution agree to exchange freely. These resolutions reflect the increasing need for data exchange, including as called for by various international conventions and agreements, but also reiterate the right of governments to choose the manner and extent of such exchanges. These arrangements for the exchange of data do not cover the full range of climate data that is sought by users. A key lesson to be drawn from this experience is that enduring agreement can be reached of free and open data exchange when there is consensus that this needs to occur for a specific purpose to be achieved, and when there is consensus on the description of the data required to achieve the purpose.

An important role of the Global Framework for Climate Services will be to facilitate further discussion and agreement among governments for the exchange of climate data needed by different communities and sectors.

PUBLIC SECTOR SERVICE PROVIDERS

Nowadays climate services can be obtained from a wide range of sources. Decision makers and other users roam widely to obtain information according to their needs and to the accessibility of different sources. For example, an agricultural trader wanting a seasonal outlook may use information from a daily newspaper, a global prediction centre, the local meteorological service, an agricultural expert, a university colleague and a private company. Increasingly, the internet is seen as the first step in the search for information.

Public sector providers include national meteorological agencies, national statistical offices, other government agencies and laboratories, universities and sectoral institutes. Their mainly public good activities include developing and managing data resources, undertaking research, developing useful data applications and contributing to public awareness and knowledge. International and regional organizations also provide specialised services as part of their research agendas and development assistance mandates. This includes, for example, the Food and Agriculture Organization’s Global Information and Early Warning System for food and agriculture and the work of several regional climate centres in Africa.

PRIVATE SECTOR SERVICE PROVIDERS

Providers in the private sector necessarily concentrate on activities where services can be privatised and their benefits captured by the client, thus justifying the effort and the payment required. Providers of climate information in the private sector include companies for which climate service provision

is their core business and also those whose main business area is something else, but who have meteorologists and climate specialists on staff and involved in applied research and development, which has spin-off uses. Some National Meteorological Services are active participants in the private sector.

Private operators are mainly active in areas such as environmental assessments, building design services, prediction of industry-specific market factors, risk analysis including for insurance purposes (such as flood and crop insurance), the application of proprietary analysis and prediction software, and consultancy. Commercial markets are mostly to be found in countries that are members of the Organization for Economic Cooperation and Development. Private suppliers can also be important contributors to public agency programmes via contracted services. For example, the United States of America-supported Famine Early Warning System Network programme for food security in Africa is managed by a private corporation.

CLIMATE SERVICES IN DEVELOPING COUNTRIES

Many developing countries recognise their great sensitivity and vulnerability to climate and accordingly provide good support to climate-related activities. A number have established sustained and effective climate services that cover all the basic functions – data archiving and provision, development of tailored services, public information, client relationships and internal training. They may also engage in research and development activities.

Nevertheless many developing countries, especially those that are least developed, confront significant difficulties in meeting their climate service needs. As will be described in Chapter 2, data records may be sparse and of short duration and in some cases are incomplete or non-existent, while human and technical capacities are often very limited. Efforts to computerise data sets and develop routine products have made progress in some countries but can be difficult to sustain. It is clear that the needs of the particularly vulnerable must be a prime target for action by the Global Framework for Climate Services.

THE ROLE OF USER INTERFACE PLATFORMS

In this section we have referred to many instances where users interact with climate experts and service providers to obtain information and guidance on how to address climate issues, largely on a one-to-one basis, and where users and sectors interact and collaborate among themselves at Climate Outlook Forums (Box 1.6). Sectors as diverse as agriculture and insurance consider climate challenges in their technical meetings. National conferences are organised on climate impacts and adaptation by climate experts and industry representatives. Adaptation policy advisers consult with sector and climate experts alike.

In addition to these settings climate experts also meet, within academia and through the international mechanisms of the World Meteorological Organization, to develop standards and methodologies for climate applications such as for data archiving and statistical analysis and for using information and predictions in sectoral decision making. Developing countries particularly rely on access to established and proven methods that can be quickly adapted and instituted in their own circumstances.

It is clear that such platforms are going to be increasingly important for capitalising on the growing interest in climate impacts and services and to develop and disseminate useable methods and tools more effectively. National platforms can be strengthened where they are present or else developed through partnerships among national climate centres, sector organizations and civil society organizations. Regional platforms and centres can play key roles as focal points and clearing houses

Box 1.6. SEASONAL CLIMATE OUTLOOK FORUMS

In several regions of the world, countries cooperate to produce a consensus seasonal climate outlook in a similar manner through periodic Regional Climate Outlook Forums. The forum concept was initiated at a workshop held in Victoria Falls, Zimbabwe in October 1996 and has developed progressively into an important element of the global capability for seasonal prediction. Convened by regional and international organizations at key seasons of the year, these forums bring together climate experts and sector representatives from agriculture, food security, water management, etc, to review climate prediction information, develop consensus-based outlooks and raise awareness of emerging or potential regional impacts. The recent Greater Horn of Africa Climate Outlook Forum held in Kisumu, Kenya under the auspices of the region's Intergovernmental Authority

on Development on 2–3 September 2010 was the 26th in a series of such biannual events and attracted 250 participants from numerous sectors.

The regional climate forums help ensure consistency in access to and interpretation of climate information for groups of countries having similar climatological and socio-economic characteristics. They generate improved understanding and interpretation of available climate prediction information and promote more coherent action among scientists, sectoral users, extension agencies and policy makers. Regional agriculture and food security outlooks are now regularly produced based on the climate outlooks developed at the Regional Climate Outlook Forums in some regions.

for countries, particularly in helping to identify and address regional needs, in sharing knowledge and exchanging data and in supporting interdisciplinary research and training. To achieve good coordination and a well-structured approach to the field, international platforms oriented to user needs will need to be strengthened. This idea is a core feature of the proposed Global Framework for Climate Services.

TECHNOLOGIES OF THE FUTURE

Most climate service organizations operate as relatively small groups and their offerings are developed through a dialogue between users, service providers and sometimes research scientists. The resulting application is usually hosted on the service provider's computers using the organization's software and database and is likely to be highly customised, meeting only local standards and being non-portable.

The emerging technology of internet-based applications may provide an alternative to this approach. These service-oriented architectures can be developed to a global standard and operated on the user's own computer system or smart phone, drawing on remote databases as required. This may prove to be a useful path to make tailored climate services and products more readily available in the future to those who need them.

Underlying such a system would be a set of databases containing global collections of essential climate variables, ensembles of output from seasonal prediction schemes and projections from climate models. Above these would be a layer of system tools for selecting, mapping and displaying data. With specific applications loaded onto their computers, the users would draw on constantly-updated information from the databases to generate needed products when desired. Users could also develop their own applications or browse existing applications for ones that suit their purposes. With the correct permissions, the applications could also reach out to other databases and services. Applications would thus be standardised, portable and re-useable.

The main benefits of this approach reside in the efficiency and standardisation that would accompany wider use of low-cost applications and the incentives for climate experts and service providers to provide high quality useful applications. With more widespread availability of tools and information there would be a greater need for climate service providers to act as advisers and intermediaries, for example assisting in selecting appropriate applications, and supporting and advising on their proper use. It is very likely that the greater use of climate information would raise the profile and level of support of operators of observation networks and climate databases and services.

1.5 FINDINGS

1. Climate is a critical factor in the lives and livelihoods of all people, and to the socio-economic development of society as a whole. The efficacy of decisions made by individuals, organizations and governments to manage the effects of climate variability and change is critically dependant upon the availability and quality of climate information.
2. The climate information needs of users are diverse and effective use of climate information is entirely dependent on the circumstances of the decision maker. Climate information must therefore be tailored to meet the needs of users and that climate services must be needs-driven. Users need access to expert advice and support to help them select and properly apply climate information.
3. Climate services are fundamentally limited not only by the availability of resources, especially in developing countries, but also by availability of observations and analyses, and by the inherent impossibility of predicting the climate accurately. It is not feasible to address all user needs, and identifying what services can scientifically and practically be provided region-by-region and sector-by-sector will need to be a core activity.
4. Prediction of climate on the seasonal timescale can provide significant benefits. However, such predictions are only possible in some circumstances and are accompanied by considerable uncertainty. Users need expert advice to use this information effectively. It is essential to create a close relationship between expert advisors and users to develop understandable and decision-relevant information.
5. There is a strong demand for climate services to deal with climate change and adaptation, particularly on the local level. There is a need for better ways of combining climate change projections with local climate data and knowledge.

CHAPTER 2

OBSERVING SYSTEMS AND DATA EXCHANGE

2.1 INTRODUCTION

Observations of the Earth's climate system provide the foundation for understanding the nature and causes of climate variability and change. They are the starting point for providing climate services. This chapter describes the current state of systems for making observations of climate-related variables concerning the atmosphere, oceans and land as well relevant environmental and socio-economic information. The issues of standardisation, quality management, data exchange and international coordination of observing systems are also considered.

2.2 OVERVIEW OF REQUIREMENTS FOR, AND MEANS OF TAKING, OBSERVATIONS

GENERAL REQUIREMENTS

Climate services depend on good knowledge of how the climate system works as well as on quantitative data on the climate. In turn, both of these requirements depend on systematic observations. Climate observations provide a picture of what has happened in the past as well as recent trends, along with offering the input needed to make predictions and projections on what is likely to happen in the future.

Observations form the basis of climate services and research at all levels, whether at local, national, regional or international scales. To support climate services, high quality observations are required from all components of the climate system, including the atmosphere, cryosphere, oceans and land. Systematic information on the ecosystems and human societies that are affected by climate is also often required in order to make climate observations useful.

Concerns about climate change have sharpened awareness of the need to know how the climate has changed or varied in the past in specific measurable terms and how it is changing and varying now. These questions can only be determined using quality observing systems and data analysis. Likewise, assessment of the effects of existing climate variability and of the impacts of future climate change, along with the development of improved risk management and proactive adaptation strategies, requires a factual base of information about the climatic circumstances of the communities involved. More generally, the growing challenge of sustainable development and the green economy will increase demands for systematic observations of climate-related factors.

OBSERVING METHODS AND SYSTEMS

Observations of climate variables can be made by networks of in situ measurements, for example by using a thermometer to take the temperature of the air surrounding it or by remote sensing technologies where satellite-based instruments and ground-based radars observe conditions at some distance from the instrument itself, such as sea surface temperature or atmospheric winds. Traditional and local knowledge are also important sources of observations of climate and other relevant environmental information.

Instrumental weather observing systems have been in place for several centuries in some countries, particularly in support of military activities, transport and agriculture. However, the longest records of the earth's climate are from palaeoclimate observations, which come from numerous sources such as tree rings, ice cores and sediments, and can extend back over geological timescales. Techniques based on phenology – the study of periodic biological phenomena, such as flowering, breeding, and

migration, in relation to climatic conditions – also provide an important means of observing changes in climatic variables. The importance of phenological monitoring as both an indicator of climate change and in the assessment of its potential impacts is already widely recognised. Indigenous communities use phenology as a traditional method of seasonal forecasting.

The variety of modern, instrumental observation systems for monitoring the atmosphere, oceans, cryosphere and land surface is illustrated in Figure 2.1. A number of emerging technologies, including various types of automated underwater and airborne platforms, are likely to make important contributions to future observation networks.

Each type of observing system has its particular strengths and weaknesses and each complements the others. Satellite-based systems are especially important for generating spatially consistent and detailed data, and for generating data in regions where in-situ observations are scarce, such as over the oceans, poles, and deserts. However, they cannot currently provide observations of atmospheric conditions (temperature, wind, moisture etc.) near the earth's surface. Most of the meteorological observing systems are designed to support weather forecasting, though the data they provide are usually archived and made available for climate related purposes.

Past weather observations have left an enormous legacy of data that now provides the basis of our knowledge on climate variability and change. However, it does not address the needs for specific climate variables that are unimportant to weather forecasting and may be inconsistent, for example due to changes in the location of stations or the instruments and observation methods used. Caution is therefore needed when combining datasets from different instrumentation platforms and observation methods, since this can lead to uncertainty in observations (see also Box 2.5). Recovering historical data records is a critical component of the development of local climate services, and data rescue efforts are often required to make old, paper weather records derived from various sources accessible in compatible, digital formats.

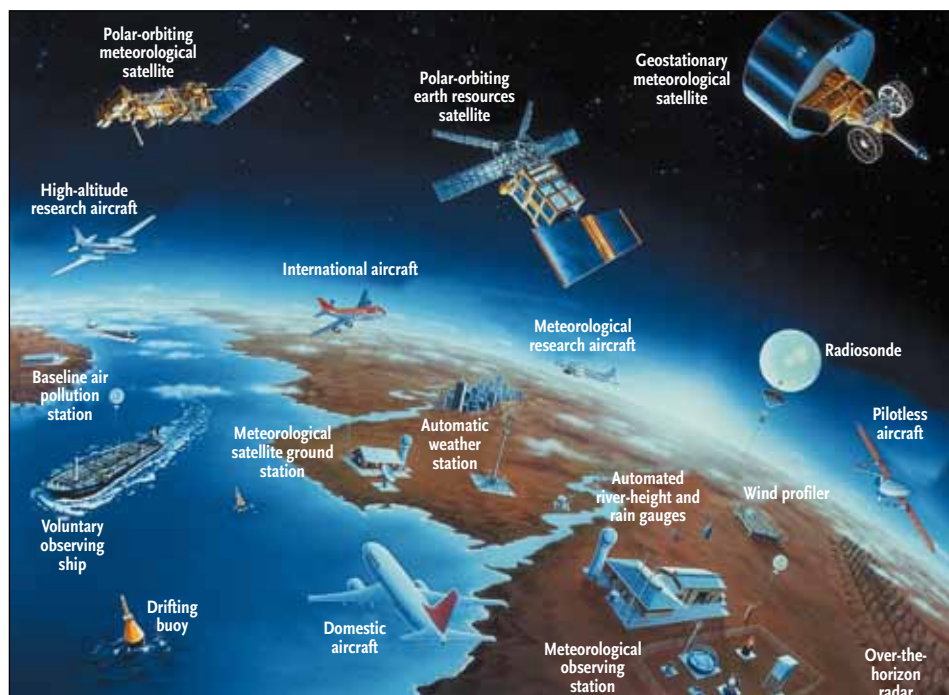


Figure 2.1. Illustration of some of the multiple observing systems in use on the ground, at sea, in the atmosphere and from space for monitoring and researching the climate system

It is only in recent decades that concerted attempts have been made to create systematic climate-related observation systems, principally through the United Nations- and International Council for Science-sponsored Global Climate Observing System led by the World Meteorological Organization. The various observing systems involved are illustrated in Figure 2.2 and more details of these are given in the following sections.

Specialised observing systems also exist to provide information to particular sectors such as agriculture, water resources and forest management. Information on the immediate environmental circumstances of communities such as river levels and urban air quality or volcanic emissions may be gathered by local observation systems, while information on the relevant socio-economic conditions of communities is normally gathered from national statistics, surveys and special studies.

REQUIRED TECHNICAL ATTRIBUTES TO SUPPORT CLIMATE SERVICES

The required attributes of climate observation systems to support climate services include geographically comprehensive coverage, frequent and reliable observations, sustained operation over decades, well-maintained instruments and the use of globally standardised observing practices. Inevitably there are tradeoffs between these factors owing to matters of network objectives, costs and historical factors. Besides the observations themselves, it is also important to record when, where and how they have been obtained. These “meta-data” (data about the data) are needed for proper understanding of the observations and for comparing times and locations.

Global climate change provides a specific challenge for climate monitoring owing to the need not only for extensive global coverage but also for precise, sustained observations in order to distinguish small rates of change (say in temperature and rainfall) from the background of natural climate variability.

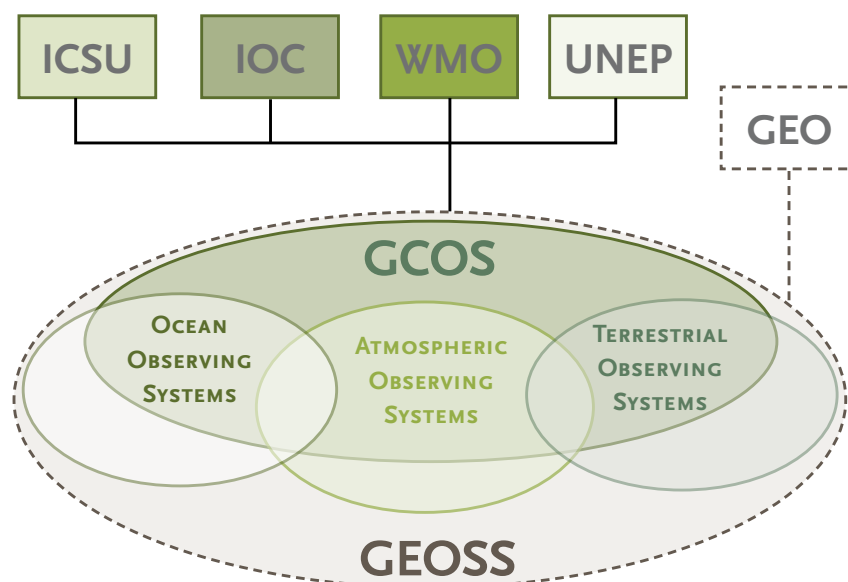


Figure 2.2. Schematic of the World Meteorological Organization-led Global Climate Observing System, with sponsors: International Council for Science (ICSU), The United Nations Educational Scientific and Cultural Organization’s Intergovernmental Oceanographic Commission (IOC), World Meteorological Organization (WMO), United Nations Environment Programme (UNEP) – and the component observing systems on which it is built. The latter are embedded within the overall framework of the Global Earth Observation System of Systems (GEOSS), coordinated by the Group on Earth Observations (or GEO).

ESSENTIAL CLIMATE VARIABLES

The Global Climate Observing System, in collaboration with the climate community at large, has formally identified a set of “Essential Climate Variables” that are required to support the work of the United Nations Framework Convention on Climate Change and the Intergovernmental Panel on Climate Change and that are technically and economically feasible for systematic observation (Figure 2.3). It should be noted that while the Essential Climate Variables are equally important for providing climate services, additional information – including socio-economic information – will also be needed.

2.3 ATMOSPHERIC OBSERVING SYSTEMS

MAIN REQUIREMENTS

The atmosphere is the most rapidly varying component of the climate system but it is also the component for which there are the longest and most extensive data records, due in large measure to the requirements of weather forecasting and warning. Chaotic, fast-changing weather systems give the atmosphere an important role in the climate system. Heat, moisture, aerosols (small particles like dust) and chemicals are moved around rapidly by winds, while evaporation, cloud formation and rainfall actively transfer heat and water. Cloud and water vapour mediate solar and infrared

atmospheric (over land, sea and ice)	Surface	Air temperature, Precipitation*, Air pressure, Surface radiation budget, Wind speed and direction*, Water vapour.
	Upper air	Earth radiation budget (including solar irradiance)*, Upper-air temperature*, Wind speed and direction*, Water vapour*, Cloud properties*.
	Composition	Carbon dioxide*, Methane*, Other long-lived greenhouse gases*; Ozone* and Aerosol properties*, supported by their precursors.
Oceanic	Surface	Sea-surface temperature*, Sea-surface salinity*, Sea level*, Sea state*, Sea ice*, Surface current, Ocean colour*, Carbon dioxide partial pressure, Ocean acidity.
	Sub-surface	Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers, Phytoplankton.
Terrestrial		River discharge, Water use, Ground water, Lakes*, Snow cover*, Glaciers and ice caps*, Ice sheets*, Permafrost, Albedo*, Land cover (including vegetation type)*, Fraction of absorbed photosynthetically active radiation*, Leaf area index*, Above-ground Biomass*, Fire disturbance*, Soil moisture*, Soil carbon.

* Those to which satellites make an important monitoring contribution.

Figure 2.3. Essential Climate Variables that are both currently feasible for global implementation and have a high impact on United Nations Framework Convention on Climate Change and Intergovernmental Panel on Climate Change requirements (Status: 2010)

radiation and provide feedbacks that are major factors in how the climate is affected by rising levels of greenhouse gases.

Observing systems for the atmosphere therefore have to measure its quickly changing properties repeatedly, including those of temperature, pressure, moisture, wind speed and direction as well as radiation levels. They also have to measure the atmosphere's chemical composition, including greenhouse gas concentrations and the properties of the aerosols it contains, which are essential for improving climate predictions. Observations of atmospheric conditions near the land surface of the Earth are particularly important, as this is where most people live and work. It is here that the many impacts of climate variability and change will be most keenly felt and where the focus of most climate services will lie.

CURRENT ATMOSPHERIC OBSERVING SYSTEMS AND THEIR STATUS

Virtually all atmospheric observing systems that have a sustained lifetime and international standardised modes of operation, data exchange, archiving and accessibility are operated by National Meteorological and Hydrological Services on behalf of Members of the World Meteorological Organization.

The World Meteorological Organization Global Observing System is comprised of a variety of observing systems including land-, ocean-based and satellite-based platforms. Included amongst the land- and ocean-based components are in excess of 10 000 surface synoptic stations (see Box 2.1) and 1 000 plus upper air stations (see Box 2.2) recording the variables necessary to support weather forecasting. The Global Climate System Surface Network is a specially selected, high-quality subset of the Global Observing System and provides a global network of approximately 1 000 specially selected surface observation stations. It is a baseline network, aimed at establishing a minimum number of appropriately distributed sites to provide globally representative climate data records of key atmospheric variables for monitoring global trends (Figure 2.4). Generally these stations are staffed by human observers who take regular readings of conventional instrumentation and send these data to national and ultimately to international data distribution systems (see Box 2.1). However, automatic weather stations are an increasingly important means of surface weather and climate observations.

The Global Climate System Upper Air Network (Figure 2.4) is also a component of the World Meteorological Organization Global Observing System. It consists of 169 stations dedicated to high quality in situ measurements of meteorological conditions in the atmosphere above the station. Upper air networks use balloon-borne “radiosonde” instruments that are periodically released into the atmosphere to take a continuous vertical sampling of pressure, temperature, humidity and winds as they rise, often to heights of over 15 km (see Box 2.2). The Global Climate Observing System network is equipped with new-generation radiosondes that are providing more accurate reference observations than is usual for some of the routine weather observation stations and therefore provide better understanding and predictions of climate variability and change.

The World Meteorological Organization Global Atmosphere Watch, consisting of 22 global and 300 regional stations, provides scientific data and information on the chemical composition of the atmosphere with a view to monitoring the effects of human activity on it.

A small proportion of stations in the Global Climate Observing System's Surface Network and Upper Air Network do not currently report routinely. The Global Climate Observing System community is working hard to re-activate these so-called “silent” stations. Their efforts are resource-limited, however, and at any time there are approximately 100 silent surface stations and 10 to 15 silent upper

Box 2.1. MANUAL OBSERVATIONS FOR CLIMATE

Although automatic weather stations are increasingly prevalent, many countries continue to take manual observations of atmospheric conditions close to the earth's surface. These synoptic observations form the basis of modern climate analysis and prediction. A full program of surface, manually-taken synoptic observations entails a human reading the instruments (Figure B2.1a) every three hours throughout the day and night and then forwarding the resulting data to some data entry system.

As taking the observation requires only about 15 minutes work per three hours, it is most cost effective to have the observer's duties integrated with some other activity, while always recognising that for the 15 minutes around the synoptic observing time (UTC 00, +3hr, +6hr, ...) the weather observation has precedence over other duties (this can be difficult to arrange).

Some countries train staff who work for other organizations such as port and airport authorities, the police force, the postal service, etc., as observers and pay by the observation. In Australia, for example, the price paid for an observation varies by the time of day (Figure B2.1b). The observer is provided with a small, specific-purpose computer that is attached to the telephone network and has on board software for encoding the observation to meet the World Meteorological Organization standards. The cost per year of a conventional, manual observation single station taken in this way, in Australia, is around US\$ 30 000. Of course, this single station needs to be a part of a larger data management and distribution network that is not costed here.



Figure B2.1a. Weather station.

Local time of observation	Price paid (\$AU)
9 am	11.49
Noon	17.24
3 pm	11.49
6 pm	12.18
9 pm	11.49
12	13.62
3 am	8.62
6 am	8.62

Figure B2.1b. Price paid for weather observations according to the time of day.

air stations. Generally these silent stations are in the developing world, and the absence of data from these stations undermines the quality of climate services in the regions where they are located.

While the framework of the Global Climate Observing System ensures that efforts to fulfil global requirements for climate observations are progressing, enhancements of observing systems at the regional, national and local levels are also required to support the full range of climate services. The more stringent requirements concerning observation networks and systems for monitoring

Box 2.2. UPPER AIR OBSERVATIONS FOR CLIMATE

Monitoring the temperature and winds through the first 10 to 15 km of the atmosphere, where the weather systems are located, is carried out using remote-based systems such as satellites and radars and *in situ* instruments borne aloft by hydrogen or helium filled balloons. This package of instruments is called a radiosonde. In essence the radiosonde transmits to a ground station data from instruments measuring temperature, humidity, atmospheric pressure and the position of the balloon. The balloon position information, that is transmitted to the ground station as it ascends, enables determination of the winds aloft.

An upper air observation may be carried out in two ways. A fully-automatic balloon release and tracking system might be used, in which case the auto-release device is pre-stocked with balloons, gas, radiosondes and can be remotely controlled from an office tens or thousands of kilometres away. The more traditional way is for the observer to fill the balloon, baseline the instruments on the radiosonde to match the relevant observations at the station, attach the radiosonde to the balloon and release it at the internationally-agreed times. For either method the ground station will receive the signals from the radiosonde, calculate the meteorological parameters and prepare a message describing the results of the observation for insertion into the data management and distribution system.

The cost of operating an upper air observing system will vary substantially between countries, but indicative costs over the 15 year lifetime of a ground station would be of the order of at least

US\$ 300 000 per year. The major cost component is the radiosondes, which cost around US\$ 250 per balloon flight. The cost of making two flights daily would result in an annual expense of over US\$ 180 000. This estimate does not include the costs of the radiosonde station infrastructure such as hydrogen filling systems and storage facilities or labour costs. While the cost of observers will vary from country-to-country, trained, skilled, reliable technicians will typically cost at least US\$ 100 000, however employed.



Figure B2.2. Releasing a hydrogen-filled balloon with a radiosonde attached – Lord Howe Island

climate, including the detection of climate change, has led to the development of special networks at the regional (e.g. Regional Basic Climatological Network) and national (e.g. Reference Climate Stations) levels. National observing network design and effective implementation are essential to providing effective climate services to communities. This increased granularity is necessary because the impacts of climate variability and change may be very different within different parts of a country due to the effects of topography or other factors (Figure 2.4).

SPACE-BASED OBSERVING SYSTEMS

Space-based observing systems, mainly satellites, provide an essential complement to *in situ* systems for many Essential Climate Variables (Figure 2.3, Box 2.3), and are the only technique to observe some variables comprehensively, such as cloud properties, the Earth's radiation budget, ozone, sea surface

temperature, sea ice and many others. Although satellites provide a very powerful tool for observing many variables, there is still a need to calibrate or “ground-truth” information from satellites against surface observations and to integrate surface and satellite data in products where possible.

Space-based observation relies heavily on two types of satellite systems. Firstly, a set of geostationary meteorological satellites is located at fixed positions 36 000 km above the equator at different longitudes around the Earth. Secondly, Low Earth Orbit satellites orbit at altitudes of around 800 km and observe a given location less frequently than geostationary satellites but at higher spatial resolution and using more capable sensors. A coordinated set of satellites of both types provides the backbone of permanent and near-global monitoring of weather. Other research and operational Low Earth Orbit satellites are dedicated to observations of land, ocean and ice (see Box 2.4).

The real time, globally-spanning nature of satellite observations provides a range of essential inputs to numerical modelling. Observations from satellites, taken primarily for weather forecasting purposes, are archived and used in climate analysis. Since some satellite data records now stretch back four decades, they are becoming increasingly important for the study of climate variability and decadal trends. However, for many climate purposes the data records from satellites currently cover too short a time span for climate trend analyses. Surface instrumental data and proxy reconstructions (e.g. from tree ring width data) of temperature, precipitation and other variables over many decades or even centuries are essential to providing a long-term view on climate processes and especially on climate trends.

2.4 OCEAN OBSERVING SYSTEMS

MAIN REQUIREMENTS

The world’s oceans, including the frozen parts, play a critical role in the climate system. They have enormous capacity to store, transport and release heat and to absorb carbon dioxide. The interactive coupling of the oceans and atmosphere give rise to the El Niño Southern Oscillation phenomenon, affecting seasonal weather and storm patterns around the world, while polar sea ice alters the globe’s albedo (reflection of sunlight) and when melting can affect ocean currents. Seasonal climate predictions require information about ocean temperature, not only for the ocean surface but also

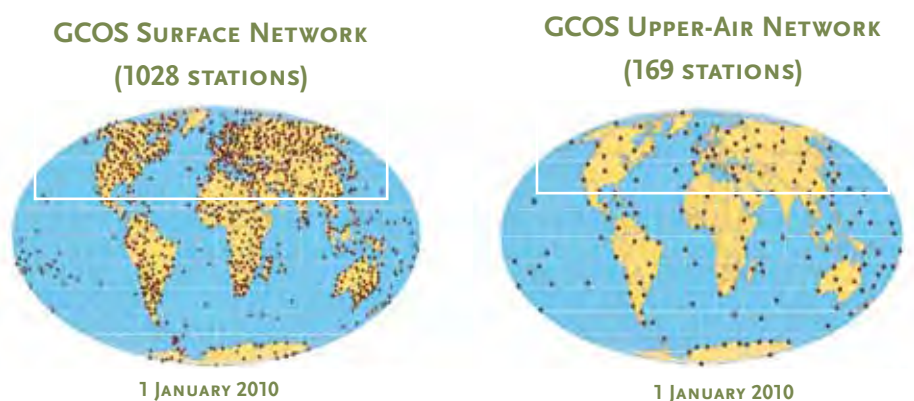


Figure 2.4. Map of the stations of the Global Climate Observing System (GCOS) Surface Network and Global Climate Observing System (GCOS) Upper Air Network

Box 2.3. SATELLITE RAINFALL ESTIMATES

Rainfall is one of the most spatially variable of all weather features, especially in mountainous areas. Often it is possible to be in bright sunlight and to see a storm raining only a short distance away. Rainfall is traditionally measured using a rain gauge, which is a little bit like a small bucket of only a few centimetres in diameter, and when in operation is located in a well-exposed site. In much of the world the density of gauges is very sparse, and over the sea there are virtually no gauges at all. A lack of gauges over the land makes it very difficult to provide accurate information about this important climate variable. While rainfall over the sea may not seem to be of much practical interest, it is of crucial concern to

scientists who need to be able to check whether their models are simulating the real world's rainfall realistically.

In the absence of gauge measurements over much of the Earth, scientists have been developing ways of estimating rainfall remotely. Remote measurements of rainfall can be made either from ground-based radars, or from satellites. Radars can measure rainfall over a radius of only about 300 km and do not work well in hilly terrain, so they do not currently provide much coverage. Satellite-based measurements of rainfall provide global coverage and in some cases can be obtained within 15 to 30 minutes of recording, and much of the data are available free of charge. However, satellite estimates do come with some disadvantages: they make indirect measurements and therefore contain inherent uncertainty; they have not been available for anywhere near as long as the gauge measurements; and they measure rainfall only over fairly large areas rather than at specific locations (although for some applications such as hydrology, spatial averages may be more useful than location-specific measurements). As a result, expert interpretation is often needed to assess when and where the data are reliable.



Figure B2.3. Heavy monsoon rains in India and Bangladesh during early July 2010. This colour-coded image shows rainfall amounts in India, Bangladesh, and the Bay of Bengal from 6 to 12 July 2010. The heaviest rainfall amounts – 400 mm – appear in dark blue. This image is based on data from the Multi-satellite Precipitation Analysis, which estimates rainfall by combining measurements from many satellites and calibrating them using rainfall measurements from the Tropical Rainfall Measuring Mission satellite. *Source:* NASA.

below the surface for many tens of metres depth, particularly so in the influential Pacific equatorial region but also in the other oceans. For decadal climate prediction, information from the full depth of the ocean may be needed.

Ocean wave and wind conditions are important to shipping and along with sea level have major impacts on coastal communities and environments. Observations of sea level are vital to scientists studying ocean currents and global climate change, to engineers for the design of coastal installations, for the provision of flood warnings from storm surges and tsunamis and in local applications such as provision of tide tables and real-time data for port operations.

Box 2.4. COSTS OF SATELLITE OBSERVING SYSTEMS

Currently there are essentially three groups of satellite contributing to weather and climate monitoring:

- Operational satellites in geostationary orbits (that is, they orbit above the equator at the same rate the Earth spins so that, relative to the earth they are stationary).
- Operational satellites in polar orbits, flying at lower altitudes than geostationary satellites and carrying a range of instruments to serve operational climate and weather analysis.
- Research and development satellites that can provide data useful for operations and on which experimental instrumentation can be tested for ultimate transition into the operational environment. There are approximately two-to-three times the number of research and development satellites flying as compared to operational satellites.

The whole-of-life costs of a satellite system include building and launching the satellite, as well as building and operating the ground stations necessary to maintain the satellite on-station/in the correct orbit receiving as well as processing the incoming data stream and output products. Clearly these costs will vary from country-to-country, but several examples in the open literature provide an indication of the scale of costs. The following

examples provide an indicative cost of satellite programmes for weather and climate. It should be noted that current operational satellite systems are entirely justified by their weather applications. Climate applications have been a welcome additional bonus. However, improved climate applications to support climate services will entail additional costs.

GEOSTATIONARY SATELLITES

The METEOSAT Program is the European operational, geostationary meteorological satellite program. A recent (March 2010) announcement indicated that for six satellites with different instrument configurations to provide operational coverage of Europe for 20 years (2016–2036), the programme cost would be of the order of US\$ 4.4 billion, that is, US\$ 220 million per year. To achieve full global coverage, six such contracts would be required, at a total cost of US\$ 1.32 billion per year. These costs include launcher services and ground operations.

POLAR ORBITING ENVIRONMENTAL SATELLITES

The United States National Polar-orbiting Operational Environmental Satellite System provides a useful indication of the costs involved in polar-orbiting satellite programmes. In 2002, the programme was estimated to cost approximately US\$ 6.5 billion for development and operations until 2018. However, the programme encountered numerous challenges, which led to restructuring in 2006 due to cost over-runs. The restructured program reduced the scale of the programme from six main satellites (in three orbits) to four satellites (in two orbits). At that time, the new life-cycle cost estimate (until 2024, due to delays) was approximately US\$ 12 billion for this reduced capability. In 2010 the programme was again restructured due to schedule delays and cost increases. The current official baseline life-cycle cost estimate is approximately US\$ 13.9 billion, or around US\$ 1 billion per year.



Figure B2.4. ENVISAT, a European satellite providing continuous observations of the Earth including measurements related to atmospheric chemistry, sea surface temperature and ice coverage.

CURRENT OCEANIC OBSERVING SYSTEMS AND STATUS

Systematic observations of the oceans, including both coastal and deep ocean zones, are undertaken by in situ surface and subsurface observing networks and by satellite remote sensing, organised under the Global Ocean Observing System that provides the ocean component of the Global Climate Observing System. Because sea water strongly absorbs light and electromagnetic radiation, only the immediate surface layer of the ocean is visible from space-based instruments. Information on ocean characteristics below the surface can therefore only be achieved through in situ direct sampling of the ocean from specialised buoys or ships.

It is clearly a very challenging task to establish and maintain instrument systems in remote oceanic settings and in the inhospitable depths below the surface. Nevertheless, there is now a set of global in situ networks that systematically observe the temperature and salinity of the upper 2 000 m of the ocean in ice-free regions (Figures 2.5 and 2.6). These include instruments on, and hung below, permanently moored buoys, for example those of the tropical Pacific array that monitors El Niño Southern Oscillation conditions, as well as buoys that drift with the currents across the world's oceans. The Argo profiling float is designed to undertake cycles of periodic submersion automatically in order to profile conditions from the surface to a depth of around 2 000 m and then return to the surface where the data can be transmitted via satellite to global data centres. Both the Argo and drifting surface buoy systems have reached their target numbers for global coverage in the last few years. This is a remarkable achievement that is helping fill a major gap in knowledge of the oceans. Nevertheless, relative to land areas the oceans are under-observed using in situ instrumentation and in the polar regions they are very poorly observed. In addition, the current technical capacity of floats does not allow in situ temperature observations of the oceans below 2 000 m, where small temperature changes could have significant implications for global sea level rise as well as for the climate centuries from now.

Satellite-based instruments complement the in situ networks with high resolution, near-global coverage of ocean surface variables that are important to climate—sea surface temperature, sea surface height, surface winds, sea ice and ocean colour. New missions are now underway to measure sea surface salinity. As with all remotely-sensed data, calibration and validation are achieved by comparing them with in situ measurements. The concept of a “virtual constellation” of satellite capacities for each of the observed ocean variables – coordinated through the International Committee on Earth Observation Satellites – is being developed among those nations that support space-based earth observing programmes as a means of avoiding duplication and of ensuring continuity of global

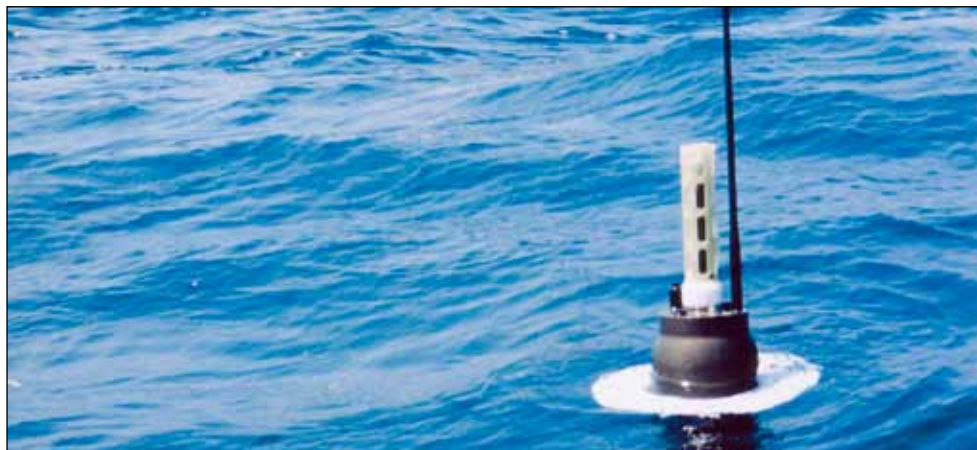


Figure 2.5. Profiling float which descends to a depth of around 2 000 m.

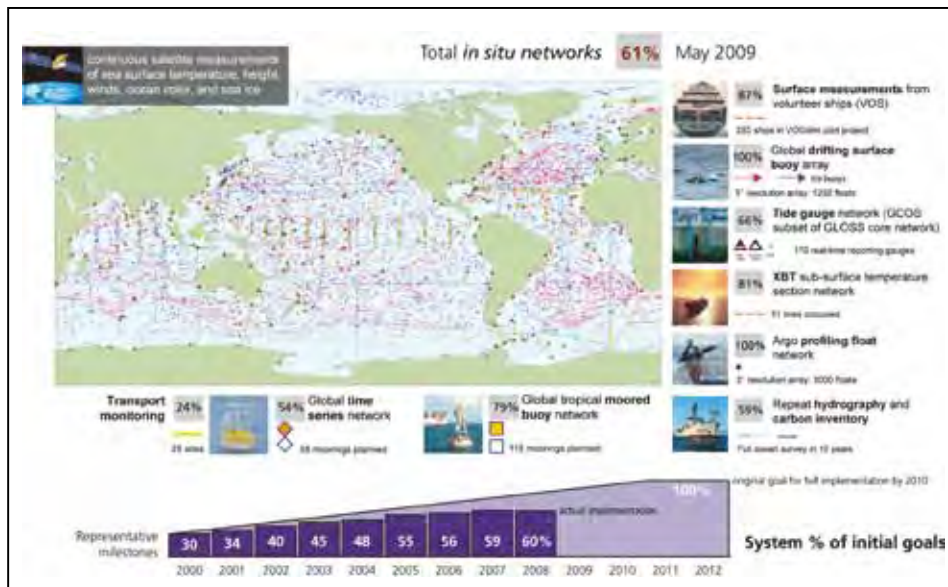


Figure 2.6. A schematic of the in situ sustained, global ocean observing networks as of May 2009, with the percent achieved of the initial target density set by GCOS-92. To sustain the networks, constant investment in redeployment and refurbishing of the instruments is needed. Progress has been slowing and has failed to meet the overall targets set for the in situ system.

observations. Commitments to fly missions adequate to cover ocean climate variables are generally reasonably good (Figure 2.7), although future gaps may occur since the lifetimes of satellite missions cannot be guaranteed.

Sea levels can be monitored using various methods including tide gauges, pressure sensors in the deep ocean and satellite radar altimetry. Records from some tide gauges stretch back more than

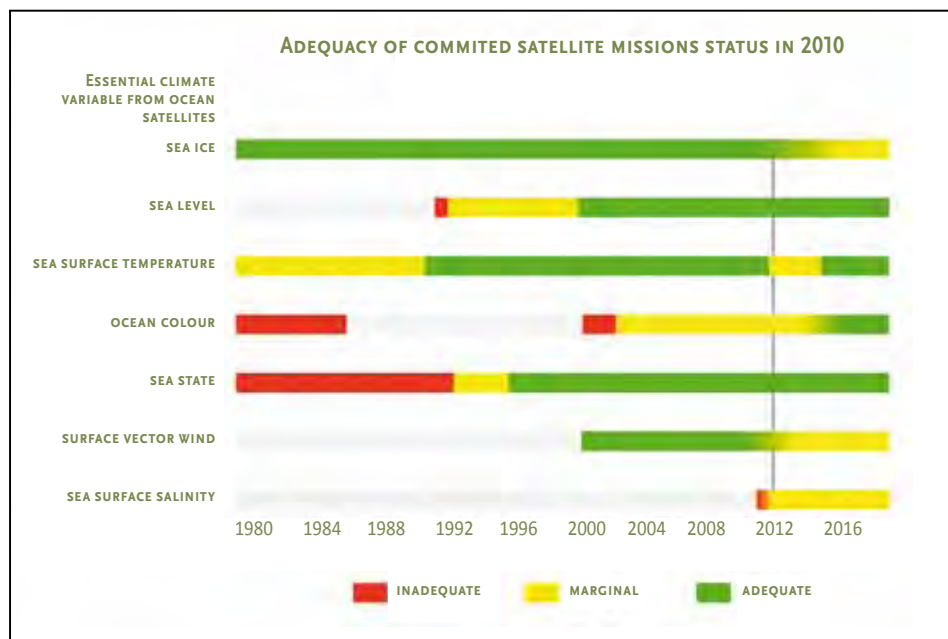


Figure 2.7. Timeline of adequacy of ocean satellite coverage in the past and commitments to future missions, by Essential Climate Variable.

200 years. While most coastal countries operate tide gauge networks, the establishment of global and regional networks of sea level stations is undertaken by the Global Sea Level Observing System, which is coordinated by the International Oceanographic Commission. The system is operated to provide information essential to international oceanographic research programmes, including those dedicated to the study of aspects of climate change. Its major main component is the 'Global Sea Level Observing System Core Network', which comprises approximately 290 stations worldwide, most of which are now operational, and forms the backbone of a more distributed network. As for many other observing networks, station sustainability is an ongoing challenge for the Global Sea Level Observing System.

2.5 TERRESTRIAL OBSERVING SYSTEMS

MAIN REQUIREMENTS

Land surface characteristics are very diverse and vary rapidly from place to place. Altitude, slope, soil, water content and vegetation directly affect the climate through heat exchange, water budgets, carbon fluxes and reflective properties (albedo). Snow and ice, whether as a seasonal phenomenon or in more permanent forms such as glaciers, ice sheets and permafrost, play an important role through their high albedo and impact on heat exchange and melt water runoff. Rapid changes in land uses, especially over the last 50 years, have radically changed the characteristics of many parts of the Earth's land surfaces. Where large areas are concerned, for example in the case of tropical deforestation and in some cases urbanisation, the regional and global climate may be affected. Almost 40 per cent of the Earth's land surface is now under some form of active management. There is a growing awareness of the need to understand the terrestrial components of the climate system better and the implications of these changes for the climate, the biosphere and human society.

CURRENT TERRESTRIAL OBSERVING SYSTEMS AND STATUS

While observations of the Earth's surface characteristics have been made at many locations and have been recorded over many past centuries, it is only relatively recently that the concept of systematic global terrestrial observations has developed. For the purposes of climate science and services a wide range of systems is needed to capture the varied data types, which include vegetation cover, vegetation seasonal stage, plant health, glacier thickness, snow cover, river discharge, wetland extent, soil type, soil moisture, land use data, wildland fire occurrence and dust storms, etc.

Some capacities for global in situ observation networks and space-based observing systems are in place and are being coordinated through the Global Terrestrial Observing System, which provides the terrestrial component of Global Climate Observing System and is led by Food and Agriculture Organization and co-sponsored by the World Meteorological Organization, the United Nations Environmental Programme, the United Nations Educational, Scientific and Cultural Organization and the International Council for Science. In addition to the Global Terrestrial Observing System there are a number of other international efforts underway to improve observation capacity, including the European Space Agency's Global Project Series.

There has been considerable progress in establishing several Global Terrestrial Networks, for example for hydrology, permafrost and glaciers, and a Global Terrestrial Network for soil moisture is planned. There is also an increasing commitment by space agencies to produce climate-relevant records from existing systems. New satellites are planned or already in orbit that will specifically focus on making

soil moisture observations. These advances have led to the improved availability of global datasets of a number of important terrestrial climate variables.

Improved mechanisms are being developed for international coordination, for example the Global Terrestrial Observing System science panels and the Land Product Validation Group within the Committee on Earth Observation Satellites Working Group on Calibration and Validation. Concerted efforts are underway to evaluate and benchmark some of the terrestrial products, improve the quality control and comparability of data and support and improve access to terrestrial observations.

2.6 SOCIO-ECONOMIC INFORMATION

MAIN REQUIREMENTS

In the climate arena, socio-economic information is needed for two main reasons: firstly, humans and their economic systems are the source and drivers of environmental change, including climate change; and secondly, they are impacted by climate and are the users of climate information and services.

At the national and community levels, both climate and socio-economic information is required for assessing vulnerabilities and risks, understanding the impacts of climate on biophysical systems, developing and implementing effective climate services, and responding to climate mitigation and adaptation needs. Socio-economic information is needed about the exposure and vulnerability of populations to climate variations. These depend on characteristics such as income, education, health and access to public services. High vulnerability to climate variability and change is often strongly associated with poverty. Where relevant, data disaggregated by sex and other variables such as age is useful for understanding the vulnerabilities of different groups. Information is also needed on the vulnerabilities of key sectors in the context of climate vulnerability and change, infrastructure and other elements of the economy that may depend on the location, size, and design of a facility or industry.

At the international and regional levels, socio-economic information is required to address matters of shared multilateral concern, particularly emissions of greenhouse gases and other pollutants, the use of trans-boundary natural resources such as lakes and rivers and the global achievement of the Millennium Development Goals and other international agreements. Given the speed of change of many social and economic factors, it is usually important to monitor the trends in key elements.

Information on cultural factors, such as beliefs about weather and climate, trust in authority, access to social networks and social capital and views on public and private goods are also important to providing climate services. This is because these factors can affect the value people place on climate information and how they use it to make decisions, as well as affecting public acceptance of measures taken on the basis of climate information.

DATA COLLECTION APPROACHES

The diversity and complexity of social concepts and human social systems provides a very challenging context for systematic data gathering. Systems for collecting socio-economic information relevant to managing climate risk are therefore much more diverse and less well-developed than those for observing the climate system itself. Moreover, many types of socio-economic data have political and

economic value or implications that can impede reliable data collection and may lead to concealment or exaggeration of the data.

Despite these difficulties, social scientists, economists and public health experts have well-developed repertoires of tools for obtaining the types of social and economic data necessary to understand livelihoods better and to answer questions of public policy importance. These tools range from legislated requirements to supply data, study of census data collection, sample surveys, longitudinal studies of communities or age cohorts, direct behavioural observation and even remote sensing.

In most countries, a national statistical authority will be a primary source of social and economic information, holding detailed information on population, family circumstances, housing, occupations, incomes, etc., and either here or in a ministry of finance further detailed national information will be available on national economic accounts, industry profiles, exports, capital stock, market characteristics, etc. Public health authorities maintain records of health and disease factors. Local governments, sector organizations, research institutes and non-governmental organizations are likely to hold specialised data sets of direct concern to them.

At the international level United Nations agencies and programmes, the World Bank and other organizations regularly consolidate and publish socio-economic data from countries in comparative formats, usually as part of internationally-agreed mandates. Some types of economic information may be available from the private sector, such as from the insurance and re-insurance industries. Lastly, the research literature contains a great wealth of focused studies that can be of direct relevance to a particular problem.

Since most climate services are still very limited, the socio-economic data needed to develop and implement the service or support a service that is decision-relevant can also be supplied by the client or group concerned. Within such partnerships, confidential data such as records of assets and other resources or production figures or losses can be readily protected. Similarly, for climate services at a national and public good level, major public agencies holding the relevant socio-economic data should be engaged in the process.

Although socio-economic data collection has not been organised in the same globally systematic way as occurs for climate observations, nevertheless there remains a need for coordination and standardisation of concepts and approaches upon which the climate services in any country can more easily build. This need is already recognised and addressed in international research programmes on the human aspects of climate and environment such as the International Human Dimensions Programme on Global Environmental Change (co-sponsored by the International Council for Science and the International Social Sciences Council), the Integrated Research on Disaster Risk programme (co-sponsored by the International Council for Science, the International Social Sciences Council and the United Nations International Strategy for Disaster Reduction) and the International Geosphere-Biosphere Programme (sponsored by the International Council for Science).

2.7 QUALITY CONTROL AND EXCHANGE OF CLIMATE DATA

DATA QUALITY AND STANDARDS

With the possible exception of local level applications, climate observations cannot be used with confidence unless they meet established international standards in terms of how they are measured and quality controlled. Common standards and good quality control enable comparability of results

Box 2.5. REANALYSIS OF PAST OBSERVATIONS

In climate science, a *reanalysis* is a method for constructing a high quality climate record that uses a diverse array of past observations combined together within a model in order to derive a best estimate of how the climate system has evolved over time.

The climate record is made up of analysis of observations taken for many other purposes, such as weather forecasting in the atmosphere or oceanographic research. However, due to changes in observing practices and data assimilation systems, many climate datasets are not homogeneous. The record can be too short to provide decadal-scale information or inconsistent because of operational changes and the absence of adequate meta-data. This can make it difficult to interpret and mask long-term variations.

Major efforts have therefore been required to homogenise observed data to make it more useful for climate purposes such as research and monitoring. Reanalyses datasets are produced using fixed, modern versions of the data assimilation systems developed for numerical weather prediction. They are therefore more suitable than operational analyses for use in studies of long-term variability in the

climate. The observations can come from many different sources including ships, satellites, ground stations and radar. By using the same model, scientists can examine climate/weather statistics and dynamic processes without the complications that model changes can cause. These reanalysis datasets currently extend over periods of up to 40 years and provide spatial and temporal resolution sometimes lacking in observed climate data sets.

Reanalyses of multi-decadal series of past observations have become an important and widely used resource for the study of atmospheric and oceanic processes and predictability. Since reanalysis was first proposed, there have been great advances in our ability to generate high-quality, temporally-homogeneous estimates of the past climate. With the ongoing development of analysis and reanalysis in the ocean, land and sea ice domains, there is a huge potential for further progress and improved knowledge of the past climate record.

across countries as well as dependable worldwide use of methodologies that use the data. Climate observations are undertaken under a wide range of circumstances and management regimes, but nevertheless need to be of consistent quality globally, with few gaps in the record over time and with appropriate spatial density and temporal frequency. Reanalysis is a powerful technique for constructing a high quality climate record from past observations from a wide range of sources that has recently been developed. It is helping make the historical record more useful for climate research and monitoring (see Box 2.5).

Standards for instrumentation and observational technique are developed by international experts and are mandated by the World Meteorological Organization and other international agencies in formal documents and specifications. For example, the observations coordinated under the World Meteorological Organization Integrated Global Observing System follow standard procedures established through the intensive work of the Technical Commissions under its Quality Management Framework. The International Standards Organization recognises these standards and also recognises the World Meteorological Organization as a body competent and authorised to set standards. There are also a number of standards relevant to sector-specific observations. The Group on Earth Observations is in the process of developing a framework called the Integrated Data Environment to establish guidelines to enable data observations from many sources to be exchanged and meaningfully compared.

Similarly, to help ensure the quality and consistency of observations, the Global Climate Observing System has developed a set of Climate Monitoring Principles to guide the collection, archiving and analysis of in situ and satellite-based climate observations.¹ These principles have been endorsed by a number of intergovernmental technical bodies. However, their implementation is often not simple or free of cost for the organizations that must change procedures and systems to be in compliance.

A number of international data rescue initiatives are also underway, including those under the auspices of the Atmospheric Circulation Reconstructions over the Earth group and others within the World Meteorological Organization. These aim to secure and inventory data, give advice on best practice for dealing with data manuscripts and data stored on obsolete technologies, and provide capacity building for national staff.

ROLE OF NATIONAL AND INTERNATIONAL DATA CENTRES

National centres and specialised international centres supported by host countries oversee a number of important activities associated with data collection, monitoring, archiving and redistribution. International data centres have been established for many groups of climate-related variables. Some undertake work to monitor and improve the flow and quality of data, while others act as international archives, collecting, quality-controlling and archiving global data and making it available to users. Data may be forwarded to data centres in near real time or retrospectively, and in some cases this occurs through direct computer access between the centre and the data producers' archives. International calibration centres maintain global reference instruments and conduct regular inter-comparisons to transfer calibrations to national standard instruments. There are increasing demands for this critical "back room" work done by international and regional specialised centres in line with the growing interest in quality climate data and the increasing volume and diversity of data that is building up with the passage of time.

MECHANISMS FOR CLIMATE DATA EXCHANGE

The technology and systems for exchanging data are generally present in most countries, though in many developing countries the speed and capacity of systems is far from adequate. A new World Meteorological Organization Information System is being developed to serve as the coordinated global infrastructure for the telecommunication and management of weather, climate, water and related data (Figure 2.8). This will progressively replace the World Meteorological Organization's existing Global Telecommunications System that is operated cooperatively by countries on a 24-hour-a-day, seven-days-a-week basis. The new Information System has been designed to meet global requirements for routine collection and dissemination not only of observed data but also of value-added analysis products. It will also support user needs for locating, accessing and transmitting data.

Another initiative to help make climate data widely accessible is the Global Climate Observing System-initiated Global Observing Systems Information Centre that has been established as an online portal that does not itself hold data but rather provides a common access point to global and regional data sets and analyses for use in various aspects of climate research. The Centre provides a central source that details the various global observing systems by providing an integrated overview of the data, information and services that comprise each of them.

The International Council of Science World Data System was established in 2008 to bring together existing stand-alone World Data Centres and individual services to form a common, globally interoperable distributed data system. The system has a broad disciplinary and geographic base,

¹ http://www.wmo.int/pages/prog/gcos/documents/GCOS_Climate_Monitoring_Principles.pdf

which includes World Data Centres for many disciplines relevant to climate services, including those outside physical climate sciences. The system is still in development and over 100 World Data Centres and Federation Services, as well as numerous other data centres, services and activities, have expressed interest in becoming part of the new system.

The Global Earth Observation System of Systems Common Infrastructure is also being developed to ensure that end-users of Earth observation data have efficient, effective access to the full suite of Earth observation content provided through the Global Earth Observation System of Systems. The Common Infrastructure facilitates interoperability among all content contributed to the Global Earth Observation System of Systems and promotes the use of standards and references, best practices, inter-calibration and data assimilation.

PRINCIPLES OF DATA EXCHANGE

Governments have long cooperated in collecting and freely exchanging the data necessary for generating weather forecasts and warnings. The rationale for freely exchanging weather data is simple – namely, that the weather at one location depends on what is happening elsewhere across the world, making it totally impractical and uneconomic for each individual country to gather information independently worldwide. Thus governments willingly collect and exchange weather data from their own territory using common standards, knowing that they will reap the benefits from other countries' investments in observing systems, enhancing the safety and wealth of their own citizens and enterprises. Perhaps less visibly, they also derive continuing benefits from the international cooperation that is involved – particularly from the rapid diffusion of new science and of methods that improve the efficiency and quality of their own investments in weather observations and forecasting, resulting in better use of weather information in economic sectors. Standardisation of methods and quality control are valuable elements found in these “unseen” benefits that are associated with cooperation.

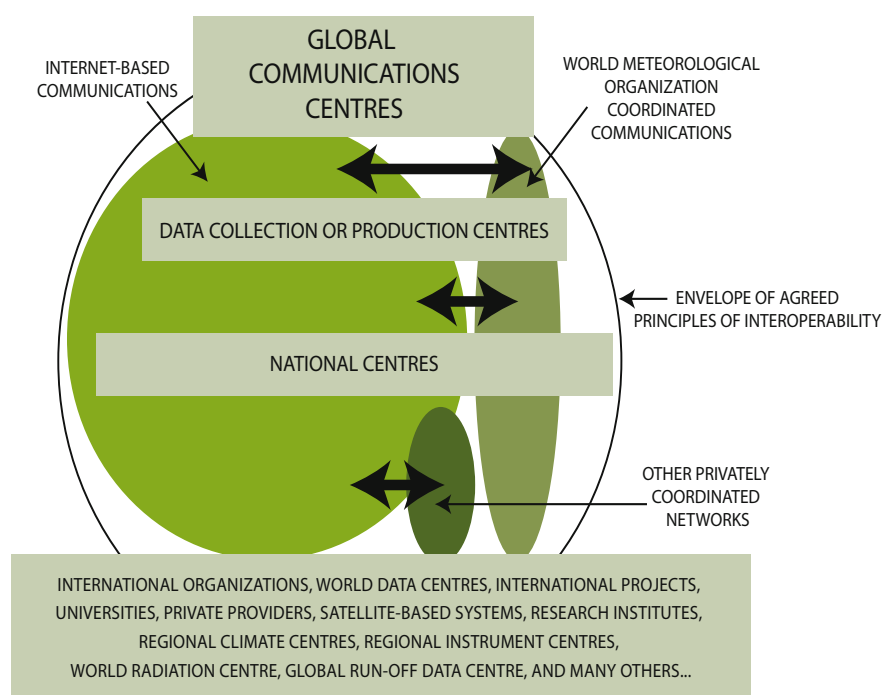


Figure 2.8. A schematic illustration of a possible Climate Services Information System that includes the World Meteorological Organization's Information System and other Internet-based and private networks working within an envelope of interoperability.

Like the weather, the climate knows no political boundaries and it is vital that the observations necessary to support climate services are quickly and reliably shared around the world in agreed-upon formats. The United Nations Framework Convention on Climate Change recognises the public-good nature of climate data and requires the Parties to the Convention to promote access to and exchange of climate data. Similarly, the World Meteorological Organization, the United Nations Educational, Scientific and Cultural Organization's Intergovernmental Oceanographic Commission and the Group on Earth Observations promote the free and open exchange of data among Member States and Territories.

2.8 GLOBAL COORDINATION MECHANISMS

THE RATIONALE FOR COORDINATION

Most climate-related observations are made by national agencies or by agencies set up by groups of nations for particular purposes. Therefore it is nations, acting individually or jointly, that are responsible for implementing and operating observing systems, for coordinating their activities through international programmes and for deciding how their data will be exchanged. International coordination mechanisms enable the relevant parties to share in defining and implementing the activities to be undertaken. This is particularly necessary for global observation systems owing to the considerable financial resources and high technical expertise involved.

EXISTING COORDINATION MECHANISMS

Numerous international mechanisms exist to coordinate the various operational observation systems and programmes that serve national and international needs related to climate. These mechanisms have developed over time as technological possibilities and demands for data have expanded and now cover a wide range of concerns from broad oversight to highly specialised technical requirements. The resulting overall picture is rather bewildering to newcomers, but for the organizations involved the distinctive and interlocking roles of each mechanism are well understood, with little overlap in function. In addition to conventional downwards coordination under direct governance responsibility or "umbrella" arrangements, coordination may occur sideways between programmes having common concerns or even upwards from specialised programmes. Here we will describe only the main components in order to illustrate the strong core capacities that are in place and that can be strengthened to improve international coordination for climate data related purposes. Coordination mechanisms for observation systems and data gathering in the environmental and socio-economic fields are much less developed, however.

THE GLOBAL CLIMATE OBSERVING SYSTEM

The Global Climate Observing System is the framework through which its partners ensure that all their individual and jointly sponsored global observing systems work together to meet the total national and international needs for climate-related observations. It is an overarching system of climate observing systems comprising climate-related networks in atmospheric, terrestrial and oceanic domains. Its main components are:

- The World Meteorological Organization Integrated Global Observing System;
- The United Nations Educational, Scientific and Cultural Organization Inter-governmental Oceanographic Commission's co-sponsored Global Ocean Observing System; and

- The Food and Agriculture Organization-led, and co-sponsored, Global Terrestrial Observing System.

The Global Climate Observing System facilitates the provision of comprehensive information on the total climate system by integrating a multi-disciplinary range of physical, chemical and biological properties as well as atmospheric, oceanic, hydrologic, cryospheric and terrestrial processes. It is designed to support all aspects of the World Climate Programme and climate-relevant aspects of other global programmes, especially the work of the Intergovernmental Panel on Climate Change and the United Nations Framework Convention on Climate Change. The global, regional and national observing networks that contribute to the Global Climate Observing System provide most of the data used for climate analysis, prediction and change-detection.

The 2010 update to the Global Climate Observing System implementation plan outlines a set of actions required to implement and maintain a comprehensive global observing system for climate. The plan contains 138 recommended actions to be undertaken, mostly over the next five years, across the atmospheric, oceanic and terrestrial domains. Many of the proposed actions are already underway. If fully implemented, the plan will provide observations of the Essential Climate Variables needed to make significant progress in the generation of global climate products and services, support research, modelling, analysis and capacity building activities, while addressing the need for observational records to improve seasonal-to-inter-annual climate predictions.

THE GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS

The Global Earth Observation System of Systems is an intergovernmental mechanism established in 2005 to expand the potential of Earth observations to support decision making throughout society. Led by its many country sponsors in the Group on Earth Observations, this system aims to link comprehensive observations from all platforms more effectively in order to meet the needs of nine key societal areas: agriculture, ecosystems, biodiversity, weather, climate, water, disasters, energy and health. The Group on Earth Observations Communities of Practice have been established for specific topics within these areas. The Global Climate Observing System has been identified as the climate-observing component of the Global Earth Observation System of Systems.

SATELLITE SYSTEMS COORDINATION

A number of mechanisms currently exist to support the coordination of climate observations from satellites. These include the Coordination Group for Meteorological Satellites and the Committee on Earth Observation Satellites. Efforts are underway for coordinated creation of historical climate records from satellites and inter-calibration through the Global Space-based Inter-calibration System. The European Organization for the Exploitation of Meteorological Satellites services the coordination requirements of its 26 Member States and a further five countries with which it has cooperation agreements. The European Space Agency also undertakes coordination efforts, including through its Climate Change Initiative.

The Space Programme of the World Meteorological Organization coordinates environmental satellite matters and activities throughout all its Programmes and provides guidance on the potential of remote-sensing techniques in meteorology, hydrology and related disciplines and applications. The Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring is a network of facilities ensuring continuous and sustained provision of high-quality satellite products related to the Essential Climate Variables on a global scale, responding to the requirements of the Global Climate Observing System.

THE WORLD WEATHER WATCH

The World Weather Watch of the World Meteorological Organization is the longstanding international cooperative programme that arranges for gathering and distributing meteorological information in real time on a worldwide scale. Since a large fraction of climate observations originate as weather observations, the World Weather Watch provides a foundational capacity for generating climate data. It combines observing systems, telecommunication facilities and data-processing and forecasting centres operated by Members and involves the design, implementation, operation and continued development of the following three interconnected elements:

- The Global Observing System, consisting of facilities and arrangements for making observations at stations on land and at sea and from aircraft, environmental observation satellites and other platforms;
- The Global Telecommunication System, consisting of integrated networks of telecommunication facilities and centres;
- The Global Data Processing and Forecasting Systems, consisting of World, Regional, Specialized and National Meteorological Centres to provide processed data, analyses and forecast products.

COORDINATION OF NON-METEOROLOGICAL DATA SYSTEMS

Coordination arrangements exist for most observation systems of global scope, typically driven by United Nations entities on behalf of governments or by international scientific organizations that oversee specialised areas of knowledge. For example, the coordination of the Global Terrestrial Observing System is hosted at the Food and Agriculture Organization, which also coordinates global collection and review of agricultural information. The World Health Organization maintains worldwide monitoring systems for diseases, including those affected by the weather and seasonal climate patterns. The United Nations Environmental Programme coordinates a wide range of environmental monitoring programmes as part of its mandate to monitor the status of the global environment and to gather and disseminate environmental information.

Other United Nations System entities that undertake climate-related coordination responsibilities in their area of concern include the secretariat of the United Nations Convention on Biodiversity and the United Nations Convention to Combat Desertification. Wildland fire provides an interesting example of coordination that involves governmental and non-governmental organizations and spans operational fire management and scientific research (see Box 2.6). The International Telecommunications Union oversees the allocation of radio frequencies and approves standards to ensure that information from terrestrial and space-based observing systems of all types can be effectively communicated.

COORDINATION ON CLIMATE-RELATED SOCIO-ECONOMIC INFORMATION

Coordination is less-well-developed concerning climate service-relevant socio-economic observational work. The United Nations Statistical Commission brings together the Chief Statisticians from United Nations Member states and is responsible for international statistical activities, especially for setting statistical standards, developing concepts and methods and implementing them at national and international levels. It also oversees the work of the United Nations Statistics Division. Many other international organizations, such as the United Nations Conference on Trade and Development, the World Trade Organization, the International Monetary Fund, the World Bank and the Organization for Economic Cooperation and Development are major actors in developing and coordinating socio-economic statistics.

Box 2.6. COORDINATION IN WILDLAND FIRE MANAGEMENT

Wildland fire provides an interesting example of coordination that involves governmental and non-governmental organizations and spans operational fire management and scientific research.

With the longstanding leadership of the Global Fire Monitoring Centre, a subdivision of the Max Planck Institute for Chemistry and the United Nations University based at Freiburg University, Germany, a range of coordination and collaborative efforts have been developed on data exchange, research, forest and fire management and related capacity building. Fourteen regional networks have been developed under the umbrella of the United Nations International Strategy for Disaster Reduction Global Wildland Fire Network, a major international scientific-technical conference is held every four years, and a multi-stakeholder international advisory committee is regularly convened. International cooperation is enhanced through bilateral agreements and the development of internationally-agreed voluntary standards for competency-based fire management training and operational systems based on the state-of-the-art science. Intergovernmental validation has been pursued through the Food and Agriculture Organization-based Committee on Forestry, which in March 2007 recognised the increasing threat

of wildfire to forest ecosystems and their sustainable management and recommended that the Food and Agriculture Organization strengthen its support to countries to address these issues, including by exchanging information and experiences, networking, developing voluntary guidelines and strategies, capacity building and international cooperation. Observations from space-based systems and the World Meteorological Organization Global Observing System stations form the backbone of the development of a Global Wildland Fire Early Warning System.

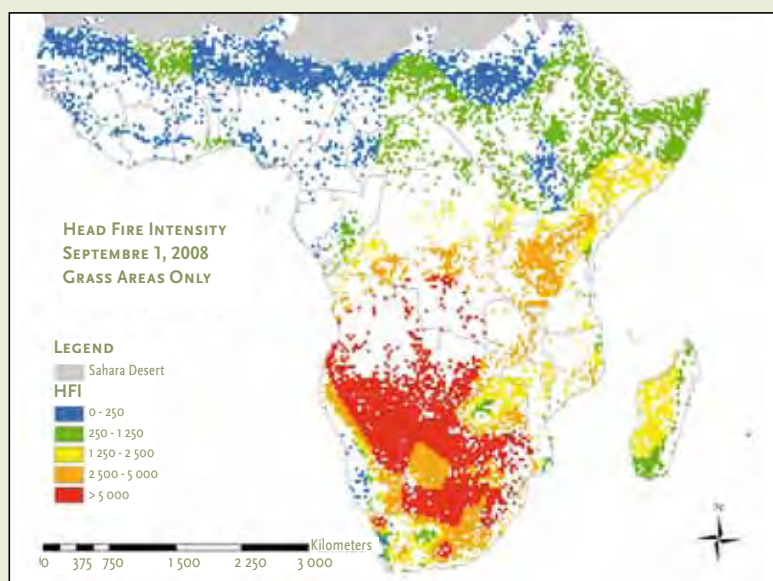


Figure B2.6. Example product of the Global Wildland Fire Early Warning System.
Source: Global Fire Monitoring Center.

2.9 RESOURCING OF OBSERVATION SYSTEMS

The human and financial resources required to establish and maintain operational observing systems are not insignificant but in most countries the fraction of the national budget applied to this purpose is nevertheless extremely small. The total global cost of maintaining and operating existing networks, systems and activities that are required to address climate needs but that are in many cases not specifically designed for climate purposes is estimated at US\$ 5–7 B per year according to the Global Climate Observing System-prepared Implementation Plan for the Global Observing System for Climate in Support of the United Nations Framework Convention on Climate Change (2010 Update). This represents approximately 0.01 per cent of the annual world gross domestic product of US\$ 58 T.

According to the same plan, the additional costs of implementing the 138 atmospheric, oceanic, terrestrial and cross-cutting actions required to improve Global Climate Observing System networks to meet requirements are US\$ 2.5 B per year. These additional costs include costs for augmenting existing systems in support of climate needs, for continuing some existing networks, systems and activities undertaken for research purposes with no plans for continuity, for the transition of systems from research to operations and for new systems needed to satisfy climate needs. The plan includes specific actions to improve the availability of near real-time and historical Global Climate Observing System Surface Network data and to improve operation of the Upper Air Network, both costed at US\$ 10–30 M per year.

2.10 FINDINGS

In reviewing the gathering and exchange of climate observations and information, the Taskforce found the following:

1. To support climate services, high quality observations are required across the entire climate system and of relevant socio-economic variables. Existing capabilities for climate observation and data exchange provide a strong basis for improving climate services globally. However, there are major gaps in climate observations, particularly over the oceans, polar regions, unpopulated regions and in many developing countries. There are shortcomings in the organised and standardised observation of biological, environmental and socio-economic variables and a need to ensure these can be adequately integrated with climate data.
2. Commitment to sustaining continuous and high quality global observations is inadequate, and some types of data needed to understand climate system processes are lacking. Enhancements to the observing networks should be implemented to fill gaps in spatial coverage and in the range of variables measured, and to improve accuracy and frequency where needed. The established in situ and space-based components of the Global Climate Observing System should be sustained and where necessary enhanced to support improved climate services. In addition other enhancements, especially at the local level, will be needed to support the full range of climate services.
3. Improving the atmospheric climate observation network in the developing world is an important step towards improving climate services for the most vulnerable. While recognising that many improvements to the Global Observing System are needed, prioritising specific actions to activate silent Surface Network and Upper Air Network stations located in the developing world would be a cost-effective method for achieving this. It would also help stimulate the development of national and local observation networks.

4. Climate knows no political boundaries – it is therefore vital that observations necessary to support climate services are quickly and reliably shared at the global, regional and local levels. Further discussion among governments is needed to enhance access to and exchange of data. Further effort is also needed to improve the inter-operability of different datasets, including between observations and model results, and to overcome restrictions on access owing to technical problems, such as incompatible formats and outdated data processing and archiving systems.
5. Existing or developing physical infrastructure for data exchange, including that operated as part of the World Meteorological Organization Information System and the International Council of Science World Data System, may provide a useful basis for providing access to climate data, information and services. The possible role of such systems in supporting the objectives of the Global Framework for Climate Services should be taken into account in planning for its implementation.

CHAPTER 3

RESEARCH THAT SUPPORTS CLIMATE SERVICES

3.1 INTRODUCTION

Climate research provides the foundation for climate services by developing and improving the techniques used to understand and predict natural and human-induced climate variability and change. To establish a sound scientific basis for climate services, this needs to be combined with other research on how climate affects society and the environment. It also needs to be understood how climate information, having inherent uncertainty greater than that found in, for example, weather forecasts, can be most effectively used in climate risk management. This chapter describes recent achievements in climate science along with existing research on impacts and decision support that would underpin a climate service system. It also provides a review of existing research coordination mechanisms.

3.2 SCIENCE AS THE FOUNDATION OF CLIMATE SERVICES

While climate science has advanced significantly in recent decades, many scientific challenges remain. There is increasing need for information about the future state of the climate and its impacts on society in order to support decision making and for developing practical applications. The climate system is inextricably linked to the Earth's biological systems and to human activities. Understanding the impacts of climate variability and change on people requires an understanding of socio-economic systems. Effective research to provide climate services therefore requires a multi-disciplinary approach to understand not only the physical climate system but also its interaction with chemical and biological systems as well as the vulnerability of society to changes in the patterns and characteristics of weather and climate.

Climate science alone is not sufficient for the effective provision of climate services. Research relevant to how information might inform decisions and judgment will be fundamentally important to them as well. Similarly, research from the social science sector is needed relating to using uncertain information as a part of decision-relevant climate services that concern impacts, vulnerability, risk and adaptation assessments. None of these research needs can be met without close collaboration between scientists (from the physical, biological, social and economic sciences), users and policy makers.

The ingredients of a successful climate research programme include: a team of well-trained scientists, access to data to underpin the development and testing of hypotheses, access to the current climate-related research literature and computing and other facilities to meet the needs of the research group. This must be joined by a program of activity relevant to meeting the demand for climate research information, while access to impacts, vulnerability, risk and adaptation literature will also be essential. Relatively small research groups have successfully tackled important issues in climate and climate change research but a key part of the improved understanding of climate has been due to the development of General Circulation Models and more recently Earth-System Models. These complex computer models require high levels of infrastructural support including state-of-the-art supercomputers, data storage and information communication systems along with large teams of scientists who specialise in mathematical representations of the various land-surface, ocean, atmosphere, cryosphere, biosphere and even human components that make up the physical climate system.

3.3 RECENT ACHIEVEMENTS IN CLIMATE RESEARCH

The research achievements of climate-related science are closely allied with the developments of weather-related science because the underlying physical principles, methodologies and technologies are common to both. However, whereas weather science has focused primarily on the atmosphere, the development of an understanding of how the atmosphere is affected by, and in turn affects, the oceans has been critical for the development of short-range climate predictions.

In this section we will describe some key achievements of climate research. This brief description barely scratches the surface of the extraordinary progress made in understanding the climate system over the past several decades, and highlights have been chosen largely on the basis that they represent important parts of the foundation upon which future climate services will inevitably be built. These examples also illustrate a little of the broad-based, long-term investments that have been made in climate research and the global nature of the coordination required to tackle the problems faced.

THE CONTRIBUTION OF WEATHER RESEARCH

Accurate weather prediction requires an accurate estimate of the current state of the global atmosphere plus an ability to model how the current state will evolve over the next few hours and days. In the 1960s and 1970s, computer-based numerical weather prediction systems became an increasingly important tool in the day-to-day forecasting of weather conditions around the globe, thus greatly improving the modelling component of the prediction effort. These advances have resulted in operational forecasts that remain routinely valid for up to two weeks under certain conditions, a remarkable scientific achievement since the theoretical limit of weather forecasting of about two weeks estimated by Lorenz in the 1960's remains applicable today.

INTEGRATING ATMOSPHERE AND OCEAN RESEARCH – SEASONAL AND DECADAL PREDICTION

The availability of real-time observations of global weather systems using satellite data combined with global analyses of conventional weather observations, including observations from ships plying regular routes between the continents, has provided invaluable data for estimating the current state of the global atmosphere, as has the implementation of components of an ocean observing system. Observational systems used in climate science have often been developed initially as a part of research projects. The moored buoy platforms in the equatorial Pacific Ocean that have been invaluable for seasonal prediction (see Box 3.1) are a case in point.

For climate services, the requirement is for predictions of longer-lasting average weather conditions and of longer-term systematic changes to climate rather than day-to-day weather. The discovery of longer-lasting climate phenomena such as the El Niño Southern Oscillation (see Box 3.1), which typically persists for about 9 to 12 months, and of the Madden–Julian Oscillation (Figure 3.1), lasting 30 to 60 days, have opened the door in recent decades to the possibility of short-term climate anomaly prediction for periods greater than the theoretical two-week limit of weather predictability.

Despite these advances, there remain challenges within the context of applying research to operations. The benefits realised from seasonal prediction have been limited for a number of reasons:

1. The predictability on seasonal timescales for some essential climate variables such as rainfall is much lower than for temperature, and depends on the time of the year and the geographical location. Predictability is generally higher in the tropical and sub-tropical regions of the globe,

Box 3.1. RESEARCH AND THE DISCOVERY OF ENSO

For centuries, mariners and fishing communities knew that in some years the ocean waters along South America's Pacific coast became much warmer than usual and the otherwise rich coastal fisheries almost disappeared. Called the El Niño, it robbed fishing communities of their food supply and livelihoods while also bringing cloud, heavy rainfalls and floods to places that usually had little rain. Meanwhile, in some years over large tracts of South Asia, Southeast Asia, Australia and the Pacific Islands, populations experienced periodic shifts in their seasonal climate patterns, oscillating from devastating droughts to high rainfalls or vice versa. In the mid 1920s, studies of atmospheric pressure records from different parts of the world by Sir Gilbert Walker showed that these climatic shifts were associated with a global-scale alteration of atmospheric pressure patterns, a phenomenon he called the Southern Oscillation. However, it was not until the 1960s that Jacob Bjerknes and others recognised the connection between the oceanic El Niño and the atmospheric Southern Oscillation which led to coining the phrase El Niño Southern Oscillation as a shorthand expression for this vast, complex ocean – atmosphere interaction.

El Niño Southern Oscillation events involve a “see-saw” of atmospheric pressure, with high (low) pressure over South East Pacific (measured in Tahiti) and low (high) pressure over Northern Australia and Indonesia (measured in Darwin). The periods when there is low pressure over Tahiti are the El Niño years, with warm water incursions in the Eastern Pacific along the equator. Generally, in El Niño years droughts are experienced in South-east Asia and over large areas of Australia and Southern Africa, heavy rainfall and flooding in arid areas of South America and East Africa and failure of the monsoons in India and West Africa. In temperate regions, El Niño is associated with wet winters in southern United States and mild winters over western Canada and part of Northern United States. The converse situation, the years of relatively high atmospheric pressure at Tahiti and low pressure at Darwin, are years of plentiful cold upwelling along the South American coast, heavy rainfall across inland Australia and normal-to-above-normal monsoons for India and West Africa. These are now known as the La Niña years.

El Niño occurs about 30 per cent of the time and La Niña occurs about 25 per cent of the time. The particular phase of the Southern Oscillation (El Niño, La Niña or neutral) is usually established between April and June, peaking between December and February, and persists for nine to twelve months and occasionally for two or more years.

Scientists were quick to recognise the potential for their understanding of El Niño-Southern Oscillation to generate seasonal climate predictions. A major international research programme, the Tropical Ocean Global Atmosphere Project, ensued to develop the necessary models and to put in place a buoy-based ocean and atmosphere monitoring system along the Pacific equatorial zone. As a result of this research project, by the mid-1980s the first successful model-based El Niño-Southern Oscillation prediction was made. Following the initial successes, the tasks were progressively adopted by national meteorological and oceanic organizations leading to the fully-operational observational and seasonal prediction capabilities that are in place today. The experience with El Niño-Southern Oscillation forms one of the foundational rationales for the Global Framework for Climate Services and provides a good example of how scientific research can be transformed into operational climate services.

falling away rapidly in the mid-latitudes, and for many areas in the tropics predictability is evident only for a few months of the year.

2. The climate research community's principal task has been to increase understanding, not to promote and deliver services to specialised user sectors. Some research institutions do have active service delivery components, engage in a multi-year interdisciplinary research and

SCHEMATIC OF THE MADDEN-JULIAN OSCILLATION - CROSS SECTION ALONG EQUATOR

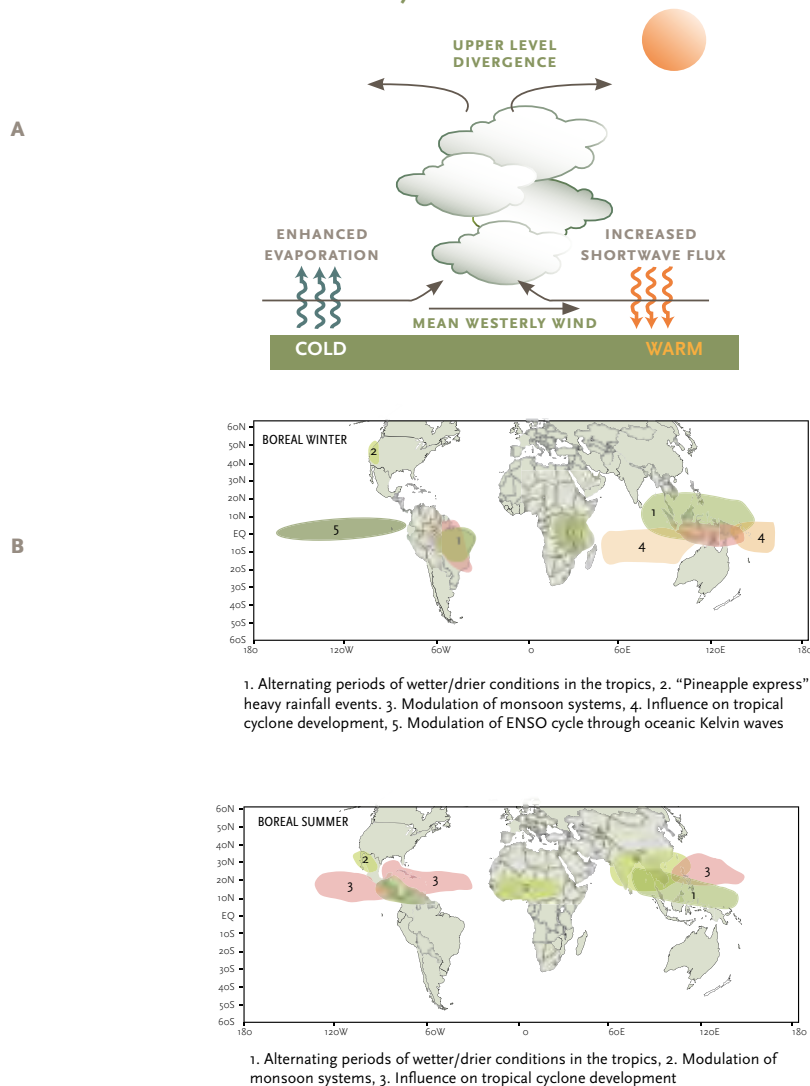


Figure 3.1. The Madden-Julian Oscillation (MJO) is a tropical disturbance that propagates eastward around the global tropics with a cycle on the order of 30–60 days. The MJO has wide-ranging impacts on the patterns of tropical and extra-tropical precipitation, atmospheric circulation and surface temperature around the global tropics and subtropics. (A) shows a schematic representation of the MJO, shown as a cross-section along the equator in the Indian Ocean-west Pacific sector. West is to the left and east is to the right. There is considerable evidence of the importance of the MJO in weather and climate and in their prediction, but the ability of simulating and predicting the MJO is severely limited due to model misrepresentation of processes key to the phenomenon. (B) shows regions and impacts where MJO activity has been seen to influence weather conditions during the 1–3 week time frame.

demonstration projects and ensure that their applied research programs are relevant to the communities that support them, however many research institutions do not have an operational mandate and have only a limited capability for disseminating their information to potentially interested parties.

3. Communicating and understanding uncertainty in climate predictions are difficult. Even given the level of skill that is achievable in those parts of the globe where climate predictability is relatively high, it is often not obvious what actions should be taken based on the predictions.

In addition to their contributions to the development of seasonal prediction capabilities, the improvements in observation networks, particularly regarding in-situ ocean measurements, led to increased knowledge about decadal climate variability and led to the possibility of decadal predictions. The decadal timescale is widely recognised as a key planning horizon for governments, businesses and other societal entities. In view of the societal relevance of decadal projections, they will be used in the next Coordinated Model Inter-comparison Project that will feed into the Fifth Assessment report of the Intergovernmental Panel on Climate Change. It is expected that the ensemble of decadal predictions will provide some information that may be useful in the process of developing adaptation strategies, as many investments on infrastructure and in industry are paid off in a few decades at most.

However, the extent to which predictability can be harnessed on decadal timescales remains uncertain and is the subject of investigation. On the decadal timescale it is not only important to consider the initial state of the atmosphere and ocean but also to include natural external changes (e.g. solar radiation) and anthropogenic forcings (e.g., greenhouse gas emissions). More research and investment is thus needed to translate information about large-scale decadal variations into the regional and local scales required for decisions. High resolution projections are also needed to provide realistic information about detailed regional changes, extremes and time series required by users. Finally, there is a clear and specific need for research on decadal predictability and prediction, given the great user expectation on this challenging issue.

CLIMATE CHANGE PROJECTIONS AND GLOBAL CLIMATE MODELS

In the 1980's, climate modellers began running computer-based models called General Circulation Models or Global Climate Models (see Box 3.2) that simulated many of the key characteristics of the earth's climate system. These models help test the sensitivity of the climate to a range of perturbations, for example the effects on the model's climate of inserting volcanic ash or of increasing the concentration of greenhouse gases such as carbon dioxide or even of fallout from nuclear warfare. The carbon dioxide experiments typically showed amplified warming at the poles and increased intensity of tropical monsoon circulation. Many of the broad-scale changes to increased carbon dioxide levels diagnosed in these early climate models are now being observed some 20 or so years later as global carbon dioxide concentration increases. This demonstrates not only the value of models in making useful predictions, but more importantly the opportunities for climate services to support decision making.

These General Circulation Models have grown ever more sophisticated over time, incorporating additional detail from the atmospheric processes they model and including ever-more-complex atmospheric chemistry and cloud representation – the representation of clouds being one of the most difficult challenges. As computing power has grown, the resolution of the models has increased, complex topography has been represented and land-surface processes, including vegetation, have been introduced.

Box 3.2. ABOUT GENERAL CIRCULATION MODELS

Predictions and projections of the future state of the world's climate are based largely on output from computer models known as General Circulation Models, especially those that couple atmospheric and oceanic physics. These computer models include three-dimensional representations of the state of the atmosphere and portrayals of the interactions between the atmosphere and the oceans, sea ice and atmospheric chemicals. The way that a General Circulation Model works is by dividing the atmosphere into a number of "grid boxes". The size of each grid box has a direct influence on the level of detail that can be captured by the model, so for example a Global Climate Model with a horizontal resolution of 50 km can only capture a weather feature that is on the order of a few hundred kilometres in size, thus missing completely even a large thunderstorm complex that may be 25 km across. A typical General Circulation Model that might have 20 layers between the surface and a height of 20 kilometres will have an average vertical resolution of 1 km, although in practice the layers are unlikely to be evenly distributed, with closer packing occurring near the earth's surface.

The obvious way to increase the features that a General Circulation Model can capture is by increasing its resolution. The other benefit of increasing the resolution is the ability to represent the earth's surface in much greater detail. For example, features such as Lake Victoria and the European Alps can be represented more exactly. These features have an enormous impact on regional and local weather and therefore on

the long term climate, so it is very important to represent them in as much detail as possible. However, increasing the resolution has huge consequences for computing costs.

Earth System Models, sometimes called Simulators, include ocean and land carbon cycles, chemical species and biological interactions. The supercomputers needed to run these computer models are among the most powerful in the world due to the enormous number of complex calculations that are required to model the atmosphere sufficiently for the coming years. Because they are so powerful, these supercomputers are also extremely expensive to procure and operate, both in terms of hardware costs and also in terms of the cost of powering and cooling them.

The supercomputers installed at the world's leading climate prediction centres each have a total peak performance approaching 1 Petaflop (1,000,000,000,000,000 calculations per second) and are regularly seen in the "Top 500 List" of most powerful computing systems.

Continued investment in the supercomputers operated by the world's leading climate prediction centres is critical if society is to sustain and improve the understanding we currently have of how the state of the world's climate is expected to change over the years and centuries to come.

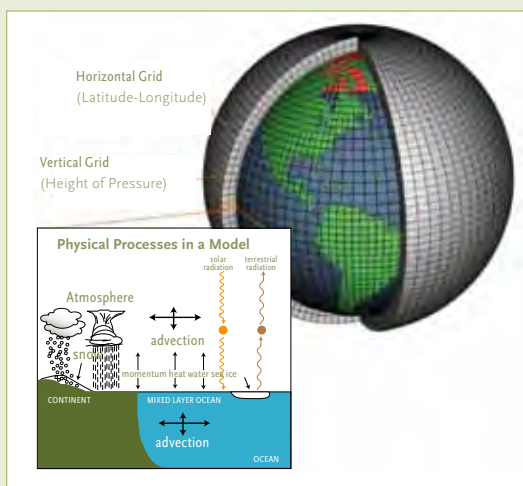


Figure B3.2. Global climate model. Climate models are systems of differential equations based on the basic laws of physics, fluid motion and chemistry. To "run" a model, scientists divide the planet into a 3-dimensional grid, apply the basic equations and evaluate the results. Atmospheric models calculate winds, heat transfer, radiation, relative humidity and surface hydrology within each grid and evaluate interactions with neighbouring points. Source: NOAA.

The most complex earth-atmosphere-ocean models are sometimes referred to as Earth-System Models. The importance of these models is that they facilitate the development of a range of scenarios for the world as it might develop to the end of the current century and beyond, and then, through explicit calculation of greenhouse gas emissions consistent with these scenarios, offer projections of possible climate change.

Through the coordination of the Intergovernmental Panel on Climate Change, the projections produced by a variety of General Circulation Models that have formed a basis for their assessments are available through the Intergovernmental Panel on Climate Change Data Distribution Centre website (see Box 3.3). This site offers an example of research results being provided to users as one ingredient of a climate service. In addition, the Program for Climate Model Diagnosis and Inter-comparison (<http://www.pcmdi.llnl.gov/>), which provides time slices of daily model projection data for use by service providers, is one of a number of other examples of web sites that provide access to assessment-related information. It is clear, however, that this type of dissemination of model results will not cater to all levels of user sophistication. One challenge is to develop climate services that can transform these data into the types of information that can meet the needs of the full spectrum of users.

DOWNSCALING – INFORMATION FOR LOCAL-SCALE DECISIONS

A second, related challenge is to take the climate predictions and multi-decadal projections from these global models and translate them, via downscaling techniques, to regional and local scales so as to provide information suitable for decision making. This process of “downscaling” can be approached using two types of methodology. The first is by running a regional model nested within the global model to provide greater detail over a selected part of the globe (model-based downscaling). The second is by using statistical techniques applied to compare the global model outputs with historical data at particular stations (statistical downscaling). Model-based downscaling allows for much more detailed representation of topography, resulting in more realistic modelling of the local and regional climate (Figure 3.2). However, because of the wide range of outputs from the different global models, multiple regional model experiments have to be run to avoid underestimating the uncertainty of the local and regional climate predictions and projections. As a result, the procedure is very computationally expensive. Alternatively, the available historical records at a station can be compared with the model climate to correct for any systematic differences. These differences can then be applied to future climate predictions and projections.

Research suggests that statistical downscaling provides more robust projections of local climate than model-based downscaling, but it relies on station data being available at the location of interest, which clearly is not always the case (see Chapter 2 on in situ observations). There also remain fundamental questions about whether differences based on past climate can be applied to future climate. Services based on down-scaled projections are being widely sought and thus further progress in this field is vitally important. In particular, there will be a focus on regional information as part of the upcoming Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Though much has been achieved in downscaling, there is much more to do in interpreting the data and designing informative climate services and products that are derived from downscaling work.

PREDICTING ACROSS TIMESCALES

These parallel developments in climate science have enabled prediction systems to be developed at a range of different timescales, but these timescales should not be considered to be independent. Weather and climate on shorter timescales are known to be important in influencing the longer-timescale climate behaviour. In addition, the regional impacts of longer timescale changes will

be felt by society mainly through the resulting changes in the character of the shorter timescales, including extreme events. In recognition of this, there is now a new conceptual framework based on a continuum of prediction problems, with a blurring of the distinction between shorter-term predictions and longer-term climate projections – so-called seamless prediction. Seamless prediction is the concept of using common forecasting systems to predict multiple timescales, in particular by extending numerical weather prediction towards climate timescales. How far and in what form

Box 3.3. THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE DATA DISTRIBUTION CENTRE

The projections produced by a number of General Circulation Models form the basis for the future climate scenarios in the Assessment Reports of the Intergovernmental Panel on Climate Change. These are available on the Intergovernmental Panel on Climate Change Data Distribution Centre web site (<http://www.ipcc-data.org>). The Data Distribution Centre is overseen by the Intergovernmental Panel on Climate Change Task Group on Data and Scenario Support for Impact and Climate Analysis and is jointly managed by the British Atmospheric Data Centre in the United Kingdom, the World Data Centre for Climate in Germany, and the Center for International Earth Science Information Network at Columbia University, New York, USA.

The Data Distribution Centre provides climate, socio-economic and environmental data, both from the past and from scenarios projected into the future. Technical guide-lines on the selection and use of different types of data and scenarios in research and assessment are also provided (Figure B3.3). The Data Distribution Centre is designed primarily for climate change

researchers but materials contained on the site will increasingly become of interest to, and be used by, educators, governmental and non-governmental organizations and the general public.

The Data Distribution Centre web site provides the following data and information:

- Climate observations as global mean time series and gridded fields
- Climate model projections and simulations as well as monthly means and climatologies (decadal and 30-year means)
- Socio-economic data
- Environmental data and scenarios
- Guidelines and other supporting material

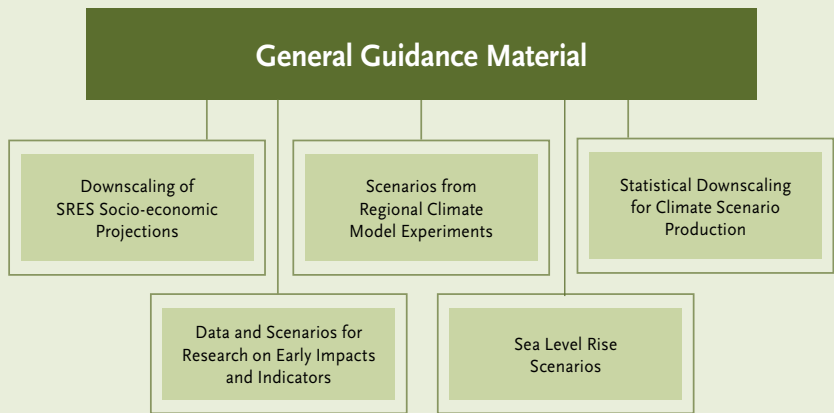


Figure B3.3. Guidance material available through the Data Distribution Centre web site (<http://www.ipcc-data.org/>)

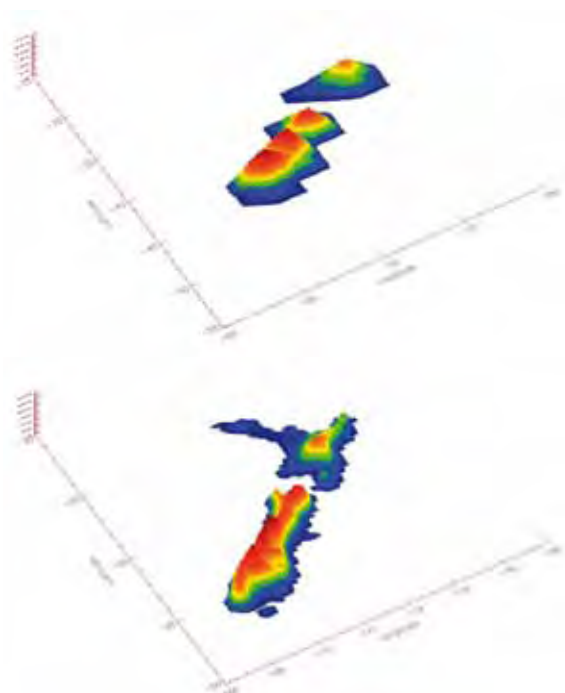


Figure 3.2. This figure illustrates how climate models “see” New Zealand with the typical spatial resolution of a Global Climate Model (GCM, top, ~140 km resolution) and a Regional Climate Model (bottom, ~30 km resolution). *Source:* NIWA.

such concepts will eventually be applied in an operational context is unclear, although the scientific benefits of assessing models across multiple timescales are intuitively apparent. More importantly, however, are the benefits from the user’s perspective. Past, present and future climate information provision should appear seamless to the users.

DEALING WITH UNCERTAINTY

Despite advances in our ability to predict the weather and climate, all predictions on a range of different timescales have some measure of uncertainty. Climate services will need to provide reliable estimates of the uncertainty of predictions to allow users to manage their own risks in an objective way. Characterising and communicating uncertainty is fundamental for decision-making. Underestimating uncertainty can lead to excessive responses that are inconsistent with decision makers’ risk tolerance and can damage the credibility of the service provider. Overestimating uncertainty leads to lost opportunities for preparing for adverse conditions or for capitalising on favourable conditions.

As in all science, a quantitative estimate of uncertainty makes any prediction much more useful. Estimates of prediction uncertainty are increasingly obtained by generating an ensemble of predictions, but the techniques for representing uncertainty are quite diverse. This is an area that requires further research (see Box 3.4).

There is not a history of applying these sorts of statistical corrections to decadal and longer-term models because of the difficulty of generating a sufficient sample of past predictions against which observed trends can be compared. To address this problem, decadal predictions are currently being performed using many models for many time slices over the past century as part of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. At climate change timescales there is a reasonably large set of model outputs available. These models are evaluated against the

Box 3.4. ENSEMBLES AND PROBABILISTIC CLIMATE PREDICTIONS

Errors in observations of current weather and in representing physical processes in climate models, together with inherent limitations in the predictability of the climate system, are the main causes of uncertainty in computer model-based prediction systems. To improve the usefulness of predictions for decision makers, greater efforts are being made to provide estimates of uncertainty with those predictions.

One commonly used method for representing the uncertainty in a prediction is the so-called ensemble approach. The objective behind ensemble prediction is to generate a sample of predictions that are representative of possible future outcomes, which can then be communicated to decision makers to provide an idea of the range of possibilities. Each individual prediction in the ensemble is made by running the model repeatedly, either using a slightly different representation of the initial weather conditions each time and/or using a slightly different

representation of the processes in the model. This method is used by all World Meteorological Organization Global Producing Centres and by international institutes for operational weather forecasting.

For seasonal and long-range prediction, the uncertainties arising from model errors tend to dominate those arising from estimates of initial weather conditions. Combining the output from different models is an effective way of addressing this problem and was a focus of activity in the European Union DEMETER and ENSEMBLES research projects. Some national meteorological centres, in collaborative partnerships, provide probabilistic seasonal climate products from multi-model ensemble prediction systems. However, because the errors from each model can be fairly large, the model outputs are often adjusted using statistical procedures and by comparing a history of predictions with the observed climate.

conditions of the last century as well as against past climates. This work, along with the validation against the reanalysis datasets described in Chapter 2, allows for a much better inter-comparison of models and provides a basis for testing the reliability of the estimates of uncertainty. Despite these initiatives, quantifying uncertainty in projections is not a simple task and it is unclear how probabilities could be meaningfully provided.

EXTREME EVENTS AND ADAPTATION RESEARCH

Extreme events have become an increasing focus of research and the Intergovernmental Panel on Climate Change is currently undertaking a Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. The impacts of extreme weather and climate events (heavy rainfall, drought, severe cold, heat waves and storms) under current climate are damaging and costly in both economic and human terms. Extreme events are by definition rare, but because of their high impact any changes in frequency and/or intensity under future projected climate conditions are of interest. The Intergovernmental Panel on Climate Change Fourth Assessment Report concluded that climate change has begun to affect the frequency, intensity and length of many extreme events such as floods, droughts, storms and extreme temperatures, thus increasing the need for additional adaptation that is both timely and effective. At the same time, gradual and non-linear change to ecosystems and natural resources along with increasing vulnerability intensify further the consequences of extreme weather events.

Expert teams assembled by the World Meteorological Organization Commission for Climatology have been coordinating international efforts to define extreme weather and climate events and to develop, calculate and analyse a suite of indices so that individuals, countries and regions can calculate their indices in a consistent manner such that all analyses will fit seamlessly into the global picture.

While research is required to understand extreme events better, as well as for assessing the potential for their frequency being altered by climate change, there are broader considerations. Research is also required to understand the factors that make people and infrastructure vulnerable to extreme events. This can turn into a fertile partnership arrangement whereby research can be transformed into climate services to help social scientists answer complex questions associated with managing the risk of extreme events. Trends in vulnerability and coping capacities can be used in conjunction with projected changes in extreme events to suggest how these events might create short-, medium- and long-term shocks to communities. This information can then be used to suggest adaptation strategies for avoiding, preparing for and effectively responding to the changing patterns of extreme events. A further area of research would try to understand the effectiveness and costs of adaptation measures, ranging from early warning to insurance to altered infrastructure and social safety nets, as well as to determine the scope and limits to adaptation.

Research in the social sciences that is required to understand decision-making criteria and the process of appraising adaptation measures is nascent in many areas of the world. There is a wealth of material concerning the need for observations, the prospects for analysis, modelling and products and the growing role of climate change. For example, the coupling of climate research in sea level rise, coastal inundation as a result of regional sea level rise and changes to storm tracks is being combined with research into water resources and with urban planning (see Chapter 5). The imperative is to conduct research that builds upon observations, modelling and predictions to generate more products that provide current climate information suitable for adaptation and to enable responses to changing climate threats.

THE DEPENDENCE OF CLIMATE SERVICES ON COMPUTING RESOURCES

The potential for climate prediction on longer scales and for higher resolution is tied to the availability of substantial supercomputer resources as well as of a number of facilities with adequate scientific staff and high-performance computational infrastructure. Significant increases in the computing capacity available to global and regional weather and climate centres have improved predictions. Future climate service computational requirements may be equal to or greater than that of a weather service and just as critical. The computing power now becoming available means that it will be possible to run global models with a resolution of a few kilometres (as required for many practical applications) as well as very large model ensembles to assess uncertainty and, increasingly, highly-resolved regional models that respond to the demand to develop adaptation policies and measures at the regional level.

3.4 BIOLOGICAL SCIENCES

Climate vulnerability and change affect biological systems on every scale and timescale. Temperature and the availability of water influence everything from the functioning of individual organisms to the distribution of entire ecosystems. Observed changes in physical and biological systems have been documented in freshwater, terrestrial and marine environments on all continents. Biological science research sits at the interface between earth and human systems. Information on biological processes and the effects that anthropogenic activities have on them is needed to enhance and strengthen climate services by improving our understanding of climate forcing and climate impacts and vulnerability. However, integration of biological sciences research into climate research remains a challenge. The most significant areas of biological research related to providing climate services are natural resource management (especially agriculture and forestry), ecosystem services and biodiversity.

Forests are a significant part of the global climate system because they cover around 30 per cent of the world's land surface. Forest type, distribution, species diversity and biomass are all dependent on climate. Drought, heat-stress, fire, retreating permafrost, shifting patterns of plant diseases and insect populations are all features of climate variability and change and affect forest distribution and health. Conversely, forests affect climate by influencing water and energy exchanges with the atmosphere and by affecting greenhouse gas and aerosol sources and sinks. Clearing forests (and other natural vegetation) for agricultural land or for other human uses has a significant impact on the climate system. Forests can also play a role in climate change mitigation strategies, for example in planting new forests to enhance carbon sinks or by reducing emissions from deforestation and degradation.

Earth System Models require ever-more-detailed representations of the land cover if they are to improve the accuracy of their representation of climate. Using data acquired from satellite-based remote sensing systems in combination with on-the-ground measurements it is possible to have a global view of the type of land cover in place, its seasonal changes and its changes in response to events such as drought, floods and bushfires. This global understanding of the relationship of large-scale biological systems to climate changes is becoming increasingly important as the computer models of the Earth's climate grow ever more detailed.

Agriculture is another sector where climate research plays an important role. The location and productivity of cropland and pasture will alter as the climate changes. Agro-meteorological models, indicators of vegetation condition, meteorological observations and rainfall estimates are used to estimate crop yields in many temperate countries and to monitor agricultural and pasture land conditions in a number of countries vulnerable to food shortages. Agriculture, however, is much more than a biological system. Climate-driven agricultural modelling research is widely relevant for tropical countries. Mitigation potential is also important for agriculture, and work is also underway to look at how these agricultural production systems would fare under different climate change scenarios.

Changes in climate can have a very significant effect on biodiversity and on the boundaries and condition of entire ecosystems. Changes in fire cycles and in bio-geographic barriers to species dispersal such as rainfall/temperature regimes drive natural ecosystem reorganization. Commonly occurring species may disappear locally, while populations of previously rare species may increase and new species may invade. We live in a time of unprecedented species extinction. Although the vast majority of these extinctions are caused by anthropogenic action (such as draining wetlands, urban expansion and deforestation), species-level extinctions as a result of climate change have been documented, reducing biodiversity.

Phenology is the study of life cycle events in plants, animals and fungi and of how these are influenced by seasonal and inter-annual variations in climate. Coordinated observation of phenological characteristics would support climate services because seasonal and geographical variations in climate variables (such as precipitation and temperature) correspond well with the phenology observed in biological systems. The importance of phenological monitoring as both an indicator of climate change (e.g. shifts in the timing of growing seasons, flowering, fruiting and migration dates) and in the assessment of potential impacts is already widely recognised. Indigenous communities use phenology as part of a traditional method of seasonal forecasting. Satellite measurements are used to assess main phenological stages of vegetation on a global scale. Regional networks such as the European Phenology Network and the United States National Phenology Networks have been created but no globally-coordinated system currently exists. Networks contributing to the Global Climate Observing System such as FLUXNET could eventually provide a framework for such coordination.

Biodiversity studies tend to be locally or regionally focused and large volumes of data describing species distributions and habitat conditions have been collected and maintained independent of each other. It is important to integrate biodiversity data and knowledge from indigenous and local communities; models using these data have also been developed for particular situations. Initiatives such as the Global Biodiversity Information Facility are making biodiversity data more accessible. However, mixing disconnected data and models with climate change scenarios and climate observations is not risk-free, and integrating global biodiversity data into climate services is an on-going challenge.

3.5 UNDERSTANDING CLIMATE IMPACTS AND VULNERABILITY

The severity of climate impacts on societies depends not only on the nature of climate hazards and the resilience of natural ecosystems but also on factors such as these societies' degree of socio-economic development, social inequalities, human adaptive capacities, health status and health services, demographic characteristics and economic livelihood alternatives. Therefore, understanding socio-economic systems is an integral part of assessing impacts and vulnerability to climate change and is necessary for adaptation planning. Socio-economic information can highlight the differential vulnerability to climate threats of regions, countries, locales and communities with different socio-economic endowments. It is also a crucial ingredient of any assessment of the vulnerabilities and adaptive capacities of different economic sectors and communities and is essential for understanding how they will be affected by climate change. Research on climate impacts and vulnerabilities could well inform the design, targeting and evaluation of climate services.

Social science research is required to understand and characterise the demographic, socio-economic and the technological driving forces underlying the anthropogenic greenhouse gas emissions that cause climate change. This information provides a crucial input to longer-term climate prediction. However, socio-economic information still lags behind biophysical and climate information in terms of quality, availability and accessibility. Although various social data sets exist, they are not generally available in the resolution necessary for localised assessment of impacts, vulnerability and adaptation – the same issues that modellers of climate and other biophysical data face. More work is needed to generate data sets that include both climate-related human and environmental data at the same spatial and temporal resolution. This would improve the relevance of climate model projections to the user.

Often, the body of relevant research and knowledge about climate-related challenges and climate-informed decision responses comes from the climate-sensitive sectors that constitute the user community. The Food and Agriculture's programmes on food security demonstrate the benefits of coupling real needs with climate science as one case in point. Here, climate and social scientists, World Meteorological Organization and other international organizations recognized the parts of the climate service "supply chain" they occupied and where they needed to make links with other organizations to fulfil user needs.

Research on climate impacts and vulnerability concentrate on the demand side of climate services. Many institutions have undertaken research into the utility and value of existing climate information products and services to the user community along with their utility in decision making with the aim of improving services. Research on the value of various types of climate information for different sectors exists and needs expanding, as this demonstration of value is often needed to spur the uptake of climate products.

A fundamental new ingredient in recent years has been the widespread understanding that the climate is changing: global warming is unequivocal. Many research organizations have undertaken a range of studies that use climate information, modelling and predictions to assess climate impacts, risks and vulnerabilities across multiple geographical scales. While such studies and programs are not part of the intergovernmental system, efforts need to be made to create databanks of the outcomes of such research systematically and to make the data and assessments generated by it more broadly available to potential users.

3.6 POLICY RESEARCH

Inevitably, policy research draws upon the outcomes of research in the physical, biological and social sciences to develop policy proposals that might be adopted by governments. The importance of integrating the provision and delivery of climate information into the non-climatic data and information required for policy-relevant analyses cannot be overstated. Climate research, data and information is used in conjunction with non-climate environmental and socio-economic data to support policy-relevant risk and vulnerability assessments as well as adaptation planning (including costing different options).

The Framework will be a policy-neutral, technical activity that may provide services to assist in policy generation but will not endorse any particular policy proposals developed using its services as part of their inputs.

3.7 COORDINATION MECHANISMS FOR CLIMATE RESEARCH

The World Climate Research Programme is the primary international mechanism for coordinating climate research. It is a component of the World Meteorological Organization World Climate Programme sponsored jointly by it and the International Council for Science, and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization. Its main objectives are to determine the extent to which climate can be predicted and the extent of human influence on the climate system. The World Climate Research Programme adopts a multi-disciplinary approach, organizes large-scale observational and modelling projects and focuses on aspects of climate too large and complex to be addressed by any one nation or single scientific discipline. It coordinates the climate modelling projection enterprise that underpins the findings of the activities of the Intergovernmental Panel on Climate Change and provides the basis for responding to issues raised in the United Nations Framework Convention on Climate Change. The World Climate Impacts Assessment and Response Strategies Programme, another major component of the World Climate Programme, assesses the impacts of climate variability. The United Nations Environmental Programme is the lead agency.

The World Climate Research Programme's initial focus on the physical climate system and its natural variability has been complemented since the late 1980s by the International Council for Science's International Geosphere-Biosphere Programme, which focuses on the role of chemical and biological processes in human-induced climate change. It has also been enhanced by further collaboration between the physical, biological and social science communities under the auspices of the Earth System Science Partnership as well as the International Human Dimensions Programme and Diversitas.

3.8 RESOURCING OF CLIMATE RESEARCH

Assessing the current level of resources directed towards climate-related research is an exceedingly difficult task for at least two reasons. Firstly, what comprises climate-related research is not well defined but undoubtedly covers activities ranging from developing new observation platforms to ocean and atmosphere modelling through to the impacts of climate variability and change on all manner of natural and human-made systems. It also includes policy research directed at improving government responses to climate-related issues. Secondly, while much climate-related research is government funded, accounting and reporting systems differ between governments to such a degree that identifying all the components of national budgets that relate to climate research and bringing them into the same economic value framework seems an impossible task.

An example of the level of funding given to climate-related research is provided by the US Government which, on 18 June 2009 enacted a bill providing, inter alia, for:

1. National Oceanic Atmospheric Administration: US\$ 200 million was allocated to enhance climate change research and regional assessments.
2. National Aeronautics and Space Administration: US\$ 1.3 billion was allocated to climate change programs.
3. National Science Foundation: US\$ 310 million was allocated for climate change programs.

This level of funding, about US\$ 2 billion spread over three agencies. An order of magnitude estimate of around US\$ 5 to 10 billion for global annual expenditure on climate-related research seems reasonable.

As indicated above, the major centres undertaking climate-related research are largely concentrated in the northern hemisphere in developed countries. These countries often participate in capacity building activities aimed at supporting scientists in the developing world. A large portion of physical climate research is global in scope, e.g. the assessment reports, and is not limited to the challenges of developed countries alone.

3.9 FINDINGS

1. Understanding of the climate system is advancing at an unprecedented rate based on the rapid development of modern supercomputing systems; the success of numerical weather prediction; a vast increase in earth-system data from satellite-borne observing systems; research on how changes in the atmosphere and the ocean affect each other; and global interest in the phenomenon of human-induced climate change.
2. One of the many challenges facing climate research is to understand better the feedbacks between the various components of the coupled atmosphere-ocean-land-cryosphere surface-biological systems-human systems as well as the overall climate system and to incorporate these understandings in climate models.
3. Ongoing improvement of existing climate services and the development of new climate services will only occur with strong support from the global research community in all relevant sectors, including the physical, biological and social sciences.

4. Effective climate services will depend on maximising the potential of existing knowledge as well as on new research developments.
5. Existing climate-related research is heavily concentrated in the developed world and the Global Framework for Climate Services should assist in bringing resources for research aimed at improving climate services to the developing world. A particular emphasis on transfer of knowledge from research to operations, which always necessitates substantial effort and dialogue from both sides, is called for with important contributions expected from the technical commissions of the World Meteorological Organization.
6. Coordination of climate-related research at the global level is achieved effectively through the World Climate Research Programme, which is directed at increasing understanding of aspects of the climate. The next challenge for the research community is to engage with the User Interface Platform of the Global Framework for Climate Services to ensure that it can consider fully the feedback of users of climate services as it makes its contribution to improving existing climate services and creating new ones.

CHAPTER 4

CAPACITY BUILDING THAT SUPPORTS CLIMATE SERVICES

4.1 INTRODUCTION

This chapter provides a summary of existing and needed capacity building support for components of the Global Framework for Climate Services, namely: research, modelling and prediction; climate observations and monitoring; climate services information system delivery; and a user-interface platform (chapter 9). It addresses capacity building from the demand side and from the supply side of climate services in four areas:

- Human resource capacity – equipping individuals with the understanding, skills, information, knowledge and training to enable them to generate, communicate and use decision-relevant climate information;
- Infrastructural capacity – enabling access to the resources that are needed to generate, archive and use climate data and decision-relevant information, including observing networks, data management systems, computer hardware and software, internet, manuals and scientific literature;
- Procedural capacity – defining, implementing and advancing best practices for generating and using climate information;
- Institutional capacity – elaborating management structures, processes and procedures that enable effective climate services, not only within organizations but also in managing relationships between the different organizations and sectors (public, private and community, including international collaboration).

In the context of the Global Framework for Climate Services, capacity building refers to investment in people, practices and institutions to stimulate and develop capacities systematically in the four areas above in order to manage and assess climate-related risk by providing decision-relevant climate information. On the supply side, capacity building efforts will have to address the secure archival of data and the production of climate information as well as its conversion into action. A comprehensive capacity building initiative will have to include stakeholders in climate product generation and delivery, advice and decision options as well as preparation and use on the demand side.

There are significant sources of bilateral funding for capacity building activities. In 2009, total net official development assistance from members of the Organization for Economic Cooperation and Development's Development Assistance Committee was US\$ 119.6 billion. Countries outside the Organization for Economic Cooperation and Development are also providing increasing amounts of bilateral funding for capacity building, as are a growing number of private philanthropists and foundations, though it is diffused across many separate sectors such as agriculture, water and sanitation, disaster risk reduction and health. Nevertheless, bilateral donors are increasingly focusing on the issue of climate and climate change and can be expected to be significant providers of capacity building resources in relation to climate services. However, without coordination of these efforts through the Global Framework, the building of effective climate services will remain diffuse.

Support and coordination currently valued at around US\$ 10 million is available annually through the World Meteorological Organization for capacity building of meteorological services and staff. This supports primarily the information-generating elements of the existing climate services framework such as observations, data rescue and management, research and services to climate-sensitive sectors. In Africa, funding for the Climate for Development project is projected to be

an order of magnitude larger than this, but existing levels of aid support for meteorology are unlikely to meet the needs of the Global Framework for Climate Services. Through the regional and development cooperation programme and the Voluntary Cooperation Programme of the World Meteorological Organization, efforts are being made to strengthen the infrastructure and the required institutions in developing countries and particularly in those that are the least developed. The Voluntary Cooperation Programme provides support to Member countries in the form of equipment, expert services, training and education and is maintained by voluntary contributions received from partners.

4.2 BUILDING CAPACITY OF CLIMATE INFORMATION USERS

The Framework would bring a new emphasis on the demand-side of climate services. While most people can understand weather forecasts and have some intuitive idea of how to make decisions based on them, for many reasons climate predictions are much harder to use and understand. Most potential beneficiaries of climate information (whether historical data, monitoring products or forecasts) have only a limited idea of how that information is relevant to them or how they might be able to access, understand and use it to identify and explore impacts, vulnerability and risks.

Where some knowledge exists, expectations of predictability, especially for longer timescales, are frequently unrealistic. However, differences in the degree of “climate literacy” between various sectors are fairly significant: agricultural scientists, for example, tend to have relatively strong training in climate matters, whereas scientists working in public health are likely to have a lesser background. Nevertheless, in general the training of potential climate information users is undeveloped in terms of understanding the possible impacts of climate variability and change on their activities, of using climate information to manage climate risks and opportunities and of engaging with information providers.

Regardless of the level of climate literacy, climate forecasts and projections are difficult to use because the level of uncertainty of the information is considerably greater than for weather forecasts and what is predicted is rarely, if ever, of immediate relevance to the user. Seasonal rainfall forecasts, for example, are typically for three-month rainfall accumulations and give no indication of when or how many heavy episodes may occur or whether there will be long dry spells. In addition, actual predicted rainfall amounts are not typically presented because the uncertainty is too great, so probabilities that refer to difficult-to-understand and not necessarily very relevant thresholds are presented instead. The problem often is not only with the magnitude of uncertainty per se, but also with the way that uncertainty is communicated. Most climate information providers lack the experience to understand how climate information might be made more understandable, and without a close partnership with the information users it is unlikely that information will be decision-relevant.

Because of inadequate understanding of the importance of climate information on the part of users and of the decision process on the part of providers, demand for climate information is often low and/or poorly informed. To address these difficulties, large-scale efforts are required to ensure that the availability of climate information translates into more effective use of such information. To achieve this, partnerships need to be established between climate information providers and users in order to identify needs for climate services. Specifically, the following issues need to be addressed through these partnerships:

- How does climate variability and change relate to the users' interests?

- How could climate information inform decision making to improve outcomes?
- Are there resource and policy constraints that might restrict what responses are possible, and can these constraints be addressed?
- Is the provision of the desired climate services scientifically and logistically feasible?

Problems in addressing any of these questions can cause bottlenecks, poor quality service provision or inaccurate assessments that prevent benefits from being realised. Many user communities lack the capacity to play their role in these steps and the scale of the efforts required lies well beyond the mandate and capacities of most if not all National Meteorological Services. In most cases, intermediary institutions such as non-governmental organizations or universities that deal closely with end users will need to take an active role. In general, the scale of the efforts required vastly outstrips current capacities in virtually all countries. In many cases the engagement with users is likely to occur at local levels, and national governments will need to provide support for climate services on sub-national scales.

BUILDING HUMAN CAPACITY

While building bridges is essential for realizing a flow of useful information, building human capacity across disciplines to engage in such partnerships and to create competency in using climate information is also required. There are numerous United Nations-supported human capacity building initiatives. The Global Change System for Analysis, Research and Training, the United Nations Educational, Scientific and Cultural Organization, and the Inter-American Institute for Global Change Research provide examples of initiatives that develop human capacity in the developing world for scientists, policy makers, technical experts and local communities to enhance resiliency to climate change. Their joint efforts in education, research and assessment, training, curriculum development and communication contribute to better-informed decision making about issues of global environmental change and development.

The United Nations Educational, Scientific and Cultural Organization works on education and outreach on climate change and variability and natural disaster preparedness, targeting the general public, educational systems and youth in Small Island Developing States and Africa. Regular interactions between climate information providers and users are enabled through Climate Change Adaptation Fora. The United Nations Educational, Scientific and Cultural Organization's Natural Sciences Sector implements major international science programmes while promoting national and regional science and technology policies and capacity building. Major programmes under the Natural Science Sector include the Intergovernmental Oceanographic Commission, the International Hydrological Programme, the Man and the Biosphere Programme, the International Geoscience Programme, and the Abdus Salam International Centre for Theoretical Physics, each of which has capacity building programmes.

The focus of the Global Change System for Analysis, Research and Training and of the Inter-American Institute is on developing scientific capacity and generating knowledge through networks of scientists and institutions. Fellowship programs offer experiential learning and education along with research and training opportunities to professionals, researchers and graduate students, building their capabilities for advancing and applying knowledge for climate change adaptation. Participating Fellows receive grants that enable them to undertake policy, post-doctoral, doctoral or teaching fellowships. The Fellows visit other institutions – Host Institutions – to implement a project of their own design that enhances their understanding of climate risks, vulnerabilities and adaptation strategies; assesses current practices for designing and implementing adaptation projects and/or promotes the integration of adaptation with planning, policy and decision-making.

Climate variability and change issues are increasingly being mainstreamed as an option in university degree courses. Multi-disciplinary courses that train professionals and academics to understand and cope with the impacts of climate variability and climate change on society and the environment are being established in universities around the world. Such courses are currently offered primarily in developed countries and scholarship programmes are necessary if candidates from the developing world are to participate. E-learning systems and virtual training could be expanded to reach developing nations at low cost by using and building on resources such as those developed by the Cooperative Program for Operational Meteorology, Education and Training (COMET®). In the longer term, curriculum development is required not only to establish core courses that address the need for experts on decision-making that uses climate information but also that integrate the basic aspects of climate science into curricula in all fields of study so that climate-informed professionals are established across all sectors of society.

While university degree programmes can be quite effective in establishing a community of highly-trained experts, the number of people reached is small. Thus there need to be shorter and more wide-reaching initiatives. Alliances or platforms including key organizations (the World Meteorological Organization, the United Nations Educational, Scientific and Cultural Organization, the United Nations Development Programme, the United Nations Institute for Training and Research) undertaking related human capacity building are needed to facilitate the emergence of an integrated human resource development programme on using climate-based information in decision making. Regional and national components of the Global Framework for Climate Services should be involved in programme development and should lead the operation of this aspect of capacity building.

Capacity building programmes specifically to promote dialogue between producer and user communities are beginning to be developed. For example, the Summer Institute on Climate and Health run by the International research Institute on Climate and Society, the Center for International Earth Science Information Network and the Mailman School of Public Health bring climate scientists and health specialists together to impart a mutual understanding of the role climate plays in driving the infectious disease burden and public health outcomes as well as how to assimilate climate information to improve the decision making process in public health.

INFRASTRUCTURAL AND PROCEDURAL CAPACITY

It is well recognised that effective climate services need strong involvement by stakeholders from different disciplines. It is important that user communities engage information providers to understand what climate information is available, how to interpret it correctly as well as understanding its underlying assumptions and limitations. Current partnerships are weak in many countries, both developed and developing. Intermediaries between climate services and end users as well as between research and end user corporations or associations are crucial for future climate services. Stronger partnerships need to be pursued with consortia of organizations or other multilateral mechanisms to create effective multidisciplinary working environments.

The Intergovernmental Panel on Climate Change Assessment Reports constitute perhaps the most obvious example of best practices for translating climate data into decision-relevant information; they involve extensive collaboration between climate and sectoral scientists. However, producers and users need to be brought together beyond the scientific community and on regional, national and local levels. A number of United Nations-driven efforts already exist to promote this engagement, including efforts by the Food and Agricultural Organization and the World Meteorological Organization, but efforts need to be expanded and are best carried out, at least initially, through collaboration between United Nations agencies.

There are effective examples taken from United Nations agencies as well as from a number of countries to translate climate information into impact assessments and policy guidance. For example, there is the Food and Agricultural Organization's Technology for Agriculture information and communication system, while in Canada the Pacific Climate Impacts Consortium and the Ouranos Consortium develop climate impact assessments based on climate variability and probable trends. The United States Regional Integrated Sciences and Assessments conduct similar research, although with a greater focus on seasonal climate variability. Similarly, the European ENSEMBLES project has brought together scientists from wide-ranging disciplines to develop procedures for reliably estimating the impacts of climate change and variability (See Box 3.4). In all these examples, partnerships and collaboration across disciplinary boundaries were key ingredients for ensuring that information remained scientifically sound and decision-relevant.

A few institutions from user communities have recognised the need to invest in raising awareness and translating climate information. One such example is the Netherlands-based Red Cross/Red Crescent Climate Centre, which is the reference centre on climate change of the Red Cross/Red Crescent family. The Climate Centre supports the Red Cross and Red Crescent Movement in understanding and addressing the humanitarian consequences of climate change and extreme weather events. The Centre's main approach is to raise awareness; advocate climate adaptation and disaster risk reduction (within and outside the Red Cross and Red Crescent); analyse relevant forecast information on all timescales; and integrate knowledge of climate risks into Red Cross/Red Crescent strategies, plans and activities. The Red Cross/Red Crescent Climate Centre interacts with groups including the National Meteorological Services through the World Meteorological Organization and the International Research Institute for Climate and Society and other scientific research groups to develop information products tailored to the movement's specific needs. The Climate Centre provides an example of how to build communities that represent users of climate information and that are able to engage with the scientific community.

INSTITUTIONAL CAPACITY

While the above examples of building informational and procedural capacities speak to defining best practices for using climate information, building institutional capacities is also important from the user perspective. The introduction of this document provided examples of climate service in disasters, agriculture, health and water. Users from institutions involved in these and other sectors need entry points into the institutions that provide climate information. A capacity to interface, sometimes through intermediaries, is necessary for building relations, including international collaboration, between users and providers.

The International Research Institute for Climate and Society has contributed to partnering climate scientists with user communities in developing countries. As an example of this contribution, the Institute has helped the Ministry of Health and the National Meteorological Agency of Ethiopia make significant progress towards developing a climate-informed early warning and response system for climate-sensitive diseases such as malaria. The formation of a Climate and Health Working Group has been critical to enabling progress. The Working Group is a multi-sectoral partnership created to spearhead the use of climate information for health interventions. Leadership from the Ethiopian Ministry of Health has ensured that the solution to the public health problem is demand driven, an essential factor in maintaining momentum given the multitude of competing priorities in the Ministry. If such Working Groups are to be successful in developing countries, a number of key ingredients are required:

- Commitment by users to help ensure that the supply of services is sustainable and comes from an authoritative source by, for example, obtaining climate services from designated national authorities rather than from other sources;

- Provision of a mandate to national climate services to assign resources to collect the necessary data and to develop the tools and products required to meet the need for climate services;
- Dedicated staff with the necessary expertise to respond to both provider and user;
- Cross-border collaboration coordinated by the relevant United Nations organizations (e.g., the World Health Organization and the World Meteorological Organization);
- Good project management to maintain an ongoing working relationship between the providers and users, which is likely to require more than just a contractual arrangement;
- A mechanism to identify strengths, weaknesses, opportunities and threats to the partnership and process for addressing issues.

In most cases, climate information providers are unlikely to have sufficient understanding of the decision makers' needs to be able to develop information products that are clearly decision-relevant. Given that climate is only one of many factors that have to be considered in climate-sensitive sectors, and given that decision makers are often severely resource-constrained, especially in developing countries, it will be very difficult to retain the user's interest unless the process for partnering climate information providers and users is led by demand.

An example of a user-led initiative is the Malaria Outlook Forum. This Forum was held in southern Africa and was based on a pre-existing annual planning meeting of disease control specialists, with climate experts invited to contribute. Because it was led by users rather than by information providers, the Malaria Outlook Forum generated a greater sense of ownership within the user community than is the case for Regional Climate Outlook Forums, while climate questions did not necessarily dominate the meeting. The timing of the Malaria Outlook Forum was also set by disease control specialists rather than by the climate community. Regrettably, the initiative has largely lost momentum in the region because a shift of interest from epidemic control to eradication has changed funding priorities.

4.3 BUILDING CAPACITY FOR THE GENERATION OF CLIMATE INFORMATION

BUILDING HUMAN CAPACITY

The World Meteorological Organization plays a leading role in coordinating the development of weather and climate scientist skills by promoting access to training programs, technology, manuals, guidance documents, technical papers and workshops. There are currently 23 World Meteorological Organization Regional Training Centres and a network of cooperating universities and advanced training institutions that contribute to the education and training effort in meteorology and hydrology as well as to establishing and developing specialised centres of excellence in various regions.

The focus of most of these centres is on the technical training of meteorologists for weather forecasting activities. The scope of these courses needs to be expanded to include training needs for developing climate information and products as well as for interacting with boundary institutions and sectoral users. To develop the human capacity needed in the Framework, a review of the education qualifications, skill requirements and job training required for climate specialists will be necessary. This review will entail establishing minimum standards of education, skills and training for climate services in the same way that the World Meteorological Organization currently does for weather

services. The requirements for certification should be defined, and organised training activities should be developed and integrated into the Regional Training Centre programmes. Universities should be encouraged and facilitated to collaborate closely with the National Meteorological Services with a view to achieving this sustainability.

Through its Education and Training Programme, the World Meteorological Organization assists National Meteorological and Hydrological Services, especially those in developing countries, in developing human resources through education, skill development and training, providing educational materials and awarding fellowships. Training activities include making and communicating observations, data management, using model outputs and remotely-sensed data along with weather services. Most of the focus has been on training weather forecasters rather than climatologists.

The Long Term Education Programme provides support to scientists from developing countries for training up to bachelors and masters levels in overseas institutes. China, Russia, and Germany currently provide host institutes for this training. In addition to providing skills, such programmes also provide an excellent opportunity for building networks. Shorter-term fellowships of up to six months are available for more focused capacity building. The Africa and Tropical Desk of the United States National Weather Service's National Centres for Environmental Prediction is an important participant in this programme and provides training for weather and climate scientists.

A number of the World Meteorological Organization Climate Information and Prediction Services training workshops held throughout the world have helped create some national capacity to develop and deliver climate information. A global network of Climate Information and Prediction Services Focal Points assists in national and regional coordination and information sharing for climate activities, although currently the Focal Point network is not operating strongly. The focus of the Climate Information and Prediction Services activities has been primarily on monitoring and seasonal forecasts, with little attention given to decadal and climate change information. These mechanisms can be effectively expanded to include regional climate change information products. For reaching larger numbers of participants and to provide more in-depth training than is possible in residence classes, training materials could be developed into an online course.

Other training programmes targeting the development of seasonal climate forecasting expertise have been held around the world, with support from centres such as the Australian Bureau of Meteorology, the China Meteorological Administration, the United States-based International Research Institute for Climate and Society, the Korea Meteorological Administration, the United Kingdom Met Office, Météo-France and the Climate Prediction Centre of the United States National Oceanic and Atmospheric Administration. Many of these programmes have been hosted by regional climate centres and have undertaken fairly regular capacity building activities linked to the Regional Climate Outlook Forums. In general, especially after short-term training workshops, regular follow-up initiatives as well as frequent interactions with specific user communities and outreach activities are crucial, but these are not yet routine in many developing regions.

There have been numerous programmes to train scientists in generating downscaled climate change scenarios. For example, the Italian Abdus Salam International Centre for Theoretical Physics hosts regular workshops and online training opportunities for scientists from developing countries. Another active player has been the United Kingdom Met Office, which frequently holds workshops for its downscaling model that include discussions concerning data requirements for impact assessments. Training on data analysis to provide scientific evidence for climate change and variability has also been conducted. Examples include the activities of the Pacific Climate Change Science Program as

well as a series of workshops focusing on climate extremes variously supported by the Asia-Pacific Network for Global Change Research, the United States State Department along with the British and Dutch Governments.

While communicating with users has been a focus of the World Meteorological Organization's Public Weather Services training, especially with regard to the media, little attention has been given to this needed area of skills among climate service providers. Training that supports the engagement of users and providers, including better communication, would need to involve multiple agencies. This engagement would ensure that information is generated and that it can be used. It is an essential component of an effective climate service system.

INFRASTRUCTURAL CAPACITY

The current infrastructure capabilities of national climate services can be gauged from the following classification:

CATEGORY I: BASIC CAPACITY

The most basic level of climate service that can be delivered is securing, archiving, and providing access to a country's climate record to provide a dataset that is foundational for information products offered in the higher categories. Limited interaction with users occurs.

CATEGORY II: ESSENTIAL CAPACITY

The next level of service involves provision of information derived from national climate records that will assist national development. Other activities of these centres would include homogeneity testing and adjustment, seasonal prediction and the development of climate watches and warnings for extreme climate events. Some interaction occurs with users in one or more sectors in order to identify their requirements for, and provide advice on, climate information and products.

CATEGORY III: FULL CAPACITY

The development and/or provision of tailored and downscaled climate products on timescales ranging from seasonal to climate change in order to meet the needs of major sectors are characteristic of the third level. This development implies the capacity and skills on the part of information providers to engage at least some user communities. There is a stronger user interface along with technical expertise for training climate specialists and for developing curricula. Some level of regional cooperation and support is provided.

CATEGORY IV: ADVANCED CAPACITY

Advanced climate services have research and modelling capabilities for climate and applied climate studies underpinned by a high level of global/regional cooperation and support.

In many countries the national meteorological and hydrological services are likely to act as primary or even exclusive climate information service providers, at least for basic and essential services. Some functions of the full and advanced services may be provided by organizations other than the National Meteorological Services because of the need for expertise in issues

such as socio-economics, health and ecosystems. However, each country may choose to implement services in different ways, with different degrees of possible involvement of National Meteorological Services as discussed in Chapter 7.

Based on responses to several recent surveys related to climate services, United Nations classifications based on economic status, the World Meteorological Organization surveys of technological (modelling and forecasting) capabilities and known training activities, the status of national climate services as of August 2010 is shown in Figure 4.1.

Figure 4.1 indicates that over one-third of countries are currently unable to provide much more than the most basic climate services and that a few are unable to provide even this level. The countries that do not reach category I are some of those that are emerging from complex disasters, including civil war, and have had most or all of their observation systems and data records destroyed. Rebuilding their climatological observation record will take years, and so efforts to reconstruct historical observations using remotely-sensed data will be essential if climate information is to be available in the short- to medium-term. Most countries, in fact, would benefit from similar initiatives to construct high-resolution datasets by merging satellite and in situ measurements. Currently there are only a few activities designed to generate such datasets (See Chapter 2 for the process that creates integrated datasets called reanalysis), and this needs to be expanded upon. More generally, enhancements to the climate observing systems is required, even in countries that have better developed climate services as discussed in Chapters 2 and 8.

Where data do exist but are stored only in paper records or on microfiche, efforts to digitize the data and prevent permanent loss have been undertaken through a series of workshops that have been coordinated by the World Meteorological Organization. While some countries such as China have invested considerable resources in digitizing their own historical records, many countries have required support. Accordingly, many of these data rescue workshops have been held in Africa, but the Caribbean and Southeast Asia have also been targeted. Funding is usually provided bilaterally, with Australia, Belgium, Finland, France, Netherlands, Spain and the United States as prime contributors.

While access to the Internet is not universal, the data and information made available on it can be used as an indicator of the types of climate services National Meteorological Services are providing and can

Category	2010 Baseline, states/territories
Less than Category I	6
Category I	64
Category II	56
Category III	39
Category IV	24
Total	189

Figure 4.1. Number of countries that were able, as of August 2010, to provide basic (category I), essential (category II), full (category III), and advanced (category IV) climate services.

also show gaps that need to be addressed by capacity building. Based on an analysis of the data and information made available on web sites of the World Meteorological Organization Members, whose National Meteorological Services participate in the World Meteorological Organization programmes, shows that:

- (a) Around 50 to 60 per cent of National Meteorological Services provide access to data. In the case of small National Meteorological Services, particularly those in Africa, this may only include climate data for the capital city (usually from the observing station at the airport) and for one or two other regional centres. In some cases, particularly in Europe, there are fees payable by those seeking extensive climate data for purposes other than research and education;
- (b) Around 50 to 60 per cent of National Meteorological Services offer seasonal forecasts except those in Europe. The explanation for the European reticence to offer services in this area may be because of the weak predictability of the seasonal climate in that region;
- (c) A relatively small percentage of National Meteorological Services address climate change on their web sites. There are at least two explanations for this, (i) there may be national policy that has assigned climate change responsibility to some other area of government and there is no will to cut across this political decision, and/or (ii), it may be a service's conscious choice not to become involved because of a perceived lack of expertise (either scientific, political or both) for dealing properly with the matter.

Providing high quality data and climate products reliably does not guarantee that the information will be used effectively or even at all, so an important component of a climate service system is strong engagement between the providers and user communities. Even category II countries are only able to provide a minimum of support to potential users, and without investment in service delivery they are unlikely to reach more than a small proportion of potential beneficiaries. In most cases, those countries with full and advanced climate services may be able to service only those users who can understand and use climate information, but they will be unable to assist most users who do not have that capacity.

Some countries have developed advanced climate services by positioning the National Meteorological Service as the core supplier of data and predictions but with other institutions engaging the user communities in order to understand their needs and to develop decision-relevant information products. Examples include Australia, whose case is described in more detail in chapter 7, and Germany. In Germany, the recently established Climate Services Center offers a wide range of science-based information and services. The Center relies on a network of cooperating partners, including German academic and private research institutions and other climate service establishments. It partners with decision-makers from industry to ensure that needs are met. These user-interfacing functions are weak even in most developed countries and all countries could benefit from shared learning in this respect.

GLOBAL AND REGIONAL INITIATIVES IN SUPPORT OF CLIMATE INFORMATION GENERATION

Given that it is unviable in the short term to build the capacity of each National Meteorological Service so that it is able to provide or support advanced climate services, the World Meteorological Organization is creating a network of global and regional service providers to meet the World Meteorological Organization Members needs regarding enhanced service delivery capacities. This worldwide three-level structure involves national meteorological and hydrological services acting on

a national scale, Regional Climate Centres providing regional, continent-wide climate information and services as well as Global Producing Centres that deliver global-scale information and services.

The Global Producing Centres currently provide global-scale seasonal prediction products that the Regional Climate Centres and National Meteorological Services can use as input for their forecasting services. The Global Producing Centres are proposed by the World Meteorological Organization Members and follow a strict designation process according to which the Centres adhere to certain well-defined standards that encourage consistency and the usability of output. These standards include a fixed forecast production cycle, a standard set of forecast products and the World Meteorological Organization-defined verification standards.

The Regional Climate Centres will provide information to the World Meteorological Organization Member States within their respective regions and assist them in delivering appropriate climate services and products, including regional long-range climate forecasts for a wide range of user groups. The first two Regional Climate Centres, in Beijing and Tokyo, were designated in 2009. There are also a number of well-established climate centres that play key roles in supporting National Meteorological Services and take some part in engaging user communities. These include the African Centre of Meteorological Applications for Development in Niamey, Niger; the Intergovernmental Authority on Development, Climate Prediction and Application Centre in Nairobi, Kenya; Southern African Development Community Climate Services Centre in Gaborone, Botswana; the Agro-meteorology and Hydrology Regional Centre in Niamey, Niger; Centro Internacional para la Investigación del Fenómeno de El Niño in Guayaquil, Ecuador; and the Asia-Pacific Economic Cooperation Climate Centre in Busan, Republic of Korea. Some of these centres are preparing to apply for formal status as Regional Climate Centres.

The roles and capabilities of these centres vary significantly, but in general they do the following:

- Exchange data and operational products
- Generate intra-seasonal and seasonal predictions
- Advise on the uses and limitations of climate information
- Train the staff of the national centres within their region

The primary beneficiaries of such regional centres are National Meteorological Services. The regional centres usually do not issue warnings or provide services directly to sectoral users because such responsibilities fall to national centres. They do, however, play a crucial role in building capacity in their regions through training and by drawing experts from developed country centres and resources from donor agencies into the region (Box 4.1). They provide a critical mass of expertise around which capacity building investment can occur.

Prior to initiating the Global Producing and Regional Climate Centre concepts, in many areas of the globe regional cooperation in climate services has led to the creation of Regional Climate Outlook Forums. These forums bring together a variety of stakeholders involved in providing seasonal forecasts where they generate mutually-agreed forecast products for the region. The Regional Climate Outlook Forums serve more than half of the world's population, most of which is in developing countries (Figure 4.2), and it is likely that these will form the basis for future Regional Climate Centres. To date the Regional Climate Outlook Forums have been heavily (but not exclusively) focused on climate service providers, so at the present time the Forum climate information products still fall far short of meeting end user needs. This is particularly the case regarding resolution, product timing for seasonal

Box 4.1. REGIONAL INITIATIVES

Africa

An important initiative taking place in Africa is the implementation of the Climate for Development in Africa project, which aims to enhance the capacity of African climate centres for generating and making widely available relevant climate-related information to end users. The project will be implemented by the African Centre of Meteorological Applications for Development, the Intergovernmental Authority on Development, Climate Prediction and Application Centre, Agro- and Hydro-Meteorology Training Centre and the Drought Monitoring Centre. The project recognises that awareness and training are important for implementing climate change initiatives and thus it includes a comprehensive climate change awareness raising program for key stakeholders, including the media. The interaction of different users and providers of climate services through the various Climate Outlook Forums to be supported by the project will also provide a platform for sharing knowledge and for building stronger networks. Climate information will be disseminated to end users throughout Africa by way of existing networks, along with print and electronic media including community radio stations broadcasting in local languages.

The grant of US\$ 30 million is being enhanced by the Climate Development in Africa Special Fund, a multi-donor facility that finances Climate Development-Africa activities and is estimated to provide about US\$ 135 million between 2010 and 2012. Donors have expressed interest in supporting the fund.

East Asia

The Tokyo Climate Centre of the Japan Meteorological Agency and the Beijing Climate Centre of the China Meteorological Administration were formally designated as the first WMO Regional Climate Centres in Asia in June 2009. The centres provide a variety of climate data and products through their own websites, as well as through that of the Regional Climate Centre Network in Regional Association II. These websites provide information on recent climate events and long-range forecasts. Regular training seminars are conducted to assist in professional capacity building of officers engaged in operational long-range forecasting in the Asia-Pacific region.

The Asia-Pacific Economic Cooperation Climate Centre was established in Busan, Republic of Korea in November 2005. The centre aims to facilitate sharing of high-cost climate data and information so as to minimise economic and human losses due to natural disasters, devising sustainable social and economic applications for this information and help with capacity building in climate prediction. It has been providing 3-month-lead seasonal predictions since 2005, and contributes to human capacity building by training scientists from developing countries in the Asia-Pacific Economic Cooperation region in state-of-the-art seasonal forecasting and applications. Additionally, the centre promotes technology transfer between economies through bilateral agreements.

South America

The Centro Internacional para la Investigación del Fenómeno El Niño was established in Guayaquil (Ecuador) in response to a United Nations General Assembly resolution calling for an enhancement of international cooperation to reduce the impact of the El Niño–Southern Oscillation phenomenon. This international centre works closely with both the International Strategy for Disaster Reduction and WMO and is supported regionally by Bolivia, Chile, Colombia, Ecuador, Peru and Venezuela. The centre currently coordinates the exchange of data and operational products in the region. It also undertakes downscaling of global-scale climate predictions to assess regional impacts and provides advice on the uses and limitations of climate information.

While the Centro Internacional para la Investigación del Fenómeno El Niño primarily deals with countries of the Andean region, efforts are also underway to strengthen regional capacity elsewhere on the continent. South American countries have recognised the need to strengthen regional capabilities in northern and Amazonian areas, as well as in the southeast, both of which have different climates and needs to the Andean region. Discussions as to how to achieve this are ongoing, but the solution would likely involve some kind of virtual climate centres, with countries in each region contributing specific capabilities.

prediction and possibly relevance to specific user needs. More needs to be done as well in areas such as fostering links between National Meteorological Services and researchers in regional universities, improving the security of, and access to, climate data and building stronger links to climate service users. However, some of the forums are beginning to develop seasonal outlooks in collaboration with organizations such as the Famine Early Warning Systems Network and are producing information that is more decision-relevant.

PROCEDURAL CAPACITIES – DEFINING AND ENABLING BEST PRACTICES

The World Meteorological Organization Commission for Climatology publishes a ‘Guide to Climatological Practices’ that defines standards for observations, data processing, basic statistical analyses along with presentation and interpretation of climatological information. The Guide is being updated because it addresses only a small proportion of questions that relate to climate service provision. Through the World Meteorological Organization Commission for Basic Systems, standards have been specified and to a large degree implemented for producing seasonal forecast products from global models, but no such standards yet exist for regional or national forecasts based on statistical models or for model-based downscaled forecasts. Similarly, no standards have yet been set for decadal and longer-range forecasts and projections, and procedures for these timescales remain active areas of research. In the interim, guidance on best practices is needed because of the large uncertainty in forecasts at these timescales and because of the potential to underestimate this uncertainty, especially when computing resources are limited.

Bespoke stand-alone software and web tools can act as packaged algorithms that promote adoption of best practices for generating climate information. A range of software products has been developed to assist countries in making downscaled and tailored forecast products for a range of timescales. These include the project Providing Regional Climates for Impacts Studies, a regional model for downscaling climate change projections, the Climate Predictability Tool and the programme called Seasonal Climate Outlooks in Pacific Island Countries for seasonal forecasts. There is also the European Union ENSEMBLES downscaling portal for research work at seasonal to climate change timescales.

The World Meteorological Organization Commission for Basic Systems and Commission for Climatology have put in place standards for verifying seasonal forecast products, but these are not yet

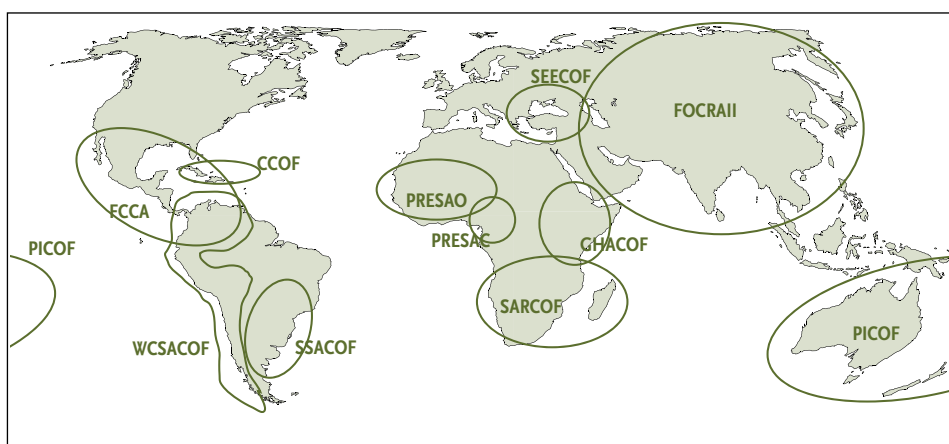


Figure 4.2. The current network of Regional Climate Outlook Forums. GHACOF – Greater Horn of Africa, SARCOF – Southern Africa, PRESAC – Central Africa, SSACOF – Southeast of South America, WCSACOF – Western coast of South America, CCOF – Caribbean, FCCA – Central America, PICOF – Pacific Islands, SEECOF – South-eastern Europe, FOCRAII – Regional Association II.

widely implemented beyond the Global Producing Centres. Skills need to be developed and software provided for implementing some of these standards. Verification standards for longer-range forecasts are currently an area of research and the United States Climate Variability and Predictability Working Group on Decadal Predictability is working on a white paper for decadal forecasts.

It is not possible to verify climate change projections in the standard way of comparing past forecasts with historical observations, but it is possible to provide some indication of the quality – specifically, the degree to which the information reliably represents the uncertainty in the projected climate – of the information in these projections. (See the section on uncertainty in Chapter 3). Given the growing use of climate information products at climate change timescales there is a need to define and implement standards for communicating the quality of this information. With the increasingly widespread availability and use of overly limited ensembles of “downscaled” climate change scenarios that have little or no quality control, the danger of misrepresenting the uncertainty of future climate underscores the need to deliver information from an authoritative source.

More generally, the relative abundance of climate forecasts and projections currently available at a range of timescales, compared with the availability of information about their quality, needs to be addressed urgently. Although in many cases procedures for evaluating climate information and best practices for generating it are still active areas of research, standards need to be defined if such information is to be disseminated according to current methods. These standards may evolve as clearer guidance is provided by the research community. The principle needs to be adopted that no forecast or projection should be provided without some accompanying information about quality.

INSTITUTIONAL CAPACITY

In many countries the absence of clear mandates on climate-related issues is a hindrance to the proper functioning of climate services. The roles that various institutes should play in a national climate service need to be defined so as to identify authoritative information providers. Clearly, the national meteorological and hydrological services will play a key role but in some countries improvements in their management structures and procedures need to be implemented first. This is equally true for any other components of their climate services. Revised management processes and procedures within these institutions are also required for them to be active participants in the global community. Based on the experiences of countries with advanced climate services, essential internal organizational standards are needed to guide governments in developing countries.

4.4 INTERNATIONAL COLLABORATION TO BUILD CAPACITY

Partnerships between advanced global institutions on climate issues and those in developing countries have been weak, reducing abilities to generate better climate services in developing countries. Many developing countries’ climate services lack sufficient visibility and are less attractive to public funding and support compared with developed countries where advanced technologies and the latest scientific findings are utilised. Capacity building components are still a major requirement for projects in developing countries. Weaknesses in infrastructure and human resources, along with limited flexibility for institutional reforms needed to respond to changing user needs have been cited as being among the main problems needing to be addressed by a capacity building strategy in these countries.

Similarly, climate research and services development and application have historically been concentrated in developed countries lying predominantly outside of the sub-tropics and tropics. In

the absence of local research capacity, greater collaboration between well-resourced scientists from the developed world and those with locally-based knowledge from the developing world is required. International research collaboration and resource allocation need to reflect the pressing planning priorities of the less-developed regions. One way to foster more balanced resource allocation is to ensure adequate representation for developing countries in international research, with adequate resource mandates and settled scientific priorities. For example, engaging scientists from developing countries in programmes such as the Intergovernmental Panel on Climate Change Assessment Reports is essential for attaining a more thorough global assessment of the observed and projected impacts of climate change and variability.

4.5 FINDINGS

1. Within the United Nations System and in the wider scientific community, climate change adaptation is a specific focus for many capacity building activities, although with the high vulnerability of many communities throughout the world, the importance of building capacity to manage shorter term weather and climate variability is also recognized.
2. Many United Nations agencies and programmes, as well as bilateral donors, provide capacity building support for climate-related activities but current efforts generally lack coordination. Capacity building requires long-term, institutional strengthening in governance, management and human resources development in technical areas such as weather, climate and water and in other areas such as leadership, partnership creation, science communication, service delivery, user engagement and resource mobilisation.
3. The Global Framework for Climate Services capacity building strategy should, in its global, regional and national components, address weaknesses in the current elements of climate services. Many of the relatively small-scale projects in building capacity in climate-related research, observations, data management and service delivery need to be scaled up so as to benefit vulnerable communities in all regions of the world.
4. In order to carry out climate services, all countries need a new generation of well-trained professionals. These professionals should include not only information providers with the capacity to engage with users but also experts who can engage with climate service providers.
5. Standards and guidance on best practices for climate service delivery need to be defined and implemented.
6. Building capacity in climate services should look to strengthen existing capabilities, particularly in the area of partnerships within and between developing and developed countries. Guidelines on best-practices with respect to capacity building should be developed in the areas of training, sustainable support, access to advice and support, implementation of technology advances, communication of advances in scientific knowledge and stakeholder engagement. Capacity building activities should be driven by users' requirements and should inform decision and policy making processes directed at national goals for sustainable development. They should also support the specific service requirements of sectors and users.
7. There are a small number of regional centres in the developing world that work closely with United Nations agencies and programmes, National Meteorological Services and the university sector in building capacity. These could form the focus of a coordinated, climate-services capacity building programme. Likewise, Regional Climate Outlook Forums are a set of natural

alliances around which future improvements in the development and delivery of climate services could be focused. However, much greater effort is required to engage representatives from the user communities in these processes and to enable a stronger demand-driven ethos in service provision.

8. Countries should be actively encouraged to devise clear definitions of mandates for the provision of climate services. Given that many World Meteorological Organization Members may not be in a position to provide a full range of climate services, one solution is to provide regional support and promote regional collaboration.

PART 2
NEEDS AND OPPORTUNITIES
FOR CLIMATE SERVICES

CHAPTER 5

EXPERIENCE OF CLIMATE SENSITIVE SECTORS

5.1 INTRODUCTION

Many sectors are sensitive to climatic conditions and practitioners in these sectors are experienced users of climate information and climate services both for planning and for operational purposes. This chapter examines a number of key sectors including disaster management, agriculture and food security, health, water resources, energy, ecosystems and the environment, oceans and coasts, transport and tourism and megacities to understand the nature of existing climate services and to identify where there are gaps and opportunities for strengthening them. It provides examples for each sector, across all timescales from short term weather events through intra-seasonal to inter-annual as well as decadal and climate change, where climate has a major influence. The aim is not to provide a comprehensive analysis for each sector but rather to provide some useful examples that demonstrate these relationships.

5.2 DISASTER RISK REDUCTION AND MANAGEMENT

EXTREME EVENTS, EXPOSURE, VULNERABILITY, RISK AND DISASTERS

Disasters occur when societies that are highly exposed and vulnerable to natural and other hazards are overwhelmed by a particular event. Most recorded disasters (91 per cent of the 2000-2009 global totals according to the Centre for Research on the Epidemiology of Disasters) are associated with naturally occurring weather and climate factors such as strong winds, heavy rain resulting in floods, insufficient rain resulting in droughts and very high or very low temperatures. Floods and storms alone account for 73 per cent of recorded disasters.

An extreme event or condition does not automatically lead to a disaster. Good planning and preparation can substantially diminish levels of exposure and vulnerability, reducing the amount of losses when events occur. Unfortunately, many countries have accumulated high levels of risk over many decades, so that even small events can lead to considerable damage.

The reasons for this are many: unplanned settlements on flood plains or unstable slopes; poorly constructed buildings; destruction of protective forests and wetlands; lack of risk data and assessments; inadequate early warning systems; ill-prepared populations and extreme poverty. In all cases, climate information plays a key role in identifying the risks and in implementing effective countermeasures.

REDUCTIONS IN HISTORICAL DEATH RATES

China's approach to floods is an outstanding example of how disaster risk can be reduced by active policies based on scientific information. In China, an estimated two million people died in the floods of July 1959 but over the recent decade 2000-2009 the average recorded annual death toll has fallen to 577, owing to the development of flood monitoring and early warning systems coupled with evacuation services.

Equally, in the Greater Horn of Africa, Bangladesh, China and India, where millions of people died from famine in the last century, such enormous death tolls have been hugely reduced thanks to food security programmes. These combine surveillance and early warning information about the climate, agriculture as well as household status and food markets, integrating the results with national and international food aid mechanisms. Seasonal outlooks are routinely used by governments in many countries to prepare for possible hard times and to avoid turning an extreme climatic event into a disaster.

While death tolls have declined significantly compared with the trend of rising population (Figure 5.1), the economic costs of disasters have generally risen (Figure 5.2), on occasion reaching an annual figure of US\$ 200 B. This trend is largely a result of larger populations and greater per capita wealth at risk, with local changes in environment and climate also a factor in many places.

POLICYMAKER CONCERN AND ACTIONS

In 2005, governments endorsed the Hyogo Framework for Action 2005-2015, which has the objective of building up the resilience of nations and communities to disasters. The Framework sets priorities for action, including increased emphasis on preparedness, awareness and risk reduction. It specifically identifies the need for scientific information and for its application in different sectors, along with the need for early warning systems related to climate variability and change. As a direct result, a number of humanitarian organizations have been seeking to realise the benefits of enhanced preparedness based on advanced warnings.

Policymakers' growing concern is the likelihood that the number of extreme weather and climatic events will increase in magnitude and/or frequency in the future as a result of increased atmospheric greenhouse gas concentrations and increasing societal vulnerability to climatic conditions. Under the Hyogo Framework, governments have identified disaster risk reduction and risk management methods as necessary measures as well for adapting to climate change. On the scientific front, the Intergovernmental Panel on Climate Change is currently preparing a Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, which will be published in 2011. Meanwhile, a number of countries and local authorities have already taken steps to reduce risks and to be better prepared, creating National Adaptation Programmes of Action as well as undertaking practical local efforts that include risk assessment along with improvements to drainage systems and water supplies. In many cases, however, these efforts are handicapped by a lack of data concerning the country's past climate and by uncertainties about changes that may occur in local climatic extremes in the future.

APPLICATION OF CLIMATE INFORMATION

An essential starting point for reducing risks is a quantitative assessment of the risks actually faced, combining information about the hazards and about population exposure. The hazard side of the equation makes use of historical data and modelling studies about tropical cyclones and other storms, rainfall, soil moisture and hill slope stability, weather patterns across mountains, river basin hydrology and flood occurrence, etc, while exposure and vulnerability information is obtained from demographic and socio-economic records and studies.

A number of countries and organizations are collaborating in the United Nations Development Programme-led Global Risk Identification Programme to develop comprehensive multi-hazard national risk profiles as part of a sustainable National Risk Information System. In South East Europe, several countries are developing systematic risk assessments with the help of a World Bank-funded cooperative study involving various international partners. In Africa, a needs assessment supported by the United Kingdom's Department for International Development has led to a large project to strengthen climate data acquisition and management systematically on the continent, focusing on data essential to address poverty, disaster risk reduction and economic development.

Climate information is also used increasingly in routine operations for risk reduction, including preparedness and response efforts by humanitarian organizations (Box 5.1). The International Federation of Red Cross and Red Crescent Societies and the World Food Programme are currently using seasonal outlook information from international centres to pre-position supplies and capacities

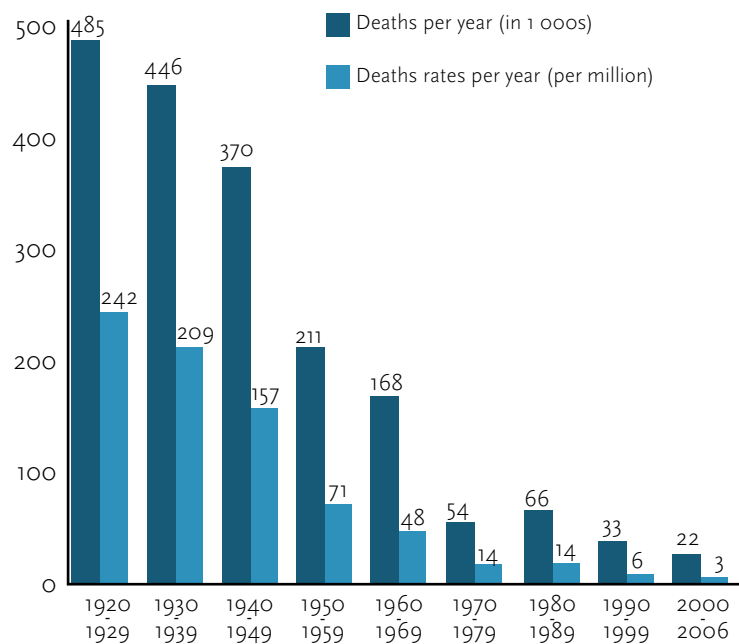


Figure 5.1. Global death and death rates due to extreme events 1920–2006. Source: Golkany, I. M. 2007. *Death and Death Rates Due to Extreme Weather Events: Global and U.S. Trends, 1900–2006*. http://www.cseccc.info/reports/report_23.pdf.

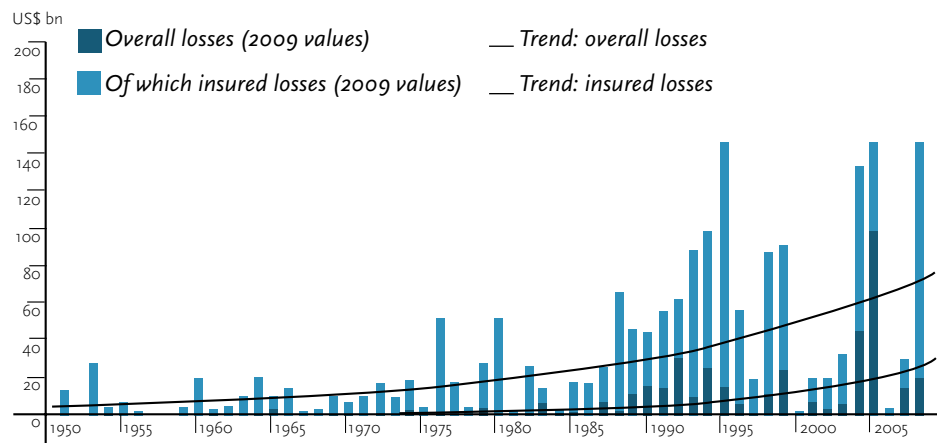


Figure 5.2. Overall and insured losses from natural disasters between 1950 and 2009. Source: Munich Re. 2010. *Topics Geo – Natural catastrophes 2009: Analyses, assessments, positions*. http://www.munichre.com/publications/302-06295_en.pdf

in regions of Africa likely to be affected by deficient or excessive rains. In addition, the Darfur Crisis Rain Timeline, produced by United States National Oceanic and Atmospheric Administration and the United States Government funded Famine Early Warning System Network, and distributed by the Logistics Cluster in Sudan, overlays the locations of refugee and Internally Displaced Persons camps with rainfall forecasts and the average position of the Inter-Tropical Convergence Zone (ITCZ) to facilitate prepositioning and planning humanitarian operations. At the beginning of operations in Darfur, this product allowed significant improvements in the efficiency of logistical operations. During

the Malawi crisis of 2001-2002, delays in the international response resulted in food aid vehicles being obstructed by floods in the following rainy season. Outlooks on winter weather conditions provided under the umbrella of the World Meteorological Organization were critical to organising support for survivors of the October 29, 2008 earthquake in Pakistan that occurred near the onset of winter. An Early Warning System for Central America has been developed that quickly identifies hazards spatially for the region: <http://www.satcaweb.org/>.

5.3 AGRICULTURE AND FOOD SECURITY

FUNDAMENTAL ROLE IN DEVELOPMENT

Agriculture encompasses an enormous range of activities, from subsistence farming to large corporate farms, and in the broadest sense includes cropping, animal farming, horticulture, harvesting wild products, aquaculture, fisheries and some forestry including agroforestry. For several billion people agriculture is a way of life, their livelihood and their only source of nutrition. Climate is a dominant factor influencing food production and food security and there is a rich base of experience concerning the use of climate information and climate risk management at all levels, from farm to global food markets.

As a result of intensive, science-based development efforts associated with the green revolution, over the period 1960 to 2007 global food grain production increased from about 850 million tons to 2350 million tons and per capita availability of food increased from 2300 kcal/day to more than 2800 kcal/day despite the rapid growth of the human population. Nevertheless, food insecurity in developing countries remains a critical concern and in some regions achieving the Millennium Development Goal of reducing the proportion of people that suffer from hunger by half before 2015 is under threat.

The number of people suffering from chronic hunger increased from under 800 million in 1996 to over a billion in 2010, most of them living in South Asia and sub-Saharan Africa. These regions are generally highly populated and have widespread poverty, large areas of low agricultural productivity due to a lack of production resources (e.g. fertilisers) and high climatic vulnerability. Agriculture also faces the generic pressures of global change, for example from competition with urban expansion for land, water and labour, from environmental decline and pollution and from unfavourable changes in climatic conditions, possibly associated with climate change. Hundreds of millions of people are affected by the problem of desertification and other forms of land degradation (see Box 5.2).

AGRICULTURAL PLANNING AND PRODUCTION CHOICES

An important requirement for agriculture is characterising its resource base in terms of climate, environment and ecosystems in order to select and develop production strategies that best suit different localities. Desirable climate information includes the usual climate parameters plus other data relevant to agriculture such as the dates of onset and termination of rainy seasons, accumulations of growing-degree-days and locally-adapted agro-climatic indices. In situ data at high spatial and temporal resolution may be needed, while satellite sensing and imagery provide widespread uniform measurements, including via indices such as the Normalised Difference Vegetation Index that has been used extensively for monitoring vegetation and for assessing and forecasting crop yield.

Agro-ecological zoning is an approach that aims to characterise geographic areas based on climate, soil, biological and yield information. It aims to improve strategies for managing farming and natural resources efficiently, for example by reducing risks when introducing a higher-yield crop or a new technology. Satellite and ground information are both essential for developing advisory systems

Box 5.1. FLOOD RISK AND THE IFRC

In 2008 the International Federation of Red Cross and Red Crescent Societies launched an emergency appeal based on a scientific seasonal rainfall forecast weeks ahead of a likely emergency.

To the populations of West Africa, one of the world's lowest-income regions, seasonal-to-inter-annual variability is particularly and immediately important, constituting a practical problem of monumental social ramifications. Of the twenty-two countries at the bottom of the United Nations Development Program Human Development Index ranking, fifteen are from West Africa, a region comprised of seventeen countries (United Nations Development Programme, 2008). Across the region, two-thirds of the active population on average works in the agricultural sector (Food and Agriculture Organization, 2009), one that is still highly climate-sensitive and dependent on rainfall. A growing majority of the population lives in ill-planned urban shantytowns built on flood plains where they settled during the prolonged drought period gripping the Sahel from the early 1970s to the late 1980s.

Against this context of high vulnerability and low coping capacity, slight changes in rainfall patterns can affect hundreds of thousands of vulnerable people at once, who either depend on the rains for their livelihoods or have no adequate drainage systems or other protective mechanisms during wet spells.

This extreme vulnerability to climate variability makes the region an ideal potential beneficiary of the type of seasonal climate information provided

through the *Prévisions Saisonnières en Afrique de l'Ouest*, West Africa's Regional Climate Outlook Forum. The Forum brings together scientists and hydrologists from national meteorological and hydrological services as well as climate forecasting centres from across the region and the world to discuss and agree on the forecast for the July–August–September rainy season in West Africa. This consensus-based forecast is considered to be the most authoritative voice on weather conditions likely to prevail during the upcoming rainy season in West Africa, Cameroon and Chad.

In 2008, unique circumstances allowed the seasonal forecast to be transmitted and acted upon by the Red Cross before the season began. There was a strong signal of likely above-normal rainfall, a visiting expert was present who was able to explain the climate information, and an institutional champion appeared who was open to innovation and willing to act on the 2008 forecast. The rainfall advice was matched by increased capacity at national as well as community levels to monitor and act on this risk information.

These advances in the use of climate information will be eroded unless sustained efforts are made to turn early warnings into early actions as standard practice, not just within the International Federation of the Red Cross and Red Crescent Societies and other humanitarian organizations but also in the larger climate-meteorological community and among donors. Only in this way can a single success story become a systematic process of receiving and acting on forecasts.

and planning strategies for new crop farming investments. Recent advances in remote sensing and geographic information systems have made the task of integrating and mapping data from a wide range of databases much easier. These spatial information systems provide powerful and accessible tools for people to use to visualise the impact of different farming configurations and management strategies. Some researchers have begun to include social and economic data in models in order to assess the structural vulnerabilities of rural populations to climatic and other resource-related risks.

The Intergovernmental Panel on Climate Change Fourth Assessment Report suggests that agriculture will be increasingly affected in coming decades by the effects of carbon dioxide enrichment, temperature increases and changes in the availability and timing of rainfall as well as by water release from glacier melting. It is likely that arid and semi-arid regions, mainly in continental areas, will experience reduced water supply and increased water stress. Climate change looms as a major threat

on a global scale to food markets and food security as well as on a local scale to particular localities and types of farming. There is some potential for technology advances to offset this in part. The types of data discussed above can also be used to identify agro-environmental hotspots where human activities are detrimental to the sustainability of an ecosystem or to the agriculture depending on it. There is increasing demand for historical data and for scenarios of future climate, coupled with agricultural data.

FARM MANAGEMENT

Climate information is particularly important for managing farm operations. Farmers have to make a number of crucial production decisions during the growing season based on climatic conditions as well as a myriad of other decisions concerning storage, trading and finance. The year-to-year variability of climate significantly affects the fortunes of most farmers. For example, total Australian crop value fluctuates by as much as US\$ 5 billion from year to year. Year-to-year variations in agricultural output are correlated with the El Niño/Southern Oscillation and are partially predictable using global climate models. Seasonal climate forecasting is used increasingly in the agriculture sector, and some major

Box 5.2. THE SAHEL EXPERIENCE



Figure B5.2. Drought affects those living in the Sahel.

The recurrent droughts experienced by the Sahel region of Africa through the 1970s and 1980s had a huge impact on society in this region, with hundreds of thousands of people displaced due to crop failure and populations on an enormous scale facing starvation. The fluctuation between dry and wet years is a typical feature of the Sahelian climate, with droughts of varying degrees occurring in two out of every five years, but the long-term failure of the rains throughout this period was unprecedented.

Due to the underlying variability of rainfall, the local population had developed means of adapting to dry and wet years and responded to the drought in a number of ways, from diversifying the range of crops grown to migrating to the cities to earn a living in a different way.

Since the early 1990's the drought has eased and agriculture has returned to previously arid areas, but there is no time for complacency since most predictions concerning the future climate point to a hotter regime for large parts of this region. The adaptation strategies adopted by the local populations are still appropriate but will become most effective when coupled with effective early warning systems that can highlight expected conditions during the season ahead. In particular, the most important decisions are likely to occur when one dry "growing season" is followed by forecasts of a high likelihood of another dry season.

Studies have shown that farmers have a strong interest in receiving forecast information on the intra-seasonal through inter-annual variability of rainfall since they have found that the traditional methodologies for predicting rainfall during upcoming years are becoming less effective due to the changing climate. Delivering this type of information effectively and integrating it into the decision-making processes of individual farmers requires a strong and dynamic partnership between the originators of the information and all other stakeholders, particularly national governments, extension agencies, lending organizations, NGOs and the farmers themselves. Only through such a strong partnership can the information truly be of use to society in the Sahel.

global traders in food commodities employ their own weather and climate experts to provide internal advice and prediction services.

Crop simulation models that run on personal computers allow farmers to examine a wide range of cropping options and management strategies for their farms, using historical climate data series and climate predictions. These are powerful tools for supporting risk management. Research using such models has shown that climate information can significantly improve decision making, especially in developing long-run strategies that help capture the benefits of good seasons and avoid damaging or costly decisions in bad seasons. However, seasonal forecasts do not typically contain all the information that is required by the crop simulation models, and so there is need for the climate services to deliver the additional information required for the crop models rather than having the crop modellers generate this information as is sometimes the case.

Satellite imagery allows monitoring of agriculturally-relevant factors on large geographical scales and is of particular interest to policymakers, multinational traders and international organizations concerned with global and regional food markets and food security. Provided there are sufficient direct measurements from the field for calibration, satellite information can provide routine operational information on crop status, water conditions and disease potential. The United Nations Food and Agriculture Organization uses these methods, combined with seasonal forecasts from Regional Climate Outlook Forums, to monitor and warn of food crises globally (see Figure 5.3).

COMMUNICATION STRATEGIES

Decision making involving millions of individuals within the complex setting of agriculture can greatly benefit from a surrounding body of rich and reliable contextual information, especially on weather and climate. This requires widespread communication of available information to farmers, managers, agricultural industries, local authorities, national policymakers and supporting scientists and technicians. Information and exchange of messages can address all aspects of the agricultural process – production, stocks, markets, transportation, etc, through community awareness creation and advocacy to sophisticated on-farm management advice using decision support models and risk management tools.

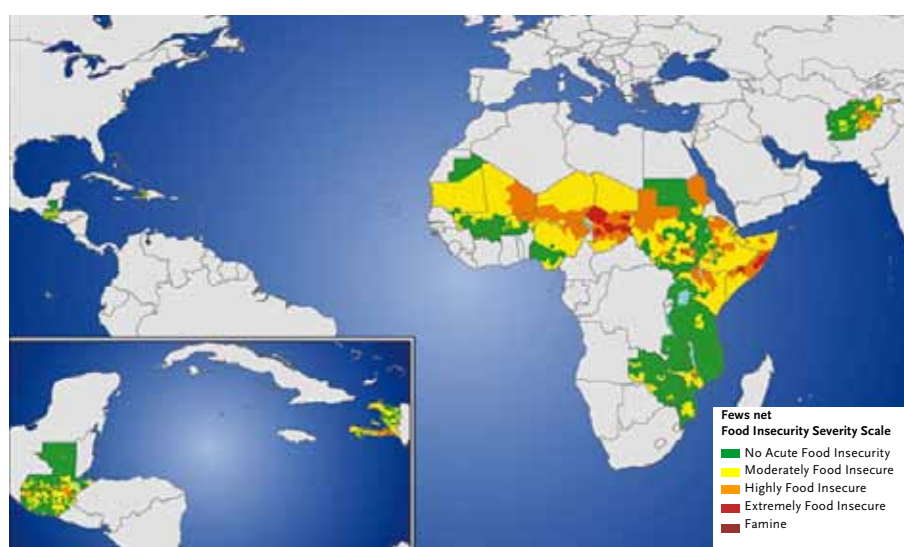


Figure 5.3. Famine Early Warning System estimated food security conditions, 3rd Quarter 2010 (July–September).
Source: Famine Early Warning System programme

Diverse communication strategies are used to reach target audiences, including indigenous knowledge, broadcast media, mobile phones, the internet and training programs (for example, the Food and Agriculture Organization's Farmer Field School). It is critical that communication strategies address cultural and social barriers to ensure that all farmers, regardless of gender, literacy or status, can benefit from the information, thus helping to enhance food security at the domestic and household level. National extension networks and regional support centres also play key roles in the outreach process through advocacy, training and research and through routine analysis as well as by generating and disseminating products. In Africa there are several long-established centres such as the Regional Training Centre for Agrometeorology and Operational Hydrology in Niamey, Niger, which was established in the early 1970s in response to the Sahelian drought; the African Centre of Meteorological Application for Development, also in Niamey; and the Intergovernmental Authority on Development's Climate Prediction and Applications Centre in Nairobi.

WORLD METEOROLOGICAL ORGANIZATION'S COMMISSION FOR AGRICULTURAL METEOROLOGY

In July 2010, representatives from 62 countries and a number of international organizations concluded the Fifteenth Session of the World Meteorological Organization Commission for Agricultural Meteorology by pledging improved agro-meteorological services to assist the farming community around the world to cope with the increasing impacts of climate variability and climate change. The Commission identified several priorities for future work including: 1) developing enhanced services for the agricultural, livestock, forestry and fisheries communities and partner agencies, including climate services; 2) encouraging development of a knowledge sharing interface between forecasters/scientists and the agricultural decision-makers; 3) supporting agro-meteorological training at regional, national and local levels; and 4) encouraging the sharing of resources among World Meteorological Organization Members and other organizations in order to build synergies and to support human health and economic development.

5.4 HEALTH

CLIMATE INFLUENCES HEALTH

Good health is a primary aspiration of human social development and is necessary for sustainable economic development. It is one of the key outcomes sought in the Millennium Development Goals.

It is widely recognised that climatic conditions influence human health. Direct effects include such phenomena as storms and floods that cause accidents and drowning as well as heat or cold stress that can aggravate pulmonary, respiratory and cardio-vascular disease. Indirect effects are extensive and include, for example, disruption of public services and sanitation during disaster events, shortages of food and water during droughts and influences on the development and spread of infectious diseases such as malaria, dengue, meningitis, cholera and influenza.

The negative impacts of climate are most pronounced for poor populations in developing countries where livelihoods are heavily dependent on rain-fed agriculture and seasonal water resources, where people are often exposed to infectious vector-borne, water-borne and airborne diseases and to local air and water pollution sources and where access to information, health services and public health regulation is minimal. In economically well-developed countries a similar pattern of vulnerability exists for the poor, the chronically sick, the elderly and those in remote communities, as evidenced by the mortality profiles of the 2003 European heat wave and the 2005 Katrina hurricane.

NEW CLIMATE-HEALTH SERVICES

There has been a growing awareness of climate-health linkages in recent decades and schemes have been devised to predict and reduce climate impacts on specific stresses and diseases. Well-known examples include heat wave prediction and advisory systems such as the National Heat Wave Plan jointly instituted by health and weather agencies in France after the 2003 heat wave (see Box 5.3). There are many intra-seasonal and seasonal predictions of maximum and minimum temperature that, whilst not predicting an individual event, do provide valuable information relating to the likelihood of increased risk of heat waves over the outlook period.

Similar forecast systems exist in many cities for air quality, where forecasts of ozone and other pollutants in hot periods are used by sufferers of respiratory conditions as warnings to protect themselves and by health service professionals to prepare for increased case loads. In some countries, speed restrictions are applied to highways to reduce vehicle emissions that lead to higher ozone levels.

Malaria early warning systems, which are currently being tried out in several African countries, make use of climatic data and forecasts, environmental conditions, population vulnerability and operational factors in order to detect conditions that are suitable to the development of an epidemic. Research has shown close relationships between malaria incidence and climate variables (see Figure 5.4). In some semi-arid areas, where occasional years of heavy rain

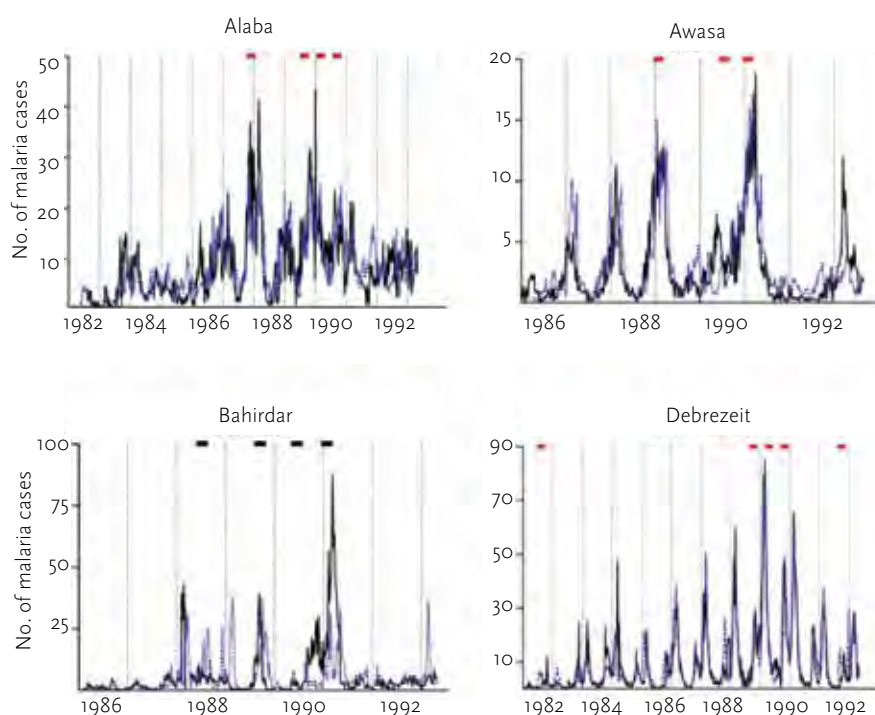


Figure 5.4. Observed and predicted number of malaria in epidemic-prone regions of Ethiopia. The solid lines are for observed cases and the dotted lines for predicted cases. The red marks are the timing of alerts triggered using predicted cases; their position along the y-axis does not have a meaning. Source: Teklehaimanot, H.D., Schwartz, J., Teklehaimanot, A., Lipsitch, M. 2004. Weather-based prediction of *Plasmodium falciparum* malaria in epidemic-prone regions of Ethiopia II. Weather-based prediction systems perform comparably to early detection systems in identifying times for interventions. *Malaria Journal* 2004, 3:44. <http://www.malariajournal.com/content/3/1/44>.

Box 5.3. RESPONDING TO THE 2003 EUROPEAN HEAT WAVE

The European heat wave in August 2003 resulted in an excess mortality of approximately 30,000 people across Europe with 2,000 excess deaths in the UK and over 14,000 in France. The vast majority of these were among older people. Excess deaths are deaths in addition to those that would normally occur during and immediately after the same period, given normal climatic conditions. There is strong evidence that these summer deaths were indeed 'extra' and are the result of heat-related conditions and highly avoidable.

There is no universal definition of a heat wave because the term is relative to the usual weather in the area. In France, seven days with temperatures of more than 40°C were recorded in Auxerre between July and August 2003. But because of the usually relatively mild summers, most people did not know how to react to very high temperatures (for

instance, with respect to rehydration) and most homes were not equipped with air conditioning.

The 2003 heat wave resulted in a number of actions across all the affected countries. France had already implemented a 'traffic light' system of warnings of hazardous weather known as the Vigilance system. As a direct result of the events of 2003, Vigilance was extended to offer warnings of heat wave conditions and a similar approach was taken in the UK and in many other countries. Warnings are issued of a heat wave when particular thresholds of daytime and night time temperature are exceeded. Due to the vast majority of excess deaths occurring amongst the elderly population, there is a need to target assistance on those most vulnerable.

The governmental response to the heat wave also covers the response by the civil defence community and the healthcare sector, etc, to the expected conditions and offers a useful demonstration of the importance of an integrated approach to hazardous weather events. For example, the plans include advice to vulnerable members of the population to seek out air conditioned buildings where they can rest and shelter from the heat.

With events on the scale of the 2003 heat wave expected to become more prevalent over the coming years due to the effects of climate change, it is vital that communities and governments have the tools in place to adapt to the increasing risks.



Figure B5.3. Pollution is a major hazard, particularly during heat waves when smoke from fires adds to other atmospheric pollutants.

can be responsible for malaria epidemics, the number of malaria cases typically peaks a month or two after the peak of the rainy season, so rainfall monitoring can provide a good indication of epidemic risk. If seasonal rainfall forecasts can be made for these areas, the warning system can broadly forecast malaria epidemic risk even further in advance. In some highland areas, temperature rather than rainfall is a limiting factor and epidemics occur during unusually warm seasons. Again, seasonal forecasts may be able to provide advanced warning of increased risks.

These advanced warnings enable health authorities to enhance their surveillance and their preventive and control measures in the specific at-risk geographic areas well ahead of any major outbreak. Guidelines developed in 2001 under WHO auspices have laid out a framework for the concepts, activities, indicators and planning required at different stages during the emergence and escalation of a malaria outbreak as it evolves into a potential epidemic.

INTEGRATED HEALTH INFORMATION

An important lesson learned from these programmes is that climate information and predictions are not magic tools that can “solve” a public health problem on their own but must be incorporated into a well-integrated public health information system and decision-making approach in order to create sustained and measurable benefits. The prospects for this partnership between climate analysts and health professionals are exciting. Recognising this, the international health community is exploring new strategies to “climate-proof” health that will improve health outcomes, prepare for a changed climate and protect hard-won development gains. A special resolution on climate and health was passed at the 61st meeting of the intergovernmental World Health Assembly in 2008. Over the next decade we can expect to see the emergence of a wide range of new services backed by new human and institutional capacities that can link the health and climate fields and come to grips with the new ideas and technologies involved.

5.5 WATER RESOURCES

FOR HEALTH AND WEALTH

Water is fundamental to life and is essential for agriculture, municipal services, industry, hydropower, inland navigation and environmental protection. Agriculture, particularly through irrigation, uses about 70 per cent of all freshwater withdrawals. Water is a carrier and diluter of waste and pollution and a conduit for various diseases and disease vectors, while also being a facilitator of hygiene and good health. Excesses of water, or prolonged absences of water, are among the greatest natural hazards for human society (see Box 5.4). The characteristics of the hydrological cycle, water resources and water hazards – magnitudes, variability and extremes – are a direct outcome of climatic processes, particularly atmospheric circulation and cloud processes, precipitation as rain or snow and evaporation. The science of hydrology and the task of managing water therefore reach deeply into the climate knowledge base and draw heavily on climate information resources and services. For instance, intra-seasonal and seasonal forecasting of rainfall can be utilised with observed data on the status (soil wetness, current river flows) of a catchment to provide guidance on the risk of flood.

The availability of water and its reliability vary greatly in different parts of the world. Mid-latitude countries, many of that are members of the Organization for Economic Cooperation and Development, generally benefit from moderate and fairly reliable rainfalls. However, many tropical and subtropical countries, including a large number of developing countries, experience low and very variable rainfalls (Figure 5.5) and hence face greater management challenges, for example for larger storage facilities and for closer management of demand. Water supply and sanitation development is an important objective for development assistance; in 2007, Organization for Economic Cooperation and Development contributions made through multilateral mechanisms alone amounted to US\$ 1.27 billion.

GROWING CHALLENGES FOR THE FUTURE

The Intergovernmental Panel on Climate Change Fourth Assessment Report suggests that Climate change is expected to have a large impact on the availability and demand for water resources, which in turn will exacerbate existing issues in other water-dependent sectors such as health, food production, sustainable energy and biodiversity. Impacts will arise as much from changes in variability and in extreme events as from changes in mean levels. In fact, water is likely to be one of the main mediums through which climate change will manifest itself and impact people, ecosystems and economies, potentially jeopardising sustainable development and poverty reduction efforts. There are growing

efforts to address these future uncertainties through the application of resilient systems and adaptive management, both of which are very dependent on climate data and expertise.

In addition, the water sector faces significant development pressures worldwide arising from growing populations, urbanisation, increased per capita demand for industrial and agricultural purposes, rapid depletion of fossil groundwater reserves, lower water tables, large scale salinisation and water pollution, declining availability of cheaply exploitable sources, public resistance to the construction of dams and other works as well as significant difficulties in establishing publicly acceptable pricing regimes for water use. The need for integrated and transparent approaches involving multiple stakeholder groups and diverse scientific disciplines add to the complexity of water management decision making. For developing countries, these problems are compounded by chronic shortages of capital for building necessary storage and reticulation works and limited capacities for technical advice and management.

MANAGING WATER RISKS

Water resources management is essentially shaped by how the extremes – floods and droughts – are defined and characterised and how the associated risks to society are managed. Estimates of historical extreme events are used as the probabilistic basis for designing virtually all major physical infrastructure, for defining floodplain zones, for sizing storm sewers and highway culverts and for pricing flood and crop insurance. To date, the hydrological extremes being experienced are still within the norms of natural historical climate variability and common design standards. However, current climate change projections point to increased frequencies of extreme values and hence to an increased potential for water-related structure failure in the future.

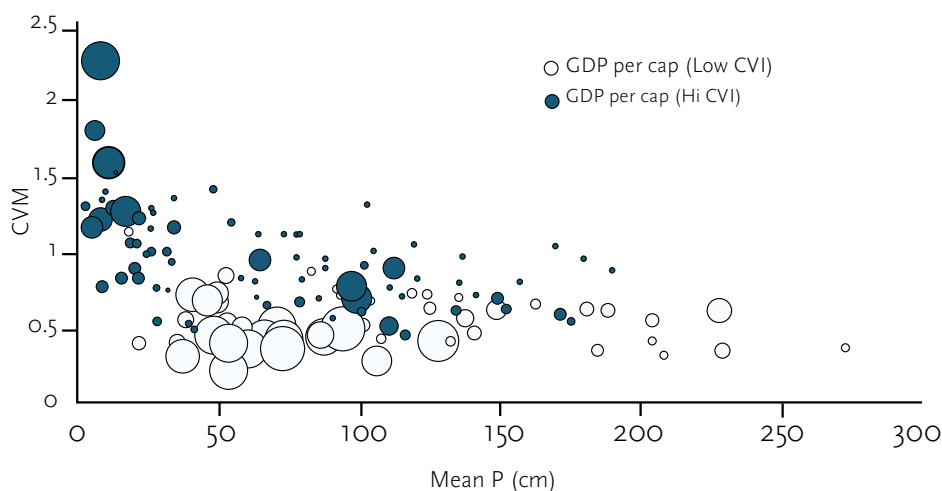


Figure 5.5. Scatter plot of mean annual precipitation (P , x-axis), the coefficient of variation of monthly rainfall (CVM, y-axis) and the per capita GDP (size of circle). Colour is for the countries that rank in the bottom half (light blue) of inter-annual coefficient of variation and that rank in the top half (dark blue). It can be seen that most wealthy nations (large circles) occupy an area on the chart that represents low variability and moderate average rainfall (i.e. the cluster of large light blue circles). Poorer countries face more challenging conditions, often having high variability and either low or high average rainfall (i.e. the scattered, small, dark blue circles). Source: Brown, C. & Lall, U. 2006. Water and economic development: The role of variability and a framework for resilience. *Natural Resources Forum* 30 (2006) 306–317. <http://onlinelibrary.wiley.com/doi/10.1111/j.1477-8947.2006.00118.x/pdf>.

Box 5.4. MAJOR FLOODS – EUROPE AND PAKISTAN

A week-long flood in August 2002 affected countries along the Danube, Elbe and Vltava rivers causing dozens of deaths, billions of dollars of damage and the dispossession of thousands of people. Countries affected included the Czech Republic, Austria, Germany, Slovakia, Poland, Hungary, Romania and Croatia. Although the rivers of Central Europe regularly flood, 2002 saw water levels reaching record levels, with the Elbe in Dresden reaching a height of 8.9 metres and threatening many of the city's cultural landmarks.

As a result of the flooding, the European Union established the European Flood Alert System that builds on and adds value to the capabilities of the weather and hydrological forecasting institutions in the region to offer timely advice to governments on likely flood events. In order for this information to make a real difference to the populations affected, there needs to be

a national infrastructure that is able to take the information and communicate it to those who need to hear it so they can respond in the appropriate manner and make the right decisions.

In August of 2010 Pakistan experienced extreme flooding, dislocating an estimated 20 million people and directly causing the deaths of around 2000 people. In terms of national impact it was a disaster exceeding that of the European floods and even the 2004 "Boxing Day" tsunami. The relatively low death toll in the Pakistan floods was in part due to warnings for the event and in part due to its slow evolution. There are fears that the indirect death toll will rise considerably above this level as sickness occurs as a result of contaminated water accompanied by poor nutrition of the displaced people.

While scientists do not ascribe climate change as the only factor in the cause of these disasters they note that it is one of the factors along with the land use changes that have occurred in the flooded areas. It is clear that effective warning systems are important however land use planning and the development of infrastructure in flood affected areas needs to take full account of climate variability as well as climate change if these devastating impacts are to be mitigated to the greatest degree possible in the future.



Figure B5.4. Facing the flood.

The water resources sector depends on a wide spectrum of climate information and analysis services, from historical observations and current climate monitoring through model-based scenarios and seasonal predictions. Requirements fall into two main categories: the design of hydrological structures and the day-to-day operation of these systems. Basic data are used for a variety of purposes, including as input parameters for estimating stream flow availability and water demand, modelling the hydrological cycle, preparing water balance and water resource assessments for river basins as well as for identifying recharge opportunities for groundwater.

Integrated studies and assessments involving detailed social, economic and environmental considerations normally make use of an expanded set of climate information. Periodic reviews of

reservoirs and basin management plans and their operating rules make use of updated data sets on climate variables such as rainfall and snowmelt timing, along with new flood and drought frequency analyses and, increasingly, climate projections as well.

There are many levels of decision making in water management – from the national policy level down to the individual household and farmer. Each user has specific requirements for climate information to factor into their decision-making processes. A farmer needs to decide which crops to plant, when to sow and when to harvest. For those farmers that irrigate, anticipated water allocation is also important information. District irrigation managers need to optimise the allocation of water under their control. Policymakers generally deal with long time horizons such as in deciding allocation rules and entitlements for water-using sectors, priorities for water use during droughts, regulations on water quality and economic development policies that impinge upon water resources.

BEYOND NATIONAL BORDERS

Quality climate data is particularly important for negotiating the design and operation of water management systems for shared basins that span more than one country. There are 263 trans-boundary river and lake basins worldwide, accounting for an estimated 60 per cent of global freshwater flow, being home to 40 per cent of the world's population and affecting 75 per cent of all countries, 145 in total. There are also around 300 trans-boundary aquifers worldwide. A growing concern of both policymakers and operators is how to allocate and use water when the climate is changing and water resources may be shrinking. There are risks that under existing policy and technical rules an operational agency may under- or over-allocate the available water supply with serious consequences, or that major investments in new infrastructure may be made too early or too late.

5.6 ENERGY

CLIMATE AFFECTS SUPPLY AND DEMAND

The energy sector is essential to modern industrial society for production processes, transportation and building services. The sector faces continued strong growth in demand both from population growth and from increasing industrialisation, well exemplified by China's reported opening of two large new power stations every week on average. At the same time, there are new pressures for reliability to meet business and social requirements for "zero-failure" supply as well as for cost-efficiency of production and delivery to meet the expectations of consumers and shareholders in what is often a very competitive market. For a number of developing countries the energy sector is not well developed and there are major shortcomings in affordable access and reliability of supply, especially in rural areas. To these concerns the problem of climate change brings the enormous long-term challenge of radically transforming the industry to replace its current heavy dependence on fossil fuel sources.

ENERGY SECTOR SENSITIVITY TO CLIMATE

The sector is particularly sensitive to weather and climate factors and is therefore a very experienced user of climate information. For example, the demand for heating, ventilation and cooling, which in the United States amounts to about 45 per cent of electricity use, is dependent on the average climatic patterns of the location as well as seasonal variations and day-to-day changes in weather. Wholesale energy prices can fluctuate wildly as a result. Markets for energy futures, which help

to smooth the impact of price fluctuations on businesses, make active use of long-range climate information. Renewable energy production must deal with the additional problem of supply-side variability, particularly shortages in rainfall for hydroelectricity, lack of wind for wind farms and cloudiness for solar energy installations. Hydroelectricity systems relying on relatively low-capacity dams are particularly sensitive to seasonal rainfall variations.

Routine operation of energy systems has diverse climate sensitivities. The capacities of electricity transmission lines decline in hot conditions, for example. Cooling water for nuclear power plants, drawn from rivers, may become ineffective in periods of hot weather, drought and low river flows. Extended-range prediction of rainfall and temperature probabilities can be a useful input in managing such systems. A climate change study for Switzerland indicates that by 2050 there will be a 5–10 per cent reduction in hydropower production due to smaller runoff and a noticeable decline in cooling capacity for its nuclear power plants. Coal fired plants may need to reduce output if their air pollution output exceeds standards during stagnant weather conditions. Production and distribution facilities including oil rigs, wind and solar farms, ports, transmission lines and substations can be damaged by tropical storms, tornadoes, tree falls, heavy snow and flooding. A dramatic example is the accumulation of ice on Canadian transmission lines during an unusual ice storm in January, 1998 that destroyed thousands of pylons and poles and shut down electricity supply for up to a month in some regions, with total losses of over US\$ 4.75 billion. There are now extended-range predictions for these types of extreme events offered by some Climate Services which, while not forecasting individual events, can still provide useful planning guidance.

PLANNING AND DEVELOPMENT

Climate information has long been used in planning and developing energy systems, including for designing and locating facilities. It is also being applied to a number of important new problems and issues. These include the question of how to achieve reliability and stability in complex networked energy systems so that the failure of one power line or computer (say from a storm or a heat wave) does not lead to large-scale blackouts as occurred in Brazil in 1999 and Canada and the United States in 2003. Climate change raises many new questions, such as how to improve energy efficiency in buildings and how to ensure that new “climate friendly” energy systems do not result in unintended consequences such as damage to ecosystems and water supplies or increased air pollution or flooding risk. The Intergovernmental Panel on Climate Change Fourth Assessment Report suggests that climate change will affect both supply and demand, which will inevitably ramp up the sector’s attention to climate sensitivities and to the data and tools needed to manage them better.

While the foregoing has potential relevance for all countries, there remains a distinctive set of issues for the energy sector in developing countries. In addition to the ongoing constraints on capital and capacities, there are often high sensitivities to climate, firstly on the demand side as cities and industries grow and secondly on the supply side, particularly with hydroelectricity, which may be the main source of economically sustainable energy in some countries.

Economic impacts can be disproportionately high. The curtailment of hydropower generation from Lake Kariba in Zimbabwe as a result of the 1991–1992 drought caused estimated losses in GDP equal to US\$ 102 million, a loss in export earnings of US\$ 36 million and the loss of 3,000 jobs. Developing countries are likely to experience major energy-related impacts from climate change, for example as cities get hotter and as glaciers and other water resources decline or change. Often a problem for developing countries is a lack of long and comprehensive series of climate data upon which to base energy system planning and management along with a lack of experienced analysts in energy and climate issues.

5.7 ECOSYSTEMS AND ENVIRONMENT

FUNDAMENTAL NATURE OF ECOSYSTEMS

Ecosystems are a fundamental consideration in scientific enquiry and environmental policy. Specific ecosystems such as mountain forests or coastal wetlands are well recognised by their distinctive appearance, which arises from the types of living organisms present in them and their latitude, altitude, rock and soil composition, slope and aspect and particularly their weather with the associated availability of water.

Ecosystems may be described as a dynamic complex of plant, animal and micro-organism communities interacting with the non-living environment as a functional unit. Scientifically they are often characterised by the interactions among particular species in the communities and by exchanges of energy, nutrients and water. They are both terrestrial based and marine based. Whilst terrestrial based ecosystems are very familiar, the diversity and importance of marine ecosystems is enormous.

Economically, ecosystems are important sources of goods and services such as food, medicines, fuel, soil fertility, structural materials, water purification, flood amelioration and recreational services, as well as storehouses and protectors of biodiversity. The term agro-ecosystems recognises the need to study and manage the world's extensive agricultural areas on the basis of ecological principles. Fisheries management is another example of a key ecosystem with high economic value relying on coordination.

The Intergovernmental Panel on Climate Change Fourth Assessment Report indicates that ecosystems can also provide climate regulation, for instance because of carbon storage in both land- and ocean-based ecosystems slowing the increase in carbon dioxide levels in the atmosphere, but also because of effects such as reducing the impact of warmer temperatures by generating a microclimate including shading, moisture retention and by increasing the roughness of the surface.

Ecosystems evolve over time and can reach relatively stable states appropriate to their physical circumstances. However, stresses such as long term changes in climate and water availability, along with disturbances such as invasion by alien species or diseases, extreme conditions of weather and climate, fire or excessive economic exploitation, may lead to system imbalances that can destroy key elements and cause potentially radical transformations.

RAPID CHANGE AND LOSS OF ECOSYSTEMS

The International Millennium Ecosystem Assessment, conducted between 2001 and 2005, concluded that over the past 50 years humans have changed ecosystems more rapidly and more extensively than during any comparable period of time in human history (Figure 5.6), largely to meet rapidly growing demands for food, fresh water, timber, fibre and fuel. This has resulted in a substantial and largely irreversible loss of the diversity of life on Earth. For example, over this period approximately 20 per cent of the world's coral reefs were lost and an additional 20 per cent degraded, while approximately 35 per cent of recorded mangrove areas were destroyed. More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850, and now agricultural systems cover one quarter of Earth's land surface. Degradation of forest land cover and soil has been equally rapid.

While substantial net gains in human well-being and economic development have resulted from ecosystem exploitation, they have incurred mounting costs of degradation, increased risks and the exacerbation of poverty for many people. Unless addressed, these trends will substantially diminish the benefits that future generations will be able to obtain from ecosystems and will be a barrier

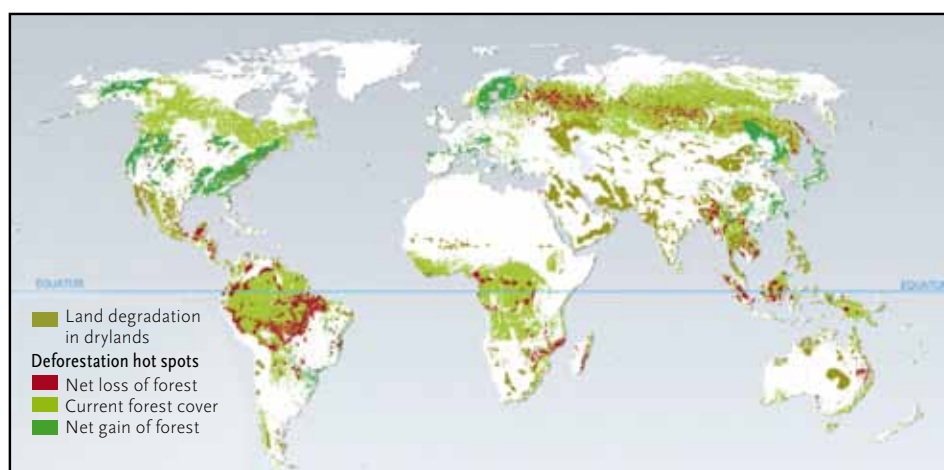


Figure 5.6. Locations reported by various studies as undergoing high rates of land cover change in the past few decades. Source: Millennium Ecosystem Assessment

to achieving the Millennium Development Goals. Many options exist, however, for conserving or enhancing specific ecosystem services in ways that can reduce negative consequences.

CLIMATE CHANGE IMPACTS

The Intergovernmental Panel on Climate Change Fourth Assessment Report indicates that climate change is projected to bring large-scale changes in factors of critical importance to ecosystem functions and environmental conditions. These include warming of land areas; contraction of snow cover, permafrost and sea ice; precipitation changes with increases in high latitudes but decreases in most subtropical land regions; likely increases in the frequency of hot extremes, heat waves and heavy precipitation; and a probable increase in tropical cyclone intensity along with other changes in wind, precipitation and temperature patterns. Ecosystems likely to be especially affected are: tundra, boreal forest and mountain regions because of their sensitivity to warming; Mediterranean-type ecosystems because of reduction in rainfall; tropical rainforests due to precipitation declines; coastal mangroves, salt marshes and coral reefs owing to multiple stresses; and the sea ice biome because of sensitivities to warming. Current pressures on natural resources and the environment are primarily associated with rapid urbanisation, industrialisation and economic development, and climate change will compound these pressures in the future.

ENVIRONMENTAL MANAGEMENT

The term environment is often used in an anthropocentric way to refer to the circumstances that humans find themselves in and are affected by, particularly with respect to air and water pollution, land degradation and ecosystem destruction. Environmental management aims to monitor such environmental conditions and to implement and manage measures to maintain clean air and water, rich landscapes and healthy ecosystems. Temperature, humidity, rainfall and wind figure strongly in environmental processes and hence also in the scientific models and tools used by environmental planners and managers. The climate is not only a key factor in specific environmental circumstances but is also the subject of environmental change because of the effects of increasing greenhouse atmospheric gases.

Climate information is used by scientists and managers in the fields of ecosystems and environment in numerous ways, including for site-specific research studies, for developing

predictive ecosystem models, for assessing projects and land use changes, for detecting and projecting trends and potential problems and for large-scale planning and policy purposes. Varied data types are needed depending on the climatic sensitivities of the matter at hand, including historical series, current weather observations, on-site measurements and climate change projections.

5.8 OCEAN AND COASTS

OCEAN INDUSTRIES AND SCIENCE

Providing climate services to those using the world's oceans and coasts reflects the diversity of the users of these important natural assets. Shipping, fisheries and off-shore drilling are three key clients of ocean climate services. The fishery sector has a strong interest in sea surface temperature patterns, including their week-to-week variation from long-term average conditions, as these have a strong relationship with ocean conditions favourable to fish populations and hence fishing zones. Shipping companies and off-shore drillers for gas and oil use historical and predicted information on winds, waves and currents in their decision-making processes. Shipping in the higher latitudes relies heavily on ice-edge climatology and forecasts.

Oceans evolve considerably more slowly than the atmosphere above them. Anomalies in sea surface temperature can persist for months, continuously interacting with the weather systems moving over them, potentially in a predictable manner that can give valuable insight into ensuing rainfall and temperature patterns from intra-seasonal to inter-annual timescales as was described in Chapter 1. Systems of buoys and satellite observations now regularly monitor conditions in the affected areas of the ocean, feeding valuable initial condition data into seasonal climate prediction models that are in turn used by a range of users.

Warming of the atmosphere and the upper layers of the ocean has contributed to the melting of the Antarctic and Greenland ice sheets as well as to an expansion of the global oceans, resulting in a global rise in sea level that is currently occurring at a rate of about 3 mm per year (and possibly increasing). The Intergovernmental Panel on Climate Change in its Fourth Assessment Report estimates that by the end of the present century the average global sea level will be somewhere between 18 to 59 centimetres higher than at the end of the last century, depending on the scenario of emissions produced between now and then. Published papers in refereed scientific literature are now indicating that this may underestimate the likely sea level rise by that time. But sea level rise will not be uniform over the globe and along the coasts since it is affected by changes in local wind, temperature regimes (Figure 5.7), uneven gravitational effects and by coastal processes such as land subsidence. Herein resides the importance of building climate services on timely, high quality and readily accessible ocean monitoring information that will enable those affected by climate change to find the best strategies to respond to the threats it poses.

Oceans play an important role in the global carbon cycle, absorbing carbon dioxide at the surface and transporting and diluting it via slow mixing and overturning of ocean waters for decades to centuries or longer. Oceanic deep bottom waters may take thousands of years to circulate. Growing atmospheric carbon dioxide concentrations have led to increased concentrations in the ocean as well and hence to increased oceanic acidity. First observed in 2003, the small decrease of about 0.1 units in ocean pH is extremely significant because it threatens the existence of all marine animals that rely on carbonate-based shells or structures, including shell fish and corals. Global monitoring of pH, particularly in areas of high shell fish productivity and extensive coral reefs, is now an important ocean service.

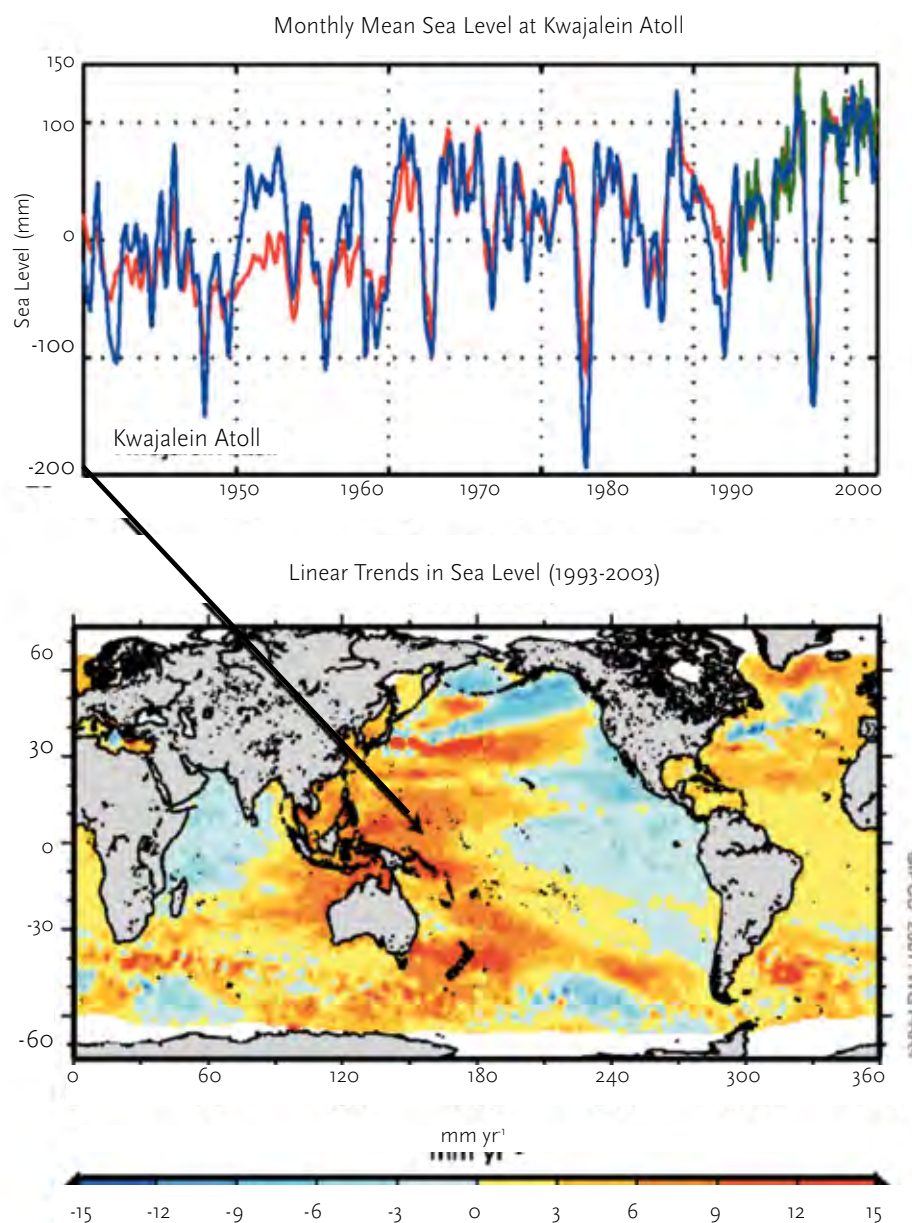


Figure 5.7. (Top) Monthly mean sea level (mm) curve for 1950 to 2000 at Kwajalein (8°44'N, 167°44'E). The observed sea level (from tide gauge measurements) is in blue, the reconstructed sea level in red and the satellite altimetry record in green. (Bottom) Geographic distribution of short-term linear trends in mean sea level for 1993 to 2003 (mm yr⁻¹) based on TOPEX/Poseidon satellite altimetry.

COASTAL RESOURCES AND RISING SEA LEVEL

Humans have long relied on the resources of coastal zones for sustenance and as an attractive location for commerce, living and recreation. Some 10 per cent of the world's population lives in coastal areas. Coastal wetlands provide habitat for many species, play a key role in nutrient uptake, serve as the basis for many communities' economic livelihoods, provide recreational opportunities and protect local areas from flooding (Figure 5.8). Coasts provide ports to support fishery operations, off-shore energy activities and long-range trading. However, human habitation alters coastal characteristics, for example dune structure, vegetation cover and drainage. In many places the ramifications of changes have not

been well appreciated, as was illustrated by the effects of Hurricane Katrina on New Orleans in 2005. In Asia, rapid economic development has resulted in the dramatic expansion of coastal cities such as Bangkok, Hong Kong, Shanghai and Singapore, with significant changes in climate-related factors – including subsidence, higher peak runoff, heat waves and air pollution. The coastal areas of major river deltas such as those of Egypt (Nile), Viet Nam (Mekong), Nigeria (Niger) and Bangladesh (Ganges and Brahmaputra) are very densely populated by relatively poor communities and are quite vulnerable to coastal storms and sea level rise. A recent study of 33 of the world's most densely populated deltas revealed that 28 of them are subsiding, which further compounds their problems.

Low-lying coastal ecosystems such as salt marshes and mangroves are particularly vulnerable to rising sea level. Rising sea levels erodes beaches, intensifies flooding and increases the salinity of rivers, bays and groundwater tables. Some of these effects may be compounded further by other effects of climate change including greater runoff and floods, and by construction measures taken to protect private and public property.

Sea level rise will exacerbate flooding during storms. When a low pressure system such as a hurricane or winter storm approaches, it creates a bulge in the local sea level called a “storm surge” which, together with the storm's high waves, often leads to coastal flooding. Considering only this effect, a recent study estimated that existing levels of coastal assets in the United States would experience a 36–58 per cent increase in annual damages for a 30cm rise in sea level and a 102–200 per cent increase for a one- metre sea level rise. Shore erosion also increases vulnerability to storms by removing the beaches and dunes that would otherwise protect coastal property from storm waves.

APPLICATION OF CLIMATE INFORMATION

For coastal planners and for those purchasing land in the coastal zone or making a living nearby, information about climate variability and change as well as about local sea level rise, including their impact on coastal morphology, will be increasingly crucial to their investments and to their way of life. Relevant data sets on coastal observations of wind, waves, atmospheric pressure, temperature, rainfall intensity and flooding can be combined with expertise in marine meteorology and coastal

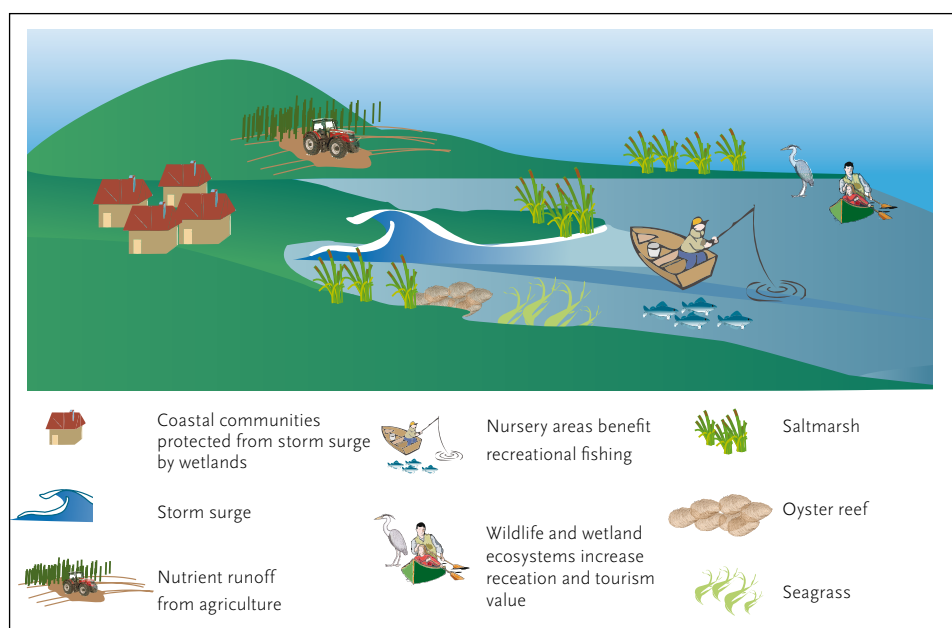


Figure 5.8. Key ecosystem services and features of coastal wetlands.

geomorphology to provide services that meet clients' particular needs. Users of climate services related to the open ocean are generally concerned with matters beyond national jurisdictions and are likely to access services coordinated through the work of international agencies such as the International Maritime Organization, the International Hydrographic Organization, the United Nations Educational, Scientific and Cultural Organization/Intergovernmental Oceanographic Commission along with the World Meteorological Organization as well as those delivered by national governments in accordance with agreed international responsibilities. For information on coastal climate, clients are highly reliant on the public good services offered by their meteorological or maritime agencies. Private consultancy services are commonly used for both ocean and coastal services as well.

5.9 TRANSPORT AND TOURISM

IMPACTS ON INDUSTRY AND INDIVIDUALS

On 18 December 2009 a train from Paris to London broke down in the tunnel under the English Channel, leaving hundreds of passengers stranded in the 51 kilometre tunnel for many long hours and disrupting the plans of thousands of others over the following days. It was soon revealed that condensation arising from the cold conditions had damaged the engine's electrical system. Three months later, on March 16 in the South Pacific Ocean, Fiji was battered by tropical cyclone Tomas, with disruptions to transport and tourism operations in the northern regions of the country. In these two cases, data and expertise on weather and climate were essential to understanding, preparing for and responding to the situation.

WELL PREPARED AND WELL WARNED

In preparing for Tropical Cyclone Tomas, for example, Fiji was able to exercise well-practised national and international mechanisms for monitoring and warning, drawing on streams of global data and predictions, regional and national observations and standardised analysis and prediction methods for tropical cyclones. Warnings and advice were disseminated via multiple communication channels to reach those at risk in Fiji's transport and tourism sectors as well as reaching public agencies, the media and other key constituencies.

DEALING WITH CLIMATE SENSITIVITIES

Globally, the transportation and tourism industries are large and generally fast growing. International marine transport moved eight billion tonnes of cargo in 2007. Commercial airlines generated global revenues of US\$ 564 billion in 2008, or about 1 per cent of global GDP. International tourism receipts in 2003 were approximately six per cent of worldwide exports of goods and services and 30 per cent of service exports. The two industries are very vulnerable to climatic and weather factors, not only from the effects of storms and other hazards but also from seasonal climate changes that can significantly alter production and transport patterns of global commodities or discourage tourists from visiting certain regions. Further, the impact of climate change on transport infrastructure is potentially significant and includes rising temperatures on roads and airstrips built on permafrost (thawing of permafrost and also the associated degradation of road/airstrip surfaces); increased frequency of freeze-thaw cycles on roads (buckling and general degradation of surface materials); increased storm frequency and sea-level rises on ports; and increases or decreases in precipitation on waterways.

Private companies that make new transport and tourist investments and operations routinely use archived data, data summaries and advice about critical climatic factors, especially about tropical

cyclone and other storms risks. Wind, temperature, sunshine and rainfall are particularly important factors in the long-run success of tourism ventures. Over the long term, climate-related changes may occur in production patterns and markets or in transport routes, including the prospect of opening summertime intercontinental shipping routes across the Arctic Ocean as climate change slowly reduces summertime sea ice. An operational seasonal prediction of sea ice would be a valuable service in this context.

5.10 MEGACITIES

INTRODUCTION

Cities and urban areas currently use around 75 per cent of the world's energy, are responsible for 75 per cent of greenhouse gas emissions and are home to about 50 per cent of the world's population. Megacities are cities with a population of ten million people or more. In 1950, New York City and Tokyo were the only megacities in the world, but by October 2007 there were 19 and it is expected that there will be about 26 by 2025 (Figure 5.9). Megacities are often located along coasts or near major rivers and deltas.

AIR POLLUTION

Poor air quality is an issue for every megacity. According to the United Nations Environment Programme, urban air pollution is linked to up to one million premature deaths each year and is estimated to cost approximately 2 per cent of gross domestic product in developed countries and 5 per cent in developing countries.

The high levels of air pollution in and around megacities are a direct result of the high levels of emissions from industry and transport. Depending on the geography and meteorology of the city, however, this may be a lesser or greater problem. In Mexico City, for example, life expectancy is expected to be reduced by up to 10 years. As governments have recognised pollution in megacities to be a major environmental problem, air quality management strategies and plans have been implemented, in some cases with encouraging results.

The first step in dealing with air pollution is to have air quality recognised by decision makers as a significant issue. The air quality of megacities must be monitored and the resulting data analysed, along with data from the health sector, to enable projections of the future cost of unmitigated pollution. This should then form the basis for climate scientists to work with planning officials to develop long term strategies for minimising pollution levels. National meteorological services, in close cooperation with public health officials, should also develop warning systems for days when risk levels are particularly high and devise strategies for helping the most vulnerable.

LOCAL FLOODING

In large cities, forests and grasslands have been replaced by hard surfaces: roof tiles, asphalt roads and concrete drive ways. Coupled with the observed increase in short-period heavy rainfall events, this increases the risk of urban flooding. Moreover, flash flood events are generally accompanied by thunderstorms and lightning, with lightning strikes in densely populated urban areas posing a particular problem. For example, the United States records around 600 deaths or injuries from lightning strikes per year.

HEAT WAVES AND BLIZZARDS

Planning for megacity transportation and energy generation and distribution systems need not only to accommodate average conditions but also to accommodate extremes. It is during extreme conditions that people rely most heavily on power for cooling (heat waves) and heating (blizzards) and it is then that food, water and medical relief will be required.

Mid-latitude continental megacities (Paris, Moscow, etc.), where people and infrastructure are reasonably well adapted to a cooler climate, can be overwhelmed by an extended period of hot weather. The heat island effect of large cities, combined with pollution and poor air flow between

	2007	Population (Thousands)		2025	Population (Thousands)
1	Tokyo	35,676	1	Tokyo	36,400
2	Mexico City	19,028	2	Mumbai	26,385
3	New York-Newark	19,040	3	Delhi	22,498
4	São Paulo	18,845	4	Dhaka	22,015
5	Mumbai	18,978	5	São Paulo	21,428
6	Delhi	15,926	6	Mexico City	21,009
7	Shanghai	14,987	7	New York-Newark	20,628
8	Kolkata	14,787	8	Kolkata	20,560
9	Buenos Aires	12,795	9	Shanghai	19,412
10	Dhaka	13,485	10	Karachi	19,095
11	Los Angeles-Long Beach-Santa Ana	12,500	11	Kinshasa	16,762
12	Karachi	12,130	12	Lagos	15,796
13	Rio de Janeiro	11,748	13	Cairo	15,561
14	Osaka-Kobe	11,294	14	Manila	14,808
15	Cairo	11,893	15	Beijing	14,545
16	Beijing	11,106	16	Buenos Aires	13,768
17	Manila	11,100	17	Los Angeles-Long Beach-Santa Ana	13,672
18	Moscow	10,452	18	Rio de Janeiro	13,413
19	Istanbul	10,061	19	Jakarta	12,363
			20	Istanbul	12,102
			21	Guangzhou, Guangdong	11,835
	Cities located near a large waterbody (sea, river or delta)		22	Osaka-Kobe	11,368
	New megacities		23	Moscow	10,526
			24	Lahore	10,512
			25	Shenzhen	10,196
			26	Chennai	10,129

Figure 5.9. The world's megacities, 2007 and 2025. Source: UNHABITAT.

major buildings, can all contribute to heat stress during these periods. At the other extreme are blizzards, bringing extreme cold and crippling ice and snow storms.

Information may need to be developed to identify the likelihood of key climate thresholds being exceeded in the years ahead. Risk management systems could be triggered when such thresholds are approached and public education campaigns could focus on advising people well in advance of ways to deal with the hazards of extreme weather.

SEA LEVEL RISE

Gradual rises in sea level are becoming a significant issue for the 13 megacities abutting oceans. Sea level rise first becomes a problem during storm events, when lower-than-usual barometric pressure causes abnormally high sea levels locally. If this local sea level rise is combined with on-shore winds, then wave setup will contribute to local coastal flooding and beach scouring. In the poorer communities of the megacities, where drainage is often inadequate, flooded slums, salt water intrusion into water supplies and failure of sanitation are all typical consequences.

All coastal megacities have major port facilities that need to deal with sea level rise. In addition, public road systems and often major international airports are located at sea level (JFK airport in New York, Osaka's Kansai airport, Los Angeles international Airport, etc). Likewise, beach management and coastal defence authorities will need to work with climatologists on management strategies. On a shorter time scale, weather warnings for events likely to lead to coastal flooding and rapid coastal erosion must be developed in close consultation with user communities.

DROUGHT AND WATER AVAILABILITY

Almost all megacities face major fresh water challenges because of excessive groundwater withdrawal, salt-water incursions into aquifers, floods and droughts disturbing water supply and increasing demand. Megacities located in the drier sub-tropics are particularly vulnerable to water shortages (Mexico City, Kolkata, Delhi, Dhaka, etc). Usually such cities are located in a part of the world where, for a number of months, rainfall is low. In a highly urbanised environment, where water requirements for individuals are high, industry requirements even higher and irrigation-supported agriculture is adjacent, there may not be enough rainfall or catchments and dams to meet all requirements.

Hydrologists, climate scientists and weather forecasters need to work closely together to integrate information from existing rainfall climatologies with rainfall patterns and the likely variability of rainfall in the medium to long-term to develop water management strategies for megacities.

TROPICAL CYCLONES

Tropical cyclones are intense storms with gale force winds near their centres. The destructive winds of a tropical cyclone can cause extensive property damage and turn airborne debris into potentially lethal missiles. The heavy rainfall associated with the passage of a tropical cyclone can produce extensive flooding, leading to serious property damage and death by drowning.

The loss of life from tropical cyclones globally has been trending downwards over the last decade, due in large part to improved warning services. However, there has been no similar downward trend in damage to property. In the developing world, more work needs to be done to provide access to shelters that can withstand the winds of these cyclones and protect people from storm surge flooding. Again, planners need to work with climate scientists to build infrastructure (roads, buildings and transport support facilities) that accommodate current and future climate conditions. Moreover,

weather forecasters need to work continually with disaster managers, community leaders and decision makers across all sectors to reduce further the impacts of tropical cyclones, particularly on the poor in developing countries.

5.11 FINDINGS

1. Demand for climate information is high across all climate-sensitive sectors and it is being routinely used for diverse uses in planning and management, through a mix of established methods and new technological capabilities. Some sectors are very experienced users of climate information, while others are relatively new. In many sectors, the use of climate information lacks systematic development, especially in developing countries.
2. Sector needs and modes of operation vary widely. For example, in some sectors, such as energy and transportation, decision processes are very concentrated, while in others like agriculture they involve millions of small users. Many existing climate services are not well focused on user needs and the level of interaction between providers and users of climate services is inadequate.
3. Climate services often do not reach “the last mile”, the people who need them most, particularly at the community level in developing and least developed countries.
4. All sectors are concerned about climate change, but many are unclear about the nature of likely impacts and cannot access the information they need to develop adaptation measures. In particular, climate information and services that can inform decisions at timescales of less than 20–30 years is currently extremely limited and is an area where research is required to exploit any potential predictability. Climate change mitigation measures, such as renewable energy development and afforestation/reforestation, are also driving demand for climate information. The Intergovernmental Panel on Climate Change Assessment Reports are an authoritative source of climate change information but are not sufficient alone, nor are they updated frequently enough to meet the specific requirements of sectors for their detailed and routine information needs, highlighting the important role that climate services can play.
5. Partnerships spanning sector expertise and climate science are central to developing effective sector-specific applications of climate information. The decision maker is not the expert and the expert is not the decision maker, but together they can create effective systems and make well-informed decisions.
6. The routine provision of climate services is very dependent on intermediaries who make links between expertise and effective application, such as applied scientists, agricultural extension officers, teachers, industry consultants, engineers, policy analysts, trainers and media personnel.

CHAPTER 6

NEEDS OF INTERNATIONAL POLICY

6.1 INTRODUCTION

A number of major intergovernmental and international policy areas are significantly affected by climate, including those addressed by the Millennium Development Goals and the United Nations Framework Convention on Climate Change. This chapter briefly reviews these policy areas and considers their needs for climate services.

6.2 THE MILLENNIUM DEVELOPMENT GOALS

MEASURABLE TARGETS FOR DEVELOPMENT

The Millennium Development Goals have been widely endorsed by governments, the United Nations, non-governmental organizations and private sector partners as a practical basis for driving development agendas and for allocating development assistance and investments. They were developed after the Millennium Summit of world leaders held at United Nations headquarters in New York in September 2000 as a means to back up the Summit's call for renewed international commitment to action on key issues of development. Poverty eradication was a primary concern. The eight specific goals intended as measurable targets for achievement by 2015 are: (1) Eradicate extreme poverty and hunger; (2) Achieve universal primary education; (3) Promote gender equality and empower women; (4) Reduce the child mortality rate; (5) Improve maternal health; (6) Combat HIV/AIDS, malaria, and other diseases; (7) Ensure environmental sustainability; (8) Develop a global partnership for development.

Progress to date towards the achievement of these goals has been mixed, varying from goal to goal and country to country.

CLIMATE AND THE MILLENNIUM DEVELOPMENT GOALS

Developing countries and communities with few resources beyond those needed for their day-to-day existence tend to be more vulnerable to climate variations and to suffer disproportionate impacts of extreme conditions such as droughts and floods. This is especially so in low rainfall regions. Across the eight Millennium Development Goals, climate services will be most relevant to Goals 1, 6 and 7 owing to the important impacts of climate on poverty and hunger, water and sanitation, certain diseases and environmental sustainability. The Global Framework for Climate Services is also relevant to Goal 8, because it will address the special needs of Africa, least developed countries, landlocked developing countries and small island developing states.

The eradication of extreme poverty and hunger requires improvement in agriculture, rural development and water resources, paying close attention to the suitability of different land uses and agricultural options in light of the local climate while considering pests and diseases, water availability and the effects of extreme weather and climate conditions. Likewise, managing malaria and certain other vector-borne or environmentally-determined diseases can be improved through climate monitoring and forecasting. For sustainable environmental management, information on past variations and spatial patterns of climate variables and their likely future changes are critical considerations.

Many examples of planning and management in sectors relevant to the Millennium Development Goals may be found elsewhere in this report. More proactive and coordinated efforts through the Global Framework for Climate Services will help the development community gain access to

climate knowledge and information and develop the technical methodologies and institutional capacities required. In considering where to focus efforts in the initial stages of development of the Framework, the Taskforce was guided by an analysis of where the Framework could make the most rapid, effective and efficient contribution to the achievement of the Millennium Development Goals.

6.3 UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

THE DEMANDS OF CLIMATE CHANGE

Almost all countries actively engage in the processes of the United Nations Framework Convention on Climate Change and acknowledge the Convention as the primary locus for intergovernmental political and technical consideration of the climate change problem. The Convention clearly acknowledges the importance of sustainable development as the context for climate change policy, along with the importance of scientific information as a foundation for action on climate change. It presents a very significant area of demand for climate information and climate services, particularly in respect to adaptation.

SCIENCE, RESEARCH, SYSTEMATIC OBSERVATION

Among other things, the Parties to the Convention commit to; “promote and cooperate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system and intended to further the understanding and to reduce or eliminate the remaining uncertainties regarding the causes, effects, magnitude and timing of climate change and the economic and social consequences of various response strategies.” The Parties also agree to “promote and cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, socio-economic and legal information related to the climate system and climate change, and to the economic and social consequences of various response strategies.”

In Article 5, the Convention elaborates further on the need for international and intergovernmental programmes and networks or organizations on research, data collection and systematic observation. It also underlines the need to strengthen relevant national scientific and technical research capacities, particularly in developing countries. Of particular note is the commitment of Parties “... to promote access to, and the exchange of, data and analyses thereof obtained from areas beyond national jurisdiction”.

GLOBAL CLIMATE OBSERVING SYSTEM

The Global Climate Observing System has long been recognised by Parties as having an important role in meeting the need for climate observation under the Convention. The 15th Session of the Conference of the Parties held in Copenhagen in 2009 considered a report prepared by the Global Climate Observing System Secretariat on progress with the Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC and noted in Decision 9 that whilst significant progress has been made since the Implementation Plan was developed, their remained shortcomings in observing systems and that not all climate information needs under the Convention are being met. The decision urged further action towards addressing these shortcomings and invited the Global Climate Observing System Secretariat to update

the implementation plan taking into account emerging needs, particularly those relating to adaptation activities.

COUNTRY REPORTING ON CLIMATE CHANGE INFORMATION

An important activity under the Convention is that of Parties submitting National Communications that provide detail on the steps they are taking or envisage undertaking to implement the Convention (Articles 4.1 and 12). In accordance with the principle of “common but differentiated responsibilities” enshrined in the Convention, the required contents of these national communications and the timetables for their submission are different for Annex I and non-Annex I Parties. The reports provide information on climate change impacts and vulnerability, adaptation activities and related information and draw heavily on climate information.

ADAPTATION REQUIREMENTS

The Parties agree in the Convention to cooperate in preparing for adaptation to the impacts of climate change, including in coastal zone management, water resources and agriculture, and for areas, particularly in Africa, affected by drought and desertification, as well as floods. Through the Nairobi Work Programme of activity and later at the 13th session through Decision 1/CP.13, the Bali Action Plan, a process was established to oversee enhanced action on adaptation identifying issues such as vulnerability assessments, integration of adaptation actions into sectoral and national planning, ways to enable climate-resilient development and reduce vulnerability, risk management and risk reduction strategies, risk sharing and transfer mechanisms as well as disaster reduction strategies. These activities directly rely on climate data, information, projections and services as highlighted in the Nairobi Work Programme (FCCC/SBSTA/2006/11 paragraphs 37–49) and in Decision 2/CP.11.

The Convention provides a process for Least Developed Countries to identify priority activities that respond to their urgent and immediate needs to adapt to climate change – those for which further delay would increase vulnerability and/or costs at a later stage. Called National Adaptation Programmes of Action, these are intended to be action-oriented, flexible, based on national circumstances and country-driven. The National Adaptation Programmes of Action, already prepared by most Least Developing Countries and published on the United Nations Framework Convention on Climate Change secretariat web site, include many projects that are closely related to climate services such as risk assessments, strengthened climate networks and early warning systems. A work programme that guides the support to the Least Developed Countries (Decision 5/CP.7) calls for strengthening the capacity of meteorological and hydrological services to collect, analyze, interpret and disseminate weather and climate information to support the implementation of National Adaptation Programmes of Action.

ADAPTATION FUNDS AND ADAPTATION ACTION

Within the Convention process, as well as outside of it, a number of large funds exist whilst others are being established to support activities to address and prepare for climate change. These include the Least Developed Countries Fund, established at COP 7 in Marrakesh, the Adaptation Fund, which is now operational, and the Green Climate Fund proposed in the 2009 Copenhagen Accord (see Decision 2/CP.15) and agreed in the Cancun Agreements (see Decision 1/CP.16). It is vital that the adaptation strategies and projects developed through these funds are based on sound climate information and that they include explicit investment in the development of capabilities for generating climate and services.

Many Parties accept the idea that a network of regional centres of expertise and support will be required to assist developing countries in the new and weighty tasks involved in addressing climate change. Within the climate science community there are already a number of regional and international centres that have the potential for contributing to such a network, for example with climate-related data, information and best practices in climate-related risk management.

Demands for climate information are increasing as countries actively plan to adapt to climate change through voluntary national efforts, and through formal processes under the Convention. If the preparation of national adaptation programmes and actions become a formal requirement of the Convention, there will be more explicit demands for climate information. A number of countries already include information on adaptation in their National Communications under the Convention.

LINKS TO THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

The role of the Intergovernmental Panel on Climate Change, co-sponsored by the World Meteorological Organization and the United Nations Environment Programme is to provide authoritative assessments of the state of the global climate and of the scientific information available on climate change. These assessments are widely used for policy development by governments and other organizations. The work of the Panel also prepares reports on topics of special interest from time to time. While independent of the United Nations Framework Convention on Climate Change process, the Panel is nevertheless important to the deliberations under the Convention and represents its primary source of authoritative, assessed, climate change science. For example, in the Bali Action Plan the Parties referred to the findings of the Panel's Fourth Assessment Report (2007) that stated that warming of the climate system is unequivocal and that deep cuts in global emissions will be required to achieve the ultimate objective of the Convention.

Continued development and analysis of climate data sets, climate variability and impacts, along with sectoral use of climate information in management and adaptation such as will be promoted by the Global Framework for Climate Services will provide essential raw materials for future assessments by the Panel. In turn, the assessments will assist in identifying the best underpinning research that can be used in developing climate services.

IMPLICATIONS FOR CLIMATE SERVICES

Many decisions taken under the United Nations Framework Convention on Climate Change speak directly to the need for climate information and climate services and set out specific expectations of the Convention Parties in respect to systematic observations, research, capacity building and adaptation. Addressing these effectively will require much better international cooperation and frameworks for information exchange and service provision. The requirements of the Convention process therefore present a major area of demand for the Global Framework for Climate Services. Already, the need for the Global Climate Observing System and for action to fill the gaps in its coverage is recognised by the Parties.

While adaptation requirements and mechanisms have yet to be specified in great detail in the Convention process, it is obvious here too that the Framework will be able to make important contributions, particularly with respect to standards, good practices, information dissemination, coordination and in avoiding overlap and duplication of effort.

6.4 SELECTED OTHER CONVENTIONS AND AGREEMENTS

CONVENTION ON BIOLOGICAL DIVERSITY

The United Nations Convention on Biological Diversity was inspired by the world community's growing commitment to sustainable development and its recognition of the value of, and increasing threats to, biological diversity. Climate is an important determining factor in the health of ecosystems and in maintaining biological diversity. According to the Millennium Ecosystem Assessment, projected climate change is likely to become one of the most significant drivers of biodiversity loss by the end of the 21st century.

Conserving natural terrestrial, freshwater and marine ecosystems and restoring degraded ecosystems will contribute to the goals not only of the Convention on Biological Diversity but also of the United Nations Framework Convention on Climate Change as well as to achieving the Millennium Development Goals, for example through improved carbon management and by providing a wide range of ecosystem services that are essential for human well-being. In the future, activities under the Convention will need more detailed information on past and future climate conditions, especially at the relatively small scales of most ecosystems.

CONVENTION TO COMBAT DESERTIFICATION

The United Nations Convention to Combat Desertification tackles desertification through an integrated approach to the problem that emphasises action to promote sustainable development at the community level. Climate services are an essential requirement. National Action Programmes, strengthened by sub-regional and regional programmes, are a key instrument in the implementation of the Convention. The Programmes include summary information on the climatic conditions of the country and spell out the practical steps and measures to be taken to combat desertification in specific ecosystems. The role of climate change in desertification is of increasing concern, particularly because of the projected increase of temperature and drought occurrence in regions that are already dry. Advanced climate information is crucial to managing droughts and will become more so in the future with the projected increase in droughts in dry and subtropical areas of the globe.

BARBADOS PROGRAMME OF ACTION

The populations of small islands are acutely vulnerable to environmental degradation, climate change and sea level rise, overexploitation of fisheries resources, land-based pollution and natural disasters, particularly from climate-related hazards. Moreover, they share a number of economic disadvantages such as small populations and the lack of economies of scale, along with narrow resource bases and high transportation and communication costs. The Barbados Programme of Action for the Sustainable Development of Small Island Developing States arose from a major intergovernmental conference held in Barbados in 1994.

A decade later an international review of progress found that many of the island countries had made significant progress in environmental management but that the pace of environmental degradation remained high. In turn this led to the 2005 Draft Mauritius Strategy for the Further Implementation of the Barbados Programme of Action, which identifies a range of needs including adapting highly climate-sensitive sectors, developing renewable energy sources and reducing disaster risks. Climate information will be essential to planning and managing these tasks.

HYOGO FRAMEWORK FOR ACTION

The Hyogo Framework for Action 2005-2015, which aims at building the resilience of nations and communities to disasters, was adopted by the governments and organizations at the World Conference on Disaster Reduction in Kobe, Japan in January 2005 and is currently in review. Its goal is stated as “the substantial reduction of disaster losses, in lives and in the social, economic and environmental assets of communities and countries” and it sets out five Priorities for Action to achieve this. Priority for action two, for example, aims to identify, assess and monitor disaster risks and to enhance early warning. This requires information about hazards, vulnerability and risks and about how these are changing. Priority for action four is concerned with reducing underlying risk factors and calls for, among other things, closer integration of strategies for the reduction of disaster risk and for adaptation to climate change. It notes that this requires clearly identifying climate-related disaster risks, designing specific risk reduction measures and an improving the routine use of climate risk information by planners, engineers and other decision-makers.

DEVELOPMENT ASSISTANCE PLANNING

International and bilateral development assistance agencies use formalised approaches and methods to develop their assistance collaboration with individual countries. In particular, the United Nations applies the Common Country Assessment / Development Assistance Framework approach and the World Bank makes use of the Poverty Reduction Strategy Paper method. Such planning, whether undertaken by international agencies or solely by the country concerned, requires a base of information on the natural endowments of the country and on the various risks it faces, in each case involving climate information. With the growing awareness of climate change, increasing attention is being paid to the possible effects of climate variability and change on past and proposed investments in infrastructure and sectors. Specific adaptation actions such as undertaking risk assessments, enhancing early warning systems and developing renewable energy production are increasingly under consideration and active implementation.

6.5 MANAGING SHARED BASINS AND RESOURCES

GROWING TRANS-BOUNDARY CHALLENGES

The prerogative of nation states to manage resources within their territories is challenged when the resources concerned, or the impacts of their usage, extend beyond territorial boundaries. Climate change is a prime example, where the global atmosphere conveys the impacts of greenhouse gas emissions arising from economic activities to all corners of the globe. On the regional level there are many situations concerning water resources where catchments, rivers or groundwater aquifers extend across many countries. There are 263 transboundary river and lake basins worldwide, accounting for an estimated 60 per cent of global freshwater flow, being home to 40 per cent of the world's population and affecting 145 countries, as well as around 300 trans-boundary aquifers. Air quality is also an issue when industrial pollution or smoke from forest fires drifts across borders. The problems are mainly those of achieving fair access to a resource and freedom from hazardous events or circumstances. Water supply and flood control are key issues here.

In general, the challenges involved are increasing, owing to a combination of rapidly-growing demand for resources, unsustainable resource extraction and the depletion of existing stocks, and the effects of climate change, particularly on rainfall and water supply and for storms and floods. Some studies have pointed to trans-boundary resource issues as a growing source of regional conflict.

INSTITUTIONS AND MANAGEMENT

Many regional or bilateral agreements exist for managing the potentially conflicting interests of the states involved. For example, the Mekong River Commission was established in 1995 by the governments of Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam, as a means of cooperating on the sustainable development of the Mekong River Basin, particularly to manage jointly their shared water resources and to develop the economic potential of the river. The Commission has launched a process to ensure "reasonable and equitable use" of the Mekong River System, with National Mekong Committees established in each country to develop procedures for water utilisation. The Commission supports a joint basin-wide planning process with the four countries, called the Basin Development Plan, which is the basis of its Integrated Water Resources Development Programme. It is also involved in fisheries management, promotion of safe navigation, irrigated agriculture, watershed management, environment monitoring, flood management and exploring hydropower options. The two upper states of the Mekong River Basin, the People's Republic of China and the Union of Myanmar, are dialogue partners of the Commission.

Africa has at least 59 shared river basins, five of which extend over nine or more countries. The Nile basin, for example, represents 10 per cent of the area of the continent and spreads over ten countries. Treaties have historically been used to manage shared water resources and the Global Framework for Climate Services would provide underpinning data to support such agreements.

ROLE OF SCIENTIFIC INFORMATION

While the immediate challenge in these situations is economic and political in nature, the effective resolution of the problem cannot be achieved without good scientific knowledge and information. Sometimes national actors may withhold relevant information, for example on upstream rainfall or river levels, but in the long run regional problems cannot be addressed unless all actors can monitor the state of the resource and the effectiveness of the management actions that have been agreed. This is even more the case now with climate change, where there is already clear evidence of changing rainfalls and runoff and where the responsibility for impacts may be considered to be global in extent.

Quality data and information, upgraded to account for climate change, will be needed not only for engineering design and operations of water structures, pollution sources and fire management but also for confidence building and for the functioning of trans-boundary agreements and institutions. The Global Framework for Climate Services could play a valuable role in this respect by providing shared and credible data exchange capacities and by transferring knowledge and developing capacities.

6.6 FINDINGS

1. The conceptual frameworks and practical commitments of intergovernmental conventions and agreements form an important area of demand for the use of climate information and also an important source of guidance for designing the Global Framework for Climate Services.
2. Climate services will be important contributing factors in the achievement of the Millennium Development Goals, particularly Goals 1 (Eradicate extreme poverty and hunger), 6 (Combat HIV/AIDS, malaria, and other diseases), 7 (Ensure environmental sustainability) and 8 (Develop a global partnership for development) owing to the important impacts of climate on poverty and hunger, certain diseases and environmental sustainability, as well as the need to address

the special needs of Africa, least developed countries, landlocked developing countries and small island developing states.

3. Many decisions taken under the United Nations Framework Convention on Climate Change involve commitments to systematic observation, research, capacity building and to exchanging data and information. Future investments in adaptation, mitigation and climate risk management will require new levels of capacity for climate services.
4. Several other conventions and agreements concerned with development and the environment, particularly the Convention on Biological Diversity, the Convention to Combat Desertification, the Barbados Programme of Action and the Hyogo Framework of Action, identify climate variability and change as key factors of concern and require climate information for their implementation.
5. Development planning tools used by the United Nations, the World Bank, other agencies and funds and bilateral donors need to be based on sound information about countries' natural endowments and about the various risks they face, including those associated with the climate.
6. Climate does not see political boundaries. Many trans-boundary agreements have been put in place by governments to manage shared resources and challenges. Their implementation depends on quality climate-related data and methodologies and on credible mechanisms for exchanging data.
7. The demand for climate services is currently expanding rapidly as greater awareness of its value becomes apparent and activities in areas such as adaptation to climate change gain momentum. The current level of resourcing, and global coordination of the provision of, climate services is insufficient to meet existing or likely future requirements.

CHAPTER 7

CASE STUDIES: EXPERIENCES AT NATIONAL LEVEL

7.1 INTRODUCTION

In this Chapter five case studies are presented that highlight the diverse needs for climate services and the opportunities for strengthening current capabilities. In Haiti it is apparent that climate information needs to be integrated into planning decisions as Haitian society is rebuilt in the aftermath of the earthquake. In Mozambique there have been successful efforts to develop services to meet knowledge gaps that became evident during the devastating floods of 2000. The case of Fiji shows a relatively small country developing climate services through its national meteorological service to meet client needs. In Australia and China relatively well-developed models of climate service provision are revealed, both involving important user-interface components to meet the needs of specific groups of users. In Australia the user-interface is developed by universities, extension officers employed by state governments and private consultants, while in China the national meteorological services provide the full range of climate services.

7.2 CLIMATE SERVICES TO ASSIST IN REVERSING THE SPIRAL OF VULNERABILITY IN HAITI: A CASE STUDY OF REBUILDING WITH CLIMATE SERVICES AFTER DECADES OF VULNERABILITY

35 SECONDS AND THE AFTERMATH

On 12 January 2010 an earthquake of 7.0 magnitude on the Richter scale hit Haiti. It was the strongest earthquake for 200 years and lasted 35 seconds. What emerged after that short time was a different country – one transformed by a disaster of almost unprecedented scale and complexity.

Some three million people – nearly a third of the population – were affected. More than 230,000 lost their lives and 300,000 were injured. The earthquake crippled Haiti's capital and economic heart, Port-au-Prince, and destroyed hundreds of thousands of homes in the city and elsewhere. 1.3 million people were forced to seek refuge in make-shift settlements in and around the capital, while half a million more sought refuge with family and friends in other parts of the country. Damage and economic losses from the earthquake are estimated to be US\$ 7.9 B – equivalent to over 120 per cent of Haiti's 2009 GDP.

Yet it was not the power of the earthquake alone that killed so many Haitians but the chronic poverty and vulnerability of the population as well. That vulnerability resulted in part from the fact that Haitian society has struggled throughout its history to plan for and manage frequent extremes in weather, particularly the hurricanes and intense rainfall that characterise the Haitian climate. Despite its tragic character, the earthquake nonetheless has provided an opportunity not just to reconstruct but to “re-found” the country, as its President has said. This case study is about the importance of effective climate services in supporting that effort.

A HISTORY OF UNDERDEVELOPMENT

The Republic of Haiti occupies the westernmost third of the Caribbean island of Hispaniola, which it shares with the Dominican Republic. Its rapidly-growing population is currently approximately 10 million, densely packed into a land area of 27,750 square kilometres. Haiti is the least developed country in the Western Hemisphere.

Socio-economic conditions in Haiti are characterised by severe widespread poverty, especially in rural areas, along with badly depleted natural resources. More than 70 per cent of the population

survives on less than US\$ 2 per day and 46 per cent are undernourished. Nearly half the population has inadequate access to clean water. Haiti's health indicators are also the worst in the Western Hemisphere, with nearly half of deaths attributable to HIV/AIDS, respiratory infections, meningitis and diarrhoeal diseases and typhoid.

The country has a long history of socio-economic fragility, political crisis and weak governance, all of which have undermined its progress towards stability and prosperity. In 2004 the United Nations intervened to help establish security, re-launching democratic politics with peaceful elections that produced a legitimate and accountable government.

CLIMATE IS INEXORABLY LINKED TO DEVELOPMENT CHALLENGES IN HAITI

Given the political and socio-economic conditions of the country it is understandable that planning for climate risks has historically been weak. However, these very conditions are inexorably linked to the Haitian climate, and failure to accommodate climatic conditions in managing agriculture, resources and socio-demographic trends has been an ever-present factor in Haiti's underdevelopment.

Approximately two thirds of Haitians work in agriculture, mainly small-scale subsistence farming, but the sector only accounts for around one third of the country's GDP. Local production provides just 45 per cent of Haiti's food consumption and dependence on food imports makes the country – especially its poorest citizens – highly vulnerable to increases in international food prices.

Rural livelihoods, on which 75 per cent of the population depend, are extremely unproductive and precarious. Haiti's agriculture sector is very vulnerable to damage from frequent natural disasters,



Figure 7.1. Haitian Deforestation. The border between Haiti and the Dominican Republic is more than just a political boundary. It also reflects the large amount of deforestation that has occurred on the Haitian (left) side of the border. One can easily see from satellite imagery the lush forests still thriving on the Dominican Republic (right) side of the border, which is in sharp contrast to the Haitian side of the border. Source: NASA/Goddard Space Flight Center Scientific Visualization Studio.

including hurricanes, flooding and landslides. Expansion of agriculture has been difficult because of the predominantly mountainous, rough terrain that limits the land available for cultivation and irrigation.

These problems are exacerbated by deforestation and environmental degradation. Only 2 per cent of Haiti's original forest-cover remains, most of it having been cut down for charcoal and timber and to make way for agriculture. More than 80 per cent of the country's watersheds are critically or totally deforested. Deforestation increases flooding and landslide risks and reduces soil cohesion so that fertile farmland is lost to erosion. Approximately 1600 hectares of agricultural land are lost to soil erosion each year, and severely eroded, infertile areas make up a quarter of all land under cultivation. This situation is in stark contrast to the high level of forest cover that has been retained by its neighbour, the Dominican Republic, which suffers far less from landslides, flash flooding and high levels of erosion of topsoil.

As the agricultural sector has become increasingly vulnerable to population pressure, environmental degradation and recurrent natural hazards, many Haitians have sought employment in urban areas. However, no jobs are being created in those areas. Haiti is thus experiencing "premature urbanisation" – the agricultural sector is not productive and urban areas are not generating economic growth.

This migration of rural poor to the cities has severely aggravated the impact of natural hazards in Haiti, especially among the poor, who often have no choice but to occupy the lowest-valued land in disaster-prone areas such as riverbanks, unstable hillsides, flood plains, coastal areas and deforested lands. Furthermore, the poor quality housing that most of the population live in is not constructed to withstand the impacts of natural hazards, including hurricanes and earthquakes.

HAITI'S CLIMATE AND THE IMPACTS OF CLIMATE CHANGE

Haiti has a hot and humid tropical climate, with temperatures almost always high in the lowland areas. Rainfall occurs throughout the year, but major rains are concentrated in April to June and August to November. Much of the country receives on average about 140 to 200 cm per year, but some areas receive much less and some mountainous areas much more.

Lying on the primary pathway of tropical storms that originate in the Atlantic and Caribbean Sea during the hurricane season, Haiti is hit by one tropical storm every 2–3 years on average and by a major hurricane every 6–7 years.

The impacts of climate change on temperature and precipitation trends are already being observed in the Caribbean and they affect Haiti directly. The Intergovernmental Panel on Climate Change's Fourth Assessment Report shows the percentage of days with very warm temperatures has increased considerably since the 1950s, with a marked decrease in rainfall over the part of the Caribbean occupied by Haiti. Sea-level rise is expected to increase risks of inundation, storm surges, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support livelihoods.

RECURRENT DISASTERS HOLD BACK DEVELOPMENT

Because of the poor living conditions of many of its inhabitants, Haiti is extremely vulnerable to the impacts of hydro-meteorological hazards. Between 1980 and 2008, more than seven million Haitians were affected by floods, storms and landslides.

Loss of human life from extreme weather in Haiti is primarily due to severe flash floods in eroded watersheds that wash down on floodplain communities in river valleys or on the coast. Flooding can be caused by hurricanes and tropical storms or simply by heavy rainfall during the rainy season. Exacerbated by deforestation (Figure 7.1), landslides often occur after heavy rain and can have serious human and economic impacts.

Recurrent hydro-meteorological disasters have been a defining feature of Haiti's faltering economic and social development. While different regions of the country have different levels of exposure and sensitivity to hazards, disasters affect the entire country. For example, in less than one month in 2008, two tropical storms and two hurricanes (Fay, Gustav, Hanna and Ike) devastated Haiti, killing 793, leaving 800,000 people in total poverty and causing economic losses equivalent to 15 per cent of GDP, particularly in agriculture and road infrastructure. These events compounded the entrenched problems that have faced the country for decades, condemning the most vulnerable members of the population to a vicious circle of poverty and increasing disaster risk.

CLIMATE SERVICES TO SUPPORT THE RECOVERY AND DEVELOPMENT OF HAITI

The daunting task facing the Haitian Government and its partners after the catastrophic earthquake is to rebuild a country already weakened by two centuries of political instability, natural disasters and environmental devastation. Rebuilding Haiti does not – and cannot – mean returning to the situation that existed before the earthquake. Despite its tragic character, the earthquake has nonetheless provided an opportunity to rebuild the country on new foundations. This will require addressing first the urgent humanitarian situation and then making a sustained effort to restart and develop economic, governmental and social activity while reducing Haiti's vulnerability to natural hazards.

Climate services will be vital to this effort. Management of climate risks – including the new risks presented by climate change – is not peripheral to Haiti's development. Improved access to climate information is needed to guide the recovery and development efforts in disaster risk management, agriculture, management and conservation of natural resources and infrastructure development.

Improved forecasting and early warning systems for hydro-meteorological hazards are vital. Observations, historical data and modelling studies relating to hurricane and flood occurrence, rainfall, soil moisture and hill slope stability are essential to improving planning and reducing disaster risks. Climate services are needed to support agriculture – the strengthening of which is vital to improving rural livelihoods and reducing food insecurity. Improving management of water resources is also a key priority for sustainable development, including improving rainwater absorption and soil retention in watersheds and protecting sources of drinking water. Data and information about past and future rainfall patterns and other climate variables are needed to inform river basin development projects and to guide and assess reforestation, soil conservation and other ecosystem management projects.

Appropriate climate services are critical for rebuilding devastated areas and for constructing new settlements and development centres, as well as for supporting infrastructure such as ports, airports and energy facilities. Weather forecasts are needed for operating Haiti's airports and ports, which are vital for the development of tourism and industry.

STRENGTHENING CLIMATE SERVICES IN HAITI

Little attention has historically been paid to the effective operation of Haiti's national meteorological capacity. Responsibility for climate services is divided between the National Meteorological Centre

and the Service National des Ressources en Eau, the latter operating the hydro-climatological network and storing, processing and disseminating collected data.

Unfortunately, these institutions saw their relatively limited operational capacities weakened further by the effects of the earthquake. The capacity to access essential local data and produce forecasts, early warnings for hydro-meteorological hazards and other operational products and services was severely constrained. This was compounded by a lack of reliable telecommunications capability.

Since the earthquake, a number of countries and organizations have supported the Haitian national meteorological services, in particular to help improve their capabilities ahead of the 2010 hurricane season. However, sustained capacity building efforts are required to improve national capabilities overall and to strengthen links with regional partners. For instance, Haiti would benefit greatly from being an active partner in a regional cooperation framework, such as the Caribbean Community Climate Change Centre. This Centre is the official archive and clearing house for regional climate change data in the Caribbean. The Climate Change Centre coordinates the Caribbean region's response to climate change, working on effective solutions and projects to combat the environmental impacts of climate change and global warming and would provide opportunities to Haitians for leveraging resources, expertise, data exchange and forecasting capabilities.

The staff capacity of Haiti's national meteorological service needs to be greatly increased by providing training and long-term educational opportunities for technical staff, forecasters and management. For example, it is highly desirable that staff spend time in an advanced climate centre where research is undertaken on climate change and its impact in the Caribbean. They also require adequate basic resources, including computers and communications facilities.

Access to local data from a modern, sustainable observing system is also very important. Likewise, the hydrological and pluviometric networks need to be upgraded and an agro-climatological network established. Electronic databases must be developed to store current and historical observational data and paper records in archives need to be accessed and digitised. Systems and tools for forecasting and disseminating weather and climate information require significant improvement.

CONCLUSIONS –THE GLOBAL FRAMEWORK FOR CLIMATE SERVICES SUPPORTING SUSTAINABLE DEVELOPMENT IN HAITI

Access to effective climate services is clearly vital to Haiti's recovery and long term sustainable development. As an immediate response to the earthquake the meteorological community in the region, coordinated through the World Meteorological Organization, has worked with the meteorological authorities of Haiti to put in place an array of weather and climate services to meet current needs. This activity has begun to build essential networks of support for meteorology in Haiti. In the longer term it is expected that the Global Framework for Climate Services will provide a mechanism to ensure sustained and sustainable support and resources for climate services in Haiti even when current international attention eventually decreases. It can bring experts together, prioritise actions, raise funds and coordinate spending. It is also expected to provide technical help to carry out regional programmes while leveraging regional networks and resources.

7.3 RISING ABOVE THE FLOOD THREAT IN MOZAMBIQUE – INTEGRATED WATER AND CLIMATE SERVICES

INTRODUCTION

Mozambique is one of the poorest countries in the world, with about 60 per cent of its 20 million people living in extreme poverty. The gross domestic product per capita is US\$ 900, putting it 212th out of 225 ranked countries. Development has been heavily undermined by hydro-meteorological disasters. The floods of 2000 that caused the death of over 700 people, affected 4.5 million more and reduced gross domestic product growth from 10 per cent before the floods to a mere 2 per cent afterwards provide a good example.

In light of the recurrent nature of hydro-meteorological hazards (floods, tropical cyclones and drought), the country has created structures for managing and mitigating the impacts of disasters. An early warning system monitors, detects and forecasts hydro-meteorological hazards and issues warnings for floods, tropical cyclones and drought. Preparedness and response to disasters is supported by annual contingency plans at national and local levels based on forecasts. Additionally, a National Master Plan for Disaster Prevention and Mitigation was approved in 2006 to implement national policy on disaster management. There is particular focus on the vulnerability to climate change of urban areas and critical infrastructure in the coastal areas, where more than 60 per cent of the total population of the country lives.

This case study is about a country with limited resources tackling the problem of extreme weather and climate events by drawing on its experiences in the year 2000 and onwards. It examines what climate information was available, how it was used before and after the floods of 2000, and assesses the current and future needs for climate information. It provides insights into efforts made to integrate weather and climate information products and services into government decision making and community risk management.

THE CLIMATE OF MOZAMBIQUE AND VULNERABILITY TO FLOODS

Mozambique is highly vulnerable to disasters caused by hydro-meteorological hazards such as floods, tropical cyclones and drought. None have been as severe and destructive as the floods of 2000, the worst in the country's history.

This vulnerability to flooding is explained by:

- its geographical location on the path of tropical cyclones that form in the southwest Indian Ocean. On average, three to four cyclones enter the Mozambique channel every year, accompanied by heavy rains and strong winds that lead to flooding in coastal areas and inland;
- its “hydrological” location, in that it lies at the lower end of nine of the 15 major shared river basins in Southern Africa (Figure 7.2), resulting in the country having to manage the downstream effects of rain that falls outside its national borders. Mozambique is thus dependent on weather, climate and dams upstream that can significantly affect floods in the country;
- its high levels of poverty that determine low levels of resilience for coping with and recovering from external shocks caused by hydro-meteorological hazards.

Climate change will increase the frequency and intensity of both floods and droughts and may affect the intensity of tropical cyclones, resulting in increased risk of disasters unless effective

disaster risk reduction and climate change adaptation strategies are put in place. Without these strategies, poor communities will continue to be disproportionately affected, since they have limited choices and lower capacities to cope and recover (Figure 7.2).

MOZAMBIQUE'S WATERWAYS AND AGRICULTURE

Around 35 per cent of the Mozambique population is chronically food insecure. Over 80 per cent of the population depends on poorly resourced subsistence agriculture. Small farm sizes, reduced fallow periods, lower yields and poor soil fertility in marginal lands and climates require major efforts for little return. Crop failure and livestock death are typical during years of poor rains. This explains, in part, the occupation of flood plains, which are preferred for their fertile soils and moisture.

On the other hand, the drought that preceded the floods of 2000 and the alterations of the natural flow of rivers due to the construction of dams upstream resulted in changes in people's perception of risk to floods. Because of long dry periods, rivers and flood plains were no longer seen by the rural population as a potential source of disaster. Moreover, people displaced during the many years of civil war lost traditional wisdom on flood mitigation measures and the dangers of living along flood plains.

Poor communities could benefit from improved climate services to protect themselves against disasters and improve their planning and agriculture management practices. Currently, most of the poor do not have access to, or know how to apply, climate information. In order to increase

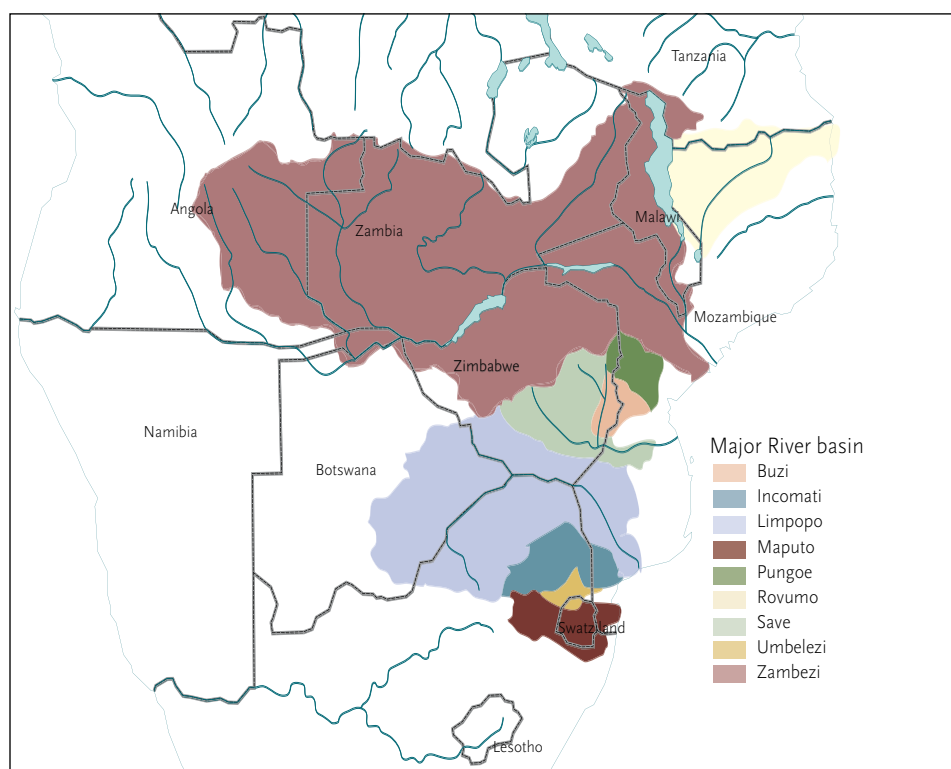


Figure 7.2. Major shared river basins in Mozambique. In response to the 2000 floods, a national early-warning system for tropical cyclones, floods and droughts has been implemented. Based on the most recent climate experience, the focus has been on flooding and tropical cyclones, and contingency planning for drought still requires development.

their productivity and reduce risks it is crucial that they are empowered through access to extension services that can interpret climate information products and recommend specific actions.

FLOOD PLAIN MANAGEMENT (THE RESETTLEMENT PROGRAMME AFTER THE FLOODS OF 2000, 2007 AND 2008)

For a country with limited resources such as Mozambique, it is not cost-effective nor is it feasible to encourage extensive development on river flood plains by improving awareness of floods and safety from flooding. Extreme flood events will still occur, with high potential loss of life and assets as well as damage to infrastructure.

A more robust approach is to control the type of development that occurs on the flood plains through incentives, central legislation or local community regulation supported by public education and enforcement where necessary. After the floods of 2000 for instance, a large resettlement programme for communities affected by floods and tropical cyclones was initiated. The aim of the programme was to transfer 59,000 families to safer locations, providing improved housing and social facilities such as schools, hospitals, training and recreation centres and water supply systems. These were built to withstand the impacts of extreme weather and climate events. However, resettlement efforts have sometimes met with social, cultural and anthropological resistance and have lacked funds for improved livelihoods to dissuade people from returning to their familiar homes.

On the floodplain itself, only food production is allowed and in cyclone-prone areas existing buildings have been retrofitted using simple techniques and local materials. Government and public infrastructure have to be built in strict accordance with these standards.

METEOROLOGY, HYDROLOGY AND EMERGENCY MANAGEMENT SERVICES WORKING TOGETHER

PAST PLANNING AND CAPACITIES PRIOR TO THE FLOODS OF 2000

Seasonal forecasts for the periods October to December 1999 and January to March 2000, issued by the National Institute of Meteorology, indicated high probabilities for above-normal rainfall. For Mozambique, above-normal rainfall is an indication of high likelihood of floods. These forecasts informed the preparation of the annual multi-sectoral contingency plan for the rain and cyclone season 1999/2000, released in October by the Disaster Management Institute, which contained scenarios for potential floods. Provincial and district structures were responsible for developing their own plans and for initiating preparatory flooding exercises.

Flood warnings were issued by the National Water Directorate before and during the floods. However, given the complexity of the disaster, warnings were not always accurate or always understood by the population at risk. In addition, the credibility of the warning system was compromised by a prior instance of a predicted drought not materialising. As a result, as the floods developed part of the population adopted a “wait and see” policy, contrary to the government’s approach.

While individual weather events were monitored and well forecast, the magnitude of the floods of 2000 was not predicted, exceeding as it did any flood in living memory. Compounding the difficult situation, the country did not have adequate meteorological and hydrological observations (following years of civil war that destroyed the observation network) or the technical and human capacities to carry out short range forecasting or modelling of extreme events outside the range of historical records.

CURRENT FLOOD WARNING SYSTEMS

Considerable momentum to improve the early warning system and other components of disaster risk management resulted from the disaster in 2000. Investments were made to improve the early warning system, e.g., the observation network was strengthened, new methodologies and tools for data analysis, forecasting and modelling were introduced and coordination of the major stakeholders in the early warning system was improved.

Overall coordination of the warning system rests with the Disaster Management Institute, while monitoring and forecasting is carried out by National Water Directorate (floods) and the National Institute of Meteorology (tropical cyclone and severe storms). Collaboration between the National Water Directorate, the National Institute of Meteorology and the Disaster Management Institute allows for integration of hydrological, weather and climate data needed to forecast floods and other hazards, supporting effective preparedness and response coordinated by the Disaster Management Institute. However, many operational procedures need to be harmonised and integrated, and technical capacities are limited.

PROGRESS AS A RESULT OF THE 2000 FLOODS

Disaster Risk Reduction is a national priority and is being integrated into sectoral and national planning and budgeting. Achievements include:

- implementation of the National Master Plan for Disaster Prevention and Mitigation to guide all disaster risk reduction activities in the country, supported by the Disaster Management Policy; annual contingency plans prepared since 1996. According to the scenarios foreseen, coordination structures and specific task groups are activated, training of local committees for risk management is accelerated and simulation exercises are carried out. These coordination mechanisms have helped considerably to optimise the use of the limited human and technical resources available in the country;
- provision of an annual budget of US\$ 3.5 M to support implementation of the contingency plans, in addition to specific allocations to sectors, provinces and districts. In 2007 and 2008 this amount was raised to US\$ 5 M in anticipation of floods;
- hazard risk assessment, hazard mapping and flood economic zoning. Forty out of the 126 districts in Mozambique were found to be flood prone and 5.7 million people are thought to be vulnerable. However, comprehensive risk assessments for all hazard prone areas are needed; and
- an early warning system that warns people of the likelihood of tropical cyclones and floods. However, there is no warning capacity for flash floods and the accuracy of the warnings requires further improvement.

THE CHALLENGE OF GOING THE “LAST MILE”

More needs to be done to improve the use of climate and weather services in Mozambique, particularly by the agricultural communities that often do not have good access to weather and climate information products and services. In taking forecasts and warnings the “last mile” to scattered rural villages, Mozambique is faced with many economic, social and cultural constraints: poverty, low levels of literacy, and language diversity, among others. Mozambique has 15 indigenous languages, and Portuguese, which is the most common language, is spoken by only about 40 per cent of the population. Moreover, migration has led significant communities to use non-indigenous

languages such as Zulu, Swahili and more recently Somali. Disseminating forecasts and warnings to the rural community inevitably involves translation into a variety of languages, a task generally performed locally. Disaster management committee volunteers at the community level, such as Red Cross volunteers and community radio stations, play an important role in disseminating information in the local languages

To meet the many challenges associated with “the last mile”, the following actions should be undertaken:

- Community-level risk assessment and integration of the outcomes into the disaster preparedness, along with real-time forecast and warning strategies
- further development of community and sector-relevant information products and services, including translation of climate outlooks and weather forecasts and warnings into local languages and their subsequent dissemination via a widely acceptable medium such as community radio broadcasts timed for maximum audience impact using local languages and addressing specific local needs
- effective public outreach programs to improve risk awareness in vulnerable communities, including targeting the youth through the introduction of curricula at rural schools
- harmonised information management systems to enable efficient information and data sharing
- development of a network of intermediaries such as government institutions, non-governmental organizations (e.g., Red Cross), community-based organizations and the media, that can take the climate-relevant information from centralised agencies such as the National Water Directorate, the National Institute of Meteorology, and the Disaster Management Institute. These intermediaries would collect and develop a set of replicable best practices, draw up a set of recommended actions, and communicate this information down to community level
- improved research into the behaviour and changing patterns of natural hazards
- creation and training of local disaster management committees composed of members of the communities and trained and organised in early warning, prevention and response
- capacity building, particularly in the area of communications infrastructure and local risk assessment skills
- integration of climate information in national development planning, specifically the Poverty Reduction Plan, and strategies for agriculture and food security

IMPROVED SERVICES FOR DISASTER RISK REDUCTION AND CLIMATE CHANGE ADAPTATION

Improvement in climate and weather services in Mozambique will require, as a primary input, the best quality short-range forecasts that are available along with high-quality seasonal predictions and state-of-the-art climate projections based on generally accepted scenarios of global and regional development. These should then be used as inputs to:

- high-resolution flood models for all catchments to facilitate the development of tailored products that would support disaster management on all time scales, and in particular, early warnings for floods, pre-flood season preparations and long-term community planning;

- high-resolution regional atmospheric models and downscaling systems to forecast extreme weather events better, improve predictions of major seasonal anomalies in climate and better understand local and regional impacts on the various projections of possible future climates. This information must be made routinely available, via intermediaries, to a wide range of sectors; and
- decision support tools to identify appropriate sets of actions that can be taken given the large uncertainty inherent in seasonal and climate change information.

Countries such as Mozambique, with a low level of technical, operational and research capacity, are not able individually to develop the services they require to manage existing climate variability effectively or adapt to climate change. The opportunity for regional cooperation within a broader global arrangement like the Global Framework for Climate Services must be taken if the most effective response to current and future climate challenges in Mozambique is to be provided.

7.4 Fiji – A SMALL ISLAND DEVELOPING STATE PROVIDING CLIMATE SERVICES

INTRODUCTION

Fiji comprises about 330 islands in the South Pacific Ocean located near the dateline and spread between 12-22 degrees south of the Equator. Its land area is just 18,333 square kilometres while its oceanic exclusive economic zone covers about 1.3 million square kilometres. The total population at the 2007 census was 837,271, of which 57 per cent were ethnic Fijians. Most people live on the two largest islands, Viti Levu and Vanua Levu, with 52 per cent living in urban areas. The literacy rate is 93 per cent and the country is making good progress towards achieving the Millennium Development Goals. Per capita annual income, adjusted for purchasing power, is close to US\$ 4,000, which puts Fiji in 156th position in the global ranking of 225 countries or territories. The climate allows for a wide range of primary production industries, sugar being prominent among them, and it is a key factor in the country's significant tourism industry. At the same time, climatic hazards - tropical cyclones, floods and droughts - cause major disruptions and losses to these sectors from time to time. Here Fiji's climate-related economic circumstances are examined along with the country's capacity to develop and supply a range of climate services for risk management, adaptation to climate change and other national needs.

ECONOMY

Fiji is a developing country with a large subsistence agriculture sector but it is also one of the largest and most developed of the Pacific island economies, with a range of industries supporting exports in sugar, garments, timber, fish, gold, tobacco, vegetables and root crops and, most recently, bottled water. Tourism is a major source of employment and foreign exchange earnings. However, there have been large fluctuations in the fortunes of these industries associated with global economic circumstances, market dynamics, internal political turmoil and climatic factors.

Over the last few decades, sugar and garment manufacturing have greatly benefited from the shelter of preferential trade agreements and have been important drivers of the economy. However, these agreements are now progressively being modified or withdrawn, resulting in or contributing to large reductions in production, exports and employment. Fiji's sugar industry also faces significant technical problems with its sugar mill capabilities as well as large reductions in cane production arising from terminations of long term leases held by tenant cane growers.

Tourism has expanded steadily since the early 1980s and is the leading economic activity on many islands. Visitor numbers totalled 602,000 in 2008 but have fluctuated widely from year to year as a result of financial crises in tourist source countries, political instability in Fiji and tropical cyclone impacts.

RECENT ECONOMIC TRENDS

Gross domestic product contracted for a third year in a row in 2009 at an estimated rate of –2.5 per cent, putting great pressure on public finances. Key factors were the impact of the global recession, the long-term declines in the sugar and garment industries and the severe flooding in January 2009 whose damage to crops and infrastructure amounted to around 5.3 per cent of gross domestic product. Other factors include the ongoing constraints of low investor confidence and the loss of assistance from traditional donors and multilateral agencies arising from Fiji's political circumstances. Tourist arrivals fell by about 25 per cent in early 2009, in part owing to the January flooding.

Fiji's CLIMATE

Fiji enjoys a tropical maritime climate with mostly adequate rainfall and without great extremes of heat or cold. Temperatures are fairly uniform ranging from about 26 to 29°C. Persistent east-to-south-easterly trade winds tend to result in cloudy and rainy conditions at the centres and at the exposed east to southeast sides of the higher islands, and in correspondingly clearer and drier conditions on the leeward west and northwest sides. The year divides into a cooler dry season from June to October and a warmer wet season from November to April when more humid winds from the north and west quarters are more frequent. Annual rainfall averages from 2000 mm to 6000 mm. The contrasts of climate between the dry and wet sides (and interiors) of the larger islands are key factors in the patterns of Fiji's agriculture, water resources and tourist development.

CLIMATIC HAZARDS

During the wet season Fiji faces the risk of damaging tropical cyclones, particularly during January and February. On average, between ten and fifteen cyclones affect some part of Fiji per decade and of these, two to four do severe damage. While specific places in Fiji may not be directly affected by a cyclone for many years, there is a chance of repeated impacts in one season as happened in early 1985 to the Lautoka- Nadi region with cyclones Eric, Nigel and Gavin.

Large-scale flooding in Fiji is mostly associated with the passage of tropical cyclones or slow-moving depressions that results in prolonged heavy rainfall. Coastal urban centres near the mouth of the main rivers on the two main islands are normally the most affected. Low-lying coastal areas can also be flooded as a result of storm tides and heavy swells during the passage of strong cyclones. Localised flash flooding from thunderstorms is also quite common during the wet season.

Droughts in Fiji are usually closely linked to the El Niño-Southern Oscillation phenomenon, which generally results in below average rainfall for the country. Major droughts occurred during the strong 1982–1983 and 1997–1998 El Niño-Southern Oscillation events but also during the more moderate 1986–1987 event. In the dry zones of the country, even modestly below-average rainfall for a few months can result in significant drought impacts.

Fiji SUGAR AND CLIMATE

Sugar cane production is concentrated in the dryer eastern and north-eastern areas of Viti Levu and Vanua Levu. It is the most extensive agricultural activity in Fiji and provides employment

for about 25 per cent of the country's economically active population. Lack of rainfall, damaging storm winds or scouring flood waters can have significant impact at cultivation and harvesting stages, affecting not only the weight of cane produced but also the quantity of sugar per unit of cane and the quality of the sugar produced. Climate outlook information, coupled with industry information, is valuable for estimating production, planning shipping schedules and improving strategies for sale and storage, as well as for consequential financial planning for the industry and government. Estimates of crop conditions and expected volumes of cane are factors in setting the start and end of the milling season and hence also determining the availability of the factories for maintenance and upgrading work between seasons. Climate information is also relevant to cane fire management and to preparations for extreme weather events.

CLIMATE SERVICES

The Fiji Meteorological Service is the focus of climate services in Fiji. A department of the Fiji Government and headquartered at Nadi International Airport, it has a staff of about 100 and an annual budget of about US\$ 1.5 M. In addition to its national role in weather forecasting and warnings, it also has the status of a World Meteorological Organization Regional Specialized Meteorological Centre (for Tropical Cyclone Forecasting), and carries regional responsibilities for meteorological services to aviation and maritime operations over a sizable part of the southwest Pacific region, including several neighbouring island countries and territories. The Fiji Meteorological Service is an active participant in the World Meteorological Organization's activities and its development over many decades has been supported by secondments, training, equipment and ongoing working interactions from other World Meteorological Organization members in the region, particularly Australia, New Zealand and Japan.

DATA AND PRODUCTS

The Service's Climate Special Services and Research Division maintains paper and computer-based data archives with detailed records dating back more than a hundred years for some stations. Data are made freely available largely on a marginal-cost basis. The Division provides a range of packaged and on-demand services, including comprehensive and well-illustrated annual and monthly summaries of climate and a range of near-real-time and climate outlook products. These include daily summaries of temperature and rainfall for the current month for 23 stations around Fiji which are made available electronically via the internet and to subscribing users in government and business.

A monthly El Niño-Southern Oscillation Update is prepared with the cooperation of a number of foreign climate institutes, providing a seven page detailed account of current El Niño-Southern Oscillation conditions and the prospects for the coming seasons with supporting maps and data tables (Figure 7.3). Additional tailored products based on the El Niño-Southern Oscillation Update are prepared especially for the sugar industry, jointly with the Sugar Research Institute of Fiji, and for the electricity industry on the Monasavu catchment in the central mountain area of Viti Levu, where the Monasavu dam is the primary source of Fiji's electricity.

RELATIONSHIPS WITH USERS

The Climate Special Services and Research Division maintains close working relationships with numerous organizations affected by weather and climate. It records details of all information requests, which are predominantly from agriculture, horticulture, forestry, water management, environmental management, construction and tourism. It has established a quality management system that will soon comply with the requirements of the ISO 9001:2008 Quality Management Systems standard (for service delivery). Surveys are undertaken on customer requirements and satisfaction with products, services and service delivery. A survey form accompanies the web-based climate outlook products

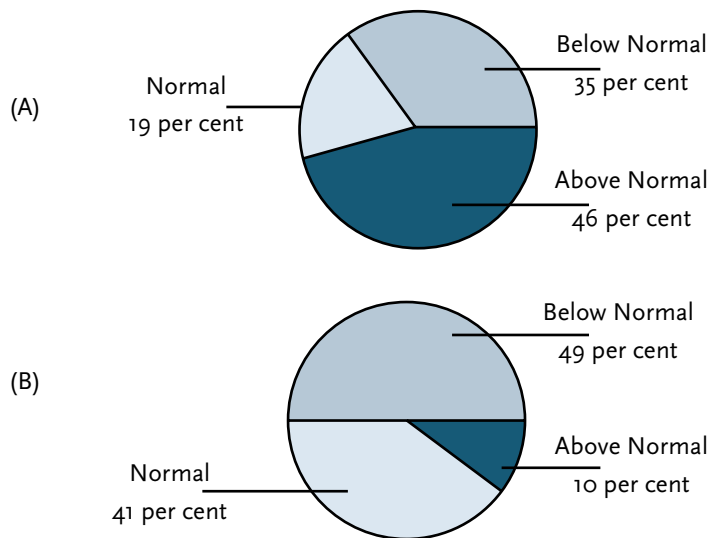


Figure 7.3. Sample of seasonal climate forecast information for April to June 2010, from “ENSO Update 2009/2010 El Niño”, Fiji Meteorological Service, issued 8 April 2010. A) Seasonal rainfall prospects for Penang Mill, on the north coast of Viti Levu, Fiji, presented in probabilistic terms, as the likelihood of rainfall being within the three terciles of the normal rainfall distribution. This shows a high chance of experiencing rainfall in the top tercile (above normal), but still a 1 in 3 chance of it being in the bottom tercile. B) As in A for the same season but for the inland mountain site of Monasavu, Viti Levu. This shows a markedly unusual situation with a very low chance of the rainfall being within the top tercile and a high chance of it being in the bottom (below normal) tercile.

addressing whether the product or service met expectations, was delivered in a timely manner and could be improved in some way.

ADDRESSING CLIMATE CHANGE

Climate change is a major concern for Fiji along with other Small Islands Developing States owing to the impacts of sea level rise and likely increases in droughts, intense rainfall and possible tropical storms as well as changes in reefs and fisheries. For example, a detailed economic assessment undertaken by the World Bank estimated that by 2050 if no adaptation is undertaken and depending on the study's climate change scenarios, Viti Levu could experience average annual economic losses of US\$ 23–52 million, equivalent to 2–4 per cent of Fiji's GDP. An Organization for Economic Cooperation and Development study concluded that Fiji's coastal resources ranked as the highest priority for action in terms of the certainty, urgency and severity of climate change impact, as well as the importance of the resources affected.

There is a strong need for better information on likely climate changes to come, on the impacts that might be expected and on effective means for adaptation. Research institutions, notably the University of South Pacific based in Suva, Fiji, and research projects such as the Pacific Islands Climate Change Assistance Programme are important sources of information. Fiji is a member of the South Pacific Regional Environment Programme and participates in its regional climate change programme, whose key areas of focus include the strengthening of meteorological and climatological capacities.

CONCLUSION

Fiji has succeeded in developing and sustaining a climate services capability by blending public and private sector interests and providing quality, innovative, client-focused products and services

that address the country's development needs. Key factors in this success include a strong national awareness of weather and climate variability, including the El Niño-Southern Oscillation phenomenon, and growing concerns about climate change; the existence of long term relationships and partnerships with the international meteorological community and with Fiji's climate-sensitive sectors; and continuing respect and support from the public and the Fiji Government.

Nevertheless, the country faces difficult economic circumstances and the Fiji Meteorological Service has continuing difficulty maintaining the network of high quality climate observations and retaining a core of expert climate services staff. Fiji's technical capacities and institutional arrangements for dealing with climate change and the new and specialised field of adaptation appear to be inadequate. As a small island developing state, Fiji clearly stands to benefit from the strengthened support that the Global Framework for Climate Services can provide.

7.5 AUSTRALIA – ENABLING A CLIMATE SERVICES “INDUSTRY”

INTRODUCTION

Australia is the sixth-largest country in the world, extending from the tropics at around latitude 10°S to the mid-latitudes around 45°S. It has one of the driest and most variable climates on Earth. The northern part of the country experiences very different climate conditions from the south, yet most of the country is desert or semi-arid and is largely uninhabited or only very sparsely populated. It has one of the lowest population densities in the world (about 2.8 per square kilometres), with most of the population concentrated in coastal areas (primarily in the south and east).

Despite its aridity and poor soils, agriculture is an important sector of the economy, providing significant export earnings. It is a major consumer of available water resources, and although only 1 per cent of Australia's agricultural land is irrigated, this area contributes almost one quarter of the gross value of the country's agricultural commodities. In a country where water resources are scarce and are expected to come under increasing pressure partly as a result of climate change, the impacts of year-to-year variability and longer-term changes in climate can be severe. Australia's climate services have developed in an attempt to minimise these impacts and have focussed primarily on the agricultural and water resources sectors.

AUSTRALIA'S CLIMATE CHALLENGES

YEAR-TO-YEAR CLIMATE VARIABILITY AND PREDICTABILITY

In a typical 10-year period Australia will experience about three years of “good” rains (although “good” rains can often mean flooding) and three years of “poor” rains. During the dry years, impacts on the agricultural sector can be devastating and may extend to many other sectors as well. The drought years are often caused by El Niño, while La Niña often brings the “good” rains. Although the influences of El Niño and La Niña mean that rainfall changes dramatically from one year to the next, they also provide a means of predicting unusual climate conditions a few months in advance.

LONGER-TERM CLIMATE TRENDS

Australia has experienced notable trends in climate over the last few decades. Over the last 50 years, average temperature has increased by about 0.7°C but some areas have warmed by as much as 2°C and virtually all parts of the country have warmed by at least some amount (Figure 7.4). Consistent with this warming are changes in the frequency of record hot days and temperature records have been

broken at an accelerating rate, indicating increases in heat-waves. Trends in rainfall are also evident: much of Australia has seen an increase in rainfall over the last 50 years but most of this has been in the arid, uninhabited parts of the country (Figure 7.5). Rainfall has decreased along the eastern and southern coasts and in the south-western part of the country, with all major urban settlements located in areas where rainfall has been decreasing. Recent trends in the south-east and south-west are consistent with those expected as a result of climate change.

OTHER CLIMATE HAZARDS

Northern parts of the country are prone to tropical cyclones, whose official season is from November to April. On average about 13 tropical cyclones form in the region per year and about six of these hit land. There has been a slight decrease in the number of observed cyclones in recent decades, probably partly a result of an increase in the frequency of El Niño events, but there has been no corresponding decrease in the numbers of severe tropical cyclones. The increasing concentrations of population in large urban coastal settlements is a nationwide phenomenon and is creating increasing vulnerability to some of the effects of tropical cyclones, which are being compounded by sea-level rise. Over the last 20 years or so sea level has risen along the eastern and southern parts of Australia (where most

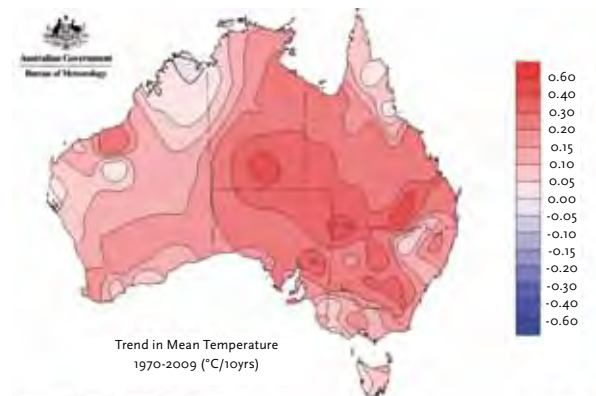


Figure 7.4. Trend in mean temperature over Australia over the 30-year period 1970–2009. Areas in red have experienced an increase in the average temperature over this period, whereas areas in blue have been experiencing cooling. Source: Australian Government Bureau of Meteorology.

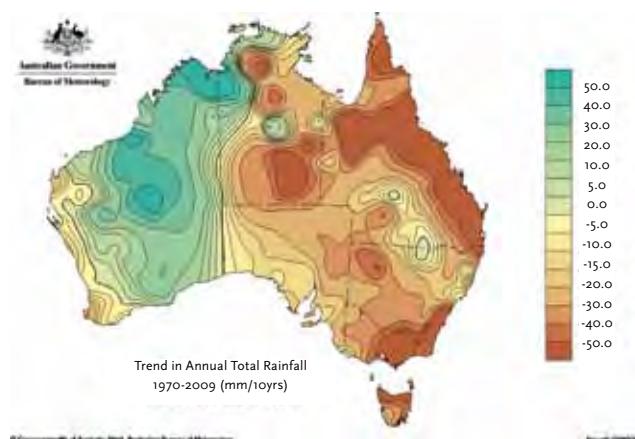


Figure 7.5. Trend in annual total rainfall over Australia over the 30-year period 1970–2009. Areas in green have experienced an increase in rainfall, whereas areas in brown have experienced a decrease. Source: Australian Government Bureau of Meteorology.

of the population are concentrated) by about 3 to 6 cm. Along the north and west coasts, the rise has been even more severe (14 to 20 cm).

Heat waves have caused more deaths in Australia than any other natural hazard. The biggest impacts are in the southern cities where the population is not as acclimatised to extreme temperatures and humidity as further north. Heat waves are becoming more frequent and intense as a result of climate change. They can have serious health implications, while resulting spikes in energy demand can create supply problems. They are also often associated with fires, and south-eastern Australia is one of the areas in the world that is most susceptible.

CLIMATE SERVICES PROVIDED

Currently, climate information is provided primarily through the National Climate Centre of the Bureau of Meteorology (Australia's National Meteorological Service) in association with its seven Regional Climate Service Centres. The Centre manages Australia's climate record, provides services around these data, conducts climate monitoring and provides predictions, while supporting climate policy development. Climate change information products are developed through the Centre for Australian Weather and Climate Research, a partnership between the Bureau of Meteorology and the Commonwealth Scientific and Industrial Research Organization. The Commonwealth Scientific and Industrial Research Organization and universities are also very active in delivering climate research outputs and provide specialist consultancy services, while the private sector provides important services in the water sector and construction, and increasingly in policy development for climate change mitigation and adaptation.

CLIMATE INFORMATION SUPPLY

Climate service provision by the Bureau of Meteorology attempts to make high quality data and predictions available, via the Bureau's website, in user-friendly formats free of charge. However, a cost recovery model has been adopted to provide information that is not available on the Bureau's website. Although the information is still free, the costs imposed are for staff time to extract data or add value, e.g. specialised statistical analyses. The intention is to enable maximum access to relevant, understandable information without having to tailor information for specific communities. Currently, predictions are available only at seasonal timescales and, unlike most other countries, the forecasts are expressed as probabilities of rainfall (or temperature) exceeding the median (e.g., Figure 7.6). Educational materials provide simple explanations of the scientific basis of the information.

This climate information is meant for a general audience but some tailored information targeted at the agricultural and natural resource management communities is provided as well, although it is purely meteorological and so does not provide direct information on climate-related impacts on agriculture or guidance for specific actions. These and other functions are the responsibility of different elements of Australia's climate information services.

Although the Bureau's approach is largely supply-driven, it is in close communication with user communities, especially the government. It generates policy-relevant information but does not attempt to recommend policy. This approach is effective when the user communities have sufficient expertise to translate climate information into action and requires a commitment from the Bureau to dedicate staff to interact closely with them.

That commitment is currently being reinforced by establishing a number of key climate and water policy positions in the nation's capital in Canberra. There staff interact closely with the lead national agency on climate change, the Department of Climate Change and Energy Efficiency. Moreover, being

co-located with all other federal level departments allows the Bureau's Climate and Water Division to develop close working relationships with them.

At the regional level, interaction with user communities is facilitated by a Regional Climate Service Centre located in each of the Bureau of Meteorology's state offices. The Regional Centres act as the main 'shop-fronts' to clients, with close interface with state government departments, universities and business entities.

TAILORING OF INFORMATION ABOUT IMPACTS

Australia has one of the most successful agricultural climate service systems in the world, largely because tailoring of information services has been driven by the agricultural research community. This has been led by the Agricultural Production Systems Research Unit, a collaborative organization with researchers from Commonwealth Scientific and Industrial Research Organization, the University of Queensland and the Queensland State Government Departments of Energy, Primary Industries and Fisheries along with Natural Resources and Mines. Its key ingredients were leadership by agricultural research, and effective partnership between agriculture and climate institutions with early and substantive participation by agriculture and natural resource management decision-makers. The initiatives were supported by joint government-industry funding for research and development.

Additionally, agencies such as the South Australian Research and Development Institute and the Department of Agriculture and Food (Western Australia) have developed specific information and extension systems aimed at linking climate science and agronomy with farming decision making in their respective regions of South Australia and Western Australia. In Western Australia, activities of the Climate Risks and Opportunities Program span climate change prediction, seasonal forecasting, yield forecasting, training, forecast delivery, weather monitoring, tools for integrating climate into farm management decisions and development of alliances to support these activities.

There is a clear recognition within the Bureau that the information they generate is only one component of a successful climate services system. Successful climate service development in

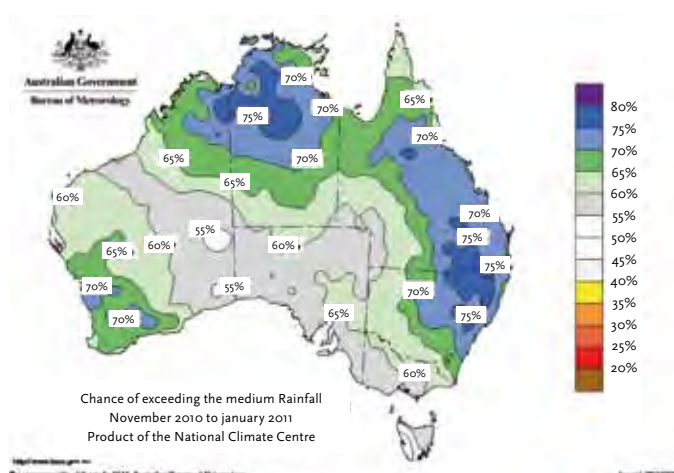


Figure 7.6. Example of a seasonal rainfall forecast issued by the Bureau of Meteorology showing the probability that the three-month rainfall total will exceed the median rainfall. Areas with probabilities above 50 per cent are most likely to experience a relatively wet season compared with previous years, while those with probabilities below 50 per cent are most likely to experience a relatively dry season. Source: Australian Government Bureau of Meteorology.

Australia has involved cooperation with the Bureau of many organizations, public and private, to add value to raw climate information. Such organizations, which include the Commonwealth Scientific and Industrial Research Organization, universities and other research institutes, have the expertise to integrate and translate climate information into language that is more directly useful to end-users. Thus user communities have taken a lead role in the development of tailored climate services, while the policy of free and open access to climate information adopted by the Bureau has enabled this development.

These tailoring, integrating and translation service providers reach end-users who might otherwise be marginalised by being unable to use the information from the Bureau. They allow climate services to be co-owned and significantly (perhaps radically) shaped by sectoral research and policy communities. With their closer links to stakeholders they are also able to translate raw climate information into practical recommendations. Moreover, with generally increasing uncertainty in forecasts over longer timescales it is not only less likely that the precise meteorological parameter of interest will be predictable but also more difficult to identify the most appropriate actions to take, and thus the service providers take on a critical role.

This gap between the climate information that is available on the one hand and its practical implications on the other is perhaps most evident at the timescale of climate change. What is required is to translate climate research and information into tools that farmers, for example, can use for adaptation.

CONCLUSIONS

Climate information services in Australia are amongst the most advanced and effective in the world. There are a number of key components contributing to the success of this system:

- High quality historical meteorological observation datasets have been developed and made freely available by the National Climate Centre.
- Raw climate information is provided at a continuum of timescales with supporting verification information and explanatory materials, all in formats and language that are accessible to a broad range of potential users.
- There is genuine participation in the design, delivery and evaluation of climate information products and services. This participation is achieved partly through direct user feedback to the National Climate Centre, which then evolves its own product design and content, but even more importantly through close partnerships between the raw climate information providers (the National Climate Centre) and institutes such as the Commonwealth Scientific and Industrial Research Organization and universities, where extensive research on products and closer ties with information users is possible.
- Tailored climate information service provision has been led by research groups with sectoral expertise and underpinned by strong support from the climate community.
- Through these partnerships, climate information has been translated into predictions and estimates of impacts that are relevant to decision-making. This has required research and effective collaboration that goes beyond climate science. There is a recognition that climate information provision should extend beyond simply providing warnings of hazardous meteorological events and help users take maximum advantage of beneficial climate conditions.

- Investment in climate information and early warning services has been coupled with investment in early response mechanisms and in the capacity to act on information. These investments include effective delivery systems involving players beyond the National Meteorological Service, ensuring that climate information reaches the largest possible audience, including the most vulnerable communities.

7.6 CHINA – MAINSTREAMING CLIMATE SERVICES

INTRODUCTION

China has a vast territory with marked terrains, exposing it to a wide range of meteorological hazards including torrential rain-induced flooding, drought, tropical cyclones (typhoons), frost and low temperatures, wind, hail, heavy fog and sand/dust storms. Compared with other countries and regions at the same latitude, the impacts of these extreme events are especially severe. For example, China is one of the world's regions most severely hit by tropical cyclones, with an average of seven typhoons hitting land each year. The impacts of typhoon-associated heavy rain, strong winds and storm surges on coastal areas are often very serious. Similarly, inland typhoon-induced torrential rain can lead to flash flooding and landslides.

Since the 1990s many of these extreme weather and climate events have become more frequent in China, partly because of global warming. Since China is a developing country with a large agricultural sector and infrastructure that is insufficiently developed to withstand natural hazards, these extremes are having increasingly significant impacts on economic and social developments. On average, various meteorological hazards affect more than 48 million hectares of croplands and 380 million people every year, with direct economic losses beyond USD 27 B, accounting for 2.7 per cent of GDP. The recent devastating flooding and associated mud- and rock-flows that occurred in Zhouqu County, Gansu Province, is one example, and drives an increased demand for better climate services that can predict the likelihood of such events and provide the information necessary to develop strategies for their mitigation.

While much of the damage is caused by rainfall-related hazards, changes in temperature are also occurring. From 1905 to 2001 average air temperature in China increased by 0.79°C. The overall upward trend in average air temperature in China over the second half of the 20th Century was more marked, reaching 0.22°C per decade.

China is affected by the East Asian monsoon, which brings rainfall in the summer half year while the winter is relatively dry. However, the main areas of rainfall change significantly from year to year, and so different areas of the country are affected by regional drought, torrential rain and flooding, in varying degrees, each year. The factors affecting China's climate are very complex. In addition to the El Niño-Southern Oscillation, the thermal effect of the Qinghai-Tibetan Plateau, the Arctic Oscillation and other factors all play important roles, considerably complicating regional monsoon climate prediction in China.

CURRENT CLIMATE SERVICES IN CHINA

MONITORING OF CLIMATE AND WEATHER HAZARDS

The National Climate Center of the China Meteorological Administration conducts global monitoring of the climate system, primarily for short-term climate prediction and to diagnose the causes of major weather and climate events. Since 1995, extreme weather and climate events in China and worldwide

have been monitored. A focus is on record-breaking events. Most of the monitoring products are released on the website of the Beijing Climate Center, and summaries of extreme weather and climate events are published weekly to the public through newspapers.

When major high-impact weather and climate events occur the China Meteorological Administration makes real-time monitoring and assessments in a timely manner, providing decision-making advisory services for the State Council, Ministry of Water Resources, Ministry of Agriculture among others and scientific guidance and services for relevant departments, sectors and the general public using television and other media.

CLIMATE PREDICTIONS

China has made short-term climate predictions for nearly 50 years. Starting from the 1960s, monthly and seasonal climate prediction products across the country have been produced and released. In particular, operational predictions and services have been targeted on severe climate events that seriously affect the national economy and people's daily life. The current operational short-term climate predictions cover extended range (10-30 days), monthly, seasonal and annual predictions as well as typhoon, plum rains (the rainy season in North China), the monsoon and cold waves.

Operational climate prediction products are targeted at decision-making authorities. Products include temperature and precipitation forecasts over the country for the next month. Forecasts are made of the number of tropical cyclones over the South China Sea and the Western Pacific and to land on China from May to October, while predictions of cold wave events from September to April are also issued. Nationwide spring and autumn temperature and precipitation predictions are made by the end of February and August each year respectively. Summer (June-August) climate trends in China and Asia are predicted, including summer rainfall and temperatures. Likewise, forecasts are made concerning the number of tropical cyclones that will develop and land on China annually, with dates of the first and last tropical cyclones expected to land on China.

CLIMATE IMPACT ASSESSMENTS

China has made great efforts to assess the impacts of climate variability and change on agriculture, the energy sector, water resources and human health. These include:

- assessments of the impacts of agro-meteorological hazards and of changes in agro-meteorological resources and hazards in the context of future climate change;
- in-depth surveys on wind and solar energy resources;
- wind power predictions at wind farms;
- meteorological predictions for power scheduling and safe operation in summer;
- risk mapping for power-line icing in winter;
- provision of the scientific basis for exploring and designing power grids;
- environmental impact assessments of power plants;
- climate feasibility demonstration for siting wind farms and nuclear power stations (including risk assessments for tornadoes, extreme winds and tropical cyclones);

- monthly and annual water resource assessments of four major river basins (middle reach of the Yangtze River, middle reach of the Yellow River, the Haihe River and the Huaihe River);
- assessment of the total volume of annual water resources in various provinces;
- monitoring and assessment of rainfall over the upper reaches of larger reservoirs;
- human comfort index forecasts;
- research concerning the correlation of meteorological conditions with diseases (respiratory, cardio-cerebrovascular diseases, psychosis, rheumatism and digestive diseases); and
- investigation of the impacts of climate change on the distribution of diseases such as schistosomiasis, malaria and dengue.

DECISION-SUPPORT SERVICES

The China Meteorological Administration has delivered a series of decision-support services, including:

- assessment of major climate events and their causes to provide a scientific basis for disaster prevention, mitigation and relief and for answering related questions from the general public (for example, an analysis of the 2006 Chongqing drought and an assessment of the historically rare large-scale freezing rain, snow and icing in southern China in 2008);
- climatic background analyses of major social events to support planning (for example, the Beijing Olympic Games, the 60th Anniversary of the founding of China, the 2010 World Expo Shanghai and the Guangzhou Asian Games); and
- climatic background analyses for post-hazard reconstructions in Wenchuan county (Sichuan province), Yushu county (Qinghai province) and Zhouqu county (Gansu province) to inform rehabilitation, infrastructure design and reconstruction projects.

Additionally, based on government interests, sustainable socio-economic development and demands for major engineering projects, decision-support services for climate change and its impacts have been implemented, most notably in the area of water resources.

CONCLUSIONS

In contrast with the situation in Australia, where much of the interaction with users of climate services is conducted by institutions other than the national meteorological service, in China the Meteorological Administration is a major government body responsible for a wide range of climate service delivery. In China the available climate information services involve basic monitoring of meteorological hazards and extreme weather and climate events, monthly, seasonal and inter-annual climate prediction products, climate impact assessments along with surveys of wind and solar energies and water resources. Thus, rather than just providing basic data and prediction services, the China Meteorological Administration provides the general public, governments at all levels and specialized users with information services in support of decision-making. Their focus is on addressing climate risks, responding to meteorological hazards and on the utilization of climate resources. This climate service mechanism has been developed over the last 10 years through a combination of government leadership, multi-sector interaction and community engagement.

While the delivery mechanisms may differ in Australia and China, in both cases it is clear that for climate services to meet user needs, cooperation and interaction between service providers and users in various economic sectors is essential. The result is jointly-produced specific climate information products that are scientifically sound and address users' needs. To date, the China Meteorological Administration has collaborated effectively with the ministries of agriculture, water resources, land and resources, forestry and health. The joint products and information produced have played an active role in socio-economic activities as well as in hazard prevention and preparedness. However, the effectiveness and benefits of climate service delivery are subject to the participation of sectors and users that are sensitive to climate. Coordination, interaction and feedback from relevant sectors are essential for the effective delivery, understanding and use of climate information.

Extensive social participation is an important factor if climate service is to play its role. In recent years, the China Meteorological Administration has interacted with all sectors of society, including through scientific outreach and lectures to inform the general public about meteorological hazards and the impacts of abnormal climate variability and change on society in order to promote social participation in climate services and to improve understanding and the spread of climate information.

7.7 FINDINGS

1. In countries such as Haiti that are overwhelmed with a multitude of problems, integrating information relating to climate and weather extremes into planning and operational decision making is crucial if resilience to future potential disasters is to be built into all levels of society.
2. In Mozambique, understanding the climatology of extreme events has been a first step towards reducing the risk of disasters. The next steps are both institutional, e.g. bringing together key agencies to develop strategies for dealing with the hazards, and operational, e.g. implementing those strategies, including by using weather and climate information to make appropriate operational decisions as early as possible in order to reduce risks.
3. Small island developing states such as Fiji are particularly exposed to threats from climate variability and change. Responding to those threats requires a level of climate services that cannot be entirely met nationally. However, by developing a vibrant national climate service supported by regional and global institutions, the necessary services can be provided. An issue arises when a small island state cannot find the resources necessary to participate in regional institutions, in which case external resources must be found and the importance of regional participation promoted so that sustainable resourcing can be put in place.
4. One model for a responsive, relevant climate service as practised in Australia is that of a national institution making freely available climate data and basic products in such a way that a wide array of sectorally-focused, value-adding intermediaries such as universities, state governments and private sector consultants can develop client specific climate services.
5. A second model for a responsive, relevant climate service as practised in China is that of a national institution engaging directly with climate information users to jointly develop products that are based on the best available climate science and data and are designed to meet user needs.

PART 3

ESTABLISHING THE GLOBAL FRAMEWORK FOR CLIMATE SERVICES

CHAPTER 8

GAPS AND OPPORTUNITIES FOR CLIMATE SERVICES

8.1 INTRODUCTION

While considerable progress has been made in developing different components of a global climate service capability, current provision and use of climate information still falls far short of its potential benefit. In this chapter, we give an overview of the gaps and shortcomings in the foundational components of climate service provision, as well as of what needs to be done to address them. This overview consolidates, and elaborates on our findings from previous chapters so as to inform our proposal for implementation and governance of the Global Framework for Climate Services, which is presented in the final two chapters of this Report.

8.2 USER NEEDS AND INTERFACING

NEEDS ARE NOT MATCHED BY AVAILABILITY AND ACCESS TO CLIMATE INFORMATION

Reducing the risks and realising the opportunities of climate variability and climate change requires making good decisions based on reliable and appropriate information about past, present and future climate, as well as properly integrating that information into the decision-making process. Appropriate use of climate information can help individuals make more informed short- and medium-term decisions that affect their livelihoods, organizations and businesses to reduce uncertainty that affects long-term planning, and governments to choose adaptation measures that reduce vulnerability to climate variability and change. But globally, and especially in developing and least developed countries, decision makers do not have the information that would help them to manage current and future climate risks, are sometimes unsure how to make good use of whatever information is available to them and are on occasion not aware that the information they need is something that could actually be provided to them. In many cases the knowledge exists to help them but is not converted into services they can access and use.

A WEALTH OF EXPERIENCE AND POTENTIAL

We have seen that climate information is being used in many ways by people in different sectors and situations. Some methods have been used for decades, such as in reservoir management or building design, while others are the result of recent research and new technological capabilities, as exemplified by seasonal malaria forecasting or rural micro-insurance. In some sectors the decision processes are very concentrated, such as in energy and transportation, while in others they are diffused and involve millions of small users, requiring extensive efforts at dissemination. Some sectors like agriculture have long experience in routinely using climate information, while others like health are relatively new in recognising the potential. A sector in one country may have strong experience but in another it may have little to show.

Across all of the sectors considered, the three core demands for climate services are for planning, operations and impact assessment. Planning concerns decisions that have ongoing impacts over multi-year and decadal time scales, often for large-scale public planning and investment but also for private investment in businesses, homes and farms. Operational management involves sequences of decision making, often associated with the annual cycle of the seasons such as in agriculture, water and energy supply, humanitarian action and tourism. Impact assessment relates to the important activity of assessing the impact of operational and planning decisions. For instance, the impact of spraying to reduce malaria needs to be assessed in light of the climatic conditions so as to ensure causality is attributed correctly. For all three demands there are many excellent examples of effective

use of climate information but too often these remain isolated in one location or sector and are not supported as a routine, widely-available service.

The potential impact of climate information use is very large. This is because the scope of economic activities affected by climatic considerations is enormous, so that even small improvements in productivity and investment effectiveness, or in reducing losses, translate into significant gains if widely applied in the sectors involved. The same is true in terms of livelihoods, since billions of people are sustained by natural resource-based livelihoods that are highly dependent on climatic factors. However, the significant gaps in the availability of information to users and lack of climate servicing capacity mean these potential widespread benefits are not being achieved in all sectors or in all countries.

DATA AND METHODOLOGY NEEDS

At the technical level, the main impediment to climate services concerns data resources and methodologies. Shortcomings in data availability and data access are subject to more specific discussion in the following section. The shortcomings in methodology are rather varied but often appear to be related to three issues: standardisation, dissemination and technology transfer. Where there is a repeated and focused need, such as in engineering calculations of wind loadings on buildings or in estimating potential evapotranspiration in agriculture, the methods are well developed and codified and may be formally endorsed by national bodies or professional societies. However, even then the methods may only have national status.

In less straightforward situations, or in settings where capacities are low, especially in developing countries, the user or service provider may struggle to locate and develop standard decision-relevant methods or even find good practice guidance for the problems they face, particularly in addressing the growing demands of systematic risk management and incorporating information from seasonal forecasts and on climate change. There is a requirement for methods to cope with incomplete data, since few places will have the entire data sets that tools and methods often assume. Good practice information is also needed on the service provision process, such as for climate data management, data analysis and user engagement. Developing and disseminating international standards, good practices and associated information is a core area of need that will be addressed by the Global Framework for Climate Services

APPLICATION OF SEASONAL CLIMATE PREDICTIONS

There is considerable room for improvement in using seasonal climate prediction information. Improvements in the sophistication of seasonal climate forecasts, for instance being able to extract further predictability in regions outside of the tropics, would benefit their applicability. As was noted in Chapter 1, the use of probabilistic and uncertain information is intrinsically difficult to communicate and use, and requires a good deal of commitment and experience to extract the value that it contains systematically. While a number of successes have been achieved, for example in water resources management and malaria forecasting, these remain to be fully developed and scaled up for regional and global use. In any case, they represent only a fraction of the potential uses that can be developed across the different sectors and so there is enormous potential for significant benefit being derived from seasonal forecasts across many sectors.

A major gap in research capability arises because much of the climate-related research currently being undertaken is occurring in the developed countries. Building capacity in the developing world to undertake research into the issues caused by climate variability and climate change will be essential to facilitate the transformation of research results developed elsewhere into nationally and locally

relevant services. Increased collaboration between developed and developing country research institutions, along with the increased investment in regional climate centres that house a research capability, will be among the measures vital for addressing this gap.

CLIMATE CHANGE - A NEW AREA OF NEED

While sector managers are usually well aware of the climate change issue and the likely general effects on their sector, it is less obvious to them what the impacts will be in specific terms and what their appropriate adaptation actions should be. However, a strong message is that the existing tools to manage climate variability and fluctuations provide ready-made solutions for responding to the challenges of adaptation. Some countries are beginning to prepare and implement national adaptation plans and to promote a risk management approach. The country or enterprise that is well adapted to the present day climatic conditions has a head-start in being prepared for future conditions.

An immediate requirement is for explicit guidance on how to adjust the standard or common tools of sectors, such as planting calendars or drainage design, to accommodate possible future changes in climate, where some skilful information can be provided. In some cases, an existing method can be easily adjusted on the basis of current trends and broad-brush projections, for example, for air-conditioning design in relation to higher temperatures. However, for longer planning timeframes where the stakes are much higher, or even when tipping points are crossed that can radically change the issues needing to be tackled, there are few if any well-established methods that can be used with confidence in long-term adaptation planning. A consequence of these uncertainties is a growing demand for decision-relevant climate information to support further studies, data analyses and methodology development targeting the particular interests of sectors and industries.

Another key requirement is reliable information on the likely changes in climate variables at the scales of interest to decision makers – for example the farm, business enterprise, city or valley. This will require more systematic methods that combine the abilities of coarser-scale global climate change models to project future climate scenarios alongside historical climate data and local meteorological models. This approach has been used by a number of groups, for instance the “UKCP09” information portal sponsored by the Government of the United Kingdom and the Pacific Climate Impacts Consortium’s Regional Analysis Tool (<http://www.pacificclimate.org/tools/regionalanalysis/>).

Efforts to mitigate greenhouse emissions will also raise questions that will demand more complex and wide-ranging climate information, for example questions on how afforestation projects will affect water supplies, on the best areas for renewable energy plants and on the availability of cooling water for nuclear power stations.

For both adaptation and mitigation, scientific data and advice will be presented with associated uncertainty and as probabilistic information even more often than in the past. The development of capacities that help users and providers build the necessary understanding, confidence and skills to quantify and utilize probability and uncertainty better in decisions and actions should be an important goal of the Global Framework for Climate Services.

AN EMERGING CLIMATE SERVICES INDUSTRY

Overall, the use of climate information is rather varied from sector to sector and lacking in systematic development. Partly this is because the climate services “industry” is fledgling and lacks a strong, coherent global basis in terms of methodologies, networks, leadership and coordination. It has

been nurtured by the meteorological community mainly through the mechanisms of the World Meteorological Organization, but it has been overshadowed by the larger operations of weather forecasting and has had little comparable support from user sectors themselves. Within each sectoral organization it has to jostle with a hundred other topics of importance to the sector, which tends to result in poorly developed and relatively narrow and disconnected streams of professionalism from sector to sector. A key role of the Global Framework for Climate Services must be to provide a platform that will grow and link climate services in all countries and sectors in a more coherent, mature and global endeavour.

RECOGNISING THE APPROACHES OF DIFFERENT COUNTRIES

For some countries, climate services are viewed through the lens of the market, with a strong orientation toward concepts of “clients” and “user-pays”, while in others the philosophy is that climate services are a public good and as such should be fully supported by government. In virtually all models the collection of data and the provision of supporting research are supported from the public purse. For developing countries seeking to embrace the user-pays model, it is unlikely that such an approach could fully meet user needs, including responding to high levels of climate sensitivity and achieving sustained development. In addition, there are often longstanding capacity shortcomings to overcome.

While countries are diverse in their climate-related circumstances and needs, they nevertheless share many common requirements ranging from exchange of data and methodologies to exchange of experience on relevant economic and institutional matters. The Global Framework for Climate Services will need to maintain a wide overview of the needs in both developed countries and developing countries and actively to create opportunities for all countries to interact and share information and experience.

PARTNERSHIPS AND INTERMEDIARIES

Practical applications of climate information usually require a partnership of organizations or people spanning the necessary range of expertise concerning a sector’s knowledge base, management and decision making processes and climate science. These teams are generally small and depend on good connections to other groups and outside sources of data and expertise. They are important incubators of new and effective applications and need to be nurtured explicitly through organizational commitment to partnerships and by conscious efforts to lower the barriers between disciplines and groups.

An important actor in creating and delivering climate services is the intermediary, the person or organization who makes bridges between expert knowledge and effective application. Examples of these are agricultural extension officers, teachers, industry consultants, media personnel, engineers, trainers and policy analysts. Once a methodology enters a mature state, having been well tested and codified, its application moves from the research and development domain and passes into routine operational use and continual improvement. Intermediaries become increasingly central at this stage of expanded, scaled-up use and will need to be active participants in the activities of the Global Framework for Climate Services.

USER INTERFACING AND PLATFORMS

One thing is very clear – the widespread and effective use of climate information requires significant interaction among many organizations and people, including from government, civil society, communities and business, and must involve decision makers, climate experts and sector disciplines.

Such interactions do not happen by chance but require user-oriented platforms of various sorts such as industry conferences, training workshops, professional societies, sector and interdisciplinary working groups, integrated research studies, technical publications, national committees, regional forums and international programmes. These are well-proven tools in many fields but in the climate services field they exist only in fairly immature forms, if at all. This is a major gap, but at the same time it is also a big opportunity that will be addressed and promoted by the user interface platform of the Global Framework for Climate Services, building on existing interactions between climate service providers and users.

8.3 OBSERVATION SYSTEMS AND SYSTEMS FOR INFORMATION EXCHANGE

Long-term observation of the atmosphere, land and ocean is particularly vital as a foundation for monitoring climate variability and climate change. It is necessary for evaluating the effectiveness of policies implemented to mitigate climate change and for improving climate prediction models and tools. Observations are also essential for managing climate variability, including for assessing social and economic vulnerabilities and for developing climate services needed for adaptation. Increasingly satellite-based observing systems are providing global coverage of a variety of climate-relevant variables, though often only in “research mode”.

GAPS IN GLOBAL ATMOSPHERIC OBSERVATION SYSTEMS

While there has been steady progress in maintaining and enhancing the global atmospheric observation systems for climate purposes, some regions of the world, typically those where conventional network coverage is poor, have seen little improvement. This is especially true for many developing nations, including large parts of Africa, and for the polar regions where there is a heavy reliance on satellite data.

Filling gaps in coverage cannot be achieved instantly. Good design, effective planning, progressive and sustainable implementation and ongoing maintenance capacity is needed. The areas of greatest need for data to support climate services have to be identified and given priority for implementation. All countries should give high priority to the need for sufficiently resourced observation networks as an essential ingredient for climate change adaptation planning and where applicable should identify this need in national adaptation strategies, including National Adaptation Programmes of Action.

Improvements in observation networks are needed in both urban and rural areas. Due to their increasing populations, urban areas will require improved observations to support urban-specific adaptation decisions. Remote rural areas that are devoid of conventional data should not be neglected, since observations there are important for improving the quality of climate models and predictions. Furthermore, communities living in remote rural areas often have livelihoods that are highly sensitive to climate variability and change. These remote sites are likely to require unattended automatic observation equipment, and for this many developing countries will need ongoing financial and technical support to ensure sustained and robust operations.

Reporting, standards and data quality require increased attention. Currently there are significant shortcomings in the frequency, reliability and accuracy of reporting from many stations to national and international centres. The availability of information about changes in instrumentation and location, which is important for adjusting to any artificial changes in climate measurements, is also inadequate.

These gaps particularly affect understanding and predicting regional climate as well as monitoring climate change, which ideally must be continuous, consistent and long term. An overarching problem is that most climate-related observation systems have been developed for purposes other than climate monitoring – generally for supporting weather forecasting – and are not being managed in a way that maximises inputs to effective climate services. Observation networks that are currently being used for weather forecasting should be strengthened and upgraded to serve the needs of climate services.

GAPS IN HISTORICAL CLIMATE OBSERVATIONS

Gaps exist in historical climate records as a result of inconsistent observations, policy restrictions on data access and technical problems. The latter include such things as incompatible formats or historical records not being in digitised form, as well as outdated data processing and archiving systems. There is scope for improving these historical records by recovering and securing the paper-based historical observations and also converting these to digital formats. Exchanging, archiving and cataloguing data should all be improved, as should recalibrating, reprocessing and re-analysing long-term records. This should be accomplished while working towards full and unrestricted access to data and products.

The integration of satellite and *in situ* data, along with other techniques such as reanalysis, can also be used to improve the coverage and quality of historical records.

GAPS IN GLOBAL OCEANIC OBSERVATION SYSTEMS

Ocean observations have had limited application outside of the shipping and fishing industries until recently. However, these observations have become critically important for improving seasonal climate forecasts and for developing forecasts for decadal time scales. The ocean observation system is relatively new for climate purposes and most elements of the system still require substantial additional national efforts to build and sustain their implementation. The major challenges to success in the coming decade can be reduced to the need for long-term funding and improved international and national organizational structures to build and sustain a truly interdisciplinary, coherent, systematic and sustained ocean observing system.

By the end of 2008, around 60 per cent of the initial 1999 design for the Global Ocean Observing System had been completed. While more work needs to be done, the ocean observing system's notable achievements to date include the deployment of more than 3000 Argo profiling floats and 1250 surface drifting buoys. However, these devices do not sample the deep ocean and do not provide data relating to the biological and chemical characteristics of the ocean that are also of interest to climate science. The primary implementation agents for oceanic observation systems have been research organizations, which often have short-term project time frames and whose objectives are primarily tied to research. A few research networks have been extended beyond their original planned purpose and timeframe to provide useful, sustained observations, but many exist with instruments likely to change at short notice, limited exchange of the collected observations and little assurance of long-term continuity for essential observations.

The fragility of the financial arrangements supporting most of the present effort is of particular concern. There has been very limited progress in establishing national oceanic or climate institutions tasked with sustaining a climate-quality ocean observation system. This is a shortcoming that needs to be addressed quickly. The satellite community needs encouragement in continuing their efforts to monitor Essential Climate Variables, particularly in the data sparse areas including the polar regions, the oceans and developing and under-populated land areas.

Data sharing of ocean observations also remains incomplete, particularly for tide gauges and biogeochemical Essential Climate Variables. Although progress has been made in some respects in recovering the ocean historical dataset, continuing efforts in data rescue, digitisation and data sharing are also required.

GAPS IN GLOBAL TERRESTRIAL OBSERVING SYSTEMS

Increasing significance is being placed on terrestrial data for estimating climate forcing and for understanding climate change and variability better, as well as for impact and mitigation assessment, and recognising the importance of these factors has led to substantial progress in terrestrial observation systems. However, progress is still slow or absent in some important areas.

Progress in establishing institutional support for *in situ* networks has been slow, leading to networks that are still poorly coordinated and harmonised despite considerable efforts on the part of the research community to keep them running. The objective of creating a comprehensive and well-coordinated reference network for *in situ* observations of the fullest possible range of terrestrial Essential Climate Variables is continuing, yet the challenge is still largely unmet. Such a network would provide observational data along with associated details relevant to applying this data in model validation, process studies and in validating observations from Earth observation satellites.

Efforts need to be made to ensure that observations crucial to our understanding of terrestrial systems, including the hydrosphere, biosphere and cryosphere, are moved from the largely research-driven funding base to a secure, longer-term monitoring network that fully adheres to the Global Climate Observing System Climate Monitoring Principles. With regard to global observations of hydrological variables, while national hydrological services are generally responsible for making the observations required by the different baseline networks there are nonetheless many other national and international agencies involved. Further coordination within the hydrological domain is therefore clearly needed.

Observations taken for purposes other than climate, but nevertheless with climate relevance, are often not made available, sometimes due to their economic or national strategic value. Furthermore, the analysis and reanalysis of historical records, both *in situ* and satellite based, has been progressing slowly and needs urgent consideration by agencies holding the records in consultation with potential users of these records.

ADDRESSING GAPS IN SOCIO-ECONOMIC INFORMATION FOR CLIMATE SERVICES

Observation of social and economic variables is vital for understanding climate impacts and vulnerabilities as well as for making predictions concerning anthropogenic climate change. The social and economic fields are complex and diverse, with data requirements that are very context-specific as well as many gaps in information and few simple options for technical recommendations on data gathering. However, it is possible to point to some generic areas of action that stand out as priorities.

There is a clear need for closer cooperation and coordination to ensure the availability and quality of the socio-economic information needed. One way of achieving this would be by developing databases on sectoral climate sensitivities and on methodologies for managing climate variability, as well as databases with information needed for systematic climate risk assessment. To some extent the problem is not so much lack of data but lack of engagement with users. There is also a lack of standardised approaches to data and its analysis that can be used with confidence by climate service providers. This would be addressed best through collaboration on data issues by scientists in socio-economic fields and through the work of international research programmes concerned with

the human dimensions of climate variability and change. Issues of data access are also a concern in the field of socio-economic information.

ADDRESSING ISSUES OF DATA EXCHANGE AND ACCESS

The technologies available for exchanging climate data and information are improving at a rapid pace. The World Meteorological Organization is in the process of implementing an information system capable of distributing observations and information globally as well as providing access to the same datasets on user request. This system has global hubs feeding regional nodes and offers the potential to be able to honour the national data policies of all data providers. It is expected that this system will be fully implemented by 2015, with some elements becoming available in 2012. The Global Framework for Climate Services should make use of this and other suitable information systems for exchanging data and information.

Despite great achievements in observation systems and data exchange, significant restrictions or difficulties exist concerning access to many datasets significant for climate purposes. A number of National Meteorological Services and research institutions may not be in a position to make their data accessible without use restrictions. In some cases this may be due to specific national or institutional policies, while in others it may be due to limited human and technological capacities or to differing views on how to maximise the economic value of pooled data.

Nevertheless, countries generally accept the principle that certain types of data sets should be made available for free and unrestricted international exchange; the challenge is therefore to use existing international deliberative mechanisms, principally within the World Meteorological Organization system, to reach agreement on which essential climate data and products are needed to provide effective climate services and should be shared in support of the protection of life and property and the well-being of all nations. This approach has been successful in the development of World Meteorological Organization Resolution 40 of its 12th Congress concerning the exchange of meteorological and related data and products which includes the climate domain of meteorology in principle, however its practical implementation in this area has been confined to the routine exchange of a limited set of so-called CLIMAT and CLIMAT TEMP messages between national meteorological services using the World Meteorological Organization's Global Telecommunication System.

Climate does not respect political boundaries. We believe that the barriers to accessing and using beneficially existing data sets is a major shortcoming and that governments and agencies responsible for climate data should give much more attention to finding and negotiating ways to reduce these barriers, including through the World Meteorological Organization processes where the implementation of Resolution 40, as it applies to climate-related data, should be reassessed and its scope widened.

8.4 RESEARCH

Comprehensive and reliable information on climate variability and change that can be used as the basis for the climate services of the future will require increased research and development efforts. Progress in understanding the various components of the Earth system that contribute to climate – including physical, biological and socio-economic factors – has revealed the incredible complexity and interconnectedness of the system. Improving our ability to predict climate and its impact requires better understanding of the entire system, particularly the processes that link the different components. Provision of decision-relevant climate services will also require research

to support its development and evolution. This will require strengthened collaboration between the physical science community and biological and social scientists. A gap in the research programmes that support climate services is the lack of cross-disciplinary, participatory research by professionals, researchers, policy makers and practitioners in climate-affected sectors. Developing practical methods for integrating climate knowledge into decision-making processes across sectors should be a focus of research supported by the Framework.

Coordinated international efforts are required to produce reliable and actionable climate information, including predictions, on finer time and space scales. They are also needed in order to offer the resulting information and services in a useful and timely manner to decision-makers. In particular, progress is required in the following areas:

- Improving the reliability of climate information, including in predictions, historical records and current climate conditions, based in part on improved access to quality-controlled observations and metadata, and grounded in institutional arrangements and communications processes
- Demonstrating the impact of climate in various sectors where the link is not currently well understood – for example, the relationship between climate variability and disease and pest outbreaks
- Improving the ability to predict the impacts of climate variability and change with a more reliable depiction of the actual range of possible climate outcomes considering vulnerabilities and the thresholds for decisions and actions
- Improving the ability of users to incorporate uncertain climate information into their decision-making, including communicating and articulating uncertainty, so that the user can incorporate a range of possibilities into their decision-making
- Assessing and optimizing current observing networks and systems; designing and testing new low cost observing technologies
- Demonstrating the efficacy of using climate information to improve outcomes in practical decision-making contexts

MODELLING AND PREDICTION

The development of our knowledge of climate processes and the construction of models of the climate system that enable seasonal prediction and climate change projections have been a substantial achievement. Current expectations are that future investments in scientific research, coupled with developments in technology, will lead to further increases in our understanding of the climate system and of our ability to make predictions about it. This will be necessary in order to address the many questions associated with adaptation to climate variability and change. There is a special need for research on decadal prediction, given that this reflects a key planning horizon in decision making.

While there is undoubtedly skill in current climate prediction and projections, and it is increasing, it is starting from a low base. On the other hand, forecasts of the weather over the next few days have become so accurate that categorical statements of when, for example, a cold front will pass through a city or when and where a tropical cyclone will make landfall can be and are routinely issued with high levels of confidence. Given that the range of possible outcomes for seasonal and longer-range climate predictions is substantially broader than that for weather, climate predictions have to be communicated expressing higher degrees of uncertainty. Increasing the spatial and temporal detail

of the information and reducing the uncertainties in these predictions, along with providing decision-relevant indications of its validity, is necessary in order to increase the usefulness of the information.

DECISION SUPPORT

There is a significant opportunity for strengthening climate services on the basis of our existing prediction capability and understanding of the climate system. While climate forecasts may be much harder to use than weather forecasts because of greater uncertainty, there is still considerable benefit that can be realised if carefully designed decision systems are in place. Besides uncertainty, under-use of climate services can be attributed to other, more significant constraints such as accessibility and relevance. The intermediate step of predicting climate impacts is making sure that they are relevant to decisions. Because the translation of climate predictions into recommended actions has been poorly developed, predictions remain considerably under-utilised. As a result, we are not currently fully exploiting recent advances in science. Therefore, while advancing science is of course vital, major improvements in climate services in coming years are likely to be based on better exploitation of our current understanding of the climate system and on improved understanding of the decision-relevance of the information.

GAPS IN OUR UNDERSTANDING OF CLIMATE IMPACTS AND VULNERABILITY

Chapters 5 and 6 of this report indicate that the impacts of climate variability and weather extremes are often not well anticipated. These impacts are unevenly distributed across societies and eco-systems. Some sections of society – for example the poor, the young and the old – are more vulnerable to climate variability and change. Some economic sectors are also more sensitive to climate than others.

In addition to improving climate predictions, we also need to improve our understanding of how climate affects people. Significantly, we need to use scientific research to highlight vulnerabilities before it is too late to deal with them. We must likewise identify ways for decision makers to use climate services to reduce vulnerabilities and to help people and sectors adapt in effective and efficient ways. Chapter 3 of this report highlights the need for interdisciplinary research to further our understanding of the decision-making processes of communities facing the challenge of adapting to climate variability and change. The impacts of climate on various climate-sensitive diseases, for example, are areas of ongoing scientific debate. Changes in malaria transmission as a result of global warming, for example, are likely to occur but details of these changes are far from clear because of the complex interplay of direct and indirect climatic effects. Thus, while there are expected to be direct impacts on the occurrence of malaria and other diseases because of environmental change, changes in human behaviour will result in additional changes in the environment and in exposure to disease that may compound, cancel or reverse the direct effects. Many other diseases do not have as direct a climate sensitivity as malaria but their occurrence is still affected by climate variability and change. Predicting how these diseases may be affected, and hence controlling their occurrence, is a task that is far from trivial.

DEMONSTRATION OF PRACTICAL BENEFIT

The uncertainties in predicting future climate conditions, the complicated impact of climate on outcomes of interest and the difficulty of identifying appropriate response strategies to anticipated impacts all point to the need for clear demonstrations of how to use climate services effectively. Some examples of the uses of climate services were given in Chapters 5 and 7 of this report. These demonstrations will help build confidence in climate services where such confidence is lacking and will also provide opportunities for continuous improvement and innovative practices as well as for making recommendations.

8.5 CAPACITY BUILDING

Capacity building requires investment in people, practices and institutions to stimulate and develop capacities in order to assess and manage climate-related risk effectively by providing decision-relevant climate information. A comprehensive capacity building initiative will have to include stakeholders becoming involved in climate product generation and delivery as well as in preparing decision options, advising and using climate information. Capacity building activities for improving all elements of the climate services framework require that those responsible for those activities be service-oriented in ways that respond to users' requirements balanced with climate science capabilities. Users' involvement in the design and ongoing evaluation of products and services, balanced by climate science capabilities, would help the service evolve. The need for sustained and informed user and provider engagement is recognized.

Chapter 4 of this report outlines capacity building activities presently in place around the globe as well as gaps in these activities. Current activities are highly fragmented and vary in focus from building the climate service delivery capabilities of developing countries, to improving services geared for specific sectors, to improving the adaptive capacities of specific target groups. What is lacking is an overall strategy to identify key gaps in the climate services framework and to apply resources systematically to deal with these.

This chapter has highlighted gaps in observations, data exchange systems and research that need to be addressed if effective climate services are to be provided globally. However, addressing these gaps requires that capacity be built to ensure that the expertise, infrastructure, institutional relationships and policies are in place to support these climate services. Specifically, the following capacities need to be developed:

HUMAN CAPACITY

Highly-skilled human scientific talent needs to be trained, especially in the developing regions of the world.

Capacity building and training must be seen as a long-term relationship of listening and learning between providers and users. Such a relationship requires access to data, methods and tools along with community collaboration and the ability to generate knowledge. It is essential that programmes are monitored and evaluated and that lessons learned are fed back into the programme and issue in useful results.

More generally, mainstreaming climate change education in curricula at all educational levels will ensure that there is a greater awareness of the impacts of climate variability and change and of effective ways of managing them.

INFRASTRUCTURAL AND INSTITUTIONAL CAPACITIES

In many countries, clear mandates need to be established for the proper functioning of climate services. Authoritative service providers need to be identified and management processes and procedures in the relevant institutions may need to be implemented.

Due to the site-specific nature of adaptation to climate change, local community and indigenous knowledge of ecosystems, natural hazards and adaptation mechanisms have been developed over long periods of time. Yet climate change and variability may overwhelm these traditional adaptation

mechanisms. It is therefore urgent to enhance human and institutional capacity to promote interaction between scientific knowledge with local community and indigenous practices.

Most countries currently can provide only basic or essential climate services (chapter 4), have an inadequate observation network and inadequately developed climate databases and have a limited capacity to generate and develop information products and to engage users. Regional capacity is generally inadequate to support the national services.

Even in developed countries, capacity to provide effective climate services is limited. There is a great need to increase significantly the computing capacity available to the world's weather and climate centres in order to accelerate progress in improving predictions. The World Modelling Summit for Climate Prediction in 2008 recommended that there be computing systems dedicated to climate that are at least a thousand times more powerful than those currently available.

PROCEDURAL CAPACITY

A vital part of the development of prediction systems relates to improving communication between scientists and users. Good communication ensures that products from climate models are useful for decision making and that users understand what can realistically be predicted and the reliability of the predictions they use for particular applications. Specialists from each sector should be engaged along with climate scientists to develop a detailed understanding of the types of decisions they need to make and the types of climate information that would help them. On the other hand, climate scientists need to provide decision makers with an understanding of the complexities and uncertainties in prediction information so this understanding can be properly incorporated into decision making.

A scientist-user interface is essential to ensure that applied research focuses on the need of the intended user for the services that are expected to issue from a successful programme. Very often, knowledge of user needs helps give a research programme direction while enhancing motivation and attracting resources. It is clear that whatever form the Global Framework for Climate Services takes as it is implemented, there must be a platform available for the research community to engage with the users of climate services.

Closer linkages between scientific research, the operational production of climate information and users are needed to ensure that climate services receive the benefits of research as soon as possible and that research covers the needs of climate service users. Standards need to be defined and developed for generating climate information, including information about the quality of the products. These evaluation processes also need to feed back into improved procedures and information quality.

8.6 NATIONAL LEVEL CAPABILITIES AND OUTPUTS

We believe that the Global Framework for Climate Services must facilitate effective coordination and development of existing capabilities so that they are sufficient to ensure effective use of climate services in every country.

The Taskforce has identified the essential capabilities that each nation requires if it is to be able to provide sustainable access for its citizens to climate services. Figure 8.1 provides an indication of the level of national capability that needs to be achieved, facilitated by the Framework, across the areas of climate observation, climate research, capacity building and user interface. It also sets out the

outputs – in terms of climate products and services – that can be expected once those capabilities are in place.

The list that follows is not definitive or exhaustive and will need to be developed further during detailed implementation planning for the Framework. However, we believe it is an important indication of the level of national capability that the Framework needs to help develop. It also provides a more detailed and practical picture of the results each country should expect from participating in the Framework.

REQUIRED CAPABILITIES	Observations	• Conduct data management including quality assurance/quality control, using Quality Management Framework principles; • Develop and maintain data archives; • Conduct data rescue; • Design and conduct life-cycle management of national observing systems for climate purposes; • Provide oversight on adherence to climate standards for observations (e.g. Global Climate Observing System climate monitoring principles) and instruments for measurement; • Historical as well as real time observations in the atmosphere, the oceans, over land and ice of the Essential Climate Variables prepared by Global Climate Observing System and partners for climate purposes, exchanged freely for use in Regional Climate Centres, for at least one Global Surface Network site; • Contribute to interoperable access via WIS to all appropriate climate observations and metadata; • Undertake to improve station density for climate studies of temperature and precipitation; • Improve observations based on user feedback.
	Research	• Participate in funded projects, field experiments; • Some engagement in applied climate research using local and other datasets.
	Capacity building	• Participate in training, as required, for data management, Quality Management Framework, data rescue, basic analysis (using, e.g., Climate Database Management System), fundamentals of climatology, preliminary training for use of climate prediction products, etc.; • Participate as appropriate in Regional Climate Outlook Forums; • Participate in training for climate services specialties, including for seasonal prediction, basic downscaling techniques, climate applications, advanced statistical procedures, etc.; • Conduct training for data management, data rescue and basic climate data analysis.
	User Interface	• Interact with users, to meet requests (for basic climatology questions) and gather feedback on products; • Conduct or contribute to regional and national climate outlook forums (Regional Climate Outlook Forums and National Climate Outlook Forums) and outlook communication; • Interact with users in one or more sectors to identify their requirements for, and provide advice on, climate information and products for their application; • Assist users to interpret/use climate predictions and products; • Get feedback from users on the usefulness and effectiveness of the information and services provided.

EXPECTED OUTPUTS	Products	• Datasets (land-based atmospheric and terrestrial, coastal/marine, some remotely sensed); • Time series for single parameters; • Long term trend maps; • Basic statistics (graphs, counts, etc.) on extremes, frequency of occurrence, spatial means for temperature (Max, Min, Mean), precipitation, and possibly relative humidity, evapotranspiration, thunder days, sunshine duration, cyclones, etc., climatological norms; • Map analysis of T, P etc, and anomalies (weekly, monthly, etc.), showing spatial patterns and climate zones; • Some assessments and analyses of spatial and temporal factors and processes involved in observed climate patterns (e.g. diagnostics on Tropical cyclones, monsoon, synoptic-scale storms, etc.); • Hazards monitoring and Climate Watch products basic assessments, advisories, analysis of climate extremes and extreme 'events', maps, graphs, imagery (e.g. satellite), observations on current (monthly) climate conditions vis-à-vis means, variance, thresholds, percentiles and weekly, 10-day, monthly, seasonal and annual basis, etc.; • Reviews and assessments of past climate patterns, e.g. World Meteorological Organization annual and multi-year reports on the State of the Climate • Application products including probable maximum precipitation, probable maximum floods , Intensity duration frequency , etc.; • National scale monthly and seasonal (generally three-monthly) climate forecasts and outlooks, plus related information on uncertainty, skill, etc. including maps of expected anomalies (e.g. for temperature or precipitation), in probabilistic format; consensus summary assessments of key features and, at national levels, may include advisories and warnings; • Improve services and products based on feedback from users.
	Services	• Data services (where permitted under current mandate and legislation); • Conduct basic climate diagnostics and climate analysis (staff will have some proficiency in climate statistics, or be able to reliably use statistical software (e.g. Climate Database Management System); • Perform basic climate assessment; • Contribute to Regional Climate Outlook Forums; • Disseminate climate products (i.e. those based on data; regional and national climate monitoring products if available; seasonal outlooks provided by Regional Climate Outlook Forums and Regional Climate Centres); • Conduct advanced statistical activities including analysis and diagnostics; homogeneity testing and adjustment; regression, development of climate indices, etc.; • Develop and/or provide (have access to and can effectively work with) monthly and longer climate predictions including seasonal climate outlooks, both statistical and model-based (down-scaled); • Add value from national perspectives to the products received from Regional Climate Centres and in some cases Global Producing Centres ; • Conduct climate watch programmes and disseminate early warnings.

Figure 8.1. Essential climate related capabilities and expected outputs of a national meteorological or climate service participating in the Global Framework for Climate Services.

CHAPTER 9

IMPLEMENTING THE GLOBAL FRAMEWORK FOR CLIMATE SERVICES

9.1 INTRODUCTION

In this Chapter we will translate our findings into recommendations for establishing the Global Framework for Climate Services. We will elaborate a number of issues and principles for implementing the Framework as a sustainable, operational system and propose immediate steps to address the most pressing needs for climate services. We will also consider practical matters of management and resourcing of the Framework.

9.2 PRINCIPLES FOR IMPLEMENTING THE FRAMEWORK

The wide-ranging consultation carried out as a part of the Taskforce's work leads us to propose the following eight key principles to be applied in the planning and implementation of a Framework that will be a global, operational capability to facilitate the more effective use of climate information to reduce vulnerability and manage climate-related risks:

Principle 1: All countries will benefit, but priority shall go to building the capacity of climate-vulnerable developing countries.

All countries stand to gain from participating in the Framework. Developing countries are generally the most vulnerable to the impacts of existing climate variability and are likely to be most affected by climate change, and these impacts will impede the achievement of the Millennium Development Goals. Moreover, climate services are often weakest in precisely those countries where they are most needed. The Framework should therefore give priority to the most climatically vulnerable countries, with particular attention to the special needs of African countries, least developed countries, land-locked developing countries and small island developing states. It should address their needs for actual climate services as well as for ongoing capacity building, technology and financial transfer from developed to developing countries with a goal to close the gap between them to meet the challenge of climate change and to achieve the Millennium Development Goals.

Principle 2: The primary goal of the Framework will be to ensure greater availability of, access to, and use of climate services for all countries.

To reach for these goals the Taskforce reiterates that the Framework must be designed to serve the needs of all users, that is, those who can use climate services beneficially regardless of their geographic location, capabilities or capacities in society. Users comprise diverse and multi-layered categories ranging from policymakers, planners and managers through to smallholders, householders and other individuals and including intermediaries such as advisory officers, technical experts, non-governmental organizations and consultants.

Users need access to knowledge, information products and data from observations and models. A key task of the User Interface Platform will be to devise ways to identify and interact with the various user groups with the aim of engaging to train and build the capacity of them in the work of developing services. The Framework will need to communicate and advocate the benefits of applying climate information.

Principle 3: Framework activities will address three geographic domains; global, regional and national.

Climate impacts are mostly a national and local (sub-national) concern. Practical responses, along with necessary data gathering and research, are organised and funded through national resources. However, climate variability, climate impacts, climate change and coordinated observation systems and research are also issues of global scale and international concern. Between these two levels there are regional institutions and projects which typically address issues of common interest in the region. Each of the three levels has characteristic requirements and responsibilities for information generation and for exchanging information with the other levels. The Framework's activities should consciously address the roles of the three components to develop capacities to enable global, regional and national responsibilities.

Principle 4: Operational climate services will be the core element of the Framework.

A range of relevant and globally consistent climate data and data products is needed on a continuing basis. Through its participating organizations, the Framework should support the implementation of operational components that function routinely, every day of the week (as required and agreed with service users), meeting agreed service standards in a sustainable fashion. This should include appropriate performance monitoring systems and targets to ensure service quality in order to build the confidence of both intermediaries in the service provision chain and users. The Taskforce believes that developing agreements for routine generation and exchange of data, data products and other information will be a critical factor on the basis of mutual benefits for all countries.

Principle 5: Climate information is primarily an international public good provided by governments, which will have a central role in its management through the Framework.

In our interactions with stakeholders, many have put strong emphasis on the public-good nature of climate information, particularly information concerning global climate variation and change. Climate information is largely funded from public resources, recognising that the costs involved are far outweighed by the benefits across a wide range of domains where the public interest is important such as public safety, health, agriculture, industry and national planning. Many stakeholders noted the need to have governments playing a central role in the management and governance of the Framework because of this strong public interest component. Users also emphasised their need to draw on information from different sources, including international centres. We also note that a rich basis of freely-available information, including research results, is a key stimulant to the development of market-based climate services and that in some countries the private sector plays a key role in transforming public information into usable products and services. The Framework will include within its data policies the principle of shared benefits between the data provider and those that add value to these data in order to create new climate-related information including through public – private partnerships.

Principle 6: The Framework will promote the free and open exchange of climate-relevant observational data while respecting national and international data policies.

Governments largely fund climate data collection and may wish to restrict its dissemination or recover part of the costs of collection through data sale. Conversely, free and open exchange of data is a foundation for the widespread practical beneficial use of climate knowledge and is a powerful incentive to research and to the development of new applications. This access dilemma has been addressed with respect to meteorological (weather and climate) data by Resolution 40 of the World Meteorological Organization's 12th Congress and with respect to hydrological data by

Resolution 25 of its 13th Congress. However, the operational implementation of Resolution 40 has generally been limited to data exchanged by way of the World Meteorological Organization's Global Telecommunication System, which includes only a limited set of the climate data likely to be needed for climate services in the future. Accordingly, we recommend that policies and activities under the Framework acknowledge and respect existing data policies while also encouraging as much free and open exchange of data as possible.

Principle 7: The role of the Framework will be to facilitate and strengthen, not to duplicate.

As shown in our definition above, we believe that the Framework should be a global vehicle to facilitate cooperation, coordination, knowledge transfer and routine information exchange. Many institutions, such as meteorological services, sector agencies, universities and private organizations already have well developed capacities and services. Moreover, strengthening existing capacities is a fast route to achieving progress. As a cooperative entity, the work of the Framework should be achieved largely through existing and future contributions and commitments from the many institutions that already generate and provide climate data and services. We particularly note the potential for national meteorological services to develop or expand their climate-related capacities and contributions, especially in data collection and product generation. Developing countries may need assistance to enable them to play their part in this.

Principle 8: The Framework will be built through user – provider partnerships that include all stakeholders.

A key to the successful implementation of the Framework will be that it supports the implementation of a responsive, operational system that makes a range of new climate services available to virtually every sector of society. The individuals, organizations and communities that make climate-related decisions will need to be encouraged to form new partnerships through the User Interface Platform that will both assist the Framework to meet their needs and facilitate the effective delivery of climate services.

9.3 THE TASKFORCE'S PROPOSAL FOR AN OPERATIONAL GLOBAL FRAMEWORK FOR CLIMATE SERVICES

In the succeeding parts of this chapter we will describe our proposal. Firstly the structure of the Framework, as proposed by the World Climate Conference-3, will be broadly endorsed with the addition of a capacity building component. Following this is a description of the way the Taskforce proposes the Framework to operate in the international, regional and national domains. In the next part of the chapter we will propose that the creation or implementation of the Framework be achieved in two ways: firstly by establishing an ongoing programmatic structure to coordinate the technical work of the Framework and secondly by creating a range of fast-track projects to upgrade national capacities in key areas. The Taskforce's proposal includes an indicative costing of these implementation activities and a brief discussion of possible sources of funding. The proposal concludes here with a discussion of the risks faced in the implementation process.

BASIC CONCEPTUAL ELEMENTS OF THE FRAMEWORK

The Taskforce endorses the basic conceptual elements as illustrated in Figure 9.1. The governance component of the Framework is not represented in this figure but will be considered in the next chapter.

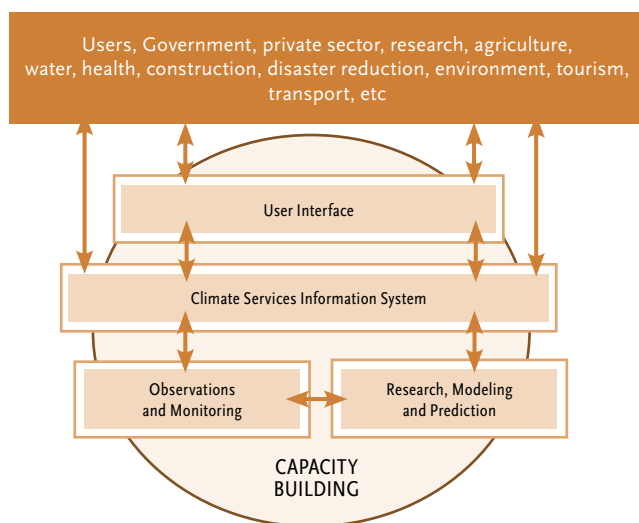


Figure 9.1. A schematic illustration of four components (in rectangular boxes) and the capacity building component (represented by a cloud that encompasses the other components) of the Global Framework for Climate Services proposed by the High-Level Taskforce. The arrows indicate channels of flows of information and interaction, with solid arrows from the Climate Services Information System to the users showing the flow of products and user feedback, while the arrows from the User Interface Platform to the users depict the flow of requirements and technical advice.

The five main elements of the Framework presented in Figure 9.1 comprise the following.

1) USER INTERFACE PLATFORM

The Taskforce stresses that the Framework must be designed to serve the needs of users, i.e. those who can use climate services beneficially. Users range from policymakers, planners and managers through to smallholders, householders and other individuals and include intermediaries such as advisory officers, technical experts and consultants. The User Interface Platform is the focus of the Framework's concerns for how climate services are developed and used. The User Interface Platform must be implemented flexibly to meet the diverse range of stakeholder interests and requirements. It should not be seen as the mechanism by which services are delivered because this will be done via the Climate Services Information System (see below). Rather, it is the Platform using which users and providers can interact to feed information about the Framework's performance back into its governance and management mechanisms. It is the most novel and least developed part of the Framework.

Users of climate information interact with diverse entities in their efforts to obtain climate information and to learn how to use it. This may be as simple as acquiring a data set or as complicated as engaging in a multi-year interdisciplinary research and demonstration project. Conceptually, this box is concerned with all such user interfacing activities, including the provider – user dialogue concerning the particular use of the climate services being provided. However, we recommend that its focus be primarily on systemic and thematic matters, particularly clarifying user requirements, improving climate services including applications of climate information and service delivery tools, developing standards and good practices as well as sharing knowledge and information. This element of the Framework will need to identify and engage the different user groups and foster interaction among users, user representatives, service providers and researchers through regional climate outlook forums, sector collaborations, expert study groups and internet-based means.

A key to the success of the Framework will be the commitment of users to making clear their requirements for climate services. Many of these users may in fact be intermediaries who have key roles in adding value to national centres and transmitting information originating from them. For example, Department of Health officials may combine climate information with relevant measures to avoid health hazards associated with climate events before communicating the information to affected communities through the communication channels they manage. The User Interface

Platform will include workshops, conferences and surveys combined with user and provider expert teams who will analyse the outcomes of service provision and develop proposals for continuously improving the Framework.

2) CLIMATE SERVICES INFORMATION SYSTEM

This is the system needed to collect, process and distribute climate data and information according to the needs of users as well as to the procedures agreed by governments and other data owners. It should be largely based on, or parallel to, the existing internationally-agreed systems for exchanging and processing meteorological data and information. In concrete terms, the Climate Services Information System comprises a network of computers and communication channels that exchange data and data products as well as agreed codes and formats for data exchange as well as international agreements on access to data and on the types of data that should be exchanged.

There are many effective ways of communicating climate data and information already in place, with use of the Internet for this purpose rapidly increasing. These communication systems are often tailored to serve particular provider – user communities, although the proposed World Meteorological Organization Information System offers generic functionality well suited to providing access to climate services globally. In the implementation phase of the Global Framework for Climate Services, early attention should be given to examining present capabilities in relation to the rapidly changing needs for climate information, since the current systems may not have been established with the needs of climate service end-users in mind. A particular concern is finding a better definition of what kinds of climate information can be made available on a free and open access basis. Some countries have stressed the importance of this issue and have urged development of a new intergovernmental climate data protection agreement to address it.

3) OBSERVATIONS AND MONITORING

The purpose of this element of the Framework is to ensure that climate observations necessary to meet the needs of climate services are generated. The Framework's needs will be almost entirely based on existing Global Climate Observing System-coordinated surface-based and satellite-based systems that already provide a wealth of data, 24 hours a day, every day. At the same time there are many gaps, including in the least developed countries and over the oceans and the polar regions. There is also a shortfall in some data types. The Global Climate Observing System has succeeded in defining the gaps in the context of meeting the needs of the United Nations Framework Convention on Climate Change and has developed a detailed Implementation Plan to address these gaps. The Global Climate Observing System Implementation Plan is aimed at addressing global needs, but there remain regional, national and sub-national needs for climate-related observations that need to be supported using other coordination mechanisms. Key tasks for the Framework will be to define the gaps that most crucially affect climate services, to bring attention to these deficiencies and to assist in efforts to fill them. These gaps fall in all data types, from oceanographic through atmospheric to biological and socio-economic. They are also likely to include past data and can be addressed through "data rescue" and the conversion of historic, paper-based records to electronic formats. The Framework should work closely with the Global Climate Observing System and other relevant scientific and user communities to address these gaps.

4) RESEARCH, MODELLING AND PREDICTION

This element encompasses the work of expert institutions to improve our understanding of climate and to develop core prediction tools, applications and products that are essential for the ongoing development and continuous improvement of climate services. The research community will also make

an important contribution to the Framework by promoting model data standards and interoperability, studying impacts and ensuring that projections on regional scales become widely accessible, along with information describing the uncertainties and other limitations of these products. In some cases research institutes will also contribute by producing and disseminating advanced prediction products.

Research strategies and programmes are well established in the field of climate and climate impacts and include many internationally coordinated programmes wherein the World Climate Research programme plays a key part. The role of the Framework will be to assess and promote the needs of climate services in research agendas, encouraging in particular the improvement of climate prediction information for the time and space scales of concern to decision makers.

5) CAPACITY BUILDING

The capacities of many elements covered by the Framework are currently inadequate and need improvement, especially in vulnerable developing countries. We use the expression “capacity building” to express the need for sustaining capacity growth over time and for systematically developing necessary institutions, awareness, technical and financial resources and the wider social and cultural enabling environment. Capacity building is not an activity that is carried out exclusively in the developing world; rather, it involves all nations and all sectors.

A task for the Framework will be to continually analyse the needs of the different elements of the Framework, particularly at national levels, and promote and implement efforts to address them. To jump start this process we have prepared a suite of priority actions to raise the capacities of those countries currently least able to participate in the Framework up to a basic level and to provide climate services (see Section 8.5).

We envisage that some of the Framework’s capacity building work will be implemented by specialist technical and development organizations and coordinated by the Framework secretariat, but there will also be capacity building activities whereby climate professionals share knowledge and experiences within and between regions. We note the very great potential for the Framework to add synergies and value to existing strategies and programmes for development and for adaptation. Therefore, the Capacity Building component should actively engage with multilateral funds and programmes that are currently gearing up to address adaptation to climate change. The Framework should address users’ capacity building needs by using the User Interface Platform element, for example through the regional climate outlook forums, major demonstration projects as well as through the programmes of national authorities, and including individual users and user groups in these efforts.

9.4 DELIVERING THE FRAMEWORK GLOBALLY, REGIONALLY AND NATIONALLY

An important dimension of the Framework is its organization and management within the three geographical domains – global, regional and national – including fulfilling their roles in the flow of data and data products. Figure 9.2 provides a summary of how we see this being arranged. As illustrated in this figure, we have concluded that all domains will need to participate in the Framework’s five main functional components to some degree, although we expect that each domain will tend to have certain predominant, though not exclusive, responsibilities.

The global domain will tend to concentrate on producing global monitoring and prediction products, coordinating and supporting data exchange and major capacity building initiatives on all spatial scales, establishing and maintaining standards and protocols and servicing certain global clients

as well as responding to needs such as food security. The regional domain will tend to concentrate on multilateral efforts to identify and address regional needs, for example through regional policy and product development, knowledge and data exchange, along with infrastructure development, research and training. The national domain will be mainly concerned with obtaining access to data and knowledge products, tailoring information to user requirements, ensuring effective routine use of information in planning and management along with developing sustainable capacities in these respects. Meeting national needs will often require focusing services on sub-national regions.

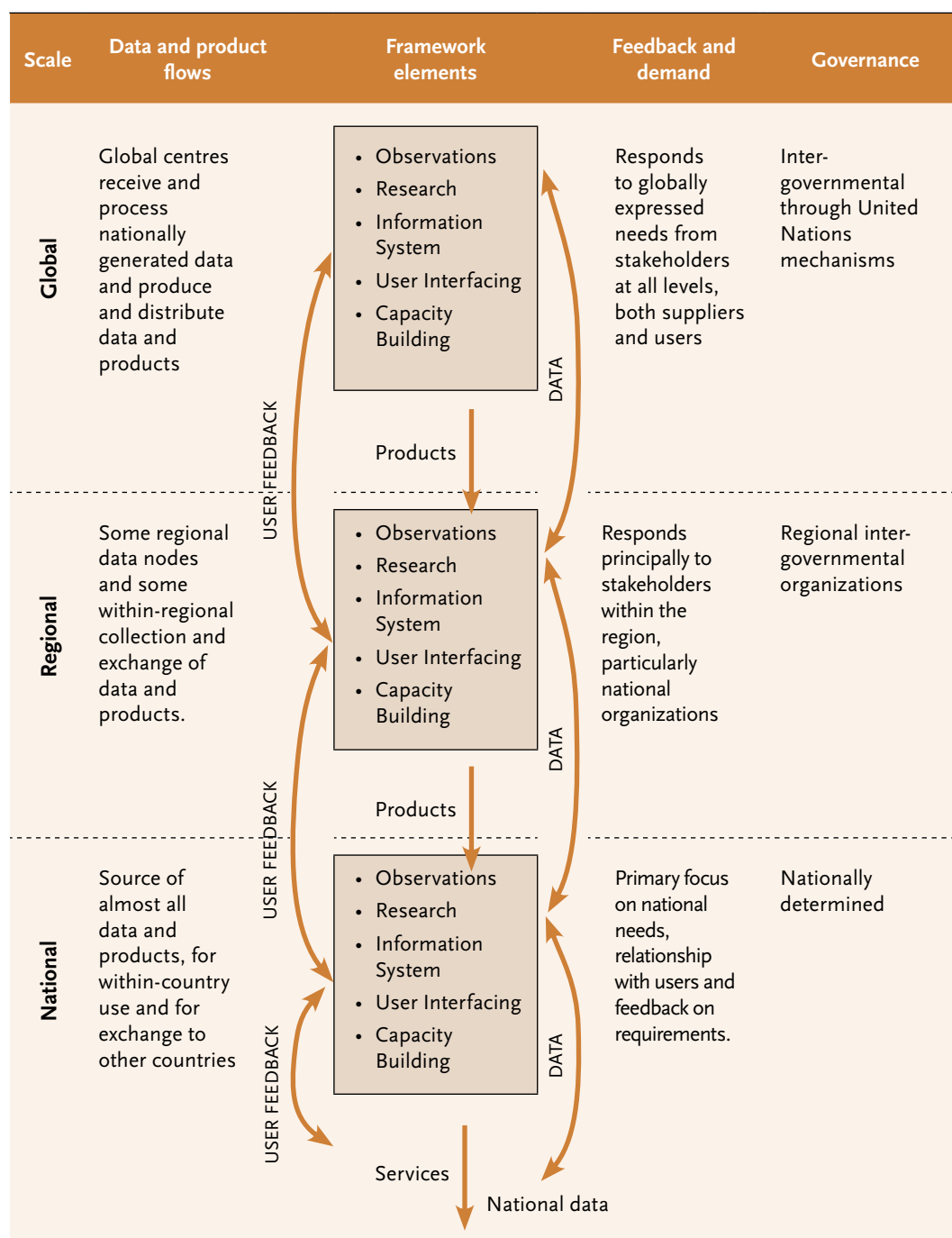


Figure 9.2. A schematic representation of the Framework's global, regional and national components

The Taskforce accordingly recommends that the Framework, working with users and providers, elaborate generic profiles for each level that cover responsibilities and needs, and encourage stakeholders to formalise their understandings and commitments to these. We also recommend that regional intergovernmental organizations and regional expert organizations be requested to develop regional capabilities to support the Framework, including identifying a regional focal organization for the Framework, considering the Framework in regional meeting agendas and in periodic regional consultations on Framework-related matters. Regional components, including real and/or virtual centres specialising in climate service matters, are likely to be needed.

FLOWS OF DATA AND DATA PRODUCTS

The flows of data and data products between the different levels are complex and cannot be properly represented in Figures 9.1 or 9.2. While factors of specialised expertise and economies of scale mean that some core products will flow from global to national level, these are still largely based on observational data that has been generated at the national level and exchanged internationally from country to country. Depending on their needs and capacities as well as on arrangements agreed and put in place between the various climate centres, users may obtain information from a range of available national, regional and international sources.

Since there are already well-established systems for climate observations (such as Global Climate Observing System) and meteorological data exchange systems (such as the communications infrastructure coordinated by the World Meteorological Organization and the information distribution system proposed by the International Council for Science), the Taskforce concludes that the data-related elements of the Framework, (i.e. the Observations and Monitoring box and the Climate Services Information System box in Figure 9.1) should be developed primarily by extending and strengthening these existing systems. At the same time, we also recommend that the Framework should specifically explore giving support to meeting the needs for generating and exchanging non-meteorological, climate-related data (for example sea level height observations, descriptions of vegetation cover, hydro-meteorological disaster-related information and climate-related socio-economic data) where we have found that the data gathering and exchange process is not well developed.

WORK PLANS, MAJOR PROJECTS AND CAPACITY BUILDING

The Taskforce proposes that the five near-term implementation objectives for the Framework be as follows:

- Establishing mechanisms to strengthen the global cooperative system for collecting, processing and exchanging observations and for using climate-related information
- Designing and implementing a set of projects that target the needs of developing countries, particularly those currently least able to provide climate services
- Developing strategies for external communications, resource mobilisation and capacity building programmes
- Establishing internal working methods, particularly for communications and for debating and deciding on implementation priorities, including for the observations, information systems, research and capacity building components
- Setting targets and establishing procedures for monitoring and evaluating the performance of the Framework

In implementing these objectives, particular attention should be paid to the following management matters:

THE NEED FOR TECHNICAL EXPERTISE

Implementation of the Framework is a technical activity and will need the full support of a range of technical experts from both user and provider communities to sustain and advance its components (observations, research, information management and exchange and service delivery) in order to meet the objectives defined by governments. An important element of the implementation strategy will be the creation of a range of technical committees comprised of experts drawn from national institutions who will work together to build a sustainable Framework to provide global access to climate services. The implementation strategy must provide draft terms of reference for the technical committees needed to implement the Framework.

COORDINATION CAPABILITY OF THE UNITED NATIONS

The United Nations System can be used to coordinate the response to governments' needs for climate services and to bring together climate service users, providers and experts who maintain climate information systems, observation systems and research and development capabilities. Mobilising this coordination capability of the United Nations will require establishing a United Nations agency-based secretariat that will be an important supporting element of the Framework. This secretariat will work closely across the United Nations System to ensure that agencies and programmes with climate-sensitive sectors are engaged. The implementation plan will need to describe the functional role and responsibilities of the secretariat.

COMMUNICATIONS AND ADVOCACY

Two communications objectives can be distinguished. First, to ensure that potential users and funders are alerted to its existence and role, the Framework will need a communications strategy to create global awareness of its scope and capabilities. This communications strategy will be particularly important in its early years of operation. A clear priority of the communication strategy will be to work with governments to highlight the benefits that flow from investing in the Global Framework for Climate Services. Second, at a more technical level the Framework will need a well-thought-through strategy for informing user groups about its various services, noting that in different cultures and for different services the optimum methods of communication will vary. An aim of this communication will be to build the capacity of user groups to derive the maximum benefit from the climate services available.

RESOURCES PLANNING

A detailed resourcing plan should be developed to determine the level of funds required to sustain the new work programme and to identify potential funding sources for the different parts of the programme. In addition to this, the plan should make clear the components of the Framework that have been implemented by governments without necessarily quantifying their cost. The plan should also identify benefits according to a cost/benefit analysis.

EXISTING GOVERNMENT COMMITMENTS

At the present time, many governments are already committing substantial resources to maintaining and developing climate service functions on a national scale. One role of the Framework is to add value to these activities through assisting in their global coordination. For a small additional contribution to

the Framework, substantial national benefits will be accessible. Collecting data to agreed standards, building regional capacities in a range of climate sensitive sectors and exchanging data and expertise regionally and globally are activities all largely sustained and enhanced by government engagement with the Framework. Therefore, a key element of the work plan should be a sustainable, ongoing programme that engages all governments to participate in and support the work of the Framework. A second key element should be the implementation of “fast track” initiatives to address key shortcomings in the provision of climate services.

9.5 IMPLEMENTATION PRIORITIES

Implementing the Framework will require that two sets of actions be undertaken in parallel: (1) establishing leadership and management capability to take the Framework forward, and (2) quickly carrying out a number of high-profile capacity building projects to enable the delivery of climate services to meet the needs of the climate- vulnerable communities of the developing world. These fast track projects aim to build the capacity of developing nations to sustain the provision of climate services over the long run and would be largely funded through resources given for aid purposes.

BUILDING A SUSTAINABLE LEADERSHIP AND MANAGEMENT CAPABILITY

Implementation of the Framework will require the establishment of a leadership team that has government ownership and support as well as support from the United Nations System. The leadership team will oversee the technical direction of the committees that are responsible for delivering the capabilities specified for the five components of the Framework: the User Interface Platform, Capacity Building component, the Climate Service Information System, the Research, Modelling and Prediction component and the Observations and Monitoring component and will include representatives from both user and provider communities.

For each component of the Framework there is currently in place functioning elements at national, regional and global levels that could make a valuable contribution to its future work. The immediate task is to engage with the expert communities that operate these existing capabilities to develop and take forward the Framework’s work plans. This core of leadership and technical expertise that will drive the implementation of all aspects of the Framework should be supported by a small, United Nations-based secretariat.

FAST TRACK PROJECTS TO UPGRADE BASELINE NATIONAL CAPACITIES

A principal near-term strategy for the implementation of the Framework is designing and implementing projects that target the needs of developing countries, particularly those currently least able to provide climate services. In this Section and in Sections 9.6 and 9.7 that follow, we will set out proposals for concrete projects that rapidly address a number of key problems. These proposals are directed at building sustainable capacity to provide climate services.

FAST TRACK PROJECTS TO BUILD CAPACITY TO INTERFACE WITH USERS

The Framework’s User Interface Platform will be the mechanism through which potential users of climate services will be able to express their requirements and existing users will be able to provide feedback about the services they receive as well as make any changes in their requirements. A robust but flexible information feedback loop is a vital part of an operational service delivery sustainable over a long period. Users of the Framework’s services will expect that their statements of requirements and

views on service quality, relevance and reliability, will be fed back to those responsible for managing each of the Framework's components (observations, research and information systems).

GATHERING AND USING FEEDBACK

The processes of gathering feedback are many and varied and depend upon the nature of the service and the situation of the service user. For public services that are widely used, random surveys across the user community may be carried out or focus groups recruited from the user community. Users of specific services are often asked to complete a survey at the time they finish using the particular service. For services routinely provided to key clients, workshops may be held involving service providers and users. With services increasingly delivered via the Internet, Web statistics such as the number of Web hits, the time spent by the user interacting with the Web products and the geographic location of the user are all used as measures of the usefulness and reach of the service.

The Taskforce notes that gathering feedback is only the first step in creating an effective User Interface Platform. The feedback collected needs to be useful to the managers of the components of the Framework. In particular, it needs to highlight ways that the Framework can be improved. For the managers of the information system, the feedback needs to assist in scoping the size of the information system, pointing out the best technologies for providing particular services and identifying trends in preference for technologies. For researchers, the feedback needs to identify services that are needed that are not yet available to decision makers, it needs to assist researchers in understanding how decision makers use particular services and how their demands for services are likely to change in the medium term. For managers of the observation systems and databases of observations, the feedback should assist in prioritising observation systems within managing systems so that the most important data are the most accessible and should aid planning to fill gaps in observing systems.

PILOT PROJECTS TO BUILD THE CAPACITY OF THE FRAMEWORK TO INTERFACE WITH USERS

The Taskforce proposes a number of pilot projects targeting the users in the priority areas of agriculture, water, disaster risk reduction and health for the period 2014-2017, broadening to other sectors on a needs basis in 2018-2021. These pilot projects aim to achieve four outcomes relevant to climate service users of climate vulnerable communities in developing countries:

1. Identifying the optimal methods for obtaining feedback from these communities
2. Building a dialogue between climate service users and those responsible for the observation, research and information system components of the Framework with the aim of developing metrics for the performance of the Framework as affected by the contributions of the components
3. Developing monitoring and evaluation measures for the Framework that are agreed between users and providers
4. Improving climate literacy in the user community through a range of public education initiatives and on-line training programmes

BUILDING THE CAPACITY OF NATIONAL CLIMATE SERVICES

Earlier in the report the Taskforce identified the essential capabilities required by each nation in order for them to provide sustainable citizen access to climate services (see Figure 8.1). From its survey of national capacities, the Taskforce has found that about 70 countries (of the World Meteorological

Organization's 189 Members) do not have the necessary basic capabilities at present. We therefore recommend that a high profile programme of fast-track projects be established to develop the capacities of these countries over the two four-year periods 2014–2017 and 2018–2021 after a two-year planning phase (2012–2013). We envisage these projects being achieved by way of a series of regionally clustered projects.

An estimation of the costs associated with raising the capacities of these 70 countries to the baseline level of capacity defined above is provided in Figure 9.3. The cost estimation process was based on survey results that show that six countries have extremely limited national climate capacity and that a further 64 countries, 36 small and 28 large, are in need of strengthening but nonetheless have a viable meteorological service already, with basic weather forecasting and service capabilities and a staff with relevant skills in forecasting, analysis and statistics. The methodology used in the survey assumed that the development of the human resources required to support climate services at national levels would be based on enhancing the skills of on-site meteorologists and meteorological technicians and on adding core climate and service delivery competencies, including communication skills. The ability of staff in national centres to participate in the activities of the User Interface Platform will be critical to the success of the national centre as well as the Framework, in that these staff will be at the front line in assessing user requirements and user satisfaction with the services provided and will be responsible for informing the other components of the Framework of the outcomes of these assessments.

It assumed that the capacities required were related to the size and climatic complexity of the country and to the populations to be served. For example, for a small country with a small number of climate zones, a climate unit of two to three experts may be adequate to provide the scope of services required. However, a very large and highly-populated country with multiple climate zones or climate sensitivities might require 10 to 25 or more experts. The costing method included considering the need to repeat training and development activities more than once in order to cover the inevitable losses arising from staff promotion and moves to other sectors by trained personnel. However, while training and infrastructure costs have been estimated, the cost of staff (that is, operating costs) has not, although staff numbers have been estimated at around 1000 and includes

Capacity Building: Interfacing with users	Investment necessary to upgrade (US\$ x M, 2010 prices)		
Period	2012–2013	2014–2017	2018–2021
Developing feedback methods		5 to 8	5 to 8
Building a dialogue between users and the “components”		5 to 8	5 to 8
Developing monitoring and evaluation processes and systems		3 to 6	3 to 6
Improving climate literacy in the user community		8 to 12	8 to 12
TOTAL	1 to 2	21 to 34	21 to 34

Figure 9.3. An estimate of the investment necessary to implement a range of pilot projects across the climate sensitive sectors to build the capacity of the User Interface Platform to meet the needs of the Framework

Capacity Building: national climate services capacity	Investment necessary to upgrade (US\$ × M, 2010 prices)		
	2012–2013	2014–2017	2018–2021
Period			
Six small countries with very low or non-existent capacity		3 to 4	0
36 small countries with an existing low capacity		20 to 25	20 to 25
28 countries with an existing low capacity		30 to 35	30 to 35
TOTAL	1 to 2	53 to 64	50 to 60

Figure 9.4. An estimate of the investment necessary to upgrade the national climate services capability of 70 countries that currently do not meet the level of essential services listed in Figure 8.1

climatologists (250), technicians (505), information technology specialists (135) and administrative staff (90).

Costs of enhancing national capabilities will include both the costs of training to upgrade existing, relevant competencies and the costs of infrastructure, equipment and tools (e.g. hardware, software, etc) as well as some operating costs. A basic preliminary activity for the programme would be to create an appropriate curriculum and to identify and prepare a suitable cadre of training experts. Some of this can be based on existing modules that have been developed by the climate expert community, for example climate data management and climate service delivery, while others may need to be developed. The costs of these preparatory activities are notionally included as the first two years of funding (2012–2013) in Figure 9.4.

National meteorological services are likely to be principal components of all national climate service plans but are unlikely to be the only government or other entities needing to be included. Other entities are likely to include academic institutions and other government departments, etc. For this exercise, however, costing is assumed to be for developing government entities rather than non-government, commercial or other private organizations. Special consideration will need to be given to assessing and developing capacities within universities, technical schools and training institutes to produce suitably qualified candidates with the core competencies needed for the work.

It should be noted that this fast track programme is focused on developing personnel and service delivery capabilities (including carrying out the activities that serve the User Interface Platform). It does not address the cost of filling national gaps in the Global Climate Observing System, owing to the highly specialised, operational nature of this System and the presence of other ongoing initiatives to correct its deficiencies.

FAST TRACK PROJECTS TO STRENGTHEN REGIONAL CLIMATE CAPACITIES

We strongly recommend the creation of a sustainable, vibrant network of regional centres capable of supporting national climate service activities as well as of meeting client needs as agreed with the countries of the region, since not all countries have, or need to have, the resources to support all aspects of a climate service. This said, the Taskforce recognises the considerable difficulties regional centres face; often there are difficulties in reaching agreement on where to locate the centre, while funds for operations can be variable over time. Moreover, for those located in the developing world,

access to aid funds is generally conditional upon government support from all of the regional partners. The Taskforce recommends that a fully effective network of regional centres be established by the end of 2021. This will require strengthening existing centres through their own voluntary effort as well as with targeted assistance as well as creating a number of new centres.

In particular, we recommend that a programme be implemented to strengthen existing regional climate centres and to establish new regional centres where there is a clear need to do so. The Taskforce considers that all regional centres should have mechanisms to respond to the needs of countries within their area of concern and should seek to operate with the formal endorsement of a relevant regional intergovernmental body.

ROLES AND ACTIVITIES OF REGIONAL CLIMATE CENTRES

The roles and activities of regional climate centres will vary according to the specific interests and needs of the region. Minimally, a regional climate centre would carry out the following operational activities:

- Interpreting and assessing relevant seasonal analysis, prediction and climate change scenario products from global centres
- Making use of seasonal forecast verification data provided by the World Meteorological Organization system of regional climate centres and lead centres, distributing relevant verification information to climate service users and providing feedback to global centres
- Generating regional and sub-regional tailored products relevant to user needs, including seasonal outlooks and downscaled global climate change scenarios
- Verifying quantitative seasonal and other forecast products, including exchanging basic forecasts and historical data
- Generating 'consensus' statements relating to regional or sub-regional forecasts
- Providing users with on-line access to climate products/services as agreed on a regional basis
- Assessing use of the regional centre's products and services using feedback from users
- Performing climate diagnostics including analysis of climate variability and extremes at regional and sub-regional scales
- Establishing an historical reference climatology for the region and/or sub-regions
- Implementing a regional climate watch
- Developing regional climate datasets, gridded where applicable
- Providing climate database and archiving services at the request of national authorities

Minimally, a regional climate centre would also carry out the following non-operational activities:

- As, and if requested by national governments, developing user forums for key climate user sectors within the region

- Providing scientific guidance on reanalysis, regionally downscaled analysis and climate change scenarios that are available through the centre
- Providing information on methodologies and product specifications for regionally agreed mandatory products and providing guidance for their use
- Coordinating training for climate service users in interpreting and using regionally agreed mandatory products, including seasonal predictions and climate change scenarios
- Giving strong support to vital, regional climate research initiatives which will be key to service creation and improvement
- Monitoring and responding to user feedback

In the long run there is a need for two or three regional climate centres in each of the six World Meteorological Organization Regions and for several trans-regional climate centres (for example, with an Arctic, Antarctic, Indian Ocean or Mediterranean focus – although the ultimate locations of climate centres must be determined by a process of stakeholder consultation), and thus a global need for approximately 15 to 22 centres.

ESTIMATION OF COSTS

At the time of preparing this Report, the World Meteorological Organization's Region II (Asia) had designated two climate centres, Beijing and Tokyo, while Region I (Africa) had identified a need for five, to be met by reinforcing some existing centres and creating some new ones. The Region II centres are fully funded by the host country governments while in Region I no funding arrangements have been fully settled. Given the uncertainty in global demand for regional centres, and given the uncertainty in host countries willingness to fund centres, it is difficult to estimate the likely costs of fast tracking the implementation of regional centres. However, noting the importance of such an initiative, an indicative costing is provided here that must be refined through a process of global, regional and national consultation.

A preliminary estimation of the costs of implementing the regional element of the Framework, based on the level of resourcing provided in comparable centres supplying the required level of services, is presented in Figure 9.4. To establish a new regional climate centre the cost has been estimated at US\$ 30 M, where the cost estimate includes needs for staff recruitment (ongoing salaries not included); property and supporting infrastructure and their maintenance; administration and operating materials and equipment; computers, software and data storage devices, including site licenses and maintenance contracts; communications equipment and expenses; vehicles; a capital development fund; and information resources such as library books, journals and electronic media.

The annual operating cost of a small regional climate centre is likely to be about US\$ 2 M per year, not including staff costs. Staff costs have been omitted from the estimate because of their high degree of variability across the globe and because in the long run these will have to be sustained by regional contributions. It is estimated that to function effectively a regional centre would minimally require six professional staff (climatologists), 12 technicians, three information technology professionals and two administrative staff. The actual size of a regional climate centre will vary based on the number of countries being served, the variation in climate across the region and the level of demand for services. Some "centres" may be virtual centres with nodes spread across countries in the region, each country supplying a different capability. Other regional centres may meet all requirements from a single location.

For the purposes of indicating the likely scale of costs of fast tracking an increased global capacity, the costs of implementing four new regional climate centres in the developing world (for example in Central Asia, South America, South Pacific and North Africa) and supplementing the running costs of a further existing four centres by 50 per cent has been calculated. Figure 9.5 summarises capital and running cost investment excluding staff costs. If supplementing were to continue beyond the 2018–2021 financial period, this would be at a rate of US\$ 8 M per year (2010 prices). It is anticipated that strengthening the secretariat to support this climate service capacity building project would need to occur in the one-to-two years prior to its commencement in order to undertake planning work.

A FAST TRACK PROJECT TO IMPROVE THE RELIABILITY OF OBSERVING STATIONS

The Global Climate Observing System community has identified 138 priority actions in its latest Global Climate Observing System Implementation Plan (discussed in Chapter 2 of this Report), however in this section the Taskforce considers achieving completion of just two components of the Global Climate Observing System that are missing in many developing countries which, if present, would provide some of the essential data for meeting national climate service requirements and for building national observation collection, management and analysis capabilities. It is also expected that undertaking the task of restoring observations capacity of the Global Climate Observing System Surface and Upper Air Networks in the target developing countries would develop skills, capacities and interest in the restoration of other national observing programs. Allied to these activities are global scale observing systems, including those that are satellite-based. The Taskforce encourages the consortia that coordinate satellite programmes to establish an operational architecture for monitoring climate and climate change from space.

The Global Climate Observing System Implementation Plan (2010 Update) estimates that the current climate observing network costs around US\$ 5 to 7 B per year to operate. Addressing the gaps they have identified would cost an additional US\$ 2.5 B per year. It is clear that climate services can be provided with the existing set of climate observations that are available globally. From a service perspective, the broad-scale global and regional products from the advanced centres meet the need for climate products of many countries. To downscale these broad scale products to meet national needs there is a requirement, *inter alia*, for local data to validate climate analyses and to assist in the interpolation of predictive products. A starting point for estimating the cost of building national observation capacity for climate purposes in developing nations is to ask; “what would it cost to ensure that all stations in the Global Climate Observing System surface and upper air networks were fully functional?” There may be higher priorities; for example it is argued that upper air observations

Capacity building: new regional centres and support for existing regional centres	Investment Required (US\$ x M, 2010 prices)		
	2012–2013	2014–2017	2018–2021
Financial Period			
Create four new centres, two in period 2014–2017, two in period 2018–2021		60 to 70	60 to 70
Supplement the running costs of four existing centres (1M pa) plus the centres created in period 2014–2017		16 to 20	16 to 20
			+4
TOTAL	1 to 2	76 to 90	80 to 94

Figure 9.5. A summary of the investment required to implement and support the Global Framework for Climate Services network of regional climate centres.

are less important than the surface network now that satellites and aircraft are providing a steady stream upper air data. It is also argued that air quality data are of increasing importance, particularly in and about megacities (as discussed in Chapter 7 of this Report). Nevertheless, it should be noted that the Global Climate Observing System's Surface and Upper Air Networks have been defined, and if fully functional would play an important role in underpinning national as well as global climate service requirements.

THE PROBLEM OF "SILENT" STATIONS

The Taskforce has identified an opportunity to address the serious problem of the "silent" stations in the Global Climate Observing System using a contingency capability to respond to maintenance issues in developing countries. In Chapters 2 and 8 we have noted that there are significant gaps in global coverage of the surface-based networks and that these gaps are most marked in the developing world. For example, in the vast oceanic areas of the world, Small Island Developing States endeavour to support the Global Climate Observing System but with relatively small economies they often struggle to find the financial and human resources necessary to maintain these observation systems.

RECOVERY AND REJUVENATION

An analysis of the reporting performance of the stations in the Global Climate Observing System's Surface Network has revealed that observations are lost for a variety of reasons, many quite simple including staff absences, temporary equipment failure and communications networks failures. Sometimes a persistent communications failure may be due to a simple software problem.

Two basic atmospheric observation systems of the Global Climate Observing System, the Surface Network and the Upper Air Network, have within them a number of stations that for a long period have supplied no observations. Rejuvenating these "silent stations", which are almost exclusively in the developing world, should be an important objective for the Framework if it is to achieve its aim of supplying access to climate services to the most vulnerable. A review of the Global Climate Observing System Surface and Upper Air Networks in September 2010 indicated that around 100 surface synoptic stations and 10 upper air stations need rejuvenation. The list of missing stations changes constantly, but for the purpose of estimating the cost of addressing major gaps in the Global Climate Observing System network of stations it is assumed here that at any given time there are around 10 to 15 upper air and 100 to 120 surface stations that do not report for substantial periods. It should be noted that this would address only the global need for observations, not regional, national and local needs, which may call for a higher degree of spatial resolution.

COST IMPLICATIONS

As indicated in Chapter 2, a surface synoptic observation station provides such basic atmospheric data as mean sea level pressure, wind speed and direction, rainfall amount over given periods, air temperature and humidity. It does this frequently throughout the day, every day of the year. To meet the needs of climate monitoring, the resulting data need to be derived from instruments that are routinely calibrated and well maintained. The cost of operating such a station varies from country to country depending on a wide range of factors such as staff costs, maintenance and calibration costs, communication costs, site costs, depreciation of major capital items and the like, but nevertheless a figure of US\$ 30,000 per year is given in Chapter 2 as an indicative cost. Similarly, an upper air station releasing two balloons carrying radiosondes aloft to provide a temperature, humidity and wind profile of the atmosphere above the station costs on the order of US\$ 300,000 per year.

PROPOSAL FOR CONTINGENT CAPABILITY

We propose that a programme be put in place that addresses the silent stations along with the most difficult data gaps in the Global Climate Observing System Surface Network (GSN) and Upper Air Network (GUAN). On the basis of the above figures, this would cost US\$ 92 x 30,000 plus 11 x 300,000, or around US\$ 6 M per year. In addition to these costs there would likely be additional “downstream” costs for facilities to process, store and re-distribute the observational data.

On the basis of these calculations, and allowing for the fact that these costs are accrual costs over the lifetime of the station and do not reflect the relatively-high initial start-up costs followed by lower ongoing operating costs, it is estimated that an initial investment of around US\$ 20 to 25 M per year for the first two years of the Global Climate Observing System restoration project followed by an ongoing investment of around US\$ 7 to 10 M per year thereafter would result in a substantial improvement in the completeness and quality of the data sets generated by the global networks (Figure 9.6). This would represent a substantial improvement in paying back the enormous investments in the networks that have been made world wide by all countries. It is anticipated that strengthening of the Global Climate Observing System Secretariat would need to occur in the year or so prior to commencing this restoration project in order to undertake planning work.

The costing of putting in place a sustainable climate surface synoptic observation station and an upper air sounding station assumed that the meteorological service was capable of supporting the station by providing trained staff, establishing communication facilities and providing data management infrastructure, instrument maintenance expertise and the like. In many cases where a missing station needs rejuvenation, it is clear that the supporting meteorological service also needs a parallel programme of institutional re-building. The programme would need to focus on the sustainability of the stations that were to be rejuvenated. To achieve financial sustainability for the programme, a long-term trust fund needs to be established supported by donors, having in place an appropriate investment strategy under United Nations oversight to smooth out variations in the level of donations over time. The World Meteorological Organization, along with all other United Nations agencies, operates specific purpose trust funds with regularly audited accounts that are able to attract support from countries and philanthropic organizations. The Global Climate Observing System already uses such a trust fund and it is argued here that this facility needs strengthening and greater support from the donor community as part of the overall strengthening of the networks it coordinates.

FAST TRACK PROJECTS TO BRIDGE THE GAP IN RESEARCH CAPACITY BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

Research into climate variability and climate change is largely carried out in major centres in the developed world, with some research capacity being fostered in universities as well as in

Capacity building: GCOS <i>in-situ</i> network	Investment Required (US\$ x M, 2010 prices)		
	2012–2013	2014–2017	2018–2021
Financial Period			
Support for surface and upper air components	1	80 to 100	28 to 40

Figure 9.6. A summary of the investment required to restore GCOS surface and upper air silent stations.

a small number of regional climate centres in the developing world. While the operation of a world-class climate modelling system requires a substantial investment in supercomputing, communications and data management systems and takes years of investment to reach a standard comparable with those of the major centres, there are important contributions to be made by smaller centres in the interpretation and validation of output from major centres' models (including the results from downscaling). They can make a similar contribution using output derived from analysis of locally collected data, from the study of national and local climate issues as well as by translating research results into locally relevant services. The Framework urges that research capacities such as these be built in developing world climate centres.

Preparing the assessment reports of the Intergovernmental Panel on Climate Change has long been a successful example of developing research capacity in the developing world. Because scientists in the developing world are encouraged to join chapter author teams as Contributing Lead Authors and Lead Authors, they are exposed to the full range of literature in their field of work. Over the period of the assessment, which typically runs for around six years, they build their skills, impart knowledge to those around them and establish a network of peers in both developed and developing countries. In order to extend this mechanism to the realm of climate services, the Framework will provide financial support for developing world researchers to participate in the research activities of developed world climate research centres while supporting visiting scientist programs at developing world climate centres. The aspect of encouraging senior scientists to spend time working in developing world regional climate centres is seen as particularly critical in building capacity in these centres. The Taskforce also sees the need to increase the number of long term fellowships at the doctoral level to enhance the overall capacity of research scientists in the developing world.

To build both research and observation capacity, the Framework will seek opportunities to support developing world scientist participation in creating instrumentation suited to the developing world. Here the focus will be on innovative technologies such as ground-based, high resolution networks sited on cell-phone towers, radars and high-density rain gauge networks operated with local support. The intent is to engender strong local support for the care and maintenance of new networks by making data instantly available and, using these data, rapidly developing services from which the community can immediately draw benefits.

Finally, the Framework will seek to promote multi-disciplinary research initiatives focusing on developing world climate-related issues such as: adaptation to drought; systems to forecast outbreaks of malaria, meningitis, dengue fever and climate-related diseases well in advance; cost-benefit methodologies for assessing adaptation options; and communication options for disseminating climate education, including disaster risk reduction strategies, to those who most need it in the developing world. The process to be adopted in such a wide-ranging research initiative is to work initially with the priority sectors of water, agriculture, disaster risk reduction and health to identify gaps in services and to support scientific understanding, bringing together teams of scientists from the developed and developing worlds to prepare research proposals offering the prospect of operational services at their conclusion and improving the likelihood of finding funding support for their undertaking within the Framework.

In each of these areas the Framework will seek to work closely with the key research groups, the World Climate Research Program, the International Science Council and others as appropriate. The indicative costing for such a programme of research is given in Figure 9.7.

Capacity building: research capacity in developing countries	Investment Required (US\$ x M, 2010 prices)		
	2012–2013	2014–2017	2018–2021
Financial Period			
Researcher exchange program	1	1 to 3	3 to 5
Research into advanced observation systems	1	3 to 5	5 to 10
Research into new services	1	3 to 5	10 to 12
TOTAL	3	7 to 13	18 to 27

Figure 9.7. A summary of the investment required to implement and support the Global Framework for Climate Services research activities.

9.6 RESOURCES FOR MANAGING THE FRAMEWORK

By far the bulk of the resources devoted to the Global Framework for Climate Services will come from the routine contribution of services and the participation of experts supported by governments and stakeholder organizations as part of their ongoing mandates and programmes. The tasks of implementing the Framework in the developing world will require support from development agencies and banks, particularly for the new initiatives we propose, and should also be supported by the country programmes of the United Nations System.

Nevertheless, the Framework will only succeed if it has a strong standing capability to lead and manage the functions of the Framework. This involves four main expenses: meetings of the governance group and its executive committee, support of technical committees, operation of a secretariat and the initiation of studies and projects. In broad terms, the costs of these might be as follows:

A meeting of an international governance group would cost approximately US\$ 250,000, of which US\$ 200,000 would be for developing country travel support. A management group, which might be comprised of around 20 people and meet at least twice each year, would require travel support of the order of US\$ 200,000 to 250,000 per year. Five technical Management Committees, each comprising up to 20 people and meeting once each year, would require US\$ 500,000 to 700,000. A secretariat with five professional officers and technical support would cost US\$ 2.5 M to 3.0 M per year. Tasks related to initiating and designing the projects we have proposed may require consultants and meeting expenses of US\$ 250,000 to 400,000 per year. These costs amount to between US\$ 3.25 M and 4.1 M per year in the two four-year financial periods (2014–2017 and 2018–2021), with start-up costs in the first two years (2012–2013) of around US\$ 2 M in 2012 rising to US\$ 3 M in the second year.

Figure 9.8 summarises all costs of implementing the Global Framework for Climate Services as estimated in this Chapter. These costs are small in comparison with current global expenditures on observations collection with, for example, the Global Climate Observing System estimate of current annual expenditures on the collection of climate observations of US\$ 5 to 7 B. The aim of the Framework is that a large net increase in global, regional and national capability to improve

climate-related decisions be achieved for a relatively small investment in increased global capacity. This leverage arises because of the existing capability that can be deployed to improve climate services in the most vulnerable communities.

9.7 TIMEFRAMES, PLANNING AND RESOURCING

The Taskforce notes that in May 2011 the World Meteorological Organization's 16th Congress will consider this Report and its recommendations and will make decisions on the next steps for the Framework. The Congress will also consider and approve the organization's budget for the next four-year financial period commencing on 1 January 2012. The seven months between the Congress and the commencement of the new financial period is a critical time during which the current high momentum should not be lost. We urge that this time should be used to develop quickly an implementation plan that aligns with the decisions of the Congress and incorporates the elements and principles developed in this report. To enable the preparation of this plan, the World Meteorological Organization would give secretariat support to a group of experts with specific terms of reference and a limited and clearly-defined timeframe for delivering the plan. These experts would be drawn from governments and United Nations agencies for this purpose.

THE TWO YEAR OUTLOOK

Immediately after the World Meteorological Organization Congress concludes its deliberations, the detailed planning for the Framework will need to commence. A detailed plan for the implementation of the Global Framework for Climate Services should include proposals for targets to be met over time and monitoring and evaluation procedures to track the progress of implementation of the Framework.

The secretariat to support the Framework will begin to take shape and the work will commence with United Nations System partners to begin to build the executive and executive committee structures.

Aggregate of capacity building fast track projects	Investment Required (US\$ x M)		
	2012–2013	2014–2017	2018–2021
Building the capacity of the User Interface Platform	1	21 to 34	21 to 34
Building national climate service capacity	1 to 2	53 to 64	50 to 60
Building climate centre capacity	1 to 2	76 to 90	80 to 94
Building observations capacity	1 to 2	80 to 100	28 to 40
Building research capacity	3	7 to 13	18 to 27
Implement a management capability supported by a United Nations-system-based secretariat	2 to 4	13 to 17	13 to 16
TOTAL	8 to 13	229 to 284	189 to 237

Figure 9.8. Estimated aggregate costs for implementation of the capacity building elements and secretariat support for Global Framework for Climate Services over the ten years commencing 1 January 2012.

A key structure will be the Capacity Building technical committee that will need to work closely with the secretariats of the participating agencies to put in place the fast-track projects to build climate service capacity in developing countries. This initial organization building phase should be completed by 31 December 2013, with fast-track projects entering their implementation phases.

THE SIX YEAR OUTLOOK

After six years of work, that is, by 31 December 2017, the Framework should have facilitated access to improved climate services throughout the world in at least four key areas; the Taskforce recommends that the water, health, disaster risk reduction and agriculture sectors be considered initially as the main candidates for high priority activities. The work of the Framework should closely involve at least five United Nations agencies or programmes, should have active technical committees in place that handle each of its five components (Capacity Building, Research and Development, Observations, Information Systems and the User Interface), should have an active communications programme to ensure that services are delivered effectively and should have participated in at least US\$ 150 M of climate-related development projects. Around September 2016, a mid-term review of the implementation of the Framework should be commenced. The terms of reference for this review should be prepared through an intergovernmental process and should evaluate, *inter alia*, the success of the Framework in adhering to its principles and in meeting the objectives and milestones laid out in this report.

THE TEN-YEAR OUTLOOK AND BEYOND

After ten years, that is, by 31 December 2021, the Framework should have facilitated access to improved climate services throughout the world and across all climate-sensitive sectors. Its work should closely involve at least eight United Nations agencies or programmes and it should have participated in at least US\$ 250 M of climate-related development projects that have been assessed as useful in meeting user needs.

Beyond 2021 it is expected that the secretariat will have matured to a size appropriate for the task it supports and that the level of project funding will be in proportion with the global community's assessment of the needs to be met by climate services and the benefits that will flow from these services. If the Framework has met its goals, all communities will have access to basic climate services and these services would reasonably be expected to be far superior to those that are available today.

FUNDING SOURCES

Resources for the Framework's secretariat would be expected to come from a combination of "in-kind" and financial contributions from within the United Nations System and from governments. The fast-track projects should be largely funded by capacity building investments from development banks, governments and private sector philanthropic donations. However, a degree of coordination and management support will come from the Framework secretariat.

9.8 RISK ASSESSMENT

Implementation of the Framework will require a detailed risk assessment carried out in conjunction with developing a timeline for undertaking key activities and projects. The risks associated with implementing the Framework fall broadly into the following categories:

- **Organizational complexity.** The Framework at the national level will require the involvement of many government agencies (including but not restricted to health, agriculture, water resources and disaster mitigation), while at the regional level it will seek support from a range of existing institutions and at the global level that of many United Nations agencies and programmes. Coordinating these cross-cutting interests in order to develop a sustainable, operational Framework will be a complex task with a degree of risk attached. To minimise risk, the initial implementation of the Framework should tackle a small number of key sectors and expand the range of operations over time on the basis of results and experience, doing so in ways that best manage the risks that complexity creates.
- **Leadership and management.** Leadership of the Framework must come from governments and the United Nations System. The United Nations will provide capable senior leaders to participate in the committees that direct the activities of the Framework. The Framework will also need a small, highly-skilled and committed secretariat. It is expected that the Framework will take around a decade to reach its full potential. The secretariat's initial task will be to develop a detailed implementation plan based on the recommendations of this Taskforce that is consistent with the decisions of the World Meteorological Organization Congress and with feedback from United Nations System partners. The Taskforce notes that there is strong government and United Nations System support for the Framework initiative and believes that building on this support in developing the leadership team will minimise the risk of poor leadership.
- **Resourcing.** The rate at which the Framework can grow to full potential will depend on resourcing levels. The resources necessary to support the Framework can be categorised in the following ways:

National contributions. Most nations are now committing resources to dealing with climate variability and change issues. Having a small part of these resources, including the expertise of key individuals, invested in engaging in regional and global processes coordinated through the Framework will provide substantial national returns. A risk for the endeavour is a low level of engagement at the national level, a risk that must be minimised by highlighting and then demonstrating the benefits of regional and international cooperation.

Regional contributions. Building capacity in climate service delivery is a key task for the Framework. It is clear to the Taskforce that skill development is needed across the sectors in all countries. As lessons are learned and best practices evolve in climate service creation and delivery, they must be transferred quickly to all countries. The world does not have time to learn the same climate service delivery lessons repeatedly, sector-by-sector and country-by-country. Regional institutions thus have a key role to play in capacity building. The risk of their non-engagement must be minimised by targeted programmes that strengthen and bring together regional institutions that can contribute to climate services.

- **Support for coordination.** The cost of generating a detailed implementation plan, the costs associated with bringing together a group to direct the Framework and the costs of supporting the technical committees necessary to put in place the sustainable Framework must all be met. Some resources will be drawn from the existing budgets of United Nations system agencies and programmes and some will necessarily be "new money". Strong government and United Nations system support will be necessary to minimise the risks associated with under-resourcing key management functions.
- **Support for High-priority Projects.** We are recommending that the Framework should successfully implement a number of high-priority projects in regions where climate services

are least-well-developed and most needed. These will be capacity building projects that engage users and providers and that are implemented with resources from aid agencies in partnership with expertise from climate centres currently delivering a range of climate services. Linking with United Nations agencies and programmes that already do related work will be essential to minimising the risk of failure, as will access to experienced project management capability through the Framework's committee on capacity building.

The ability of the Framework to address the matters listed above and to achieve success in improving everyone's access to climate services will be heavily dependent on the governance and management arrangements that are put in place. This issue is considered in detail in Chapter 10.

9.9 RECOMMENDATIONS

Recommendation 1: We, the High-Level Taskforce, unanimously recommend that the international community make the commitment to invest on the order of US\$ 75 M per year to put in place and sustain a Global Framework for Climate Services. This investment will build upon existing investments by governments in climate observation systems, research, and information management systems to return to the community benefits across all societal sectors but most importantly, and most immediately, in disaster risk reduction, improved water management, more productive and sustainable agriculture and better health outcomes in the most vulnerable communities in the developing world.

Recommendation 2: To ensure that the Global Framework for Climate Services provides the greatest benefit to those who need climate services the most we recommend that the following eight principles be adhered to in its implementation:

Principle 1: All countries will benefit, but priority shall go to building the capacity of climate-vulnerable developing countries

Principle 2: The primary goal of the Framework will be to ensure greater availability of, access to, and use of climate services for all countries

Principle 3: Framework activities will address three geographic domains; global, regional and national

Principle 4: Operational climate services will be the core element of the Framework

Principle 5: Climate information is primarily an international public good provided by governments, which will have a central role in its management through the Framework

Principle 6: The Framework will promote the free and open exchange of climate-relevant observational data while respecting national and international data policies

Principle 7: The role of the Framework will be to facilitate and strengthen, not to duplicate

Principle 8: The Framework will be built through user – provider partnerships that include all stakeholders

Recommendation 3: We recommend that the United Nations System establish, as a matter of urgency, an *ad-hoc* technical group to develop a detailed implementation plan for the Global Framework for Climate Services based upon the broad strategy outlined in this report, this plan to be endorsed by governments through an intergovernmental process prior to its implementation.

The detailed implementation plan should identify high priority projects to advance the Framework in areas where this would assist in reducing vulnerability to climate change and variability. In addition to the fast-track, capacity building projects, the implementation plan should describe a sustainable programme to underpin the coordination needed to maintain the operational capabilities of the Framework. The implementation plan should set targets to be achieved over the next ten years, further elaborate the roles and responsibilities of components of the Framework that contribute at the global, regional and national levels and of the secretariat that supports it, and include a risk assessment.

Recommendation 4: We strongly recommend that governments and development assistance agencies give high priority to supporting national capacity building that will allow developing countries to participate in the Framework. Further analysis of national needs is required, but in the meantime we recommend a number of fast track projects as outlined in above. To ensure effective national access to global climate information by the largest number of countries, we recommend an initial strategy to strengthen rapidly or create the regional elements of the Framework. These regional elements should be led and hosted by countries of the region based upon regional agreements and should be tasked with supporting information flow and assisting national capacity building at national level.

CHAPTER 10

GOVERNANCE ARRANGEMENTS

10.1 INTRODUCTION

In this Chapter, two options are proposed for the governance of the Global Framework for Climate Services. A governance mechanism is needed to provide high-level ownership and direction for implementing the Framework and for overseeing its ongoing planning and management, including monitoring and evaluation functions. It is also required as a key means of motivating international cooperative action across multiple sectors and organizational interests, which is a central challenge to the success of the Framework. It is also needed to mobilise and guide resources to the Framework from multiple funding sources. The governance mechanism will support essential normative functions such as developing technical standards, disseminating information, modelling cross-sector interaction and developing coherent advocacy messages.

The options proposed here are administratively modest, in line with the Framework's facilitation and coordination role, and seek to make full use of existing organizational mechanisms as far as possible. At the same time they are suitably sophisticated in order to deal with the Framework's complex organizational setting, the diverse needs of governments and major stakeholders and the high levels of scientific and technical expertise involved.

10.2 MAIN REQUIREMENTS AND CONSTRAINTS

The mechanism will require careful crafting in order to respect the role of governments, respect and strengthen organizations' mandates and clarify their roles and responsibilities in the Framework as well as maximise commitment and cooperative behaviour by all stakeholders. A good understanding of stakeholder motivations and capacities is thus required. The principal stakeholders are governments; international and regional organizations that are responsible for or represent climate-sensitive sectors or user constituencies; the World Meteorological Organization in particular, owing to its responsibility for existing climate data systems; and the relevant scientific communities.

Many governments have emphasised to us their expectation that governments will have a central role in the Framework's governance and implementation. We fully concur with this, given the international public good nature and public financing of most climate information and services, and we believe that to be successful the Framework must enjoy a high level of interest and support from governments. It is also important that the Framework be appropriately recognised in the international and national policies and programmes on climate change being developed by governments.

User interests should be strongly represented in the Framework's governance. A core challenge for the Framework will be to combine the concentrated and motivated interests of the meteorological world with the diverse and partial interests of the many relevant sectors and user interests. While meteorological (weather and climate) and climate (climate only) institutions are expected to provide the backbone of the Framework, the real achievements will only occur with the energetic and synergetic engagement of those who stand to benefit from the use of climate information. For this reason, special efforts will need to be made to involve user representatives and sector agencies at the highest levels of the Framework's governance and implementation.

We recognise that the Framework will not fit common organizational models such as those of government departments, research institutes or private businesses. The power of the Framework

will not come from electoral mandate or financial capital but from its capacity to convene relevant parties and to forge agreements between them that help each party to identify and achieve its own goals better. The requirement to motivate and obtain agreement and commitment is present at all levels of the Framework. We have heard from many governments, organizations and individuals and are confident that the Framework's organization can be developed by blending a range of models and mechanisms appropriately.

We are agreed that the United Nations System provides the right home for the Framework's governance and implementation. There are several reasons for this. The global scale of the climate issue, the linkages between climate variability and climate change and the role of climate in sustainable development all require international coordination. The central role of governments in the Framework naturally points to using existing multi-lateral mechanisms. Lastly, valuable synergies can be achieved by linking the Framework's activities closely to those of other United Nations System entities, particularly the major development and technical agencies, programmes and funds.

The governance mechanism should also reflect a number of common principles such as efficiency, transparency, accountability, flexibility, equitability and participation, etc., of course the most important requirement is that the mechanism should actually work well in practice. It must be able to facilitate the near-term implementation objectives of the Framework as well as shape and manage its long-term growth and evolution.

10.3 CRITERIA FOR SUCCESS

Establishing criteria for the success of the Framework is important for a number of reasons. This will set out realistic objectives for the organization and serve as a valuable management tool for measuring progress. In the event that progress is not up to expectations these criteria should lead inevitably to a review process to identify issues and options for remediation.

The first criterion for success must be that rules for a working structure are established. The Taskforce expects that within a year of approval by the World Meteorological Organization's Congress, the Framework's key management group will have met, have adopted an implementation plan and have agreed upon the technical committees that will implement the Framework under its guidance.

In the longer term the Framework will be measured by:

- its recognition by governments and the level of their tangible support for the Framework;
- its ability to build and sustain partnerships, particularly with United Nations agencies and programmes, stakeholders representing users, managers of observation and climate information systems, research and development organizations and regional and national climate institutions;
- the increase in the overall use of climate services and the impact of climate services provided under its auspices on planning and other decision making in target communities as confirmed by systematic surveys of user communities;
- the increase in climate data and information exchanged globally and regionally;

- the effectiveness of transitioning climate research outcomes into climate services as measured by the increase in the range of services available, including number and types of decision support tools and the reduction in the uncertainties associated with key climate products;
- its ability to undertake projects funded by aid agencies and other donors; and,
- its ability to attract the resources necessary to sustain its ongoing, long-term activities.

10.4 PROPOSED OPTIONS FOR GOVERNANCE

The Taskforce initially considered five options for governing and implementing the Framework:

- Creation of a new agency in the United Nations System
- Hosting within the mechanisms of an existing United Nations Systems entity
- Creation of a new intergovernmental board within the United Nations System
- A joint committee linked to the mechanisms of several interested United Nations Systems entities
- Creating a not-for-profit foundation outside of the United Nations System

After detailed consideration of these options, particularly of their ability to comply broadly with the requirements outlined above, the Taskforce concluded that two general options should be examined in more detail, the first based on an intergovernmental panel and the second based on a blend of hosting and joint participation by United Nations System entities. These two options are explored in more detail below.

The creation of a new United Nations agency was rejected by the Taskforce because of the likely political and financial hurdles involved and the time required to achieve such a result and because we felt the Framework did not require such a weighty approach. The not-for-profit foundation was rejected by the Taskforce principally because it could not easily provide the intergovernmental capabilities, universal membership and governmental linkages needed.

10.5 OPTION A. CREATE A NEW INTERGOVERNMENTAL BOARD WITHIN THE UNITED NATIONS SYSTEM

We envisage that such an intergovernmental board would be established initially under co-sponsorship of an interested United Nations agency, making use of its governing assembly for all formal intergovernmental decisions. We concur with the proposal of a number of countries that the World Meteorological Organization and its quadrennial intergovernmental Congress would be best suited for this sponsorship role and to act as channel of accountability.

Once in place, plenary sessions of the intergovernmental board, involving all interested governments, would meet periodically, probably annually, and would make decisions following the processes of the World Meteorological Organization Congress. This board would be open to membership of all

countries as well as having mechanisms to ensure the participation and advice of major stakeholders such as United Nations entities and relevant technical organizations. It would elect a chair and a small executive committee to conduct the affairs of the board between sessions as well as creating a number of subsidiary technical management committees (including the User Interface Platform) to oversee and contribute to the Framework's implementation work. We suggest that, for reasons of simplicity and to emphasise the intended result rather than the mechanism, the board be named the Intergovernmental Board on Climate Services instead of the Intergovernmental Board on the Global Framework for Climate Services.

We propose that there be a high level technical management committee for each of the five major elements of the Framework (see Figure 9.1) that would meet inter-governmentally. The management Committees would be comprised of representatives of major stakeholders (providers and users), based on technical competence and equitable international representation, and the chairs of these committees would be ex-officio members of the executive committee. If other international committees with similar roles exist, efforts would be made to co-opt these committees to serve the needs of the Framework. Figure 10.1 provides a schematic representation of our model for the intergovernmental board.

There would be a small secretariat based in a United Nations agency (indicated as agency "A" in Figure 10.1) to support the work of the intergovernmental board and its committees. The head of the secretariat would be accountable to the chair of the board for all strategic and work programme matters and to the hosting agency for local administrative and fiduciary matters. The Taskforce believes that the World Meteorological Organization is the best equipped organization to host the secretariat.

EXISTING RELEVANT MODELS

In identifying this option, the Taskforce was mindful of the governance arrangements of the Intergovernmental Panel on Climate Change, which has been the key voice for science in the global climate change debate for several decades and has succeeded in motivating and coordinating a vast voluntary cooperative effort to generate very significant policy guidance products.

We recognise that the tasks of the Global Framework for Climate Services, being focused primarily on operations and development activities, are quite different from those of the Intergovernmental Panel on Climate Change, yet there are nevertheless significant parallels in terms of stakeholders and governance requirements. We also understand that, as a result of recent discussions surrounding the Intergovernmental Panel on Climate Change, its secretariat is likely to be strengthened to increase the transparency of its operations. If the option of a board is chosen for the Framework, we would recommend that the lessons learnt from the recent reviews of the Intergovernmental Panel on Climate Change be taken into account, particularly when developing its working procedures.

Another model to draw lessons from is the Intergovernmental Oceanographic Commission, which is administratively hosted by the United Nations Educational Scientific and Cultural Organization. Its role is to promote international cooperation and to coordinate programmes in marine research, services, observation systems, hazard mitigation and related capacity development in order to learn more about the nature and resources of oceans and coastal areas and manage them better.

The Group on Earth Observations, which coordinates the Global Earth Observation System of Systems, is also relevant as a model that combines the interests of governments and major agencies in a voluntary partnership to develop new projects and coordinate their strategies

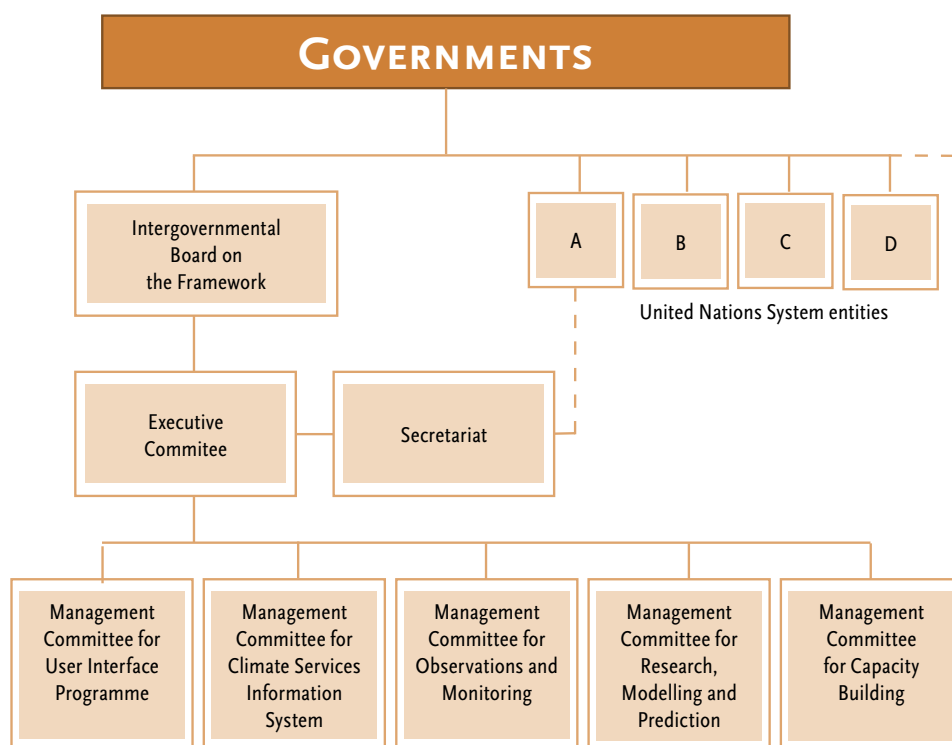


Figure 10.1. Schematic representation of Option A, for an intergovernmental board.

and investments. As of October 2010, its members include 85 governments and the European Commission as well as 61 intergovernmental, international and regional organizations that have been formally recognized as participating organizations.

LINKAGES WITH EXISTING MECHANISMS

The working arrangements of the Framework's board would need to make good use of the various existing committees and mechanisms of the United Nations System to avoid duplication of efforts. In particular, it would be opportune for the board's Management Committee on Observations and Monitoring to be headed by the chair of the Global Climate Observing System's Steering Committee and to have common or overlapping membership. Similarly, the management committee on Research, Modelling and Prediction could be linked to the Joint Scientific Committee of the World Climate Research Programme, while the management committee on the Climate Services Information System could be linked to the World Meteorological Organization's Inter-commission Task Team on its World Meteorological Organization Information System. Other relevant committees include those of the various World Meteorological Organization Commissions, particularly those for Climatology, Agricultural Meteorology and Hydrology as well as the Joint Technical Commission for Oceanography and Marine Meteorology and the thematic committees of the Group on Earth Observations. Further exploration is needed to ensure that the Framework committees are similarly well-linked to the relevant bodies in United Nations System organizations concerned with development, food security, health, etc. The management committee on Capacity Development would benefit from the leadership of a development organization such as the United Nations Development Programme for example. We would expect that the management committee on the User Interface Programme would need to develop a federated approach with subcommittees for at least the sectors that are chosen as priorities for the Framework's work programme.

The secretariat would support the chair of the board and the chairs of management committees to organise meetings, distribute information, keep records, maintain correspondence, produce reports and publications and undertake communications activities. It would consist of a director-level officer as head, along with senior officers for each of the five management committees as well as support staff for administration and communications. The secretariat's hosting agency would provide necessary office space, computer systems and administrative support.

FEATURES OF OPTION A

The main advantages of Option A are that the Framework would have a clear and independent realm of responsibility, direct accountability to governments, potentially strong involvement of national technical experts (often as the representatives of governments) and the independence and high profile that would help secure good access to United Nations System entities and processes. Having the reporting line of the intergovernmental board operate through an existing intergovernmental assembly avoids the need for a new political level body and thus allows the board to concentrate on the more technical matters of intergovernmental interest that are specific to the Framework. It also offers better possibilities for the formal involvement of United Nations entities and non-governmental stakeholders in the work of the Board. Since the board's technical committees would meet intergovernmentally, there would be a strong capacity to combine technical and governmental interests and to guide and make commitments on resources for an international operational system. This is a feature of some existing intergovernmental mechanisms such as the Joint Technical Commission for Oceanography and Marine Meteorology, an organization that has been proposed as a good model for the Framework.

We do note that the option of an intergovernmental board would require governments to devote additional energy to a new intergovernmental mechanism and need additional resources to maintain the necessary formal processes, particularly to ensure the participation of developing countries. One lesson learned from the experiences of the Intergovernmental Panel on Climate Change is that there is a need to have in place a clear set of operating procedures at the outset in order to ensure the transparency of the operation and the efficiency of processes. Preparing and approving such documentation in advance of launching the implementation actions for the operational components of the Global Framework for Climate Services would extend the time frames for implementation compared with using existing United Nations mechanisms.

Engaging the user community would happen at a number of levels. At the technical level, each of the technical committees would interact with the User Interface Platform and involve key stakeholders from the user communities in their deliberations. At the level of leadership and management, governments may also choose to nominate key stakeholders from the user communities to participate in the Framework's intergovernmental processes.

10.6 OPTION B. DEVELOP A JOINT BOARD WITHIN THE UNITED NATIONS, HOSTED AND CONVENED BY AN EXISTING AGENCY

In this option, illustrated in Figure 10.2, a joint board of relevant United Nations System entities (agencies, organizations, programmes, departments and independent funds) would be created to provide leadership and direction for the Framework. The role of governments in this case would be exercised through the existing intergovernmental assemblies of these entities, via the introduction of specific agenda items concerning the Framework. The officers of the participating entities would then represent the decisions of their assemblies in the deliberations of the joint board. The expression

“joint board” is proposed here to emphasise that its overall role is to set joint policy rather than manage detailed implementation.

The joint board would be convened by the head of a United Nations agency acting on behalf of the United Nations System and reporting regularly to the United Nations Chief Executives Board. The convening agency should also host the secretariat. The joint board would be open to participation of all United Nations System entities when meeting in plenary, which we suggest should occur on an annual basis. The supreme bodies of interested United Nations agencies and programmes would provide the membership of the joint board. The joint board would be tasked with overseeing the implementation and operation of the Framework. The executive committee would approve work programmes and budgets, and each member would ensure that appropriate endorsements and resources were in hand from its organization. The executive committee would elect its own chair. Management committees to oversee and contribute to the work of the Framework’s five elements and a secretariat would be established as already described above for Option A. Innovative consultation mechanisms would need to be developed to ensure the active engagement of governmental technical experts and non-governmental stakeholders in the work of the joint board.

Close cooperation, combined with a degree of joint management involving relevant intergovernmental agencies (possibly through the Executive committee and the technical Management Committees), would also be critical. The work of intergovernmental organizations in the sphere of development, health, environment and disaster management, to name just a few climate-sensitive sectors, will find services increasingly important in day-to-day operations and in longer term planning. Such inter-

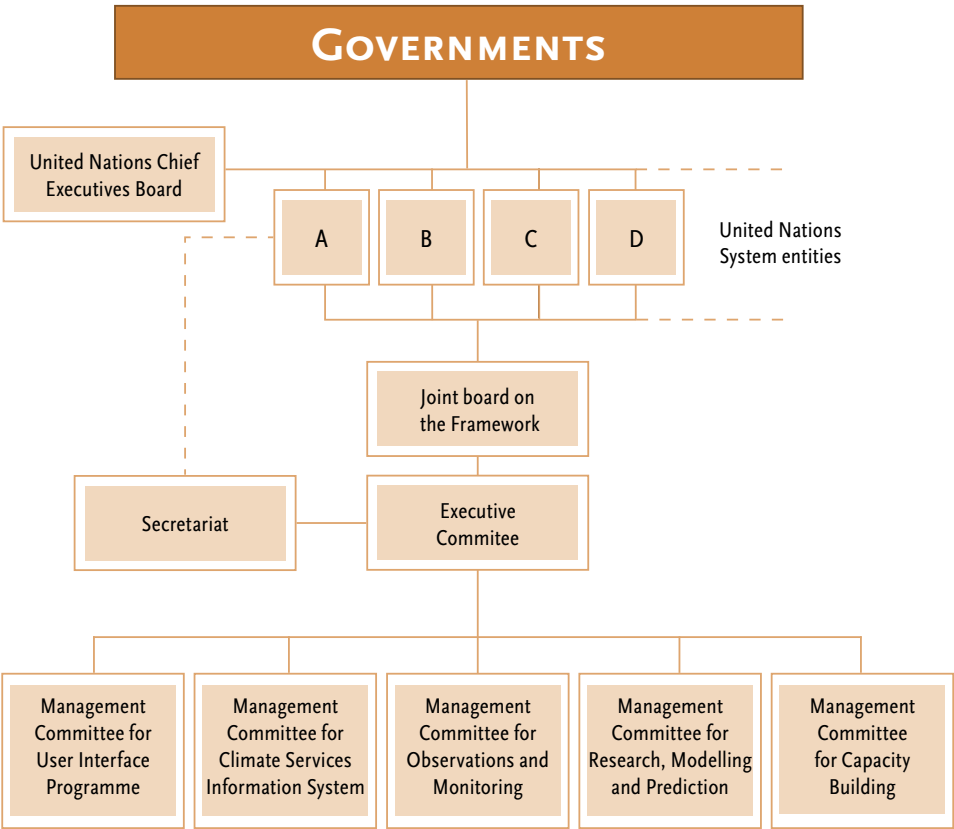


Figure 10.2. Schematic representation of Option B, the United Nations-led option for implementing the Global Framework for Climate Services.

agency collaboration would also be an essential vehicle for assuring broader access and capacity for using the climate services and products facilitated through the Framework.

RELATED COORDINATING MECHANISMS IN UNITED NATIONS

Possible models for this option currently exist in the United Nations System, notably in the form of United Nations Water, United Nations Energy and the United Nations International Strategy for Disaster Reduction, though none of these has the operational requirements of the Framework. Each has a small secretariat and undertakes limited programmes devoted to advocacy, coordination and policy development. None of these coordination bodies has any significant operational mandate; this remains the prerogative of the member organizations.

United Nations Water, for example, aims to coordinate policy and programmes related to water access, management, quality and risks. It meets twice a year, the meetings comprised of senior programme officers of the 27 member organizations. About 20 civil society organizations are affiliated partners and participate in open and consultative parts of United Nations Water meetings. A standing chair is elected on a rotating basis and holds office for several years. Outputs of United Nations Water, generated largely by groups of its members, include the three-yearly World Water Development Report, specialised reports such as on gender perspectives on water resources and sanitation, and an advocacy brief on the pivotal role of water in climate change adaptation. The United Nations International Strategy for Disaster Reduction is a larger and more independent entity, headed by a Special Representative of the United Nations Secretary-General and reporting through him to the United Nations General Assembly. It also convenes a biennial Global Platform for Disaster Risk Reduction, which is comprised of government technical representatives and leaders of relevant civil society organizations. This novel arrangement aims to share knowledge, make assessments and provide directions for strategy and priorities in disaster risk reduction.

The United Nations Chief Executives Board, which meets twice each year under the chairmanship of the United Nations Secretary-General, acts as a clearing house and coordinating mechanism across the United Nations System. It considers overarching and strategic issues, such as meeting the challenge of the United Nations to “deliver as one” to its member governments, and the challenges of supporting states in their responses to climate change. The Board has been kept informed of the development of the Global Framework for Climate Services and would provide a natural focus for high-level United Nations System commitment in the future.

FEATURES OF OPTION B

Option B has many similarities to Option A. The main difference is that the Framework’s driving forces are more firmly located in the United Nations and in its technical agencies. The option can be implemented quickly and can immediately engage the many mechanisms of the United Nations System, particularly at programme levels. Likewise, the financial requirements for governance and management are likely to be lower.

However, there would be significant challenges and overheads, firstly to bring the needs of the Framework onto the heavy agendas of numerous United Nations System entities and secondly to obtain coherent and timely government direction from the many disparate intergovernmental processes concerned. This would put greater responsibility on the key officers of the Framework to set its policy directions independently. Much would depend on the nature of the leadership of the joint board and its convenor. We use the term “convenor” to emphasise the facilitating role involved and the need to promote leadership, commitment and teamwork across the joint board and the executive committee.

The User Interface Platform will have a particularly critical role in establishing credible mechanisms for engaging non-United Nations stakeholder organizations in the governance arrangements, while governments will have to involve user community representatives along with those from the provider agencies in their Framework-related processes.

The Taskforce believes that, in this early stage of the Framework's development, the World Meteorological Organization would be best placed to convene the joint board at the level of the Secretary General and that it should also host the secretariat. As in Option A, the head of the secretariat would have dual lines of responsibility, e.g., to the chair of the executive committee for all strategic and work programme matters and to the head of the hosting agency for local administrative and fiduciary matters. We would propose that the members of the joint board, and particularly the agency members of the executive committee, should provide significant support to the secretariat, including through secondments and cash contributions.

Finally, the Taskforce notes that in order to put the Framework in place rapidly it may be necessary to launch it with an Option B arrangement, with provision in its founding documents for it to be transformed into an Option A-type organization if governments feel this is necessary.

10.7 SUMMARY POINTS

The Taskforce has endeavoured to create viable governance mechanisms for both of the two options presented above. In the long run at least, Option A would provide the best basis for driving the design and implementation of a truly effective and sustainable Global Framework for Climate Services. Climate impacts are a growing concern, and the problem merits the higher level of government engagement that would accompany the establishment of an intergovernmental board. Furthermore, there remains considerable opportunity for the United Nations System to develop and use mechanisms similar to those described in Option B to support the Framework, irrespective of the choice of approach to governance. Certainly the strong engagement and support of the United Nations System would be especially useful during the preliminary phase that would be required to debate, design and put into place the intergovernmental board, should this or another similar formal mechanism be chosen. Finally, there remains the opportunity to take some elements of Option B into an Option A arrangement, for example, the joint board.

10.8 RECOMMENDATION

Recommendation 5: The Taskforce is unanimous in recommending the following two options be considered for governance of the Framework:

- a) An Intergovernmental Board on Climate Services would be established to provide leadership and direction for the Framework. It would report to the World Meteorological Organization Congress. The Board would be open to membership of all countries and would meet in plenary session periodically, probably annually. It would develop formal mechanisms to engage the United Nations and other stakeholders in its work. It would elect a chair and a small executive committee to conduct the affairs of the board between sessions as well as designating a number of technical management committees to oversee and contribute to the Framework's implementation work. These technical committees would work intergovernmentally and where possible would be based on relevant existing international committees.

- b) A joint board of relevant United Nations System entities (agencies, organizations, programmes, departments and independent funds) would be created to provide leadership and direction for the Framework. The United Nations System joint board would report regularly to the United Nations Chief Executives Board as well as to governments through the plenaries of the sponsoring United Nations agencies and programmes. The Joint Board would establish an executive committee and five technical management committees to implement and manage the Framework, the technical committees working intergovernmentally. Mechanisms to engage non-United Nations stakeholders in the work of the Board would be developed through both the User Interface Programme and, up to the level desired by governments, through participation in national delegations.

The Taskforce recommends that Option A be adopted and that the Secretary General of World Meteorological Organization convene the first intergovernmental plenary meeting of the Global Framework for Climate Services by the end of 2011. World Meteorological Organization should lead the process and put in place arrangements to ensure full participation of all interested United Nations agencies and programmes.

ANNEX I

TERMS OF REFERENCE FOR THE GLOBAL FRAMEWORK FOR CLIMATE SERVICES

PREAMBLE

The High-level Declaration adopted by the World Climate Conference-3 decided to establish a Global Framework for Climate Services to strengthen the production, availability, delivery and application of science-based climate prediction and services. The Declaration requested the Secretary-General of the World Meteorological Organization to convene an Intergovernmental Meeting of Member States of WMO to approve the terms of reference and to endorse the composition of a High-level Taskforce of independent advisers. The Declaration further decided that the taskforce should prepare a report, including recommendations for proposed elements of the Global Framework for Climate Services as well as for the next steps to develop and implement the Global Framework for Climate Services.

SCOPE OF WORK

The High-level Taskforce will undertake its work in accordance with the WCC-3 Declaration and will:

1. Develop the components of the Global Framework for Climate Services and define the roles, responsibilities, and capabilities of the elements within the Global Framework for Climate Services and clearly illustrate how it will assist the integration of climate information and services into national planning, policy and programmes for, among others, water resource management and development, health and public safety, energy generation and distribution, agriculture and food security, land and forestry management, desertification, ecosystem protection, sustainable development, and poverty reduction, taking into account the special needs of Africa, Small Island Developing States, Least Developed Countries, and Landlocked Developing Countries;
2. Develop options for governance of the Global Framework for Climate Services, ensuring its intergovernmental nature, and provide the reasoning for the preferred option(s);
3. Outline a plan for implementation of the Global Framework for Climate Services, which includes:
 - Ensuring the central role of national governments;
 - Proposing a range of options for immediate and longer-term actions to realize the Global Framework for Climate Services;
 - Specifying measurable indicators, with timelines, for the actions necessary to implement the elements of the Global Framework for Climate Services;
 - Estimates of costs of implementation of these options, with clear indications of the financial resources and enhanced technological capabilities required, and their likely sources, to ensure effective global implementation; and,
 - A strategy for capacity-building in developing countries, particularly African countries, Least Developed Countries, Small Island Countries and Landlocked Developing Countries;
4. Make findings and propose next steps in relation to:
 - i. The role of the UN System and other relevant stakeholders, as well as the mechanisms for their contributions;

- ii. Approaches to global data policy (addressing data gaps, ownership, data protection, confidentiality, exchange, applications and usage) that would lead to enhanced capability of the Global Framework for Climate Services, taking into account Resolution 40 of the Twelfth WMO Congress and Resolution 25 of the Thirteenth WMO Congress;
 - iii. Improving systematic in situ observations and monitoring of climate especially in data-sparse areas, in order to increase data availability, including for research and prediction;
 - iv. Approaches for reviewing the implementation of the Global Framework for Climate Services;
 - v. Strategies for building capacity in developing countries in accordance with their needs and priorities, including their access to output of global and regional climate models and the underlying technology embedded in the models, and their ability to independently develop/improve in-country climate services capacity;
 - vi. A strategy for promoting a common global understanding of the Global Framework for Climate Services and for coherent and coordinated messaging and information sharing;
5. Determine its own rules of procedure with consensus on the guiding principle for decision taking;
 6. Be open and transparent in its functioning, making publicly available, including through the WMO Website, the following:
 - A report of each meeting held, including a list of participants;
 - Any submissions received; and,
 - Any “White Papers” generated as a part of its research activities.

SUPPORT FOR THE TASKFORCE

Secretariat support will be provided by the World Meteorological Organization, which will host its secretariat and seek funding and other support for its work.

ANNEX II

GLOSSARY

Adaptation: The process or outcome of a process that leads to a reduction in harm or risk of harm, or a realisation of benefits associated with climate variability and climate change.

Capacity building: The process by which people, organisations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems, and the wider social and cultural enabling environment.

Climate: Climate is typically defined as the average weather over a period of time. The quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense, is the state of the climate system, including its statistical description. For the purposes of this report, we have used the term climate to represent time periods of months or longer.

Climate change: Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. The Intergovernmental Panel on Climate Change uses a relatively broad definition of climate change that is considered to mean an identifiable and statistical change in the state of the climate which persists for an extended period of time. This change may result from internal processes within the climate system or from external processes. These external processes (or forcing) could be natural, for example volcanoes, or caused by the activities of people, for example emissions of greenhouse gases or changes in land use. Other bodies, notably the United Nations Framework Convention on Climate Change, define climate change slightly differently. The United Nations Framework Convention on Climate Change makes a distinction between climate change that is directly attributable to human activities and climate variability that is attributable to natural causes. For the purposes of this report, either definition may be suitable, depending on the context.

Climate change projection: A projection of the response of the climate system to emission scenarios of greenhouse gases and aerosols, or radiative forcing scenarios based upon climate model simulations and past observations. Climate change projections are expressed as departures from a baseline climatology, for example, that future average daily temperature in the summer will be 2°C warmer for a given location, time period and emissions scenario.

Climate model: A simplified mathematical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedbacks between them.

Climate product: A climate product is a management tool for all climate data which allows access to useful climate information that is suited to particular needs of the end-users as well as practical guidance on how they can use it. It encompasses a range of activities that deal with generating and providing information based on past, present and future climate and on its impacts on natural and human systems.

Climate service: Climate information prepared and delivered to meet a user's needs.

Climate variability: Climate variability refers to variations in the mean state and other statistics relating to the climate on all temporal and spatial scales beyond that of individual weather events. Climate can and does vary quite naturally, regardless of any human influence. Natural climate variability arises as a result of internal process with the climate system or because of variations in natural forcing such as solar activity.

Disaster: A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources. A disaster is a function of the risk process.

It results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk.

Disaster risk reduction (disaster reduction): The conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development.

Downscaling: The process of reducing coarse spatial scale model output to smaller (more detailed) scales.

Ensemble: A set of simulations (each one an ensemble member) made by either adjusting parameters within plausible limits in the model, or starting the model from different initial conditions. While many parameters are constrained by observations, some are subject to considerable uncertainty. The best way to investigate this uncertainty is to run an ensemble experiment in which each relevant parameter combination is investigated. This is known as a perturbed physics ensemble.

External climate forcing: One component of the Earth's natural climatic variability, is that due to external variability factors, which arise from processes external to the climate system, chiefly, volcanic eruptions and variations in the amount of energy radiated by the sun.

Extreme weather and climate events: Extreme events refer to phenomena such as floods, droughts and storms, that are at the extremes of, or beyond, the historical distribution of such events.

Forecast: Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area. Generally used in reference to weather forecasts, and hence to weather a week or so ahead.

General Circulation Model: A General Circulation Model, or sometimes called a global climate model, is a mathematical model of the general circulation of the planet's atmosphere or oceans based on mathematic equations that represent physical processes. These equations are the basis for complex computer programs commonly used for simulating the atmosphere or oceans of the Earth. General Circulation Models are widely applied for weather forecasting, understanding the climate, and projecting climate change.

Greenhouse gas: A gas within the atmosphere which absorbs and emits energy radiated by the Earth. Carbon dioxide is the most important greenhouse gas being emitted by humans.

Hazard: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Mitigation: Action taken to reduce the impact of human activity on the climate system, primarily through reducing net greenhouse gas emissions.

Observation: Observation, or observed data, refers to any information which has been directly measured. In climatology, this means measurements of climate variables such as temperature and precipitation.

Outlook: A term referring to a scenario of climatic and economic and social conditions over a coming season or two, usually developed by consensus among a group of experts and mainly used in the context of Regional Climate Outlook Forums.

Prediction: The main term used for estimates of future climatic conditions over a range of about a month to a year ahead.

Probability: Probability is a way of expressing knowledge or belief that an event will occur, and is a concept most people are familiar with in everyday life. Probabilistic climate projections are projections of future absolute climate that assign a probability level to different climate outcomes.

Projection: A Projection is an estimate of future climate decades ahead consistent with a particular scenario. The scenario may include assumptions regarding elements such as: future economic development, population growth, technological innovation, future emissions of greenhouse gases and other pollutants into the atmosphere, and other factors.

Regional Climate Model: A regional climate model is a climate model of higher resolution than a global climate model. It can be nested within a global model to provide more detailed simulations for a particular location.

Risk: Risk is conventionally defined as the combination of the likelihood of an occurrence of an event or exposure(s) and the severity of injury or cost that can be caused by the event or exposure(s). Understanding the risks and thresholds, including uncertainties, associated with climate is one principle of good adaptation.

Risk management: The systematic approach and practice of managing uncertainty to minimize potential harm and loss. Risk management comprises risk assessment and analysis, and the implementation of strategies and specific actions to control, reduce and transfer risks. It is widely practiced by organizations to minimise risk in investment decisions and to address operational risks such as those of business disruption, production failure, environmental damage, social impacts and damage from fire and natural hazards. Risk management is a core issue for sectors such as water supply, energy and agriculture whose production is directly affected by extremes of weather and climate.

Sea level rise: Sea level rise can be described and projected in terms of absolute sea level rise or relative sea level rise. Increasing temperatures result in sea level rise by the thermal expansion of water and through the addition of water to the oceans from the melting of ice sheets. There is considerable uncertainty about the rate of future ice sheet melt and its contribution to sea level rise.

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Uncertainty: Uncertainty refers to a state of having limited knowledge. Uncertainty can result from lack of information or from disagreement over what is known or even knowable. Uncertainty may arise from many sources, such as quantifiable errors in data, or uncertain projections of human behaviour. Uncertainty can be represented by quantitative measures or by qualitative statements. Uncertainty in climate change projections is a major problem for those planning to adapt to a changing climate. Uncertainty in projections of future climate change arises from three principal causes: natural climate variability; modelling uncertainty, referring to an incomplete understanding of Earth system processes and their imperfect representation in climate models; and uncertainty in future emissions.

Variable: The name given to measurements such as temperature, precipitation, etc. (climate variables), sea level rise, salinity, etc. (marine variables) and cooling degree days, days of air frost, etc. (derived variables).

Vulnerability: Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function

of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. Vulnerability to climate change refers to the propensity of human and ecological systems to suffer harm and their ability to respond to stresses imposed as a result of climate change effects. The vulnerability of a society is influenced by its development path, physical exposures, the distribution of resources, prior stresses and social and government institutions. All societies have inherent abilities to deal with certain variations in climate, yet adaptive capacities are unevenly distributed, both across countries and within societies. The poor and marginalised have historically been most at risk, and are most vulnerable to the impacts of climate change.

Weather: The state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity and barometric pressure.

ANNEX III

BIOGRAPHIES OF THE TASKFORCE MEMBERS

Co-chair Mahmoud Abu-Zeid, (Egypt)

is a Water Management expert who has held the position of Minister of Water Resources and Irrigation in government of Egypt from 1997–2009. Earlier he served as the President of the National Water Research Centre, Egypt. With a doctorate in groundwater engineering from the University of California, USA, he has long international experience in teaching and research. He is presently the president of the Arab Water Council, having spearheaded the World Water Council, an International multi-stakeholder platform from its inception in 1996 till 2003 and continues to be its Honorary President. Fellow of Economic Development Institute, the World Bank. He is also on the UN Secretary Generals' Advisory Board on Water and Sanitation (UNSGAB). He was the chairman of Governing Council of the African Water Facility from 2005–2009. Mr Abu-Zeid has been awarded many prestigious national and international prizes including a Medal of the Republic of First Order, the King Hassan II Great World Water Prize (2003) and American Society for Irrigation and Drainage Award, 1996.

Co-chair Jan Egeland (Norway)

is an Executive Director of the Norwegian Institute of International Affairs and Associate Professor at the University of Stavanger. Mr Egeland was the UN Under Secretary-General for Humanitarian Affairs and Emergency Relief Coordinator from June 2003 to December 2006. During 30 years of humanitarian experience through the United Nations, the International Red Cross and Red Crescent, the Norwegian Governments and NGOs he has visited or worked in more than 100 countries, drawing international attention to humanitarian and environmental disasters. In 2005, he initiated the global humanitarian reforms that lead to the successful UN Central Emergency Response Fund with contributions from 115 UN member states. It also resulted in more predictable international response capacity as UN agencies, governments and NGOs now work through thematic clusters. Mr Egeland has been Special Adviser to the UN Secretary General for Conflict Prevention and Resolution (2006–2008) and for International Assistance to Colombia (1999–2001). He was Secretary-General of the Norwegian Red Cross (2002–2003). From 1990–1997, he was State Secretary in the Norwegian Ministry of Foreign Affairs. Mr Egeland holds a Magister in Political Science from the University of Oslo. He has published extensively and received a number of awards for his work on humanitarian and conflict resolution issues. In 2008 he published “A Billion Lives – An Eyewitness Report from the Frontlines of Humanity”.

Joaquim Alberto Chissano (Mozambique)

served as the second President of Mozambique for 19 years from 6 November 1986 until 2 February 2005. He studied medicine in Portugal. In 1962, he joined the Mozambique Liberation Front (FRELIMO) as a founding Member. In 1974, he took office as Prime Minister of the Transition Government that led Mozambique to the proclamation of its National Independence. In 1975, Mr Chissano was appointed Minister of Foreign Affairs. As Head of State, Mr Chissano successfully led the deep socio-economic reforms in the country, which culminated with the adoption of the 1990 Constitution that led Mozambique to the multi-party system and to an open market. Mr Chissano occupied high posts in several international organizations, including Chairperson of the Community of Portuguese Speaking Countries (CPLP); Chairperson of the Southern African Development Community (SADC); Chairperson of the SADC Organ for Cooperation in the fields of Politics, Defence and Security; and Chairperson of the African Union. After retiring from office, he was appointed by Kofi Annan in 2005

Envoy of the UN Secretary-General for the September 2005 Summit to Review the Implementation of the Millennium Declaration, as well as Special Envoy of the UN Secretary-General to Guinea-Bissau. He is member of the Club of Madrid, The Hunger Project (Board of Directors) and the Nelson Mandela Institution (for Science and Technology). Currently, he is the Chairperson of the Joaquim Chissano Foundation and of the Africa Forum of Former African Heads of State and Government.

Angus Friday (Grenada)

was Permanent Representative of Grenada to the United Nations and Chairman of the Alliance of Small Island States (AOSIS) from 2007 to 2009. Mr Friday was Director and Managing Director of Glenelg Spring Water Inc., in Grenada, which he joined in 1997, as well as Chief Executive of Atlantean Inc. in Grenada, an economic development consultancy firm he founded in 2001. In 2006, Mr Friday developed a finance strategy for Grenada's National Export Strategy. The same year, he was appointed Chairman of the Garden Group, Deputy Chairman of the Grenada Board of Tourism and Director of Petro Caribe Grenada Ltd. From 1997 to 2001, he was Chief Executive of IntegriSys Ltd., a medical informatics company employing internet-related technologies, which he founded. From 1995 to 1997, he was Managing Director of Health Systems Integrated Ltd., a medical technology company he co-founded, which established the first National Health Service intranet. From 1993 to 1995, Mr Friday was a healthcare relations physician for pharmaceutical firm Merck & Company in the United Kingdom, where he set up national "multi-fund" groups with leading United Kingdom general practitioners. Mr Friday holds a Doctor of Medicine degree from the St. George's University School of Medicine in Grenada and a Master of Business Administration degree from the Strathclyde Graduate Business School in Scotland. Mr Friday is currently consultant with the World Bank.

Ricardo Froilán Lagos Escobar (Chile)

is a lawyer, economist and social democrat politician, who served as president of Chile from 2000 to 2006. His presidency was characterized by improvements in the country's infrastructure, the creation of unemployment insurance, a health programme guaranteeing coverage for a number of medical conditions, the 'Chile Barrio' housing programme, extending compulsory schooling to 12 years, the signing of a revamped constitution. After his presidency in 2006, Mr Lagos established a foundation in Santiago called Democracia y Desarrollo (Democracy and Development). From 2006 to 2008, Mr Lagos was President of the Club of Madrid, an organization of 66 former heads of state and government created to strengthen democracy across the world. He co-chaired the Inter-American Dialogue's Board of Directors. Since May 2007, he has been a Special Envoy of the United Nations Secretary-General on Climate Change. He also currently teaches political and economic development at Brown University in the United States of America.

Eugenia Kalnay (Argentina/USA)

is a leader in the field of global numerical weather and climate prediction and analysis, including data assimilation and ensemble forecasting. She was awarded in 2009 the fifty-fourth International Meteorological Organization Prize, the most prestigious international prize in meteorology and climatology. Ms Kalnay received her undergraduate degree in 1965 from the University of Buenos Aires, Argentina. She became the first woman to obtain a PhD in meteorology from the Massachusetts

Institute of Technology in 1971 and the first female professor in the Department of Meteorology there. Ms Kalnay is the author of several publications and has received a number of awards, including the NASA gold medal for Exceptional Scientific Achievement (1981), the American Meteorological Society Jule G. Charney Award (1995) and the First Eugenia Brin Professorship in Data Assimilation (2008). She is a member of the US National Academy of Engineering. Ms Kalnay is currently Distinguished University Professor in the Department of Atmospheric and Oceanic Science at the University of Maryland (USA).

Fiaame Naomi Mata'afa (Samoa)

is a Samoan high chief and a senior member of Cabinet in Samoa. She is one of the longest standing Members of Parliament for the electoral constituency of Lotofaga in the political district of Atua. For over 30 years, Fiaame Mata'afa has worked on, and been a role model for, promoting and advocating socio-economic and political equality for women and girls in Samoa, through her NGO involvement and her role as politician and Minister of Education. She was Minister of Education for 15 years (three terms). She is the current Minister of Women, Community & Social Development in Samoa. She is the Pro Chancellor of the University of the South Pacific and is a former Executive Board Member of UNESCO and the Commonwealth of Learning. She studied political science at Victoria University, Wellington, New Zealand. She was a former President of the Samoa Young Women's Christian Association YWCA and an Executive Board Member of the World YWCA. She is currently the President of the Samoa National Council of Women and Chairperson of the Inailau Women's Leadership Network.

Julia Marton-Lefèvre (Hungary/France/USA)

is Director General of the World Conservation Union (IUCN), which brings together governments, NGOs and scientists in a unique world partnership of over 1 000 members across the globe. Prior positions have included Rector of the UN-mandated University for Peace, Executive Director of LEAD International and Executive Director of the International Council for Science (ICSU). She is a member of the Board of Directors of the International Institute for Environment and Development, the Board of Trustees of the Bibliotheca Alexandrina, the Council of UPEACE and of the Earth Charter. Prior board memberships have included the World Resources Institute, International Research Institute for Climate and Society, the International Advisory Board to the Lemelson Foundation, environmental advisory boards to the Dow Chemical Company and to The Coca-Cola Company and to the China Council for International Cooperation in Environment and Development. She has also served on ICSU's Committee on Science and Technology in Developing Countries (COSTED); the InterAcademy Council's Panel on Promoting Worldwide Science and Technology Capacities for the 21st Century. Ms Marton-Lefèvre was a member of the International Organizing Committee for the Second World Climate Conference. She was active contributor to the process of the establishment of the WCRP and GCOS.

Khotso Mokhele (South Africa)

is non-executive Chairman of the Board of Directors of Impala Platinum Holdings Ltd (Implats) since 2004. In addition, he is non-executive Chairman of the Board of Directors of Adcock Ingram Holdings Ltd., African Oxygen Ltd., Zimbabwe Platinum Holdings Ltd., and Tiger Brands Ltd. Mr Mokhele

obtained his B.Sc. in agriculture at the University of Fort Hare, South Africa, and his M.Sc in food science and PhD in microbiology at the University of California in the United States. He also completed the Stanford Executive Programme at Stanford University's Graduate School of Business. Mr Mokhele was Vice-President for Scientific Planning and Review at ICSU (2005–2008) and Chairperson of ICSU Committee for Scientific Planning and Review (2005–2009). He was Founder President and CEO of the National Research Foundation (1999–2006), Vice-President and then President and CEO of the Foundation for Research Development (1992–1999), Founder President of the Academy of Science of South Africa (1996–1998). Mr Mokhele was South Africa's Representative on the Executive Board of UNESCO (1997–2001) and served as Chairperson of Special Committee of the UNESCO Executive Board (1999–2001). He also served as Chairperson of National Skills Authority advising the Minister of Labour, South Africa (2005–2007).

Chiaki Mukai (Japan)

is a Japanese medical doctor (PhD degree from Keio University) and surgeon. In 1983, she was appointed Chief Resident in Cardiovascular Surgery and later promoted to Assistant Professor in Keio University. In 1985 she was selected by the National Space Development Agency of Japan (NASDA) as one of the three Japanese candidates for a US Space Shuttle mission and in 1994, she flew on the second international microgravity laboratory mission. As a NASDA science astronaut, she became a visiting scientist at the NASA Johnson Space Center from 1987 to 1988. She has been a visiting professor of the Department of surgery at Keio University school of medicine since 1992. In 1998, she flew again as a payload specialist with US Senator J. Glenn, the first American to orbit the earth. From 2004 to 2007, Ms Mukai was a visiting professor at the International Space University where she taught health management for the ISS mission and space medicine research. Ms Mukai has been Head of Space Biomedical Research Office at the Japan Aerospace Exploration Agency (JAXA) since October 2007.

Cristina Narbona Ruiz (Spain)

holds a doctorate in Economics from the University of Rome. From 2004 to April 2008, she was Minister of Environment in the Spanish government. Under her ministerial tenure, Spain became the 3rd largest producer of wind energy in the world. From 1985 to 1991, she was the Director General of the Mortgage Bank of Spain. In 1991 she was appointed Director General of housing and architecture at the Ministry of Public Works, Transport and Environment. Then in 1993, she was named Secretary of State for Environment. She also held the position of Deputy Spokesperson of the Socialist Group at the Parliament Environmental Commission. In March 2004, she was elected to Congress as Deputy for Madrid. In May 2008, Ms Narbona Ruiz was nominated as Permanent Representative of Spain to the Organization for Economic Co-operation and Development (OECD). She chaired the WMO Conference on Social and Economic Applications and Benefits of Weather, Climate, and Water Services (Madrid, March 2007). Ms Narbona Ruiz is a professor of international economics at the University of Seville.

Rajendra Singh Paroda (India)

is an internationally renowned Indian agricultural scientist who held several important portfolios and assignments at the national and international levels. In particular, he has been the Chairman of the Governing Board of the International Crops research Institute for the Semi Arid Tropics (ICRISAT)

(1997–98). He is a former Director General of the Indian Council of Agricultural Research (ICAR) (1994–2001). He is a member of the Policy Advisory Council of the Australian Center for International Agricultural Research (ACIAR) and a member of the Governing Board of the Commonwealth Agricultural Bureau International (CABI). Mr Paroda is the President of the Indian National Academy of Agricultural Sciences (NAAS) and a fellow of the Indian Science Academy and the Third World Academy of Sciences (TWAS). He has also been the Chairman of the Global Forum on Agricultural Research (GFAR) and Executive Secretary of the Asia-Pacific Association of Agricultural Research Institutions (APAARI). Mr Paroda is the recipient of several prestigious awards and honors, including the Norman Borlaug Award (2006) and the Padma Bhushan award (1998).

Qin Dahe (China)

is a glaciologist and the first Chinese ever to cross the South Pole as a member of the 1989 International Cross South Pole Expedition. Mr Qin is an Academician of the Chinese Academy of Sciences and of the Third World Academy of Sciences. He has been praised as one of China's most outstanding scientists. He served as Administrator of the China Meteorological Administration and former Permanent Representative of China with the WMO from 2003 to 2007. He is a member of the Joint Committee for the International Polar Year 2007–2008. Mr Qin was awarded the fifty-third International Meteorological Organization Prize in 2008 for his achievements in cryosphere and climate research, his leading role in the preparation of IPCC Scientific Assessments Reports and his contribution to meteorological services at the national and international levels. Mr Qin co-chaired the Nobel Peace Prize winning IPCC Working Group I during the Fourth Assessment period.

Emil Salim (Indonesia)

is an economist. He has doctorates in economics from the University of Indonesia and the University of California at Berkeley in the United States. He served as State Minister for Population and Environment of Indonesia for almost 15 years and has been entrusted to a number of governmental positions, including Minister of State for administrative reform and Vice Chair of the National Planning Board (1970–1973), Minister of Transport, Communication and Tourism (1973–1978), Minister of State for Development Supervision and the Environment (1978–1983), Minister of State for Population and the Environment (1983–1993). Internationally, Mr Salim has had a distinguished role in a number of environment related bodies and initiatives. He was vice-chair of the UN High Level Advisory Board on Sustainable Development (1992) and a member of the WHO Commission on Health and Environment. He was a member of the UN World Commission on Environment and Development (from 1984 to 1987), chair of the 10th UN Commission on Sustainable Development (2001–2002), chair of the Preparatory Committee of the World Summit on Sustainable Development in 2002. He was co-chair of the World Commission on Forests and Sustainable Development and chair of the Third ASEAN Environment Ministerial Conference. Mr Salim has also been strongly supportive of the work of many NGOs on environment issues.

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