Guidelines on Frameworks for Climate Services at the National Level

World Meteorological Organization, Geneva

October 2012

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Note

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Foreword

Adapting to climate change, in particular through better risk management, is a defining challenge of our times, especially in developing countries, Least Developed Countries, Small Island Developing States and other structurally weak and small economies that are highly vulnerable to the adverse impacts of climate variability and change. Coping with the consequences of climate variability and change is challenging people, especially the poorest and the most vulnerable, to become empowered with new tools and capacities.

In response to this important need, the World Climate Conference-3 held in 2009 unanimously decided to establish a Global Framework for Climate Services (GFCS), an international framework to guide the development of climate services. The vision of the GFCS is to enable society to better manage the risks and opportunities arising from climate variability and change, especially for those who are most vulnerable to such risks. This will be done through the development and incorporation of science-based climate information and prediction into planning, policy and practice. The greatest value of the GFCS will occur incrementally through the delivery of a multitude of climate services at national and local levels.

For individual countries, the framework will enhance local decision making through improved access to global climate data and products. Partnerships between the providers of climate information and services and the user communities will be essential for assigning clear roles and responsibilities, including mandates for the collection and assembling of climate data and information, for the development and delivery of climate products and services, and for promoting the uptake and use of those products and services.

The High Level Taskforce (HLT), constituted to further develop the GFCS concept and scope out the next steps in its implementation, recommended that by the end of 2017, access to improved climate services should be facilitated globally in four priority sectors (agriculture, disaster risk reduction, health and water). Climate information will normally be tailored to suit a range of purposes – from advice to policy makers to facilitating operational decision making by communities and stakeholders in different economic sectors. The process will typically involve the translation of temporal and spatial information about the climate into decision support tools to suit the needs of specific sector applications.

Climate-sensitive Least Developed Countries (LDCs) and Small Island Development States (SIDs) stand to gain the most from better climate information but are often precisely where climate services are weakest. The Framework will give priority to capacity development in these countries.

This guidance document has been prepared to explain how the emerging Global Framework for Climate Services (GFCS) might be reflected in the implementation and operation of climate services at the national level. I hope that all countries will find it a useful resource in guiding the development and provision of those services to all socio-economic sectors.

Michel Jarraud
Secretary General
World Meteorological Organization

Preface

The purpose of this guidance document is to provide advice to countries on how the emerging Global Framework for Climate Services (GFCS) might be reflected in the implementation and operation of climate services at a national level.

Part 1, comprising Sections 1-3 summarise the GFCS with an emphasis on how it might manifest itself in a national context, with Section 1 outlining the basic structure of the GFCS, Section 2 defining climate services, and Section 3 identifying the national entities that would be expected to contribute to the major components of the GFCS.

Part 2, comprising Sections 4-9, deals with specific implementation issues, identifying what needs to be done nationally to ensure that: the basic infrastructure is in place to support national climate services; capacity building programs are activated to build the right skills base; and information and products are presented and communicated in ways that lead to safer, healthier and thriving communities.

These guidelines are interim pending release of the approved GFCS Implementation Plan in which there will be information on activities at the global, regional and national scales along with initial implementation activities. The initial implementation activities will include the development of frameworks in several countries that will ensure coordination and engagement, for the generation and delivery of climate services.

Part 1: National Context for the Global framework for Climate Services

1 Introduction to the Global Framework for Climate Services

The High-Level Taskforce established following World Climate Conference 3 compiled a list of Principles that should govern the Global Framework for Climate Services approach to implementation. They are:

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: 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

It is important in the context of these guidelines to stress Principle 3; specifically that the essential concepts of the GFCS apply at all space scales from global through regional and down to the national and sub-national or local level. Indeed, it is certain that the greatest value of the GFCS will occur incrementally through the delivery of a multitude of climate services at national or local levels. Hence the GFCS Vision Statement and the schematic diagram for the GFCS (Figure 1) are fully compatible with its explicit implementation in a national context. Accordingly, these nationally focused guidelines should be read with close reference to the emerging and evolving documentation for the GFCS.

The vision of the Global Framework for Climate Services is to enable society to better manage the risks and opportunities arising from climate variability and change, especially for those who are most vulnerable to such risks.

This will be done through development and incorporation of science-based climate information and prediction into planning, policy and practice.

The Global Framework for Climate Services (GFCS) is being designed around five major components or 'pillars':

- User Interface Platform
- Climate Services Information System
- Observations and Monitoring
- Research, Modelling and Prediction
- Capacity Development

These five pillars do not function as stand-alone entities and as Figure 1 demonstrates they need to interact with each other in order to make the production, delivery and application of climate services fully effective. *In scaling and scoping the GFCS to a particular country it will be essential to identify institutional structures and programmes that are already delivering climate services or have the potential to contribute to their delivery, and where needs are not being met to develop plans and proposals for filling the gaps*.

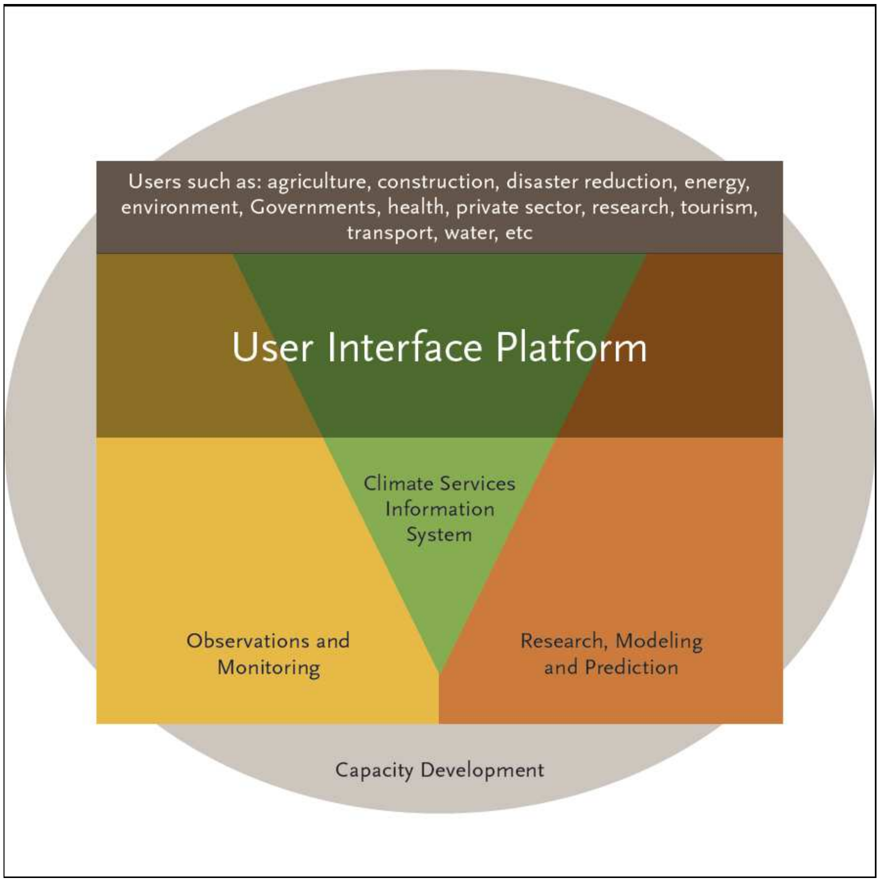

Figure 1: A schematic illustration of the pillars of the GFCS, indicating the encompassing role of Capacity Development. The concepts underlying this diagram are especially applicable at national and sub-national or local levels.

2 Climate Services – What are they?

The concept of climate services adopted for the GFCS includes a series of necessary actions associated with the:

- Accumulation of knowledge about the past, present and future state of the climate system, without which there can be no climate services;
- Identification of the type and form of services involving information about the climate and its effects that are needed within the community at large and within specific sectors that are particularly sensitive to climate variability and change;
- Development and delivery of advice and a range of 'products' based on climate knowledge and driven by identified needs; and
- Effective uptake and application of the advice and products to help achieve desired outcomes.

To be effective, knowledge on the state of the climate, including its variability and long-term trends – both past and future – needs to be translated and tailored into information about risk and opportunities that are pertinent to the given geographical and socio-economic context. Products that describe what is happening or might happen within the physical climate system can be critically important in helping decision-makers in climate sensitive sectors to formulate their options. Furthermore, information for enlightening decision-making can be positive or negative with respective to the desired outcomes: as well as warning of increased climate-related risks, information can also highlight climate-related opportunities.

Climate services will be most beneficial when they are tailored to suit a particular purpose: political leadership for advice on long-term policy making (climate change projections); governmental and private agencies for guidance on medium-term decision-making (inter-annual climate variability); and the wide diversity of community interests, including agriculture, industry and commerce for short-term decision making (weather and climate forecasts and warnings up to seasonal time scales). The process will typically involve the translation of temporal and spatial information about the climate into decision support tools to suit the needs of specific sector applications, with the means of carrying out the translation underpinned by applied climate research that targets each climate sensitive sector.

The development and implementation of a targeted climate service will generally require multidisciplinary and multi-institutional collaboration to assess the climate-related risks across the spectrum of activities associated with the targeted sector.

Management of climate-related risk has become a central socioeconomic development issue. Deriving benefits from climate information as a resource in the short-term involves, for example, the identification and early warning of an impending climate related hazard that could result in a disaster. In the longer-term, the benefits will come from an exploration of the options for adapting to climate change. Short-term, contemporary problems will attract the attention of decision-makers rather differently than distant, longer-term concerns, which typically carry higher inherent levels of uncertainty.

Learning how to minimize the impacts of climate-related hazards and optimize the benefits of benign periods of climate, will present strategic opportunities for building national and community resilience and for enlarging socio-economic benefits regardless of the climate time scale.

All countries are having difficulties in coping adequately with the increasing effects of hydrometeorological disasters, whether through a growth in the number of severe events, through increased exposure, heightened vulnerability, or all three. Efforts have to be directed towards strengthening capacities at national and local levels, drawing on international support where necessary. Critical will be the creation of enabling mechanisms that can make development decisions with respect to mitigation and opportunity, as well as to the building of resilience towards future climate risks.

The socio-economic consequences of hydrometeorological hazards are often most keenly felt at the local level; consequently, climate risk management requires that decision-making be based on climate information that can be 'downscaled' to a local context.

Decisions related to climate risk management have to be based on reliable, relevant, useable and timely information about the climate. Consequently, establishing a coherent national plan for climate services should aim first at identifying, and where necessary creating, the scientific and technical foundations for this information. A range of coordinated actions can then be initiated that will lead to the availability and uptake of operational climate services with the following outcomes:

- Widespread social, economic and environmental benefits through better-informed climate risk management and an improved capability for adaptation to climate variability and change.
- More effective use of climate information and prediction services in all national climate sensitive sectors, with a consequential higher return on infrastructure investment;
- Improved arrangements for national observation networks, better access to climate predictions, and sustained operational mechanisms that facilitate the flow of climate information at national and local scales;

- Greatly increased provider/user interactions;
- Enhanced community understanding of climate variability and change along with the associated risks and opportunities.

3 GFCS at the National Level

Addressing the wide variety of user needs for climate services within a country is beyond the capacity of any single institution. Consequently, managing climate risk requires the development of strategies, plans and programmes that will facilitate interactions between different institutions, administrative mechanisms, projects, and human and financial resources engaged in disaster risk reduction and adaptation to climate variability and change. In some countries clear institutional mandates and legislative instruments may be needed to ensure the proper functioning of climate services. Interactions will typically involve the following institutions and activities:

- National Meteorological and Hydrological Services (NMHSs);
- National agencies for agriculture and forestry, marine (coastal and ocean), water resources, health, energy, the environment and disaster management, and other climate sensitive sectors;
- National and local government committees that deal with policy formulation involving a consideration of climatic issues;
- National Climate Forums;
- Universities and other institutions conducting climate system and climate applications research as well as observations and climate monitoring activities;
- Non-governmental organisations whose activities are sensitive to climate variability and change;
- Private/public partnerships aimed at tackling problems with a climate dimension;
- Funders and donors;
- Wide range of user-stakeholder engagement activities.

Achieving coherent collaboration and integration of the delivery and uptake of climate services at the national level will likely be a challenging task; it is important that attention is first directed at establishing or consolidating the key institutional components and pathways of the national system for delivering climate services that other entities can then tap in to as required.

Given the complexity of and requirements for delivering a comprehensive set of climate services to meet national needs, GFCS implementation at a national level should aim for an effective, efficient and economical programme or plan that makes optimum use of the existing infrastructure, its institutions and mechanisms. The nature of each GFCS pillar is described in the report of the GFCS High Level Task Force[1]. Reiterating that these pillars and the overall framework must work well when scaled to a national and local level, their essence for the purposes of this guidance may be slightly reformulated as follows:

3.1 User Interface Platform

The User Interface Platform (UIP) provides the structure for users, climate researchers and climate service providers to interact on climate related concerns of national and local importance. The objective of the UIP is to ensure that end-user[2] needs for climate services

[1] Climate Knowledge for Action: A Global framework for Climate Services, WMO-No. 1065, World Meteorological Organization 2011.

[2] The term end-user here refers to someone who applies information provided as a climate service or climate service product (primary or value-added) in a decision-making context to improve outcomes or

are identified and dealt with. All users, researchers and climate service providers should make use of the UIP concept to strive for agreements that best match the credible climate information available to what is needed to inform decision-making. This mutual understanding will provide the basis for developing an end-to-end operational climate service that generates, delivers, and supports the uptake and application of a set of relevant and useable products. The interchange between provider and user will identify the capacity requirements needed for a particular climate service to be effective and sustainable, from both provider and user perspectives. The development of new products may require further research or additional observations and hence there must be procedures and processes in place for responding to the identified needs.

To promote success, the UIP will focus on achieving the following outcomes:

- *Feedback: that allows providers to obtain information on how effectively their products are meeting the needs of user communities;*
- *Dialogue: that provides opportunities for people responsible for research, observations, product delivery, and applying climate information to meet and communicate on either a bi-lateral or multi-lateral basis for assessing how well the components of the service chain (inputs, outputs and take-up) are performing individually and in relation to each other;*
- *Evaluation: that monitors the development, delivery and effectiveness of climate services as agreed between users and providers;*
- *Outreach: that improves climate literacy in targeted sectors and the wider user community through a range of public education initiatives and on-line training programmes.*

These outcomes are more likely to be realised and sustained if there is an identifiable national focus or 'clearing house' that will steer clients and users to the information that they are seeking. For example a single Web Portal that provides links to sites where sector-specific information, products and software tools can be obtained, and where opportunities are presented for conducting forums, exchanging ideas and obtaining feedback on particular topics. Establishing and maintaining this primary portal will require a long-term commitment by a single agency or organisation with the necessary knowledge, skills and resources. Contributing agencies representing specific sectors will also need to commit to establishing and maintaining their information sites linked to the national Web Portal.

Some kind of organisational structure will be required for a national counterpart to the UIP. To facilitate the collaboration that will be necessary between different agencies, and also between service providers and specific users, there will generally be value in establishing formal agreements. Such agreements, variously called Memorandums of Agreement or Understanding, or Service Agreements, provide a basis for the collaboration to be undertaken to achieve a set of expected outcomes or the nature of services to be provided. They will also include descriptions of the expected commitments of each party, how the parties will interact with each other, timelines, financial arrangements, termination options, and how general administrative matters will be managed. Such agreements, unlike contracts, are generally not legally binding on the parties.

3.2 Climate Services Information System

Implementation of the Climate Services Information System (CSIS) at the national level should encompass the principal mechanisms through which information about climate (past, present and future) is routinely collected, stored, processed and disseminated. Within these

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mitigate damaging effects. There may be a number of intermediary users who employ primary climate services to develop value-added services for end-users. Primary climate services encompass the delivery of products and information about the past, current or future state of the climate system over a specified domain.

mechanisms will also lay the responsibilities for generating the basic climate products and services that will inform often-complex decision-making processes across a wide range of climate sensitive activities and enterprises. The CSIS will rely on the Observing and Monitoring pillar for high quality climate data sets and on the Research pillar for climate prediction and projection capabilities.

The CSIS at the national level will comprise a physical infrastructure of one or more institutions with computer capabilities, tools and operational practices that, together with professional human resources, will be capable of developing, generating and distributing a range of primary climate information products and services to meet identified national and sub-national needs.

This infrastructure will also be able to draw on information delivered by global and regional producing centres to underpin as necessary the products developed specifically for national needs. Further, noting the sixth principle of the GFCS, the CSIS in a national context needs to operate within a policy environment that promotes the free and open exchange of national data and access to international data and products, while respecting international data policies and commercial interests.

In most countries there is an urgent need to develop a broad framework for managing environmental and related applications data of national significance that sets standards for collection protocols and schedules, quality control, archiving and subsequent access. Such a framework would lead to greater interoperability between data sets from different sources.

In practice, most countries already have one or more institutions carrying out CSIS functions to varying degrees. However, there are large differences in the existing capacities between countries, with some capable of providing only the most basic of climate services. There is an important requirement for CSIS operations and products generated at the national level to adhere as far as possible to internationally established standards and procedures for the development and routine exchange of data and products, which will help ensure adequacy as well as compatibility, especially where products are exchanged between countries. It is intended that a climate services 'toolkit' will be developed under the auspices of the GFCS, which will facilitate and promote the adherence to these standards and procedures (See Section 9.4).

Ideally there should be a single institution or network of institutions that can develop authoritative products about the past, present and possible future states of the climate system, and that can also translate them or provide advice on translating them into the diverse suite of climate services that will typically be required at national and local levels for various sectors.

A core national institution that provides at least a base range of primary climate information and data products could facilitate close collaboration with and between other national institutions that contribute data and information about the climate and its effects on national well-being.

The mandates (roles and responsibilities) of contributing institutions should be clearly defined as part of the strengthening and streamlining of the CSIS structure at the national level. An ideal model would have the National Meteorological and Hydrological Service (NMHS) as the operational nucleus or core of a collaborating group, with the NMHS responsible in large part for the development and delivery of routine primary climate services. Other supporting institutions, which in large part will rely on these primary climate services, could include universities engaged in climate system and climate applications research, institutions responsible for long-term planning and adaptation strategies in specific climate sensitive sectors, and disaster risk management institutions.

The extent to which a NMHS can play the pivotal CSIS role will depend on its strengths, capabilities and given mandates. *The competence/capability of a NMHS to support and contribute to climate risk management will depend on its capacity to access and process routine and specialised observational data, to manage and analyse climate data, to convert* *the data into logical and usable information and products, and to contribute to the development of a range of decision support tools.*

Currently, NMHS engagement in the delivery of climate services occurs mostly through the making of climate observations, managing and analyzing the data collected, and distributing descriptive products about the climate – its past, present and possible future states. The engagement diminishes to varying degrees as one moves into the value-added domain of customised climate products and the application of tools.

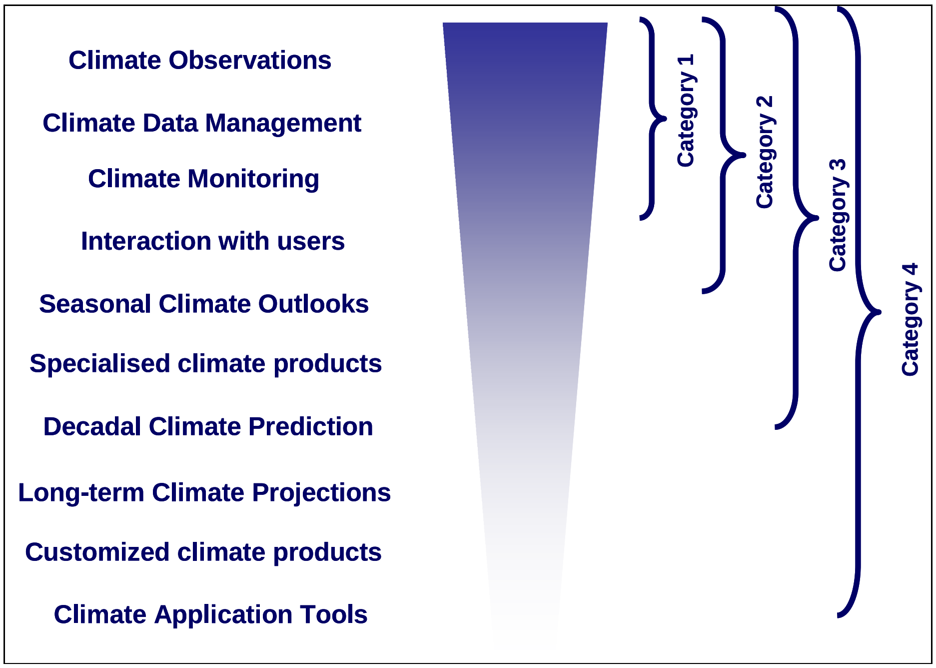

Figure 3: Hierarchy of national climate services

An incremental hierarchy of national climate services (Figure 3) can be categorised as follows:

- Category 1: A basic range of climate data services and information products;
- Category 2: Essential climate data services and information products;
- Category 3: A comprehensive range of climate data services and information products; and
- Category 4: Provision of advanced climate services.

The functional capabilities of these categories are described in the following paragraphs, together with the expected capabilities of NMHSs contributing to or delivering the services at each level.

Category 1: Basic climate data services and information products

Functions of a Category 1 capability include design, operation and maintenance of national observing systems; data management including QA/QC; development and maintenance of data archives; climate monitoring[3;] oversight on climate standards; climate diagnostics and climate analysis; climate assessment; dissemination via a variety of media of climate products based on the data; participation in regional climate outlook forums and some interaction with users, to meet requests and gather feedback.

[3] Climate monitoring is the process of describing through analysis of observational data the characteristics of past and current climate states over specified domains and time periods.

All NMHSs should be able to function at the Category 1 level, i.e. performing the basic functions of a national climate centre. At present all but a very few NMHSs provide some measure of the basic climate services through their observing, archiving, data services and basic analysis capabilities. Optimally, climate service staff should be proficient in climate statistics, including basic homogeneity testing and quality assurance techniques, etc. They should also be capable of interpreting products provided by RCCs in order to place national/local conditions within a broader scale context.

Category 2: Essential climate data services and information products

In addition to encompassing all Category 1 functions, Category 2 climate services should include the capacity to develop and/or provide monthly and longer climate predictions including seasonal climate outlooks, both statistical and model-based; be able to conduct or participate in regional and national climate forums; interact with users in various sectors to identify their requirements; provide advice on climate information and products; and get feedback on the usefulness and effectiveness of the information and services provided.

A NMHS delivering Category 2 climate services would add value from national perspectives to the products received from RCCs and in some cases GPCs, conduct climate watch programmes and disseminate early warnings. Staff in category 2 NMHSs should be proficient in the development and interpretation of climate prediction products, and in assisting users in the application of these products.

Category 3: Comprehensive range of climate data services and information products

In addition to encompassing Category 2 services, organisations delivering Category 3 climate services would have the capacity to develop and/or provide specialised climate products to meet the needs of major sectors and should be able to downscale long-term climate projections as well as develop and/or interpret decadal climate prediction (as and when available). They would serve to build societal awareness of climate change issues, and provide information relevant to policy development and National Action Plans.

NMHSs delivering Category 3 climate services would be capable of supplying climate information to all the elements of Climate Risk Management, and would include products supporting risk identification, risk assessment, planning and prevention, services for response and recovery from hazards. They could also supply information relevant to longer-term climate variability and change, as well as advice related to adaptation.

A NMHS functioning at the Category 3 level would contribute to regional-level climate activities and could serve as a node in a Regional Climate Centre Network. Category 3 NMHSs would have staff with special knowledge in risk assessment and risk management, and who may have knowledge of financial tools for risk transfer.

Category 4: Advanced climate services

In addition to the ability to deliver Category 3 services, organisations delivering the Category 4 services would have certain in-house research capacities, and would be able to run Global and Regional Climate Models. They would be able to work with sector-based research teams to assist them in developing applications models (e.g. to combine climate and agriculture information and produce food security products), and to develop software and product suites for customised climate products.

NMHSs functioning at the Category 4 level could serve as a Global Producing Centre, a Regional Climate Centre or as a node in a Regional Climate Centre Network. Staff would have modelling and statistical expertise in a multi-disciplinary context, and would be able to downscale global scale information to regional and national levels. They would also be required to receive and respond to user requirements for new products.

All countries should assess their current capabilities using the above criteria as guidance and, as appropriate, aim to establish <u>*fully functional*</u> *institutional capacity to deliver climate services at the level of one of the specified categories.*

All national CSIS providers especially NMHSs need to strengthen the production, availability, and delivery of their climate data and information products. They also need to work closely with users in various sectors, either directly or through 'boundary organisations'[4] *to ensure the most effective application of their data and products.*

In delivering products directly to end-users, CSIS entities are acting in a UIP role and need to adhere to the underlying principles. In many instances, however, CSIS efficiency and cost effectiveness will lie in CSIS entities collaborating with UIP oriented 'boundary organisations' that already have close relationships with end-users within specific sectors. Adopting this strategy would likely be more efficient than striving to develop separate relationships and client understandings within the inevitably broad range of national sectors that exhibit sensitivities to climate variability and change. Where such 'boundary organisations' do not exist within a country, these capabilities could be developed through the collaboration of existing national agencies, using the NMHS, if appropriate, as the core provider of primary climate services. As an interim or indeed an alternative approach, support could be sourced from one or more multi-disciplinary agencies already operating at a regional level that would be willing to collaborate with and support the efforts of national institutions, including NMHSs, in providing a country's climate services.

While all efforts have to be made to improve the scope and breadth of national climate services beyond a basic level, the GFCS is designed to provide new opportunities for any country that is presently constrained with respect to human, technical and financial resources to make use of a Regional Climate Centre or other regional centres of excellence to obtain products and information that are beyond its own capacity to generate.

3.3 Observations and Monitoring

To generate and deliver effective climate services, high quality observations are required not only for the physical climate system, but also for relevant socio-economic variables in order that the effects of climate variability and change can be evaluated and addressed by responses that have a solid data foundation. Monitoring products such as extreme value statistics derived from routine observations are of prime importance to planning decisions, for instance in disaster risk reduction and climate adaptation through the development of mitigating and resilient infrastructure.

The Observations and Monitoring pillar will support:

- The provision of high quality climate datasets based on *in-situ* and space based observations, as well as data processed from model outputs (Reanalysis data) and data recovered from old archives (Data Rescue);
- The provision of regular reports on the state of the climate informing on inter-annual, annual variations and long term changes in all components of the climate system: Atmosphere, Ocean, Cryosphere and Biosphere;
- The development and updates of national data bases on climate hazards to support early warning systems against extreme weather and climate events and their impacts;
- The provision of high resolution gridded data sets with resolution as low as daily time-steps focusing on key variables, i.e. precipitations, temperature, relative humidity, evapotranspiration, snow water equivalent, soil moisture and vegetation indices;

[4] A 'boundary organisation' may be defined as one that has capabilities in interpreting and using primary climate data and information in combination with other relevant information, with the aim of providing advice and guidance to particular climate sensitive sectors.

Existing national capabilities for climate observations and arrangements for data exchange will provide the starting point for building the national infrastructure for climate services. In this respect, national climate services will clearly benefit from the observing and monitoring systems operated by the NMHS and other organisations that already make environmentally related data freely available on a systematic basis.

There are, however, major spatial and temporal gaps in climate observations and historical data within national borders and areas of responsibility (which may include areas of open ocean), and especially in sparsely populated regions and throughout many developing countries. Furthermore, there are major shortcomings in virtually all countries with respect to the organisation and standardisation of biological, ecological, environmental and socio-economic observational programmes and data management practices. Such data are critical for describing and understanding the often-complex reactions to climate variability and change within a climate sensitive system. Responding to this challenge and ensuring that the variables chosen and data collected are compatible with the available climate data will likely be a major undertaking for most countries.

It will be important for all organisations with the potential to contribute to the GFCS at the national level to work together to scope out, agree on, and develop a national observations and monitoring effort that has a reasonable chance of being implemented, given the inevitable practical and resource constraints.

3.4 Research, Modelling and Prediction

The main functions of the Research, Modelling, and Prediction (RMP) pillar of the GFCS are to improve relevant scientific knowledge and science-based climate information, and to facilitate their transitions into operational climate service provision by assisting with the development or improvement of tools and methods for effecting the transitions. RMP will also target research towards developing and improving practical applications and products to satisfy the needs of users identified by the other pillars.

Users and decision makers need to know the limits of current scientific understanding, how to efficiently use the provided information taking into account its inherent uncertainty, and how to effectively and accurately communicate their identified needs to scientists. Scientists for their part must accommodate these needs in establishing research priorities along with what is required to advance scientific understanding of the Earth's climate system.

The capacity for conducting research on the climate system or for conducting applied climate research varies very widely between nations, with many having little or no capacity at all except perhaps in narrowly targeted applications.

From an international perspective, research strategies and programmes are well established in the fields of climate system science and climate impacts science; they include the many activities coordinated by the World Climate Research Programme (WCRP), the International Geosphere Biosphere Programme (IGBP), and Diversitas. However, research strategies and programmes in the more applied areas, which are perhaps of more use to users, are not so well established, and the GFCS provides an opportunity to develop user-driven research strategies and programmes.

Countries with the capacities to do so should continue to contribute to global climate related research efforts and at the same time seek to coordinate their resources within the framework of a broadly based national programme of climate research, which would then serve to support not only their own national climate services but also through programmes of technological transfer the climate services of other countries with less developed research capabilities.

3.5 Capacity Development

The capacities of a number of the elements covered by the GFCS are inadequate within many countries, especially in the developing and least developed countries. The expression "capacity development" is used to communicate the requirements for:

- Sustaining capacity growth over time;
- Systematic development of institutional entities;
- Raising awareness of problems at hand and appropriate response actions;
- Acquisition of technical and financial resources; and
- Fostering the wider social and cultural enabling environment.

Capacity development should aim to support the strengthening of existing capabilities in the areas of governance, human resources development (training, knowledge development and recruitment of climate services personnel), partnership creation, science communication, product development and generation, service delivery, resource mobilization and infrastructure development, all of which are essential for a country to manage climate risk effectively. The national foundational capabilities and infrastructure that make up these components may already exist or be in development; it is important for efficiency and effectiveness that they are well coordinated and that attention is focused on user needs. A specific goal could be to raise the capabilities of a national Cat 1 Climate Service provider to Cat 2 or 3 over time, by drawing on the expertise of RCCs and others for training in the provision of primary climate services.

Capacity building with respect to effective servicing of a community with primary climate data and information products requires a set of training programs and projects that will provide national CSIS entities, including NMHSs, with the tools and expertise: a) to deliver reliable and accurate data services; and b) to inform the community on the status of the current climate and its likely evolution in the short term and its possible trajectories over the long term.

From the end-user perspective, capacity building efforts by national CSIS and UIP entities are required to enhance: a) understanding of climate variability and change; b) the ability to recognise and respond to risks and opportunities by using climate information, and c) the interpretation and effective application of climate information and products within given sectors and contexts.

Personnel in all national CSIS and UIP entities will benefit significantly from training in communication skills that will enable them to converse, present and write accurately and confidently on science-based topics, including strengths, weaknesses and limitations. Communication techniques will generally be specific to the targeted clientele, and especially so when dealing with specialists in climate sensitive sectors such as agriculture, health and energy, and also when dealing with the media (print, radio, television, Internet-based). The media are essentially conduits to the wide and diverse general public, although targeting specialist media outlets may enable the transfer of information to somewhat narrower audiences, such as the farming or tourism sectors. It is important in this light that capacity building programmes for improving a country's climate services include adequate in-country activities, e.g. in the form of workshops, pilot studies and user forums, to ensure that climate services are attuned to community needs, are applicable to the regional environment, and are sensitive to local culture.

Attention to indigenous knowledge about weather and climate, and the use of local languages and dialects can be critical in ensuring the uptake and effectiveness of climate services.

Part 2: National Implementation

4 Operating Climate Services

Notwithstanding that the concepts and components of the GFCS apply regardless of scale, there is a recognition that for practical reasons the GFCS will need to be implemented within global, regional and national sub-contexts as illustrated schematically in Figure 2, with processes that ensure linkages and adequate interactions from one scale to another.

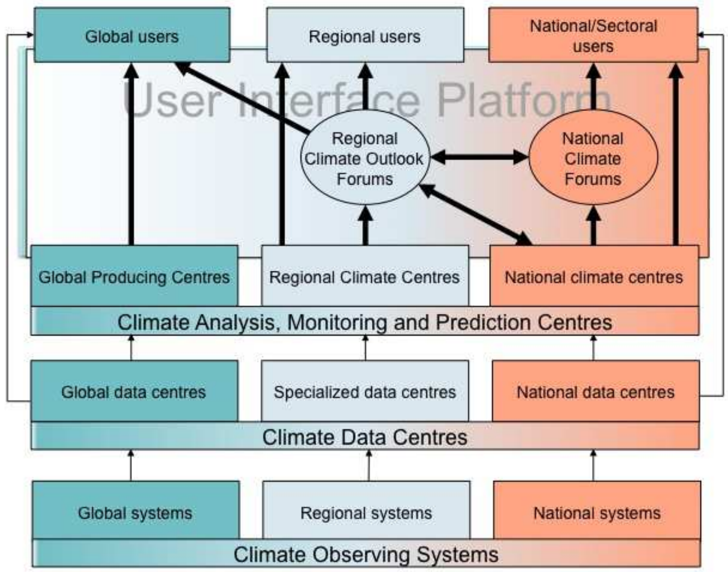

Figure 3: Data and primary information flows (thin lines) and value-added information flows (thick lines) into and through the elements and structures required for generating and delivering climate services. Implicit are the linkages and respective data and information exchanges between climate observing systems, the various climate data centres, and the climate analysis, monitoring and prediction Centres. Evident from this figure are the central roles to be played by the Regional Outlook Forums and their national counterparts in synthesising and clarifying information fed by the CSIS entities through the various processes of the User Interface Platform, which will be more diverse and complex than the three basic geographic scale elements shown here.

The principal “bottom-up” requirements for the development and delivery of information about the climate to support a national programme of climate services are:

a) The establishment and maintenance of a network of observing sites to collect the data required for generating the range of climate services identified to meet national needs. Such data will also support efforts in global and regional modelling and prediction, which in turn will lead to improved predictions and downscaled products for national use.
b) The storage in appropriate, secure, quality-controlled digital forms all national climate and related data considered necessary to meet essential present and future national and international needs in a wide range of sectors such as agriculture, health, and energy;
c) Provision of prompt, efficient and responsive climate data services;
d) An ability to apply and promote the application of climate data and climate knowledge in support of national goals;
e) Provision of an effective national climate monitoring service;
f) Development of a comprehensive an ongoing description of the national climate;

g) Provision of climate prediction services to the extent permitted by contemporary understanding of climate processes;

h) Establishment of relationships with users of climate information that provide opportunities for assessing how information is used and how a product range might be expanded and improved.

4.1 Climate Observing Systems

The simplest observing site may consist only of a basic rain gauge. More comprehensive sites will have a wind vane, an anemometer and a standardised enclosure that typically houses an array of basic instruments for reading off temperatures and humidity. Other sites will consist of partially or fully automated weather stations that telemeter data at intervals as short as a few seconds, while some will have systems for recording meteorological parameters throughout the depth of the atmosphere. There are also many other specialised ground-based systems for measuring and recording wind velocity, thermal radiation, ozone and other trace gases.

Systems for the collection of data on the state of the climate system are the bedrock for generating climate services. Without adequate climate data there can be no climate services.

The requirements and standards of observing systems and their component instruments for measuring the state of the climate system are described fully in the relevant WMO Manuals and in a range of documents developed by the Global Climate Observing System (GCOS). A selection of the latter's publications is at Annex 1.

Historically, weather and climate observing systems have been developed and administered separately to meet a diverse set of requirements. A multiplicity of stand-alone systems has inevitably led to incompatibilities and deficiencies, duplication of effort, and higher overall costs. The WMO is now implementing the WMO Integrated Global Observing System (WIGOS) as an all-encompassing approach to the improvement and evolution of meteorological and related observing systems. It is important to stress that WIGOS will continue to rely on individual countries installing and maintaining observing systems that conform to the required standards with respect to instrumentation and operating procedures.

The needs for climate data are not the same across all applications. Climate change detection and attribution need high-quality, homogeneous, long-term data. For this purpose the GCOS baseline systems, especially the GCOS Surface Network (GSN) and the GCOS Upper-Air Network (GUAN), are the essential benchmarks for ensuring the overall homogeneity of the global/regional databases. Countries that accommodate GSN and GUAN sites should pay particular attention to conforming to the required standards for recording and transmitting observations from these sites.

All countries should seek to define and establish the climate observing networks essential for characterising the varying and changing nature of the climate system within their national boundaries and other areas of responsibility.

For adequately sampling climate variability, especially in vulnerable regions, the high observing and reporting standards along with the commitment to continuity and homogeneity of the GSN should be extended wherever possible to the principal national observing sites and especially to those sites contributing to broader scale networks such as the WMO Regional Basic Climatological Networks (including Reference Climate Stations). The GCOS Climate Monitoring Principles (Annex 2) provide the 'Gold Standard Rules' for planning, developing and operating observing systems. The importance of adhering to these Rules for the rigorous monitoring of climate variability and change cannot be stressed too highly.

Not all climate applications, however, need the level of stringency and completeness demanded of baseline stations, but clearly the better and more reliable the data the better will be the climate services provided. Development of metadata associated with the observing systems is critical. In particular, if it is not possible for some reason to follow WMO standards for observational equipment and practices at a particular site, any differences from the standards should be documented, including calibration information if possible.

The most significant variables for the majority of applications are the so-called *Essential Climate Variables*. For surface variables they include temperature, precipitation, mean sea-level pressure, winds, humidity and solar radiation. For many other applications, data on evaporation and evapotranspiration, soil temperatures, cloudiness, visibility, and event phenomena such as thunderstorms, hail, dust-storms, frosts, etc are required, as well as documentation of protracted phenomena such as heat waves, cyclones, floods and droughts. For many purposes monthly and daily data are adequate, but for other applications hourly and even higher-frequency data are required.

Remote-sensing systems, especially satellites, also have a vital role to play in generating data for a wide range of climate services; using them to greatest effect in a local context will require appropriate means for integrating the data with *in situ* observations. *Regional Climate Centres will be able to assist those countries without the facilities or capacities to handle the typically large data sets associated remotely sensed climate data.*

While much attention has been given to the observing requirements for monitoring the 'health' of the climate system from a global perspective, less attention has been given to observing systems operating at a finer spatial resolution or in areas subject to local effects. For example, because many climate services are specifically designed for major population centres, high quality data are also required from in and around large towns and cities that may not necessarily be suitable for monitoring global or regional climate change.

Just as for the GFCS, WIGOS is fully scaleable, i.e. its key features as expressed for a global context can be recast for application at the national level:

Requirements: The development of national observing systems should be requirements-driven. A review of priorities and requirements would provide the basis for strengthening existing observing systems to meet community needs for climate services as well as for making contributions to WIGOS.

Technology: Ongoing rapid growth and improvements in technology will provide a basis for enhancing the capability, reliability, quality, timeliness and cost-effectiveness of observations. To take advantage of these developments, national plans for observing systems should strive where feasible to adopt the international standards and best practices set by WMO and its partners.

Quality: Meeting the quality requirements and expectations of users will be critical to the success of a national climate observing system. Achieving this goal may require an examination of current national observing practices, including all processes involved in quality management and effective oversight.

Management Efficiency: Top priorities for a national climate observing system are sustained and strong governance, and management efficiency. Developing a national climate observing system will require effective collaborative mechanisms, especially where there are efforts in train to develop a more comprehensive and integrated national environmental observing system. Such collaboration will promote greater mutual commitment, rationalization of observing sites, and optimization of data transmission and processing systems, as well as clarity in roles and responsibilities.

Capacity Building: Specialised training activities should be reflected in national implementation plans for observing systems, especially those of least developed countries, landlocked developing countries, and Small Island Developing States. Efficiencies can be obtained from conducting these activities within a regional context in which there may be several countries with similar needs. Capacity building should not be limited to scientific and technological concerns, but include human resources development, resource mobilization, and communications and outreach activities.

NMHSs, as recognised in WMO's Convention,[5] are a fundamental part of national infrastructure and play an important role in supporting vital functions of governments. The climate observations and data gathered by NMHSs are the foundations for developing national climate services and consequently there is a direct correlation between the comprehensiveness and efficiency of operation of a national climate observing system and the range and quality of the climate services that can be generated and delivered.

Functioning national telecommunications networks are critical to the effectiveness of national climate observing systems. Through these networks observations are transmitted rapidly to centres where they can be processed and analysed to generate a wide range of climate service products to fulfil national requirements, with the data also archived for posterity.

GCOS has engaged with developing countries at both national and regional scales to facilitate improvements in climate observations. Through the GCOS Regional Workshop Programme, 10 Regional Action Plans have been produced, each of which contains project proposals designed to address high-priority atmospheric, terrestrial, and oceanic climate observing needs as defined by the countries of each region. Countries should seek to encourage and where possible contribute to the implementation of these projects, which have received the endorsement of both the WMO Congress and the Conference of Parties to the UNFCCC.

4.2 Gathering Applications Data

As indicated above, much attention has been placed on taking observations and gathering data about the current and past state of the climate system, building typically on systems implemented to maintain weather forecasting and warning services. Over the past decade or so there has been significant growth in making systematic observations and gathering data from the oceans and a wide variety of terrestrial environments. To a great extent the acceleration was spurred on by the research community's recognition of the need to view all the various domains as a physically and dynamically coupled single "earth system". The addition of human and wider ecosystem dimensions, and the increase in 'impacts' studies have led to the need for a more systematic approach to the gathering of data in these domains. Understanding how climate variability and change affect the health and resources of a community or the viability of an ecosystem and the resources that it provides demands a commensurate level of knowledge on how these communities and ecosystems respond over time to climate and other forces. Routine and specialised "observing systems" to gather epidemiological data on climate modulated diseases and infestations, water resource supply and demand data, crop production statistics, energy generation and use, and tourism information are all critical for delivering data that can be used to tailor climate services to suit the particular needs of those sectors. While applications data already exist in developed countries, the methods of collection, storage and access may not always be optimal for climate impact studies. In developing countries the availability of and access to applications data are often rudimentary at best. Consequently in most countries there is an urgent need to develop a more holistic approach to data collection that sets standards for collection protocols and schedules, quality control, archiving and subsequent access.

4.3 Data Archiving and Data Services

The management and archiving of data from most core national meteorological observing networks are supported by NMHS budgets, as they are the primary data resource for both

[5] The WMO Convention, adopted on 11 October 1947 and revised in 2007, reaffirmed "the vital importance of the mission of the National Meteorological, Hydrometeorological and Hydrological Services in observing and understanding weather and climate and in providing meteorological, hydrological and related services in support of relevant national needs which should include the following areas: (a) Protection of life and property; (b) Safeguarding the environment; (c) Contributing to sustainable development; (d) Promoting long-term observation and collection of meteorological, hydrological and climatological data, including related environmental data; (e) Promotion of endogenous capacity-building; (f) Meeting international commitments; (g) Contributing to international cooperation."

weather and climate services. Data should generally be made freely available or at the cost of providing them to other national users, although it is accepted that special conditions for provision and use may be applied, especially where data are to be used within a commercial context[6].

In some countries climate data may also be collected by organisations whose activities are especially sensitive to climate and hence have requirements that are better served through the establishment of their own networks of observing stations. Such entities could include agricultural enterprises, energy producers, air quality authorities, water managers and natural resource developers. All countries should strive to identify such data sources and where possible ensure that the records become part of the national climate archive. While it may not be possible to insist that such data meet the high standards required for monitoring background climate change, they will likely be invaluable in a wide range of application studies. Notwithstanding, all organisations collecting climate and related data for whatever purpose should be informed of the importance of adhering to standards of accuracy and continuity.

A national climate database is a critical piece of infrastructure that can be drawn on for a very wide range of applications. Understanding and allowing for the effects of weather and climate are essential for agriculture and food production, for health, transport, tourism and the built environment, to name just a few. As a climate database grows in time and scope, so does its value in maintaining national well-being. All countries should seek to invest in a relational climate database management system, the complexities and capabilities of which should be matched to the national requirements for climate services. WMO has been fostering the development of climate database management systems designed to meet the particular needs of developing countries. Where necessary, national climate database capabilities can also be supported and supplemented by drawing on specialist capabilities within Regional Climate Centres and Networks.

In some cases it may be appropriate to operate a distributed national climate database, where different data types are collected, archived and managed by different agencies. This approach would most likely work for applications and impacts data but it would be highly preferable if not essential for the organisations responsible for delivering Category 1 and 2 climate services to be solely responsible for the database or archive that contains the Essential Climate Variables.

The chief general requirements for climate data in supporting most climate services and applications are that they be reliable, quality controlled, accessible, as far as possible complete, and long-term. Many services and applications require access to historical data, which may require a program of data rescue activities. Data archaeology is critical for establishing reliable and extended climate records, along with metadata[7] to guarantee traceability and transparency when adjustments are necessary to ensure homogeneity.

The availability of a climate database system will facilitate a range of quality control and homogenization procedures that can be applied to historical data held in a national archive. WMO has endorsed a long research effort in the development of statistical methods for homogeneity assessment and data correction. Inter alia, the joint WMO/WCRP Expert Team on Climate Change Detection and Indices (ET-CCDI) has been promoting the development of software for testing the homogeneity of data, an example of which is available as a free

[6] At the 64th Session of the Executive Council, 25 June–3 July 2012 it was agreed that this matter would be reviewed in the context of existing WMO regulations on the exchange of meteorological data.

[7] Metadata in this context are records attached to a climate data series that include information about the instruments used and the location and nature of the observing site, along with details of any changes to them over time and also to any changes in the way the observations were made. Metadata records should also accompany generated data sets describing how they were constructed and may have changed over time.

download[8]. WMO can also provide advice on computerised quality control procedures that will facilitate the application of appropriate corrections to historical and incoming climate data.

The importance of longer-term records of daily data, in particular, to enable studies of high impact climate events cannot be over-emphasised. Consequently, every effort should be made to incorporate daily data into the national climate database, especially for rainfall and temperature. As necessary, special efforts should be made to seek external resources for and assistance with the data computerisation and quality control processes.

One of the primary uses of a national climate database is for generating the statistics and descriptions for characterizing the climate of a country, which will typically include analyses of averages and higher order statistics over specified time periods, e.g. months, seasons, years and decades. Statistics on daily maximum, mean and minimum temperatures, and rainfall totals are valuable for many applications in diverse areas such as agriculture, refrigeration, heating, building design, tourism and so on. Current computer and telecommunication technologies offer considerable scope and flexibility in how clients can now be provided with this information. In this regard, the WMO Guide to Climatological Practices provides useful advice on methods and procedures for generating and distributing data and value-added products from a national climate database. The climate sections of NMHS websites of WMO Members[9] also provide a wealth of examples on how climate data and statistics can be delivered and displayed.

4.4 Analysis, Monitoring and Prediction

The traditional notion of climate suggested that around 30 years of data were adequate to characterize the climate of any region, which gave rise to the notion of a 30-year climate 'normal'. There was, of course, evidence of global scale glacial and interglacial epochs, but they are typically on the scale of thousands of years and longer. The growth of the instrumental record, in many regions to 100 years or more, along with intermediate timescale studies of proxy records of the past climate, have made it clear that climate is anything but static on any timescale[10]. Consequently, the past 30 years has seen the development of operational 'synoptic climatology' or as it is now more generally termed "climate monitoring", i.e. the continuous tracking of the varying statistics of climate for a range of timescales. Advances in observing, computing and communication technologies have significantly enhanced the ability to monitor climate variability and change, and WMO is now promoting the implementation of Climate Watch Systems, which at the national level will seek to alert communities of any impending or emerging climate conditions that could affect the target community.

Data on extreme events are essential for effective monitoring of the climate, and hence for managing the effects of climate variability and change as well as for formulating climate change adaptation strategies. Extreme fluctuations in temperature and precipitation are the most common and high impact manifestations of local climate variability in most regions, and can have significant effects on community economies and livelihoods, including food and water security and health. To assist in the analysis of extremes, the WMO Commission for Climatology has produced the document *Guidelines on analysis of extremes in a changing climate in support of informed decisions for adaptation (WMO WCDMP No. 72)*. Persistent and widespread anomalies in rainfall and temperature associated with the El Niño-Southern Oscillation phenomena, for example, which might last for many months, can also have very serious long-term social, economic and environmental consequences.

For countries with a sufficient number of reasonably well-spaced and long-term records, gridded data sets can be used to produce a wide range of climate products dealing with

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[8] The software package for data homogenization (RHtestsV3) is based on the freely available statistical package R and can downloaded with guidance documentation from

http://cccma.seos.uvic.ca/ETCCDI/software.shtml

[9] Websites of WMO Member NMHSs may be found at http://www.wmo.int/pages/members/

[10] See: *The role of climatological normals in a changing climate WCDMP-No. 61 WMO-TD No. 1377*

spatially coherent analyses of totals, averages, anomalies and trends. For those countries with fewer observing stations, it may be possible to obtain gridded data sets from a Regional Climate Centre or a Global Producing Centre for use in conjunction with the individual national records.

The range of climate monitoring products that can be produced, even from a single variable point data set, can be quite large, with the number of potential products expanding quite rapidly as more variables and data points are included in the data sets under investigation. With computer analysis capabilities expanding rapidly, two main approaches are possible:

a) Identifying, producing, making available, and updating as appropriate a few key analyses that will serve the needs of most clients; and
b) Allowing clients to specify, and even generate on-line, analyses that will best meet their own needs by having them stipulate the key parameters for an analysis; for example the period over which a trend is to be calculated, the level of smoothing of a graphed time series, or the geographical domain of an analysed map.

There are a number of 'open source' computer programs for carrying out these statistical analyses and presenting the results in graphical or map-form displays. Distribution can be in hard-copy form, via digital media (CD-ROM, DVD, USB Data Drives), the Internet (email), the World Wide Web, or even by MMS.

Notwithstanding the almost limitless variety of ways to present statistical information about the climate, there are good reasons for identifying a restricted set of standard methods to reduce the scope of inconsistencies of different climate data sets and climate monitoring products, especially when they are to be exchanged between countries. The ET-CCDI has also supported the development and distribution of a number of software packages for calculating standard climate indices, which facilitate the direct comparison of climate trends and anomalies across different regions and periods.[11]

An indicative set of national climate analysis, monitoring and prediction products might include the following:

Historical climatology products:

Rainfall analyses/maps; climate normals (temperature, relative humidity, evapotranspiration, rainfall, thunder days, sunshine duration, cyclones); climate graphs (humidity, rainfall, sunshine, temperature), spatial means, minimum and maximum temperature maps on a range of timescales, climate zone maps; climate extremes frequency maps, assessments and analyses of spatial and temporal factors and processes involved in observed climate patterns.

Climate monitoring products:

Weekly to monthly and seasonal spatial analyses of accumulated rainfall, average temperature, and other standard parameters together with their anomalies from long-term means; lists of monthly and seasonal averages and anomalies for key locations, e.g. centres of population or locations of interest to agriculture; extreme values of temperature, wind and rainfall experienced during the period; and the onset, continuation or breaking of drought conditions.

Other monitoring products, which might be more readily obtained from a Regional Climate Centre or Global Producing Centre, would include indices of large-scale atmosphere-ocean features, e.g. Southern Oscillation Index (SOI); Multivariate MJO Index; monsoon indices; ocean temperature analyses, and other parameters derived from deterministic, single and multi-model analysis and forecasting systems.

[11] Software packages for calculating data indices can also be downloaded with guidance documentation from http://cccma.seos.uvic.ca/ETCCDI/software.shtml

Climate forecasts/outlooks:

Monthly to seasonal scale forecasts or outlooks. Where there is no indigenous capacity for generating seasonal forecasts, they may be sourced from a Regional Climate Centre and/or Global Producing Centre, possibly with downscaling of the broad-scale seasonal forecasts to better suit national requirements.

Climate summaries:

Monthly and seasonal climate summaries; bulletins and reports on anomalies and extremes (droughts, floods, heat waves etc.); special advisories on El Niño/La Niña evolution or impacts or severe climate events, e.g. frequency/severity of cyclones, heavy rains, strong winds, heat/cold waves and related risks.

All countries should aim to produce national *State of the Climate* reports on at least an annual basis. In addition their value as a reference for a wide range of in-country users, they provide a baseline for documenting ongoing climate variability and change for national reporting under the environmentally related conventions including the UN Framework Convention on Climate Change, the Convention on Biodiversity and the Convention to Combat Desertification. The WMO Commission for Climatology is working on guidelines and standards for developing products for national climate monitoring.

Climate change products:

Time series and trend maps of rainfall and temperature for extended periods, typically for ten years and longer; and statistics on any observed changes in the frequency and intensity of extreme events. Global climate change projections out to decades or a century or more are becoming increasingly available as a result of research stimulated by the work of the Intergovernmental Panel on Climate Change. Again, where there is no local capacity, the NMHS or other responsible organisation can seek the assistance of a Regional Climate Centre in obtaining climate change projections suitably downscaled for national use.

The principles and procedures for generating these products are described in the WMO-100 Guide to Climatological Practices[12], which is designed to provide advice and assistance to WMO Members in developing national activities linked to climate information and services. The Guide describes basic principles and modern practices in climatology that are important in the development and implementation of all climate services, and outlines methods of best practice. It also provides references to other technical guidance and information sources.

5 Supporting Research

Effective downscaling of global modelling and prediction to regional and national scales will be critical to the development of a wide range of improved national climate services. There are a number of regionally focused research programmes and projects endorsed by WCRP and other regionally oriented groups that could be targeted as part of such an effort. They focus, for example, on monsoon systems, downscaling experimentation over specified regional domains, and regional climate projections for climate impact studies. Efforts to develop national programmes of climate research should keep abreast of the work of the WCRP committees and panels responsible for implementing these and similar initiatives.

As noted above, the development of a product or service from its research base requires significant interactions with the intended user community, and a number of strategies can be applied to help transfer research results into products and services:

- **Case Studies** involving *inter alia* the exploration of best practices, stress on the importance of sharing information, the setting of benchmarks, and learning from failures;

[12] http://www.wmo.int/pages/prog/wcp/ccl/documents/WMO_100_en.pdf

- **Pilot Projects** that allow a product to be developed in a 'real-world' environment, to be tested under a number of scenarios, and made sufficiently flexible for uptake more broadly;
- **Market Research** in the form of needs and feedback surveys, user workshops forums, and the careful use of focus groups;
- **Business and Technology** – Exploration of appropriate business models and use of the Internet, including social networks.

Nations with little or no climate research capability should use the facilities, services and advice offered by Regional Climate Centres, Global Producing Centres, regionally oriented 'boundary organisations', and regionally focused research activities, as well as the insights provided by the Regional Climate Outlook Forums, linking them where possible with National Climate Forums (see Section 6). Internationally funded development projects also offer a considerable range of opportunities for the transfer of technical knowledge and expertise to meet a national need (See Section 8).

6 National Climate Forums

Regional Climate Outlook Forums (RCOFs) were originally instituted in the 1990s to improve the communication of climate information and seasonal predictions in particular amongst the nations of Africa. They have since then spread to virtually all parts of the globe. Climate Outlook Forums, whether regionally or nationally focused, seek in general to review the current status of the climate in the domain of interest, to reach consensus among participants on current and expected seasonal conditions and, on the basis of the review and consensus, to deliver a range of climate monitoring and outlook products. The forums bring together climate experts on a regular basis, typically monthly or seasonal, to produce the climate outlooks based on input from the NMHS, or NMHSs in the case of an RCOF, and from other organisations generating climate monitoring and prediction products on climate variability. These forums provide opportunities for networking, and knowledge and skills development for the climate professionals.

Such forums also provide excellent opportunities for sharing knowledge as well as products with user communities, for enhancing feedback from user communities to the providers of climate information, and for catalyzing the development of user specific products. The forums can review impediments to the use of climate information, allow sharing of successful lessons in the application of climate products, and enhance the use of sector specific applications. National Climate Forums that deal with a range of topics in addition to the "Outlook" would provide greater opportunities for tightly focused discussions on the significance of a seasonal forecast, related risk information, and warnings for decision makers in specific sectors as well as for the broader community.

The format of national climate forums will vary from country to country, but the aim should be to include the following types of activities:

- A meeting (face-to-face, by teleconference or online) of climate experts from operational and research institutions to develop a consensus for the national climate outlook, which will encompass:
    - o Presentation of key points on the current status of the climate system, e.g. recent rainfall, areas affected by drought or floods, temperature extremes, and any other unusual conditions or events that set the scene for the coming season;
    - o Preparation of a consensus national outlook/forecast based on input from whatever statistical or dynamic models are available – inputs can be sourced from within country or external groups generating seasonal forecasts;

- Capacity building activities that will benefit primary climate information providers in their dealings with intermediaries[13] and specific users, and will build knowledge and skills (perhaps in association with distance learning opportunities);
- Sharing of experiences in creating new products or improving existing material;

- A broader forum involving both climate scientists and representatives from user sectors, including intermediaries, for presenting and discussing the:
  - Current status of the climate system;
  - Consensus climate outlook;
  - Expected effects on and implications for specific sectors;
  - Possible response strategies;
- Special media briefings or releases to ensure effective communication of the forum discussions and outcomes to the wider community.

There would be value in scheduling a national climate forum to follow shortly after the relevant RCOF, which would then allow the consensus on the broader scale outlook to inform the national outlook. Ideally, national representatives should 'participate' in the RCOF, noting that such participation could be by electronic means, e.g. telephone, video or on-line, depending on the RCOF format. In some cases it may be appropriate to convene sub-national or sector-specific climate forums, e.g. for agriculture prior to a sowing season, or health in advance of a malarial prone season.

7 Engaging the End-User Community

It is important to understand the different perspectives of providers and end-users with respect to the information about climate that is being transmitted from one to the other. Providers generally develop an analytical view of the information while it is being prepared for dissemination. End-users, by contrast, tend to view the information from the perspective of how some outcome to be experienced might be modified by external factors, i.e. the effects of climate variability. The provider tends to focus on the information as an end product, while the end-user views the information as part of the input to what might be a complex decision-making process. These analytical and experiential processing 'systems' can often be mismatched, especially when personal experience and vivid descriptions are favoured over statistical information. Such 'realities' have implications for how information will be received and used (see also Section 9)[14].

- Communications that are designed to create, recall and highlight relevant personal experience and to elicit actions can lead to more attention being given by decision makers to using forecasts of climate variability and climate change projections as well as to a greater public interest and engagement.
- Likewise, the translation of statistical information into concrete experience with simulated forecasts, decision-making and its outcomes can greatly facilitate an insightful understanding of both the probabilities of something happening and the consequences of incremental change and extreme events; thus motivating actions and contingency planning.
- While the engagement of experience-based, response driven decision-making can make risk communications more relevant and motivate behaviour, experiential

[13] Intermediaries could be sector-focused agencies, 'boundary organisations' or individuals (e.g. extension workers in agrometeorology) who 'interpret' climate information or provide value-added products or services to address specific end-user needs. In the context of the emerging Global Framework for Climate Services such intermediaries can be thought of as parts of the User Interface Platform.

[14] Report of WMO Conference on *Living with Climate Change and Variability: Understanding the uncertainties and managing the risks*, Espoo, Finland 17-21 July 2006, WMO/TD-No. 1512, 2009

processing is also subject to its own biases, limitations and distortions, which need to be recognised and corrected.

- Ideally, climate forecasts and communications should encourage the interactive engagement of both analytic and experiential processing systems in the course of making concrete decisions about how to mitigate or adapt to global climate change.
- One way to facilitate this engagement is through group and participatory decision-making, which will allow individuals with a range of knowledge, skills and personal experience to share diverse information and perspectives and work together on a problem, for example as in a National Climate Forum, a workshop, or through a multi-disciplinary project team.

Addressing the following key areas would significantly improve the communication of climate information to user communities:

1. *National coordination*

   The establishment of a national mechanism for improving coordination across all relevant agencies with mandates to communicate climate information, and for assisting them in providing better services. This mechanism could be in the form of an authoritative and consistent source of climate information, as for example in the United Kingdom with the UK Climate Projections, UKCP09, and the UK Climate Impacts Programme.

2. *Understanding user needs*

   The necessity for key provider agencies, including intermediaries, to identify their specific user groups and to review their understanding of user needs.

3. *Capacity building*

   The need to increase the ability of intermediaries and end-users to understand, value-add and make informed decisions from climate information.

4. *Communication of products and services*

   The development of a communication protocol agreed to by all stakeholder agencies to ensure consistency and clarity of communication, especially during periods of climatic extremes.

5. *Media interactions*

   Recognition that mass media outlets will often be the major channels for distributing both weather and climate information to the majority of users, and hence the need for ongoing engagement and development of strategies to ensure the information is presented to maximum effect.

6. *Integration and value adding*

   The importance of providers of primary climate products and information to the community and intermediaries proactively seeking opportunities to work together to provide outputs more conducive to value adding and integration with other information to assist decision-making.

7. *Research and its communication*

   Further enhancements of mechanisms to ensure that end-user needs are regularly communicated to climate information providers and researchers, and the parallel need for a scientific review process to assist in establishing research priorities in areas such as knowledge acquisition, model development, improving predictive skill, and the designing of tools that generate useful, action-oriented products.

Given the complex nature of the three-way interactions between climate, societies and their economies, and the broader environment, any rational attempt to address real-world problems must be inherently multi-disciplinary. Some countries have established multidisciplinary centres of excellence, usually as partnerships or consortiums involving for example several universities, government research groups and operational agencies. Some centres have an interest in working in an international/regional environment, and could be engaged to assist with a particular problem if no local expertise were available.

Such ‘application centres’ could fulfil the requirements expected of the GFCS User Interface Platform, and would be able to contribute to the establishment of a national framework for climate services *inter alia* by assisting in:

- Identifying the investment and capacity required for infrastructure, research and operations;
- Building collaborative arrangements between the various stakeholders;
- Maximising resources for priority areas of infrastructure, research and operations.

Means of improving engagement with stakeholder and user communities include:

- Targeted consultations (e.g. with representatives from specific sectors);
- Formal evaluation procedures on existing climate services;
- Cooperation on education and training including the development of interdisciplinary curricula on climate and its applications;
- Soliciting feedback through surveys; during lectures, conferences, field days; and when meeting with working and reference groups involving end-users;
- Offering ongoing opportunities to comment through provider websites on climate services being provided, including the use of ‘social media’ tools.

At a country level it is expected that each government will take an approach that best meets the nation’s needs for climate services. In the interests of efficiency this may require in some cases a national “stock-take” of climate capability. Any stock-take would be expected to identify the important role the NMHS plays in gathering, managing, storing, analyzing and using the meteorological and hydrological data required to service the community in general and also key economic sectors. Initial planning of the GFCS has identified a number of important sectors for which the value of climate information is already well recognised. Concentration of efforts in countries where the climate services for these sectors are not well established should therefore yield early results (See Section 8).

In some countries universities, research institutions, departments of environment, health and agriculture will also have key roles in the development and provision of climate services. In the interests of building a strong national climate service capability it will be advantageous to strengthen cooperation between them and the NMHS. Further, it would be helpful for authoritative entities to be identified or as necessary created to bring together climate stakeholders to:

- Consolidate national needs for climate services,
- Formulate training programmes for users,
- Set standards and protocols,
- Monitor the uptake of services
- Assess user satisfaction with services being provided.

Some countries have national planning committees for key socio-economic sectors such as agriculture, health, water, the environment, and disaster management, all of which exhibit sensitivity to climate variability and change. Such committees will generally have important links to executive government and, because of their important role in setting government policy, matters relating to climate variability and change should feature as a standing item on their respective agendas. Involvement in the work of these entities will help NMHSs raise their visibility and focus recognition on their importance in the national infrastructure. The low profile of NMHSs in government was identified frequently in a recent survey as a major factor limiting their involvement in both climate adaptation and mitigation activities.

8 GFCS Exemplars

The scientific and technical sessions of the World Climate Conference 3 (WCC-3) generated considerable information from a wide range of climate sensitive sectors on how well they were coping with climate variability and change and what their future needs were, *inter alia* for climate services. The white papers prepared for these sessions[15] are a significant resource for advice on how to develop national structures for delivering climate services to particular sectors.

The High-Level Taskforce, established to develop the scope and thrusts of the GFCS following the WCC-3, recommended four initial priority sectors, namely agriculture and food security, disaster risk reduction, health, and water. The Global Framework for Climate Services will therefore focus considerable early attention on these areas. The following sections seek to outline some specific guidelines on how these sectors might be supplied with climate services at the national level including how providers, intermediaries and end-users might interact. For each priority sector the expected benefits are summarised, as they provide useful guidance in themselves on the sector's needs and priorities for climate services. It is anticipated that the GFCS Implementation Plan will layout a number of specific goals for each of these sectors to be met within the following periods:

- ~2 years (Nov. 2012 to May 2015)
- ~6 years (June 2015 - May 2019)
- ~10 Years (June 2019 - May 2023)

Access to energy is critical to the alleviation of poverty and national development, and the fact that climate variability and extremes can significantly affect energy production and demand is well recognised. It is anticipated, therefore, that climate and energy will be taken up by the GFCS as an early follow-on to the current four priorities.

8.1 Agriculture and Food Security

There are few areas of human activity so dependent on weather and climate as is agriculture and perforce food production. Agricultural production is still largely controlled by weather and climate, despite the impressive advances in agricultural technology over the last half century.

During WCC-3 it was stressed that to enhance agriculture's adaptive capacity to climatic risks, there is a great and urgent need for policies and infrastructure that promote the collection, management and dissemination of meteorological and related data, especially in the developing world. Achieving these goals will improve the understanding of climatic impacts on land degradation and agricultural production, and lead to identification of the potential coping/adaptive strategies.

One continuing issue is how to express probabilistic forecasts so that they can be more effectively incorporated into public policy and decision-making for the different socio-economic sectors, and particularly for agriculture. In many cases, including the more developed countries, relatively little systematic uptake of seasonal outlooks by the agricultural community has been achieved. It is critical therefore that this important issue continues to receive urgent attention, through collaborative efforts involving both climate and agricultural scientists with the support of communication specialists (See Section 10). *It is important to recognize that local conditions, capabilities and circumstances will be strong determinants in designing the best ways of communicating probability based information; what may work in one country or cultural setting may not necessarily work in another.*

Nonetheless, timely and accurate weather and climate services to agriculture do offer considerable benefits because of the ongoing challenges to many forms of agricultural production posed by strong and persistent climate anomalies, extreme events, and climate change. These natural pressures on agriculture will continue to have significant effects on socio-economic welfare of many communities, especially in lesser-developed countries.

[15] http://www.wcc3.org/sessions.php

Agriculture and Food Security Benefits of successful implementation of the Global Framework
▪ A wide array of agricultural decisions makers, including government policy makers, agricultural extension services, farmers, research and university institutions, agribusiness and crop insurance industry, and farm management groups can make better informed decisions by using climate services, and as a result the sector and society will benefit from improved resilience to climate extremes and from increased and more reliable agricultural productivity; ▪ Improved use of more reliable seasonal climate forecasts reduces the sensitivity of rural communities and industries to failed crops and misguided logistics. Use of more understandable language of probabilistic forecasts for farmers enhances their yields; ▪ Key climate variables for agricultural decision making (rainfall, soil moisture, temperature and solar radiation, supplemented with humidity and wind speed) are more easily available and understood by agricultural and rural communities improving yields and livelihoods; ▪ Needs that were met in an *ad hoc* fashion by a growing pool of sources of data products, services and information are met in a more routine and coordinated manner avoiding duplication of efforts and reducing costs; ▪ Improved decisions can be communicated through sources agriculture users already know and trust (farmer associations, Non-Governmental Organizations, village leaders).

There is a long tradition of collaboration between the meteorological and agricultural communities, which is embodied in the work of the WMO Commission for Agricultural Meteorology. The principal operating guidance for providing weather and climate services to agriculture can be found in WMO-No. 134 “Guide to Agricultural Meteorological Practices”, which is available as a complete download or as separate chapters. This publication also has an appendix with a list of periodicals and agricultural bulletins containing examples of what can be produced at a national level.

Also relevant is the World AgroMeteorological Information Service (WAMIS) for disseminating agrometeorological products issued by WMO Members. In a central location, WAMIS allows easy evaluation of the agrometeorological information products available as well as insight for product generators on how they might improve their own products. The WAMIS web site[16] will also host a resource and tools section to further help improve the quality and presentation of climate services to agriculture.

8.2 Disaster Risk Reduction

Natural hazards are severe and extreme weather and climate events that occur naturally in all parts of the world, although some regions are more prone to certain hazards than others. Natural hazards become natural disasters when people’s lives and livelihoods are destroyed. Human and material losses caused by natural disasters are a major obstacle to sustainable development. Reliable forecasts and warnings issued in forms that are readily understood can protect lives and property, as can the education of people on how to prepare for hazards and hence reduce the likelihood of disastrous outcomes.

[16] http://www.wamis.org/index.php

Natural hazards occur across many time and spatial scales and each is in some way unique. Tornadoes and flash floods are short-lived violent events that affect relatively small areas. Other hazards, such as droughts, develop slowly but can affect large areas of a continent and entire populations of smaller countries for months or even years. In temperate latitudes, protracted periods of hot weather (heat waves) in summer can lead to severe heat stress in vulnerable populations. An extreme weather event can involve multiple hazards at the same time or in quick succession. In addition to high winds and heavy rain, a tropical storm can result in flooding and mudslides. The impacts of geophysical hazards such as earthquakes, tsunamis and volcanic eruptions can be significantly exacerbated if they are accompanied or followed by even mildly inclement weather.

With the appropriate use of meteorological, hydrological and climate information as part of a comprehensive multi-sector, multi-hazard, and multi-level (local to global) approach, considerable achievements can be realised. Among the issues hampering efforts at national to local levels to reduce risks associated with natural hazards is a lack of data concerning a country's past climate. Past climate data are essential for quantifying hazard characteristics of a region, in particular the frequency, severity and location of climatic extremes. Hence, as stressed in Section 4.2, it is critical that every effort be made to retrieve and computerise all available data at the highest temporal and spatial resolution possible in order to capture the characteristic features of particular hazards.

Disaster Risk Reduction

Benefits of successful implementation of the Global Framework

- The dissemination of warnings of approaching middle- and long-range hazards (in addition to use of operational short-range weather forecasts) enable the protection of lives through appropriate preparedness and enhanced lead-time to respond;
- Land-use planning informed by climate information to reduce risk enables the protection of vulnerable populations and ecosystems through the careful location of critical infrastructure, by distancing industries that could contaminate soil and water supplies in a disaster from people and fragile ecosystems, and by impeding the development of settlements in high-risk areas such as unstable mountain slopes and flood-prone land;
- The resilience of livelihoods to disaster is enhanced by planning based on short-, middle- and long-range hazard forecasts that enable income diversification and the protection of assets exposed to extreme weather and climate, such as non-weather-dependent seasonal employment and cultivation of drought-resistant crops;
- Data and observations on extreme weather events and patterns and on climate events (e.g. frequency and distribution of drought, floods, heat waves, extreme winds, etc.) are available in sufficient quality and quantity to support the availability of weather index based insurance, allowing more users in climate sensitive sectors (e.g. agriculture) to achieve increased livelihood security;
- Ecosystems that mitigate hazards, such as forests on slopes and mangroves in coastal areas, are protected or restored in the light of climate forecasts and projections.

While there is a significant difference between a hazard and disaster – with not every hazardous event becoming a disaster – special attention should be paid to gathering and documenting the meteorological and related conditions associated with the latter, since the information can often be used later in strengthening resilience during the post-disaster reconstruction phase. The disaster databases compiled for example by the re-insurance group MunichRe and the Centre for Research on the Epidemiology of Disasters (CRED) are useful resources for identifying events for which complementary weather and climate data sets at a national level could be compiled.

While historical climate data remain the prime resource for analysing hydro-meteorological hazards patterns, emerging trends in rainfall and temperature over the past several decades suggest that hazard characteristics may be changing. For instance what had been a 1 in 100-year flood or drought in a location may now be returning as a 1 in 30-year event. Essentially the statistics of the past ten to twenty years may be more representative of the current climate than the longer-term statistics. While there are statistical techniques for generating pseudo-records from relatively short records, the best hope of obtaining data for estimating future risk is through modelling of the climate system. Some of the climate projection data sets being prepared for the 5th IPCC Assessment may be amenable for investigating the likely frequencies and intensities of future hazards.

An essential starting point for reducing risks, however, is a quantitative assessment that combines information about the hazards with exposures and vulnerabilities of the population or assets, e.g. agricultural production, infrastructure and homes. The hazard side of the equation uses historical data and forward looking modelling and forecasting about environmental conditions such as tropical cyclones, rainfall, soil moisture and hill slope stability, mountain weather patterns and river basin hydrology. This information must be augmented with socio-economic data that quantifies exposure and vulnerability (for instance casualties, construction damages, crop yield reduction and water shortages). Equipped with the quantitative risk information, countries can develop a number of risk management strategies that may be specific to an exposed or vulnerable sector including:

- Early warning systems to reduce casualties;
- Medium and long-term planning to reduce economic losses and build livelihood resilience, e.g. land zoning, infrastructure development, water resource management, agricultural planning;
- Financial instruments such as weather-indexed insurance and risk financing mechanisms to transfer or dilute the financial impacts of disasters.

These strategies should be underpinned by effective policies, legislation and legal frameworks, and institutional coordination mechanisms, and complemented as well by capacity building efforts in information and knowledge sharing, education and training.

The natural hazard most frequently associated with climate is drought, primarily because drought is caused by a deficiency in the expected rainfall over an extended period, e.g. several months or more. Drought then is different from most other natural hazards in that it develops slowly, sometimes over years, and its onset can be masked by a number of factors. Drought can be devastating as water supplies dry up, crops fail to grow, animals die and malnutrition and ill health become widespread.

The gradual onset of drought and the persistence of the climatic anomalies that are at its root cause render it as perhaps one of the few truly climatic hazards. Most other meteorological hazards are manifest as short-lived events by comparison and are more likely to be referred to as weather-related hazards. The climatic dimension arises when there are suggestions of trends in the frequency or intensities of a recurring hazard. There are several drought watch systems in use throughout the world, with the U.S. Standardized Precipitation Index being the most common measure for monitoring deficits in precipitation over time. Identifying low accumulated rainfall totals in terms of the SPI or, as in the case of the Australian Drought Watch System, percentiles across a region enables the preparation of interpolated maps of accumulating rainfall deficiencies for periods typically of 3 months or more.

8.3 Health

Climate fluctuations affect human health through a number of direct and indirect mechanisms. Direct mechanisms include episodes of heat or cold stress, which aggravate existing health conditions such as pulmonary and respiratory disease. Episodic extreme events, such as hurricanes and floods can cause accidental injury and/or the breakdown in public services, such as sanitation systems, which then also result in direct effects on health. Longer and more protracted climatic events such as drought can lead to malnutrition in communities that do not have access to externally produced food and water. Indirect mechanisms include the affect of climate anomalies on the risk of infectious diseases such as malaria, dengue, meningitis and cholera. Although the relationships between health and climate have long been recognized, the development of modern medicine has tended to downplay the significance and pervasiveness of the threats. In recent years, however, concern about climate change has rekindled interest in the relationship between health and climate.

Climate-related health impacts are most pronounced in poor populations in developing countries, particularly the Least Developed Countries (LDCs), where vulnerable people lack the basic infrastructure to cope with climate variability and change. In such countries, the livelihoods of millions of people are heavily dependant on rain-fed agriculture and seasonal water resources. Communities also suffer the most from infectious (including water-borne and vector-borne) diseases and have the least access to health services and public health regulation.

Health

Benefits of successful implementation of the Global Framework

- High quality data from different sectors (trans-disciplinary data sets) for application to complex environment-health issues are available at the appropriate format and scale, in a manner that resolves privacy and ownership issues, making a valuable contribution to public health;
- A greater understanding of current patterns and burdens of many diseases, and of the linkages to environment and climate, is developed, allowing for their integration into Early Warning Systems to prevent populations from getting infected;
- Widely disseminated and understood seasonal forecasts provide the ability to plan more effectively when expected conditions favour enhanced risk of disease;
- Existing health priorities, goals, and technical agendas are enhanced and performance is improved to serve recognized international agendas such as the Millennium Development Goals, the Hyogo Framework for Action and the International Health Regulations;
- The health needs established by the World Health Assembly in relation to Climate and Health are advanced (including a four pillar action plan to address climate change in the areas of advocacy and awareness, research, coordination amongst UN agencies and partners, and strengthening health systems).

The priority activities identified in GFCS planning documents to foster and support health/climate partnerships are to:

- Accelerate the translation of research to operations,
- Enhance the quality, frequency of climate informed health decisions, and

- Build upon current collaborative initiatives between the climate and health community.

Other practical areas of collaboration include risk assessment, integrated environmental and health surveillance and monitoring, and health service delivery that support the areas of communicable disease control, emergency health management, and environmental health management.

Collaboration between the meteorological and health communities has been more episodic than that between agriculture and meteorology for example, and there is no equivalent WMO Technical Commission to the CAgM. Nonetheless, there have been a number of very fruitful joint projects and activities over the years that have reaped real practical benefits at the national and local level. Early warning systems for heat and cold stress, and for diseases modulated by season conditions and interannual climate variability are common examples of past collaborative efforts.

Actions on which the health and climate communities might collaborate effectively at a national level include:

- **To recognize and build upon the range of existing activities and collaborations** between the meteorological and health community to translate and apply climate science to health policy, research, and practice at global, regional, and national scales.
- **To provide operational guidance** to health partners on how to use climate services and information products, particularly to enhance risk assessment, health surveillance, and health service delivery processes, including risk management.
- **To facilitate the mainstreaming of climate services into health policy and practice** in order build a health sector that is resilient to climate related pressures.

The collaboration may involve a national CSIS entity providing climate services directly to health professionals or indirectly through intermediaries or boundary organisations. Such engagement at the national level could include:

- Reinforcing, revising and where necessary changing existing policies in order to make data, information and services freely available to the research and operational health community and to related humanitarian actors that modulate health outcomes.
- Establishing and strengthening climate and weather related health surveillance and response systems.
- Establishing strong national networks and links to international networks and programmes for research and implementation of climate risk management for public health.
- Improving assessments of the efficacy of climate-sensitive interventions.
- With the assistance of climate scientists, service developers and providers, conducting professional training courses in the use of climate information for public health decision-making in centres of learning, e.g. in schools of public health training for graduate and non-graduate health professionals.
- Integrating weather and climate services to create a seamless prediction system, and working with researchers from other disciplines to create tools relevant to health decisions
- Developing verification and quality assurance of climate products relevant to health outcomes.

8.4 Water Resources

The fundamental drivers of the hydrological cycle are embodied in the earth's climate system and hence are subject to change whenever the climate system manifests variability and change, with consequential effects on water resource availability and demand. Disruptions to the hydrological cycle and hence water resources will likely be one of the early and primary consequences of early climate change. Given the critical importance of water to virtually all sectors of human endeavour, such disruptions will affect sustainable development, jeopardise economic development, and exacerbate poverty through follow-on consequences to health, food production, sustainable energy and biodiversity. Increased water related risks associated with the changes in frequency of extreme events, such as flash floods, storm surge, and land slides, will put further stress on these sectors. It is critical to understand at a national level the processes driving changes to water supplies, the likely sequences of the changes, and their manifestation at different spatial and temporal scales.

Water management options for facilitating adaptation to increasing climate variability and climate change should include operational and demand management changes and modifications to infrastructure. Decision-making frameworks for getting the right balance in this mix of options and arriving at robust solutions should also be encouraged. Adopting alternatives that perform well over a wider range of future scenarios will improve system flexibility, which again requires an appreciation of existing and potential uses of water resources.

Water

Benefits of successful implementation of the Global Framework

- Climate information services are used as regular inputs to decisions in the water sector, from short-term water allocation or use to longer term infrastructure development and operations in order to ensure enhanced management of water resources;
- The applications of climate information services can be shown to result in greater efficiencies and effectiveness in the sustainable use of water resources across the sector.
- Improved access to accurate and reliable climate information results in appropriate and robust design and construction of water-related structures such as culverts, bridges and dams thus safeguarding large investments;
- Climate prediction services support improved water resources management and prioritized allocation of resources to the wide variety of water demand sectors, including urban water supply, irrigation systems, flood storage capacity, etc.;
- Users of climate information and services in the water sector are fully aware of, and understand the limitations of, the data and science behind the services and take this into consideration when using the services;
- Climate information services are provided to the water sector in formats and content that enable direct ingestion in water-related decision-making systems;
- Greater understanding of the impacts of climate variability on water resources availability is enabled through the adequate and knowledgeable use of long time series of climate data in support of hydrological modelling;
- A wide cross section of other users from the water sector benefit, including, for example, power generation, fisheries and conservation, navigation and recreation.
- A wide variety of communication channels between the climate and water communities are open, transparent and easily accessible.

The foundations of a collaborative effort between providers of national climate services and water managers were considered at the WCC-3 water and climate session, with the following elements recommended:

- Climate information, whether for short, medium or long term, should be tailored to serve water managers' needs at national, regional and local levels; water professionals must take the responsibility to specify their information needs.
- Vulnerability assessment of water infrastructure should be conducted.
- Increased oversight, inspection and regulation of infrastructure during operation and maintenance
- Life cycle management of ageing water infrastructure
- Development of forecasting methods for informing water management measures such as better reservoir and emergency operations;
- Strengthening emergency management and preparedness plans for managing risks associated with extreme weather/water/climate related events;
- Risk based planning and design of new infrastructure to account for climate uncertainties;
- Development of a new generation of risk-based design standards for infrastructure that will be resilient to more intense hydrometeorological events.

As for agriculture, there is a long tradition of collaboration between the meteorological and water communities, with the WMO Commission for Hydrology, UNESCO's International Hydrological Programme and the IUGG's International Association of Hydrological Sciences forming the primary international institutional framework for the collaboration in the areas of flood forecasting, water resource management and hydrological research respectively. The principal operating guidance for providing weather and climate services to hydrology can be found in WMO-No. 168 *Guide to Hydrological Practices*:

Volume I: Hydrology – From Measurement to Hydrological Information

Volume II: Management of Water Resources and Application of Hydrological Practices

The two volumes of the Guide are available as complete downloads or as separate chapters.

Also relevant is the Hydrological Operational Multipurpose System (HOMS)[17], established by the World Meteorological Organization for the transfer of technology in hydrology and water resources. HOMS consists of the organized transfer of proven hydrological technology that is used operationally in all facets of hydrology and water resources management. Included are network design, observations, collection, processing and storage of data, hydrological modelling, and best practice guidelines for hydrological forecasting and water resources management.

[17] http://www.wmo.int/pages/prog/hwrp/homs/homs_en.html

9 Mechanisms for capacity development

In a recent WMO Survey on the role of NMHSs in adaptation to climate change, many respondents cited constraints on the following resources as limiting the ability to provide climate-related products to interested stakeholders:

- Professional staff
- Computing equipment,
- Observing systems and consumables,
- Internet access and other communications facilities,
- Suitable applications software, and
- Financial resources in general

Capacity building activities can be grouped into the following 4 major sub-components:

- Basic scientific and technological training
- In-service training
- Technological transfer and support
- Developing and delivering climate services

A national programme that combines all 4 sub-components will be needed to develop a new breed of climate service provider.

9.1 Basic scientific and technological training

The WMO Education and Training Program defines the two key personnel categories that underpin the day-to-day operation an institution delivering primary climate services:

- Meteorologist
- Meteorological Technician

Personnel who have undertaken the basic meteorological educational courses for these categories may need additional training in climatological topics in order to qualify fully as ‘climatologists’ or ‘climatologist technicians’; otherwise the requirements are not dissimilar.

The essential instructional outcomes for a meteorologist/climatologist are:

(a) The acquisition of knowledge concerning physical principles and atmospheric interactions, methods of measurement and data analysis, behaviour of weather systems (through the synthesis of current weather data with conceptual models), and the general circulation of the atmosphere and climate variations.

(b) The application of knowledge based on the use of scientific reasoning to solve problems in atmospheric science, and participation in the analysis, prediction and communication of the impacts of weather and climate on society.

It is intended that satisfying these requirements will provide an individual with the knowledge, skills and confidence to carry on developing their expertise and provide a basis for further specialization. Individuals wishing to work in areas such as climate analysis and forecasting, climate modelling and prediction, and research and development will need to undertake further education and training to meet the specialised job competencies in these areas. In addition, individuals are expected to continue enhancing their knowledge and skills by participating in continuous professional development throughout their careers.

The requirements will usually be satisfied through the successful completion of a bachelor degree or equivalent in meteorology/climatology or a postgraduate programme of study in meteorology/ climatology following attainment of a tertiary degree that includes foundation topics in mathematics and physics – such topics are typically covered in science, applied science, engineering or computational courses.

The training for a meteorologist/climatologist technician aims to provide an individual with a basic knowledge of atmospheric phenomena and processes, together with skills related to the application of this knowledge. To satisfy these requirements it is necessary for an individual to achieve learning outcomes that cover:

(a) The acquisition of basic knowledge concerning physical principles and atmospheric interactions, methods of measurement and data analysis, a basic description of weather systems, and a basic description of the general circulation of the atmosphere and climate variations.

(b) The application of basic knowledge to observe and monitor the atmosphere and interpret commonly used meteorological diagrams and products.

The requirements will usually be satisfied through a post-secondary programme of study at a specialised meteorological training institution or college of further education.

Full details of the requirements for both categories are set down in Chapter B4 of Volume 1 of the WMO Technical Regulations: General Meteorological Standards and Recommended Practices. To be effective and to meet the baseline standards it will be important for all entities generating and delivering primary climate services to have an appropriate mix and adequate complement of staff resources in these two categories. For developing countries, achieving this objective will require identifying suitable candidates, selecting appropriate training/educational institutions, either in-country or in another country, and acquiring resources through bursaries, scholarships and other forms of assistance to support the candidates' attendance at the training courses.

9.2 In-service training

It is intended that satisfying the basic requirements for professional and technical personnel delivering primary climate services will provide an individual with the knowledge, skills and confidence to continue developing their expertise and provide a basis for further specialisation.

Individuals wishing to work in areas such as climate data management, climate monitoring, and provision of climatological information and products to users will need to undertake further education and training to meet the specialised job competencies in these areas. In addition, they are expected to continue enhancing their knowledge and skills by participating in professional development activities throughout their careers. Rewarding career paths are important for encouraging skilled personnel to remain in an organisation, as are appropriate succession strategies for ensuring that capacity is not lost if skilled staff do leave to seek employment elsewhere.

The Internet is being increasingly used for in-service training with a number of 'on-line' climate modules now available for the ongoing education of climate services personnel. Several countries also run Advanced Climate Courses that are aimed primarily at people with basic professional training in meteorology/climatology, but in some cases may also be suitable for meteorological/climatological technicians or for people working as intermediaries or in 'boundary' organisations. In special cases where a high level skill set is required, e.g. in order for a climate services centre to reach a particular baseline as described in Section 3.2, it may be necessary to arrange for suitably qualified staff to undertake more formal specialised tertiary level courses; such courses might be taken on a full-time or part-time basis.

'Summers Schools' also provide opportunities for extended study and training in both specific disciplinary themes and interdisciplinary topics. These events are best held in collaboration with institutions and projects that have a long experience in organizing them, such as International Centre for Theoretical Physics (ICTP), US National Centre for Atmospheric Research (NCAR) Advanced Studies program, Swiss NCCR Climate, IGBP IMBER/SOLAS, US IRI, and the Inter-American Institute. These activities target mainly early career scientists worldwide, with an emphasis on the participation of young scientists from developing regions/nations.

9.3 Technological transfer and support

There are several avenues for organizing and arranging the transfer of technological capacity and ongoing support. For building personnel skills they include:

Scientific Exchange: The encouragement of visiting scientists to foster collaboration between institutions and centres in the developed world and scientists and institutions in the developing countries. Such exchanges boost the capacity of scientists from developing countries to levels at which they can actively participate in scientific research or work confidently in an operational environment, generating predictions with skill comparable to that expected in a Regional Climate Centre.

Train-the-Trainers: The promotion of and support to experts in selected areas of climate science from developed countries to spend a few weeks training targeted groups of scientists based in developing nations. Such initiatives could be achieved through strategic partnership with WCRP sponsors (e.g. WMO, IOC and ICSU) and/or with international partner programmes/organisations such as START, Inter-American Institute for Global Change Research (IAI), Asia-Pacific Network for Global Change Research (APN), ICTP and the World Bank.

Special Topics Conferences and Workshops: Participation of scientists from the developing countries and young scientists in operational and research planning and coordination meetings, workshops and conferences.

Fellowships and Scholarships: Opportunities offered by established education programs aiming at supporting the training and education of the next generation of climate experts. Activities should be targeted at helping young scholars to better analyze and interpret climate information products for adaptation planning and risk management.

Climate Services Toolkit

Many developing countries lack the resources to acquire and assemble the state-of-the-art technologically based systems required to operate a modern and effective climate service. Such systems typically comprise a collection of computers, scanners, printers, database management systems, analysis, monitoring and prediction tools/software, and most importantly a robust, high-quality and reliable connection to the Internet. For the most part these systems will need to be brought in and tailored to suit national/local needs.

Capacity building in the development and delivery of primary climate services requires, as noted above, a set of training programs and projects that will enable climate service providers to acquire the tools and expertise to deliver reliable and accurate data services, to inform their respective communities on the status of the current climate, and to provide outlooks on its likely evolution in the short term and its possible trajectories over the long term. Further, climate services personnel will benefit significantly from training in communication skills.

In any realistic scenario, the availability of additional resources for climate service provision is going to fall short of the ideal requirements to meet the new demands. One partial solution to this problem being proposed by the WMO CLIPS programme is to make available a suite of certified tools that can be used by climate service providers and users to facilitate the production, communication, and application of climate information products. A climate information and prediction services toolbox or toolkit would consist of a set of software products and accompanying training modules that are specifically designed to support the generation and use of climate information and prediction products to meet identified user needs. To avoid the possibility of a proliferation of inconsistent and unsatisfactory tools, a set of standards will need to be established, along with a process for certifying new tools. Some examples of tools and systems already developed and achieving wide acceptance follow.

Climate Database Management Systems

Modern Climate Database Management Systems (CDMSs) offer improved data archiving, quality control, access and security, and much greater utility for users. Any climate database will be underpinned by some underlying model of the data. Quality Control processes ensure that data are checked and, to the extent possible, error-free.

Several countries have developed CDMSs and made them available to other countries in need. Although sometimes more expensive and complex to operate from a technological perspective and therefore requiring more specialist skills to administer, the new CDMSs offer significantly improved data access and security, and much greater utility for users.

> *Climate Database for the Environment (CliDE)* is being produced as part of the Pacific Climate Change Science Program, a key activity of the Australian Government's International Climate Change Adaptation Initiative. CliDE is being supplied to the mostly small National Meteorological Services of several Pacific Island countries but could be used by similarly sized meteorological services elsewhere. It provides a capability to store meteorological and related observations in a robust climate database management system via a user-friendly interface. CliDE can be used to securely store historical and current data, and to ingest manual and automatic observations.
>
> Climate staff can key in meteorological and related data from observation recording booklets, sheets, and monthly registers. Station details can be recorded, including instrumentation, observation site details, and a history of any changes made to those sites (Metadata). Electronic data are imported as comma-separated files (CSV) or in the now superseded CLICOM formats. In addition, there is an edit capability to review and amend data as required. All meteorological data are stored as SI units where appropriate. When non-SI units are key-entered, the values are automatically converted.
>
> CliDE produces pre-formatted reports and line plots of key meteorological parameters, e.g. maximum temperature, minimum temperature, rainfall. Data can be transferred to global and regional data centres in CLIMAT formats, and can be passed directly to other analysis and prediction systems such as those described below.

Aside from advances in database technologies, more efficient data capture has been made possible with an increase in Automatic Weather Stations (AWSs), electronic field books, i.e. on-station notebook computers used to enter, quality control and transmit observations, the Internet and other advances in technology.

Climate Watch Systems

Inter-annual variations are intrinsic to global and regional atmospheric and oceanic circulation. Many variations are recurrent such as the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO). They correlate significantly with anomalous patterns of monthly, seasonal and annual rainfall and temperature, and with the onset of extreme weather and climate events. Droughts, heat waves, cold waves, flooding, extreme windstorms, landslides, bush and forest fires, and coastal erosion are commonly triggered by such anomalies. As a consequence of global warming weather and climate extremes are expected to become more frequent, more widespread and more severe.

Climate Watch Systems based on adequately equipped national and regional CSIS capabilities can continuously monitor and assess the state of the climate, evaluate available long range forecasts, and when conditions warrant provide clear and concise climate early warning information on weekly to monthly and seasonal time scales. A climate advisory from a Climate Watch System that has been developed through continuous and iterative collaboration with users would result *inter alia* in heightened awareness in the user community concerning a particular state of the climate system and the initiation of preparedness activities by likely affected sectors.

Seasonal Climate Predictability

The results of research on the climate system have shown that there is forecasting skill to be derived from relationships established from historical data. Using predictors based on recent observations, subsequent climate conditions from several months to a year or more can be forecast under certain conditions. As occurred with weather forecasting, numerical models are also beginning to demonstrate forecasting skill on monthly and seasonal timescales. There are now a number of software packages for generating seasonal predictions that can be readily employed in operational environments such as the climate office of a NMHS. Following are short descriptions of two such packages.

The Climate Predictability Tool (CPT)

The Climate Predictability Tool (CPT)[18] is a software package for constructing a locally relevant seasonal climate forecast model, for performing model validation, and for producing forecasts given recent data. CPT was originally developed by the International Research Institute for Climate and Society to enable forecasters at NMHSs in Africa to produce updated seasonal forecasts for their respective countries. It helped provide greater consistency in inputs to the Regional Climate Outlook Forums (RCOFs) by avoiding such problems as “artificial skill”; it also facilitated consensus building. CPT is now used widely beyond the RCOFs.

The underlying goal in developing the CPT has been to promote the widespread creation and communication of quality-controlled seasonal climate forecasts that address specific needs of different user groups. The CPT uses the two main approaches for generating seasonal forecasts: using large-scale models of the global atmosphere, known as general circulation models (GCMs), or using a statistical approach to relate seasonal climate to changes in sea-surface temperatures, such as those associated with El Niño, or to other predictors. In the GCM case, predictions are made for large-areas and hence are not very applicable for specific locations. In addition, because of the coarse scale at which the GCMs operate, the geography in the models is often distorted, and so geographical locations can be displaced. These GCM outputs therefore need to be adjusted so that they can be applied at the local level. The CPT tool is designed to perform both forms of prediction, namely the downscaling of GCM output, and purely statistical predictions.

Seasonal Climate Outlooks for Pacific Island Countries (SCOPIC)

SCOPIC[19] is a decision support system for generating probabilistic predictions (seasonal climate outlooks) for rainfall and temperature or indeed any other climate related parameters for which there is demonstrated predictability, such as sea level. SCOPIC was developed to transform the Australian Bureau of Meteorology's operational seasonal climate prediction system into a standalone PC software program for use by National Meteorological Services of Pacific Island nations.

A ‘useful’ relationship between a predictor and predictand must first be identified. In the Pacific the dominant relationship will generally be a connection to the El Niño/Southern Oscillation phenomenon. There must be a sufficient sample of data, typically 25 years of monthly data, in order to ‘train’ SCOPIC in the relationship for a particular location of interest. The data being predicted will in most cases be rainfall or temperature, although in principle any data could be used. Some further applications of SCOPIC that have been trialled include predicting the likely onset of serious malaria outbreaks in the Solomon Islands and its use in water management in Fiji, Kiribati and Samoa. Other features of SCOPIC include a Drought Monitoring Tool and a Tropical Cyclone Season Severity Outlook. In its present form, SCOPIC could be used in any location where there are reasonably robust and reliable statistically based predictors.

Work is currently underway to incorporate information derived from a coupled climate prediction model into SCOPIC as the basis for making local predictions.

[18] http://iri.columbia.edu/climate/tools/cpt/
[19] http://www.bom.gov.au/climate/pi-cpp/scopic.shtml

Regional Climate Modelling System (PRECIS)

There are now several modelling systems that will generate regional climate projections, which countries with very modest computing resources can employ. PRECIS (Providing REgional Climates for Impacts Studies[20]) is a climate modelling system that allows the United Kingdom Met Office Hadley Centre regional climate model to be set up over any region of the globe and run on a PC with a simple user interface. It also includes a suite of data processing, analysis and display tools so that experiments can easily be set up, run, analysed, and the output data made available for wider application and dissemination. PRECIS is designed for researchers (with a focus on developing countries) to construct high-resolution climate change scenarios for their region of interest. These scenarios can be used in impact, vulnerability and adaptation studies, and to aid in the preparation of National Communications, as required under Articles 4.1 and 4.8 of the United Nations Framework Convention on Climate Change (UNFCCC). Alternatively, a number of Regional Climate Centres have or are planning to develop the capacity to generate and distribute climate projects for their region of interest or for a specified country within the region on request.

While examples of such technology transfer activities are becoming more common, their number and distribution will need to be augmented significantly and placed on a more systematic footing to ensure that the proposed CSIS baselines are met. It is important to recognise that ongoing in-country support and maintenance for many computer based systems provided under technology transfer schemes cannot always be guaranteed. Accordingly, all such initiatives should identify as an integral part of the planning process how ongoing support in terms of maintenance and upgrades will be provided in order to ensure the long-term sustainability of any climate service that relies on the system provided.

10 Communicating the Message

Communication techniques will generally be specific to the target clientele, with the adoption of different approaches for dealing with specialists in climate sensitive sectors, such as agriculture, health and energy, compared to what will work when dealing with the media (print, radio, television, Internet-based). The media are essentially a conduit to the wide and diverse general public, although targeting specialist media outlets may enable the transfer of information to somewhat narrower audiences, such as the farming or tourism sectors.

10.1 A Case Study for seasonal forecasting

In the following case study, a climate service provider set out to explore how it might improve the presentation and hence communication of its well established Seasonal Climate Outlook service. A survey of almost 400 primary producers had revealed that most farmers largely used their own observations and weather forecasting skills, relying mostly on general knowledge, intuition and what other people were doing around their area, rather than on structured approaches to drought management for example. Further, anecdotal evidence suggested that users found the Seasonal Climate Outlook, the service provider's 'flagship' climate product, difficult to understand in its current format and thus not easy to apply in everyday decision-making situations. A review of international efforts to convey seasonal forecasts found that other agencies were presenting their information in a similar way and thus were likely facing the same communication issues. To address these problems, the service provider commenced a 'Seasonal Climate Outlook Review Project'.

Multi-disciplinary Project Team

The project team involved scientists from the Climate Prediction group, communications experts and a marketing advisor. It also utilised the services of two specialist consultants: a marketing company and a 'user centred design' company. The aim of the project was to investigate users' experiences with the Seasonal Climate Outlook and to determine how it might be improved.

[20] http://www.metoffice.gov.uk/precis/intro

Project design

The project involved five stages of market research, with the 'user centred design' activity occurring in an iterative fashion in response to information gained at each stage of the market research. This approach allowed alternative Seasonal Climate Outlook options to move from broad concepts to more detailed designs. The stages were:

- *Stage 1: Interview 10 internal experts*. The aim here was to document existing internal knowledge to ensure that the marketing research consultants were as informed as possible before approaching external users.
- *Stage 2: Interview 10 high-level external Seasonal Climate Outlook users.* High profile experts in key stakeholder groups, e.g. emergency services and agriculture, provided their views on short term and strategic needs. This information helped to ensure that the mass user online survey would be targeted towards the key issues.
- *Stage 3: Online survey of mass user group* (961 respondents). The mass user group was quizzed about their experiences with the Seasonal Climate Outlook, and were asked to respond to both specific questions and open-ended questions. This mix of question types allowed capture of both qualitative and quantitative information. Importantly, respondents were tested to see if they were interpreting the forecast maps correctly and if they really did understand key terms such as 'median'.
- *Stage 4: User-workshop –* At this workshop, 12 representative users were presented with a very wide range of alternative design concepts developed by the project team and asked for feedback, which helped to create a 'short list' of preferred design concepts.
- *Stage 5: User-testing – Interviews*. A final set of interviews with 37 key end-users in diverse locations had the side benefit of helping to strengthen relations between climate services personnel and key end-users. The interviewers were supported in this activity by the project's marketing representative who providing them with a pre-interview coaching session on how to conduct effective and neutral interviews.

Capacities

The most important and not unexpected finding was that users found probabilistic information very difficult to understand and that their comprehension levels were low. Users assigned high value to the Seasonal Climate Outlook and relied upon the forecast, yet they were also dissatisfied with how it was presented. Other concerns were the use of complicated text and language, difficulty navigating around the service provider's comprehensive website to find what they were looking for, and many had little understanding of the concept of 'forecast skill'.

The project also learnt that in broad terms there were two distinct user groups: 'simple' users and 'advanced' users. Simple users wanted key headings, uncomplicated graphics, easy navigation, educational features, 'laypersons' language, and a broad overview that they could digest quickly and easily. Advanced users wanted to be able to drill-down into details and have easy access to a far broader range of options and specificities. The majority of users wanted:

- 'Podcasts' from climatologists;
- The ability to tailor the information to their unique needs;
- Zooming capabilities on websites displaying map-based information;
- The ability to change the time-frame and easily access past seasonal information;
- Simplified language and improved text layout;
- Ease of navigation through a website.

Alternative design concept

The alternative Seasonal Climate Outlook design concept included:

- An ‘Overview Map’ that presented the key ‘highlights’ of temperature, rainfall and tropical cyclone outlooks. It only depicted information where there was a significant deviation from the median and where there was good skill.
- A Podcast. (3-5 minutes; not much longer than the weather on the TV news)
- A revised Confidence map. The confidence map was changed from red to green; enhanced with educational features and simplified language, plus it was made more readily accessible via ‘tab’ navigation from the outlook maps.
- ‘Tailor My Outlook’ – the new outlook maps were provided in two versions: ‘simple’ and ‘advanced’. Both allowed users to configure the information to suit their needs.
- Text solutions. The use of ‘talking headings’, which could be expanded to provide more information; text laid out in dot-points rather than long sentences/paragraphs, and the use of plain language.

Results of user testing of alternative designs

The set of alternative design concepts based upon the above principles was well received. At the end of the process, the existing Seasonal Climate Outlook was tested alongside several new designs, and tellingly it was ranked least liked by the users surveyed.

Challenges in moving forward

The incorporation of the new design concepts into established operational products brought a number of challenges. It was recognised that significant staff and IT resources would be required to develop and test the new prototypes, along with a sustained effort in the area of ongoing user consultation. One coordination challenge was the need to strive for a similar ‘look and feel’ across the organisation’s entire web product range. Finally, users sought far greater use of graphical or pictorial representations of data and information. This requirement poses scientific issues related to how data and information are best ‘visualised’ so as to appear ‘neat and clear’ yet also scientifically accurate.

Key GCOS Publications

Title	GCOS Number
Guide to the GCOS Surface Network (GSN) and GCOS Upper-Air Network (GUAN) (2010, also in Russian, French and Spanish)	144
Guideline for the Generation of Datasets and Products Meeting GCOS Requirements, May 2010	143
Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC, August 2010	138
GCOS Reference Upper-Air Network (GRUAN) Implementation Plan 2009-2013, July 2009	134
Synthesis of National Reports on Systematic Observation for Climate - August, 2009	130
Practical Help for Compiling CLIMAT Reports (also in Russian, French, Spanish,	127

Global Climate Observing System (GCOS) Climate Monitoring Principles

Effective monitoring systems for climate should adhere to the following principles.

1. The impact of new systems or changes to existing systems should be assessed prior to implementation.
2. A suitable period of overlap for new and old observing systems is required.
3. The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e. metadata) should be documented and treated with the same care as the data themselves.
4. The quality and homogeneity of data should be regularly assessed as a part of routine operations.
5. Consideration of the needs for environmental and climate-monitoring products and assessments, such as IPCC assessments, should be integrated into national, regional and global observing priorities.
6. Operation of historically uninterrupted stations and observing systems should be maintained.
7. High priority for additional observations should be focused on data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution.
8. Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation.
9. The conversion of research observing systems to long-term operations in a carefully planned manner should be promoted.
10. Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

Furthermore, operators of satellite systems for monitoring climate need to:

(a) Take steps to make radiance calibration, calibration-monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system; and

(b) Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term inter-annual) changes can be resolved.

Thus satellite systems for climate monitoring should adhere to the following specific principles:

11. Constant sampling within the diurnal cycle (minimising the effects of orbital decay and orbit drift) should be maintained.
12. A suitable period of overlap for new and old satellite systems should be ensured for a period adequate to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations.
13. Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured.
14. Rigorous pre-launch instrument characterisation and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured.
15. On-board calibration adequate for climate system observations should be ensured and associated instrument characteristics monitored.

16. Operational production of priority climate products should be sustained and peer-reviewed new products should be introduced as appropriate.
17. Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.
18. Use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when these exist on decommissioned satellites.
19. Complementary in situ baseline observations for satellite measurements should be maintained through appropriate activities and cooperation.
20. Random errors and time-dependent biases in satellite observations and derived products should be identified.

The ten basic principles were adopted by the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) through decision 5/CP.5 at COP-5 in November 1999. This complete set of principles was adopted by the Congress of the World Meteorological Organization (WMO) through Resolution 9 (Cg-XIV) in May 2003; agreed by the Committee on Earth Observation Satellites (CEOS) at its 17th Plenary in November 2003; and adopted by COP through decision 11/CP.9 at COP-9 in December 2003.