Climate Services for Supporting Climate Change Adaptation

Supplement to the Technical Guidelines for The National Adaptation Plan Process

GFCS
GLOBAL FRAMEWORK FOR CLIMATE SERVICES

World Meteorological Organization
Weather • Climate • Water

Climate Services for Supporting Climate Change Adaptation Supplement to the Technical Guidelines for The National Adaptation Plan Process

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EXECUTIVE SUMMARY

Because of the current and projected impacts on climate due to the high levels of greenhouse gas emissions, adaptation is a necessary strategy at all scales in a changing climate. At its seventeenth session, the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) established the National Adaptation Plan (NAP) process as a way to facilitate effective adaptation planning in least developed countries (LDCs) and other developing countries. The four key elements that need to be undertaken in the development of the NAPs include: Laying the groundwork and addressing gaps; Preparatory elements; Implementation strategies; and Reporting, monitoring and review. Implementation strategies in the NAP Process involve decisions related to climate risk management which have to be based on reliable, relevant, useable and timely information about the climate. A number of activities in the different elements of the NAP Process require effective and timely climate services which consist of the collection of climate data; generation and provision of a wide range of information on past, present and future climate; development of products that help improve the understanding of climate and its impacts on natural and human systems; and the application of these data, information and products for decision-making in all walks of life and at all levels in the society.

The World Climate Conference-3 (WCC-3) held in Geneva in 2009 unanimously decided to establish a Global Framework for Climate Services (GFCS), a UN-led initiative spearheaded by WMO. 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 development and incorporation of science-based climate information and prediction into planning, policy and practice. The scope and thrusts of the GFCS include five initial priority sectors, namely agriculture and food security, disaster risk reduction, energy, health, and water. The National Meteorological and Hydrological Services (NMHSs) play an important role in the provision of climate services at the national level that are needed in support of the NAP process. The efforts of NMHSs can contribute to enhancing the safety and well-being of society, ending poverty, sustaining development and economic growth, improving access to clean drinking water, enhancing food production, achieving good health outcomes, mitigating and adapting to climate change, exploiting renewable energy sources and increasing the prosperity of the population in their countries as follows:

1) NMHSs can provide effective and timely climate services such as analysis of current climate and future climate change scenarios, assessment of climate vulnerabilities and identification of adaptation options, enhancement of capacity for planning and implementation of adaptation etc.,

2) Partnerships between NMHSs and academia, government departments, international and non-governmental organizations, and where appropriate and possible, the private sector and civil society, provide better data coverage and information processing, higher resolution models, and more precise and useful specialized products for societal benefits, including opportunities to better support government and other decision-makers regarding safety, economy, and security.

3) NMHSs can provide weather and climate information to the farming community that can be particularly helpful to anticipate, prepare for and respond to agriculture or food security risks, on both short time scales to address problems triggered by climate extremes (i.e., droughts, thermal extremes) as well as longer term risks associated with climate change (e.g., increased frequency of cyclones, desertification).

4) NMHSs can assist disaster risk reduction through provision of historical and real-time data on loss and damage, provision of multi-sectoral plans to reduce disaster risk, climate information to guide decisions regarding appropriate levels of investment in reducing risk, and risk financing and transfer.

5) NMHSs, working together with the public and private sectors, can implement multi-hazard early warning systems to significantly reduce the number of fatalities caused by weather, water- and climate-related natural disasters, enhance resilience of societies, sustain productivity and economic growth, and reduce damage to property.

6) NMHSs can provide weather and climate information that can help health decision makers improve, inter alia, understanding of the mechanisms of climates impact on disease transmission and occurrence, and estimate populations at risk (e.g. risk mapping). NMHSs can also provide decadal climate projection maps for human vulnerability assessment and adaptation planning. Such tools and methodologies can help the officials in the health sector to incorporate the information generated in routine health decisions.

7) NMHSs can provide long time series of climate data to the water sector in support of hydrological modelling to enable greater understanding of the impacts of climate variability on water resources availability and through provision of improved climate prediction services on time scales from seasons to decades and spatial scales from local to regional to 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.

8) NMHSs can provide a range of services to support decisions by water managers that include identification of extreme weather and climate hazards that pose water-related risks; identification of populations vulnerable to weather and climate hazards, including those in the coastal zone; implementation of risk management and emergency preparedness practices and procedures; development and implementation of water and environmental policy; and development and implementation of water and flood management policies and strategies.

9) NMHSs can provide detailed and tailored weather and climate information (historical and projected) for initial assessment of energy resources; for the development of codes, standards and site-specific designs and policy to assist with the construction and maintenance of energy system infrastructure; for site selection and financing; for operations and maintenance; and for energy supply in a balanced/integrated manner to meet the energy demand.

NMHSs are encouraged to continue their active role in the UNFCCC Least Developed Countries Expert Group (LEG) process and to provide technical advice to LDCs for preparing and implementing NAPs and other contributions to the LDC's work programme.

CLIMATE SERVICES FOR SUPPORTING CLIMATE CHANGE ADAPTATION

1. INTRODUCTION

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans (IPCC, 2014). Impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, and wildfires, reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability. Impacts of such climate-related extremes include alteration of ecosystems, disruption of food production and water supply, damage to infrastructure and settlements, morbidity and mortality, and consequences for mental health and human well-being. Climate-related hazards exacerbate other stressors, often with negative outcomes for livelihoods, especially for people living in poverty. Climate-related hazards affect poor people's lives directly through impacts on livelihoods, reductions in crop yields, or destruction of homes and indirectly through, for example, increased food prices and food insecurity.

Because of the current and projected climate disruption precipitated by high levels of greenhouse gas emissions, adaptation is a necessary strategy at all scales in a changing climate. The United Nations Development Programme (UNDP) emphasizes the use of strategies to respond to climate change impacts: "Adaptation is a process by which strategies to moderate, cope with and take advantage of the consequences of climate events are enhanced, developed and implemented" (Lim and Spanger-Siegfred, 2005). The capacity and potential for humans to adapt is unevenly distributed across different regions and populations, and developing countries generally have less capacity to adapt (Schneider et al. 2007).

Climate services develop and provide science-based and user-specific information relating to past, present and potential future climate and address all sectors affected by climate, at global, regional and local scale. They connect natural and socio-economic research with practice. They help society cope with climate variability and change through the transformation of climate-related data – together with other relevant information – into customised products such as projections, trends, economic analysis and services to the user communities in different sectors. For example, the provision of more and better climate services will allow farmers to fine-tune their planting and marketing strategies based on seasonal climate forecasts; empower disaster risk managers to prepare more effectively for droughts and heavy precipitation; assist public health services to target vaccine and other prevention campaigns to limit climate-related disease outbreaks such as malaria and meningitis; and help improve the management of water resources. These activities all contribute to appropriate adaptation planning to a changing climate.

2. PROCESS TO FORMULATE AND IMPLEMENT NATIONAL ADAPTATION PLANS (NAPS) TO COPE WITH CLIMATE CHANGE

At its seventeenth session, the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) acknowledged that, because of their lower level of development, climate change risks magnify development challenges for LDCs (UNFCCC, 2012) and that national adaptation planning can enable all developing and LDC Parties to assess their vulnerabilities, to mainstream climate change risks and to address adaptation. With this in mind, the COP established the National Adaptation Plan (NAP) process as a way to facilitate effective adaptation planning in LDCs and other developing countries (UNFCCC, 2012).

The agreed objectives of the national adaptation plan process are:

(a) To reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience;

(b) To facilitate the integration of climate change adaptation, in a coherent manner, into relevant new and existing policies, programmes and activities, in particular development planning processes and strategies, within all relevant sectors and at different levels, as appropriate.

National Meteorological and Hydrological Services (NMHSs) can help to meet the demand for climate services to address climate change and adaptation, particularly at the local level, by combining climate-change projections with local climate data and knowledge. These products can then be used to devise adaptation strategies including preparing for, and adjusting to, changing patterns of extreme events. Climate services, such as those developed under the Global Framework for Climate Services (GFCS), provide essential information for adaptation at the national and local levels and should receive commensurate support.

2.1 Key features of the NAP Process

The NAP process:

- Is **not prescriptive**. The guidelines for the process assist LDCs to undertake the steps and activities that can ensure effective adaptation. Based on their different levels of progress with adaptation thus far, countries are able to select which steps and activities to undertake in order to move forward;

- **Seeks to enhance the coherence of adaptation and development planning** within countries, rather than duplicating efforts undertaken in a given country;

- Facilitates **country-owned, country-driven action**. LDCs have full ownership of the NAP process within their countries. The NAP process seeks to harness and build upon national-level capacity, with support from various partners, as appropriate;

- Is designed so that **countries can monitor and review it on a regular basis, and update their NAPs in an iterative manner**. This is important, given that better quality climate data and projections, as well as other information useful for the planning process, will increasingly become available, and the impacts of climate change in the medium and long-term will be better understood.

2.2 Elements of National Adaptation Plans

Initial guidelines for the formulation of NAPs by LDC Parties are given in the annex to the UNFCCC decision 5/CP.17. They are divided into four main elements: (a) Laying the groundwork and addressing gaps; (b) Preparatory Elements; (c) Implementation strategies; and (d) Reporting, monitoring and review. An example of how the NAP Process can progress for a country is shown in Figure 1.

Elements of the NAP process

1. Laying the groundwork and addressing gaps

This element on laying the groundwork and addressing gaps aims to create a national mandate and strategy for the NAP process that establishes clear responsibilities for government ministries and departments, and specifies key milestones and expected outputs of the NAP process and the frequency of such outputs over time. Activities undertaken under this element would be planned with a view to identifying weaknesses and gaps in enabling environments, and addressing them as necessary, to support the formulation of comprehensive adaptation plans, programmes and policies, through, inter alia:

(a) Initiating and launching of the NAP process

(b) Stocktaking: identifying available information on climate change impacts, vulnerability and adaptation and assessing gaps and needs of the enabling environment for the NAP process

(c) Addressing capacity gaps and weaknesses in undertaking the NAP process

(d) Comprehensively and iteratively assessing development needs and climate vulnerabilities

2. Preparatory elements

In developing NAPs, consideration would be given to identifying specific needs, options and priorities on a country-driven basis, utilizing the services of national and, where appropriate, regional institutions, and to the effective and continued promotion of participatory and gender-sensitive approaches coordinated with sustainable development objectives, policies, plans and programmes. Activities may include the following:

(a) Analysing current climate and future climate change scenarios

(b) Assessing climate vulnerabilities and identifying adaptation options at the sector, subnational, national and other appropriate levels

(c) Reviewing and appraising adaptation options

(d) Compiling and communicating national adaptation plans

(e) Integrating climate change adaptation into national and subnational development and sectoral planning

3. Implementation strategies

Activities carried out as part of the implementation strategies would take into consideration the following:

(a) Prioritizing climate change adaptation in national planning

(b) Developing a (long-term) national adaptation implementation strategy

(c) Enhancing capacity for planning and implementation of adaptation

(d) Promoting coordination and synergy at the regional level and with other multilateral environmental agreements

4. Reporting, monitoring and review

These activities, including national adaptation plan documents, could be included in national strategies and plans, as appropriate. Under this element, Parties should undertake a regular review, at intervals that they determine:

(a) Monitoring the NAP process

(b) Reviewing the NAP process to assess progress, effectiveness and gaps

(c) Iteratively updating the national adaptation plans

(d) Outreach on the NAP process and reporting on progress and effectiveness

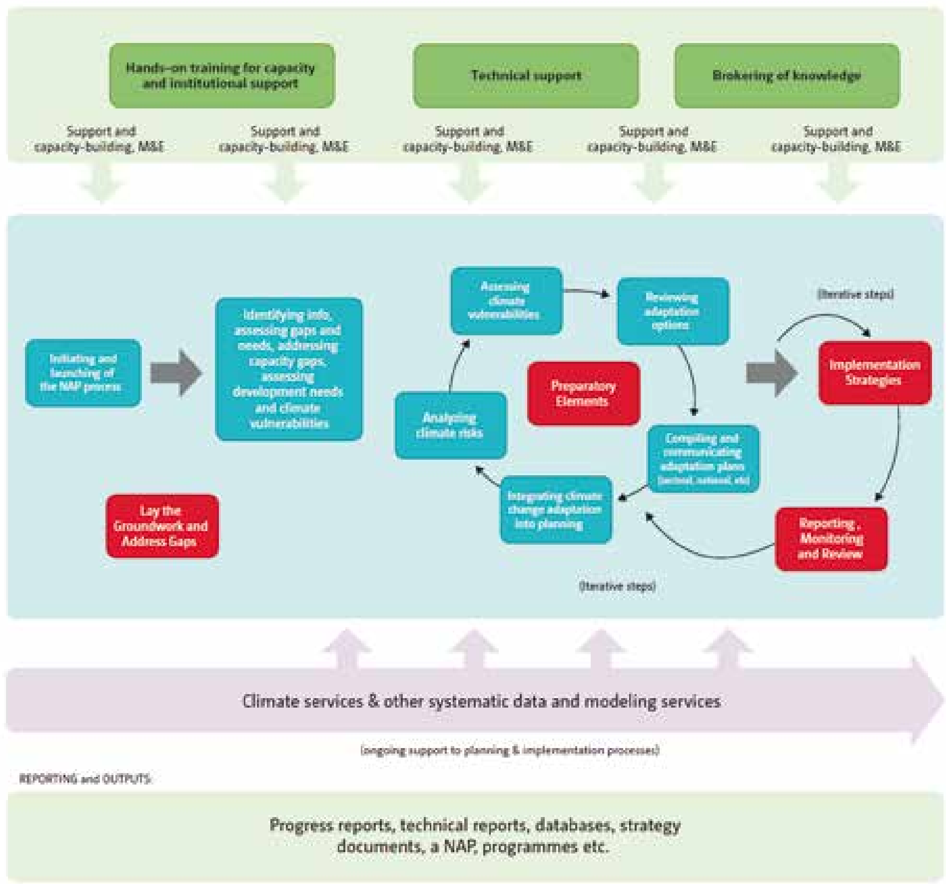

Figure 1. An example of how the NAP Process can progress for a country (Source: Least Developed Countries Expert Group, 2012).

3. NEED FOR CLIMATE SERVICES TO SUPPORT THE NAP PROCESS

A number of activities in the different elements of the NAP Process described above such as analysis of current climate and future climate change scenarios, assessment of climate vulnerabilities and identification of adaptation options, enhancement of capacity for planning and implementation of adaptation etc., require effective and timely climate services. A new World Bank report entitled "Shock Waves: Managing the Impacts of Climate Change on Poverty" (Hallegatte et. 2015) shows that between now and 2030, good, climate-informed development gives the best chance for warding off increases in poverty due to climate change. Short-term, contemporary problems such as identification and early warning of an impending climate related hazard that could result in a disaster will assist the decision-makers in undertaking pro-active actions to cope with disasters.

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, with international support where necessary. It has been estimated that upgrading all hydrometeorological information and early-warning capacity in developing countries would save an average of 23,000 lives annually and would provide between $3 billion and $30 billion per year in additional economic benefits related to disaster risk reduction (Rogers and Tsirkunov 2013). Hence there is a strong need for adequate resourcing for the delivery of hydrometeorological services and contribute to guaranteeing the sustainability of such services as part of longer-term development (WMO, 2015a).

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. The WMO Strategy for Service Delivery (WMO, 2014a) laid out seven steps which are intended to help NMHSs to review their current service delivery practices and start implementing the Strategy.

Climate services consist of the collection of climate data; generation and provision of a wide range of information on past, present and future climate; development of products that help improve the understanding of climate and its impacts on natural and human systems; and the application of these data, information and products for decision-making in all walks of life and at all levels in the society. Depending on the user's needs, these data and information products may be combined with non-meteorological data, such as agricultural production, health trends, population distributions in high-risk areas, road and infrastructure maps for the delivery of goods, and other socio-economic variables. International cooperation in seamless research on hydrometeorological and climate services has led to advances in predictive accuracy and increased lead time facilitating applications in a wide range of user sectors (Fig. 2).

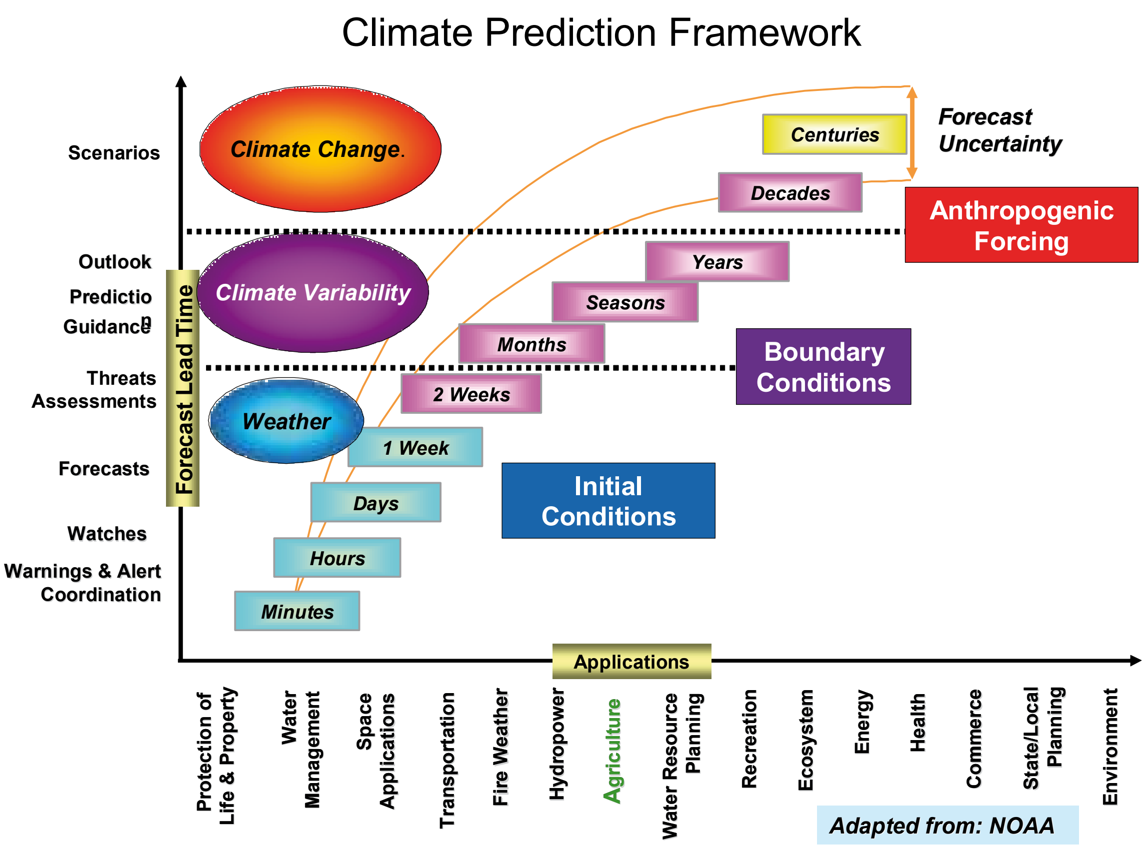

Figure 2. Seamless hydrometeorological and climate services

Implementation strategies in the NAP Process involve decisions related to climate risk management which have to be based on reliable, relevant, useable and timely information about the climate. Some examples of climate products and the nature of climate services they provide are shown below:

a) 8-14 Day Probabilistic Outlooks: provide information to decision makers in weather and climate sensitive sectors and for businesses sensitive to intra monthly climate variation.

b) Weekly Regional Hazards Outlooks for Food Security: The outlooks provide advance notice of food security issues in the regions of interest. The outlooks are preliminary input to the Famine Early Warning System Network (FEWSNET) monthly food security outlooks.

c) One-Month Temperature and Precipitation Outlooks: provide information to decision makers in weather and climate activities and for businesses sensitive to seasonal and inter-annual climate variations.

d) Monthly and Seasonal Drought Outlooks: These outlooks provide advance notice of potential drought improvement, persistence, or development for the upcoming one-month and three-month periods to aid various sectors of the economy (agriculture, water resources management, forestry, energy, recreation, finance).

e) Monthly climate outlook: Monthly forecasts of temperature, precipitation and sunshine duration across a country (presented in various formats including text, maps and tables). This information is used by the energy and water sectors, for example, to anticipate resource needs.

f) Annual climate outlook: For Government (contingency planning), industry (particularly energy and water sectors); probabilistic forecast maps, plumes, histograms; and heat stress index maps.

A coherent national plan for climate services could enhance community understanding of climate variability and change along with the associated risks and opportunities. Hence all countries around the world are now being encouraged to develop and implement national plans for climate services to enhance social, economic and environmental benefits through better-informed climate risk management and improved capability for adaptation to climate variability and change.

4. GLOBAL FRAMEWORK FOR CLIMATE SERVICES

The World Climate Conference-3 (WCC-3) held in Geneva in 2009 unanimously decided to establish a Global Framework for Climate Services (GFCS), a UN-led initiative spearheaded by WMO to guide the development and application of science-based climate information and services in support of decision-making in climate sensitive sectors. Thirteen heads of state or government, 81 ministers and 2,500 scientists unanimously agreed to develop the GFCS. Following the decision of WCC-3, a High Level Task Force (HLT) was appointed through an intergovernmental process to prepare a report that was to include recommendations on the proposed elements of the GFCS and the next steps for its implementation. The HLT produced the report "Climate Knowledge for Action: A Global Framework for Climate Services" as the basis for GFCS (WMO, 2011a).

To ensure that the Global Framework for Climate Services provides the greatest benefit to those who are most in need of climate services, the HLT recommended that the following eight principles be adhered to in its implementation:

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

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

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

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 vision of GFCS is designed to support the Sendai Framework for Disaster Risk Reduction (SFDRR), which succeeded the Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters (HFA), and was adopted at the Third World United Nations Conference on Disaster Risk Reduction (WCDRR-III) held in Sendai, Japan, in March 2015. The vision supports both the SFDRR's overarching goal to "Prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience" and it's four priorities for action:

(a) Understanding disaster risk;

(b) Strengthening disaster risk governance to manage disaster risk;

(c) Investing in DRR for resilience; and,

(d) Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

As shown in Figure 3, GFCS places emphasis on hazard analysis through the use of historical and real time hazard data and meteorological, hydrological and climatological forecasts and trend analysis. This analysis in combination with the analysis of exposure and vulnerability helps in effective risk assessment which facilitates effective decision making to promote societal resilience.

The vision of GFCS also supports the Sustainable Development Goals (SDGs) adopted by world leaders at the UN General Assembly in New York, in September 2015.

The GFCS Implementation Plan (WMO, 2014b) highlighted the priorities for early focus under different priority areas and the deliverables and targets over 2-, 6- and 10-year horizons. Significant improvements in national climate service provider capabilities are expected to be realized during the second phase of implementation (the development phase).

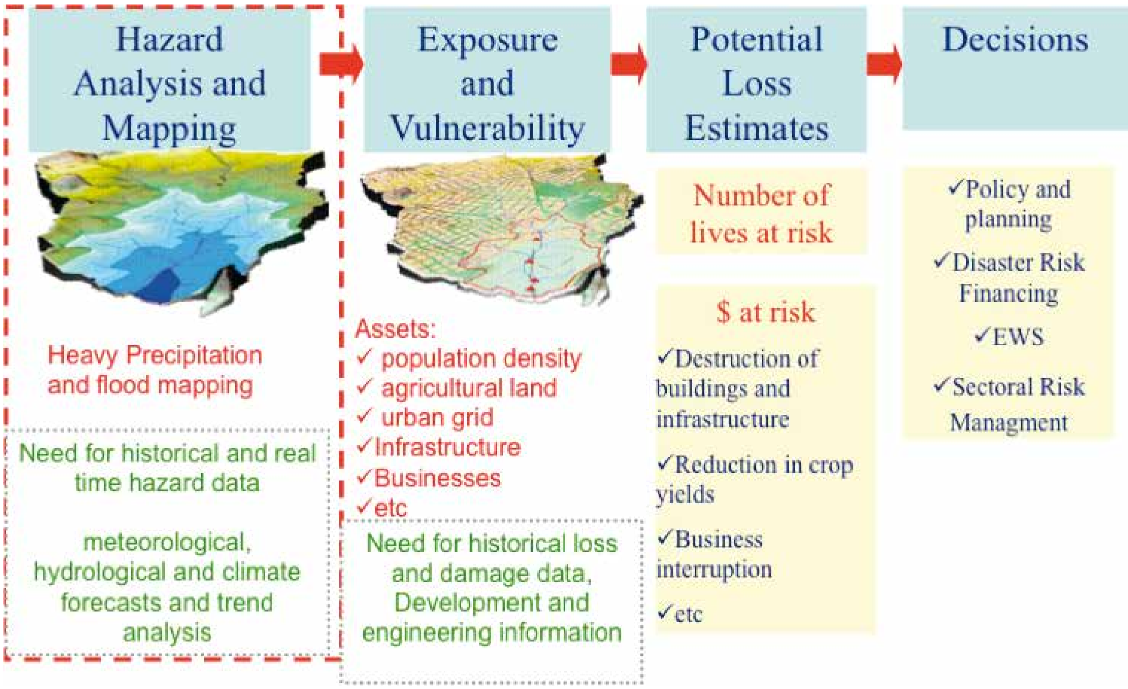

Figure 3. GFCS facilitates hazard analysis and risk assessment to promote sectoral risk management and societal resilience

4.1 Pillars of GFCS

The GFCS is an end-to-end system that uses observations, technology and scientific understanding as inputs for the development of climate services to meet user requirements.

GFCS is designed around five major components or 'pillars', as shown in Figure 4.

User needs are met by each of the pillars as follows:

- User Interface Platform (Users can make their voices heard through the Platform and make sure climate services are relevant to their needs)
- Climate Services Information System (The production and distribution system for climate data and information products that address user needs)
- Observations and Monitoring (The essential infrastructure for generating the necessary climate data)
- Research, Modelling and Prediction (To advance the science needed for improved climate services that meet user needs)
- Capacity Development (To support the systematic development of the institutions, infrastructure and human resources needed for effective climate services)

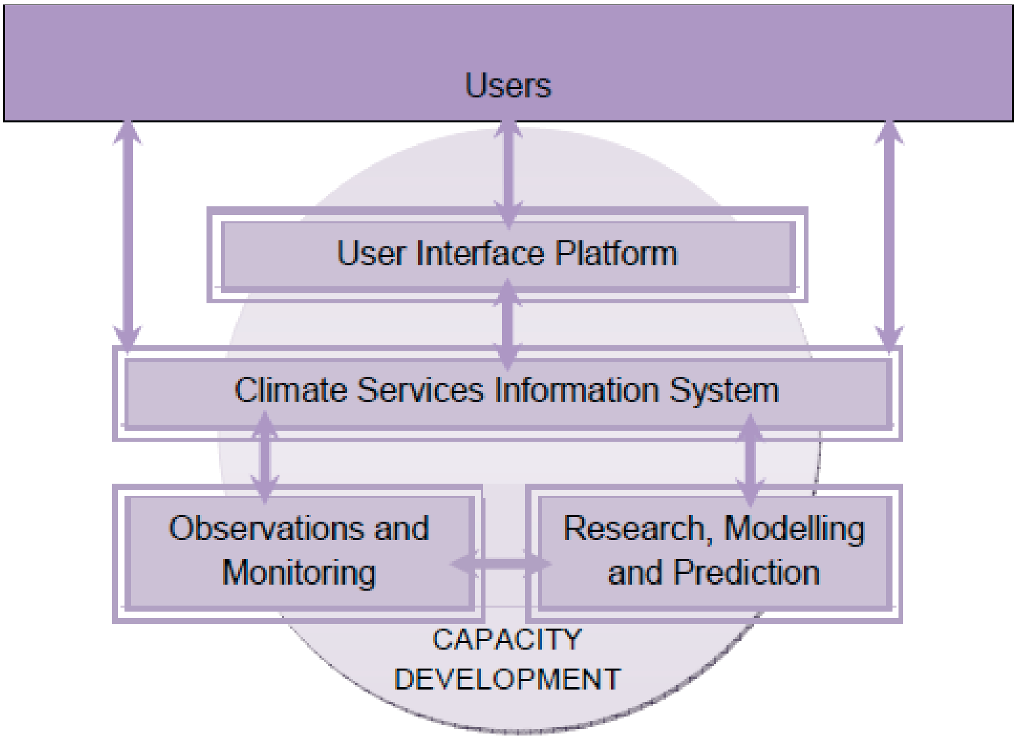

Figure 4. A schematic illustration of the pillars of the GFCS, with the indication that the Capacity Development component encompasses the other components. Arrows depict flows of information and feedback. The concepts underlying this diagram are especially applicable at national and sub-national or local levels.

These five pillars do not function as stand-alone entities and as Figure 4 demonstrates they need to interact with each other in order to make the production, delivery and application of climate services fully effective.

4.2 Priority Areas of GFCS

The scope and thrusts of the GFCS include five initial priority areas, namely agriculture and food security, disaster risk reduction, energy, health, and water. GFCS therefore focuses considerable early attention on these areas. There are some specific guidelines, which are described in the sections that follow, on how these sectors might be supplied with climate services at the national level including how providers, intermediaries and end-users might interact.

5. ROLE OF NATIONAL METEOROLOGICAL AND HYDROLOGICAL SERVICES (NMHSS) IN THE PROVISION OF CLIMATE SERVICES AND SUPPORT TO THE NAP PROCESS

The Convention of WMO reaffirms the vital importance of the mission of the NMHSs in observing and understanding weather and climate and in providing meteorological, hydrological and related services in support of relevant national needs which should include:

(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; and

(g) contributing to international cooperation.

The Guide to Climatological Practices (WMO, 2011b) provides guidance to NMHSs in developing national activities linked to climate information and services. NMHSs adhere to the basic principles and modern practices important in the development and implementation of all climate services and the methods of best practice in climatology.

It has taken many years of research, investment, coordination, collaboration and effort, to develop the present capability to provide weather and climate services through the active involvement of 191 NMHSs around the world. Over time, knowledge about the weather has improved and the use of weather forecasts has evolved into routine of daily life where an increasing number of decisions are dependent on them. As climate is the accumulation over time of weather conditions and climate information is generated based on the similar models that require similar inputs, climate services are naturally and strongly rooted in the existing capabilities for the provision of weather services.

As has been the case since the beginning of the modern era of societal and environmental management, knowledge of weather, hydrological and climate processes is key to all aspects of human endeavours as observed from their influence on cultures, traditions and development paths of societies. It is within this framework that NMHSs in various countries have been well positioned to monitor, forecast and issue warnings on a wide range of weather-, climate and water-related events that affect human life and socioeconomic development (WMO, 2015b). For example, with regard to natural hazards, NMHSs have been tasked to monitor and provide warnings of individual events, and to sensitize the population on their impacts to save lives, enhance resilience of societies, sustain productivity and economic growth, and reduce damage to property.

Beyond the year 2015, the SFDRR; the SDGs adopted by world leaders at the UN General Assembly in New York, in September 2015; and the new agreement under the United Nations Framework Convention on Climate Change (UNFCCC) to be adopted in Paris in December 2015 will have a significant influence on the demands from NMHSs for user-oriented weather, hydrological, climate and related environmental services to meet the evolving needs of governments, partners and other decision-makers to achieve sustainable development. The myriad advances in science and technology provided by NMHSs and their partners, that include the provision of multi-hazard early warnings and related services, 24 hours a day, 365 days a year, and climate services through the GFCS, can provide societies with the underpinning information to reduce and mitigate the impacts of natural hazards, and maximize the benefits from weather- and climate-related opportunities. The efforts of NMHSs contribute to enhancing the safety and well-being of society, ending poverty, sustaining development and economic growth, improving access to clean drinking water, enhancing food production, achieving good health outcomes, mitigating and adapting to climate change, exploiting renewable energy sources and increasing the prosperity of the population in their countries.

Guide to Climatological Practices

The first edition of the WMO Guide to Climatological Practices was published in 1960, and the second edition appeared in 1983. While many basic fundamentals of climate science and climatological practices have remained consistent over time, scientific advances in climatological knowledge and data analysis techniques, as well as changes in technology, computer capabilities and instrumentation required the revision of the Guide, and hence the third edition of the Guide to Climatological Practices was brought out in 2011 (WMO, 2011b).

The third edition of the Guide includes six chapters ie., Information on Climatology and its scope, the Organization and Functions of a National Climate Service, and International Climate Programmes; Climate Observations, Stations and Networks;
Climate Data Management; Characterizing Climate from Datasets; Statistical Methods for Analysing Datasets; Services and Products. Procedures in the Guide have been taken, where possible, from decisions on standards and recommended practices and procedures. The main decisions concerning climate practices are contained in the WMO Technical Regulations, Manuals, and reports of the World Meteorological Congress and the Executive Council, and originate mainly from recommendations of the Commission for Climatology.
http://www.wmo.int/pages/prog/wcp/ccl/guide/guide_climat_practices.php

5.1 **Support provided by NMHSs to Adaptation in the Priority Areas of GFCS**

Climate services are inextricably linked with traditional weather services in observing elements of climate and weather, in keeping and preserving records and developing and delivering the weather and climate services and being the main source of climate information. NMHSs are the official authoritative source, and in most countries, the single source for weather and climate data and the single voice, on weather warnings in their respective countries, and, in many, they are also responsible for climate, hydrology, air quality, seismic and tsunami warnings and for space weather.

NMHSs all around the world design, operate and maintain the national observing systems; handle data management including quality analysis and quality control (QA/QC); develop and maintain data archives; undertake climate monitoring; provide the oversight on climate standards; carry out climate diagnostics, climate analysis and climate assessment; disseminate via a variety of media climate products based on the data; and participate in regional climate outlook forums and some interaction with users, to meet requests and gather feedback.

Partnerships between NMHSs and academia, government departments, international and non-governmental organizations, and where appropriate and possible, the private sector and civil society, help society make better decisions based on more complete and accurate weather, water and climate information. These partnerships provide better data coverage and information processing, higher resolution models, and more precise and useful specialized products for societal benefits, including opportunities to better support government and other decision-makers regarding safety, economy, and security. NMHSs work with these partnerships to develop appropriate national frameworks that facilitate the gathering and sharing of data, and expertise to make the information easy to access in real-time, in useful forms, and at low cost. Climate services provided by NMHSs, within the framework of WMO, in the different priority areas of GFCS are described below with appropriate reference to the elements of the NAP process.

Climate Products, Climate Models and Climate Outlooks

Climate Products:

According to WMO's Guide to Climatological Practices (WMO, 2011b), climate products include the following:

a) Climatological data periodicals: Most NMHSs issue monthly bulletins containing data from a selection of stations within particular areas or states or the country as a whole. Some services also publish periodicals for different intervals such as a week or a season. These periodicals contain timely climate data that can be of great importance to various economic, social and environmental sectors.

b) Occasional publications: Occasional publications are designed for those users who need information in planning for capital investments or in designing equipment and buildings to last for decades and centuries; for members of the general public whose interests are academic or casual; and for researchers in the atmospheric and oceanic sciences. They are also designed to summarize or explain unusual events, such as extreme weather, and to describe or update an important predicted event such as a strong El Nino.

c) Standard products: It is usually beneficial to develop a standard product that can be used by a wide range of users. For example, both energy management entities and fruit growers can make use of a degree-day product. Such standard products fill the gap between the climate data periodicals and those tailored for individual users. Increasingly, products are being requested and delivered using the Internet.

- *The Role of Climatological Normals in a Changing Climate (WMO-TD No. 1377)*
   http://www.wmo.int/pages/prog/wcp/wcdmp/documents/WCDMPNo61.pdf

d) Specialized products: It is often necessary to develop products that are specific to an individual user or sector. Developing these products involves analysing the data and presenting the information with a focus on the specifications that will enable the user to gain optimum benefit from the application of the information. Flood analysis is one example of such a product as flood frequency estimates are required for the planning and assessment of flood defences; the design of structures; and the preparation of flood risk maps.

- *Technical Material for Water Resources Assessment (WMO No. 1095)*
http://www.wmo.int/pages/prog/hwrp/publications/Technical_report_series/1095_en_4_Web.pdf
- *Integrated Water Resource Management as a Tool for Adaptation to Climate Change*
http://www.apfm.info/publications/manuals/Cap-Net%20IWRM%20Adaptation%20to%20Climate%20Change%20Tool.pdf
- *Urban Flood Management (WMONo. 1372)*
http://www.apfm.info/publications/manuals/Cap-Net%20WMO%20Urban%20Flood%20Management.pdf
- *Guide to Hydrological Practices (WMO No. 168)*
http://www.whycos.org/chy/guide/168_Vol_II_en.pdf
- *Heatwaves and Health: Guidance on Warning-System Development*
https://drive.google.com/a/wmo.int/file/d/0BwdvoC9AeWjUb2NHYVNyQU5QaW8/view?pli=1

e) Climate monitoring products: For monitoring and diagnosing the climate of a country, it is necessary to understand current climate conditions in the country as part of the global climate system. In addition to monitoring local climates for national interests and relating current episodes to historical patterns, the climate service should aim to place the local variations within a larger regional and even global context and provide summarized information. Good monitoring products are essential for climate predictions and updates.

f) Indices: Climate indices are widely used to characterize features of the climate for climate prediction and to detect climate change. They may apply to individual climatological stations or describe some aspect of the climate of an area. Indices usually combine several elements into

characteristics of, for example, droughts, continentality, phenological plant phases, heating degree-days, large-scale circulation patterns and teleconnections. Examples of indices are the El Nino–Southern Oscillation (ENSO) Index; the North Atlantic Oscillation Index etc.,

Climate Models and Climate Outlooks include the following:

a) Climate predictions and projections: A climate prediction is a probabilistic statement about the future climate on timescales ranging from years to decades. It is based on conditions that are known at present and assumptions about the physical processes that will determine future changes. A climate projection is usually a statement about the likelihood that something will happen several decades to centuries in the future if certain influential conditions develop. In contrast to a prediction, a projection specifically allows for significant changes in the set of boundary conditions, such as an increase in greenhouse gases, which might influence the future climate.

- *Regional Climate Outlook Forums*

https://www.wmo.int/pages/prog/wcp/wcasp/clips/outlooks/climate_forecasts.html

b) Climate scenarios: A major use of global climate models is the generation of climate scenarios. A climate scenario refers to a plausible future climate constructed for investigating the potential consequences of human-induced climate change, but should also represent future conditions that account for natural climate variability. The IPCC reports and publications (for example, IPCC, 2013) provide a good source of information about climate scenarios.

- *IPCC Publications portal*
  http://ipcc.ch/publications_and_data/publications_and_data_reports.shtml

c) Global climate models: Global climate models (GCMs) are designed mainly for representing climate processes on a global scale. They provide the essential means to study climate variability for the past, present and future. Initially, GCMs were directed at coupling the atmosphere and ocean; most state-of-the-art GCMs now include representations of the cryosphere, biosphere, land surface and land chemistry in increasingly complex integrated models that are sometimes called climate system models.

d) Downscaling: Regional climate models: The downscaling relates the properties of a large-scale model to smaller-scale regions. The approach can be either dynamical or statistical, or a combination of the two. The dynamical approach involves nesting limited area high-resolution models within a coarser global model. Tools used in this process are known as regional climate models (RCMs). They typically use the synoptic and larger-scale information from a GCM to drive a regional or mesoscale dynamical model.

e) Local climate models: Unlike global and regional climate models, which seek to model the climate of the entire globe or a large part of the globe over an extended period of time, local climate models attempt to simulate microscale climate over a limited area of a few square metres to a square kilometre for a short time.

f) Reanalysis Products: The time-critical nature of weather prediction means that the initializing analysis must usually begin before all observations are available. Reanalysis uses the same process (and often the same systems), but as it is done weeks or even years later, it is able to use a more complete set of observations. These reanalysis systems generally incorporate a prediction model that provides information on how the environment is changing with time, while maintaining internal consistency.

g) Climate Outlooks: Climate outlooks are forecasts of the values of climate elements averaged over timescales of about one month to one year. The climate elements typically forecast are average surface air temperature and total precipitation for a given period. Since the ENSO phenomenon has a significant impact on the climate in many parts of the world, forecasts of the beginning, end and intensity of ENSO events and forecasts of tropical Pacific Ocean sea surface temperatures are also included in climate outlooks.

The examples of different climate products and data displays are available in the WMO's Guide to Climatological Practices (WMO, 2011b).

5.1.1 Agriculture and food security

It is very well known that agriculture is inherently sensitive to climate conditions and is among the sectors most vulnerable to weather and climate risks. The relationships between weather, climate and production risk are well recognized (George et al. 2005). Despite the impressive advances in agricultural technology over the last half a century, climate variability has a large influence on agriculture, which is heavily dependent on rainfall, sunshine and temperature. Of the total annual crop losses in world agriculture, many are due to direct weather and climatic effects such as droughts, flash floods, untimely rains, frost, hail, and severe storms (Hay 2007). The number of hydrometeorological hazards in particular (such as droughts, floods, tropical storms and wild fires) which were measured on an average of 195 per year in 1987-1998 increased to 365 per year in 2000-2008 (WMO, 2014b). Human-induced climate change has introduced a new complicating factor into the food security equation, which is modifying natural climate variability.

Agriculture and food security in the 21st century faces multiple challenges. Extreme weather, climate variability, and long-term climate change pose important challenges to future agriculture and food security. Climate-related disasters such as droughts and floods can lead to crop failure, food insecurity, destruction of key livelihood assets, mass migration of people, and negative national economic growth (WMO, 2014c). Adverse weather and climate conditions directly affect agricultural productivity, livelihoods, water security, land use, agricultural marketing systems, market instability, food prices, trade and economic policies; and small-holder farmers, fishers, livestock herders and forest dependent communities are often highly vulnerable to these impacts. Climate change is expected to affect all of the components that influence food security: availability, access, stability and utilization.

Climate change will act as a hunger risk multiplier, exacerbating the risk factors that impact food security. The IPCC has highlighted multiple climate risks to agriculture and food security, and described the potential for meteorological information to improve early warning systems for meteorological risks. Climate change will exacerbate existing threats to food security and livelihoods from a combination of increasing frequency of climate hazards, diminishing agricultural production in vulnerable regions, expanding health risks, increasing water scarcity, and intensifying conflicts over scarce resources, which will likely lead to new humanitarian crises, as well as increasing displacement. Fisheries are threatened by changes to the environment associated with increased emissions of greenhouse gases, including higher water temperatures and increases in ocean acidification, changing marine fish distribution. Climate change can affect the production and health of animals, and the suitability and range of pasture lands.

Climate services in agriculture extend to where it can help develop sustainable and economically viable agricultural systems, improve production and quality, reduce losses and risks, decrease costs, increase efficiency in the use of water, labour and energy, conserve natural resources and decrease pollution by agricultural chemicals or other agents that contribute to the degradation of the environment (WMO, 2014c). Climate services are critical for the food availability and stability which are two of the four aspects of food security.

5.1.1.1 Weather and climate data

Under the activity 2 on stocktaking of the first element of the NAP Process ie., laying the groundwork and addressing gaps, one important question relates to the type of data and knowledge available to assess current and future climate risks, vulnerability and adaptation. Another question relates to identification of gaps regarding the capacity, adequacy of data and information, and required resources to engage in the NAP process. This activity establishes the knowledge base for developing a NAP, drawing on available data and information. A gap analysis will identify areas that require strengthening in order for the country to successfully undertake the NAP process. Potential barriers to the design and implementation of adaptation will be identified and a plan to address them developed. Another activity under the second element of the NAP Process (preparatory elements), is related to the analysis of current climate and future climate change scenarios. One question that needs to be addressed here is as to which climatic

patterns in the country, according to observed data, are most important in terms of adjustment, adaptation or acclimatization of social systems? In the priority area Agriculture, the aspect of the weather and climate data collection and sharing provides useful information to these activities in the NAP Process.

Data collection and sharing is an important task in determining weather and climate impacts to agriculture and food security outlooks. The agriculture and food security community relies on appropriate and timely phenological, environmental, and climate information at relevant spatial and time-scale data points to make informed decisions. Priority activities include upgrading the monitoring and data collection network in rural areas, increasing the sharing of data from existing networks, and improving systematic data archival and management. Available, accessible, comprehensive and useful weather and climate data can help agriculture and food security decision-makers improve their understanding of climate's impact on agricultural development and food systems, and their estimates of populations at risk (risk mapping). Weather and climate data can be particularly helpful to anticipate, prepare for and respond to agriculture or food security risks, on both short time scales to address problems triggered by climate extremes (i.e., droughts, thermal extremes) as well as longer term risks associated with climate change (e.g., increased frequency of cyclones, desertification etc.,).

An excellent example of an existing activity that is improving the use of meteorological and climate data is the LEAP food security early warning tool in use in Ethiopia. Such early warning systems for drought, famine and climate extremes have great potential for improving food security.

One priority action area is the improved data collection and use (meteorological, agrometeorological, climatic, agronomic, pest and disease) which includes the following activities (WMO, 2014c):

- Share data from existing networks;
- Upgrade the monitoring and data collection network in rural areas, as well as systematic data archival and management;
- Improve the reporting of yield, area and production statistics in countries as well as of other data (i.e. pest and diseases).

NMHSs can provide weather and climate information to the farming community that can be particularly helpful to anticipate, prepare for and respond to agriculture or food security risks, on both short time scales to address problems triggered by climate extremes (i.e., droughts, thermal extremes) as well as longer term risks associated with climate change (e.g., increased frequency of cyclones, desertification). Currently available databases with the NMHSs increase climate knowledge and improve prediction capabilities in order to facilitate agricultural and food security decision-making from international policy level to local operational farm management strategies. Through the analysis of the long-term climatic data and by using the current weather observations, NMHSs provide agrometeorological advisories and services to the farming community on a regular basis during the cropping season to enable the farmers make appropriate operational decisions on their farms for efficient soil and crop management and improve agricultural productivity.

5.1.1.2 **Information Products and Services**

Under first element of the NAP Process ie., laying the groundwork and addressing gaps, activity 3 focusses on addressing capacity gaps and weaknesses in undertaking the NAP process. Activity 4 focusses on comprehensively and iteratively assessing development needs and climate vulnerabilities. Under the second element of the NAP process (preparatory elements), one important question that needs to be answered is regarding the appropriate indices of climate trends which could support planning and decision making. Two other activities in this element cover the aspects of assessing climate vulnerabilities and identifying adaptation options at

sector, subnational, national and other appropriate levels and reviewing adaptation options. In the priority area Agriculture, emphasis is placed on assessing the needs of the agriculture sector, provision of appropriate data, information products and services (Table 1) to the agricultural community and how the capacity gaps and weaknesses in this process can be addressed.

Table 1. Weather and Climate Data, Information Products and Services to the agricultural community

Area	*Variable(s)*	*Information products and services*
Weather	Air temperature	a) Temperature probabilities b) Chilling hours c) Degree-days d) Hours or days above or below selected temperatures e) Inter-diurnal variability f) Maximum and minimum temperature statistics g) Growing season statistics, that is, dates when threshold temperature values for the growth of various kinds of crops begin and end.
	Precipitation	a) Probability of a specified amount during a period b) Number of days with specified amounts of precipitation c) Probabilities of thundershowers d) Duration and amount of snow cover e) Dates on which snow cover begins and ends f) Probability of extreme precipitation amounts.
	Wind	a) Windrose b) Maximum wind, average wind speed c) Diurnal variation d) Hours of wind less than selected speed.
	Sky cover, sunshine and radiation	a) Per cent possible sunshine b) Number of clear, partly cloudy, cloudy days c) Amounts of global and net radiation.
	Humidity	a) Probability of a specified relative humidity b) Duration of a specified threshold of humidity.
	Free water evaporation	a) Total amount b) Diurnal variation of evaporation c) Relative dryness of air d) Evapotranspiration.
	Dew	a) Duration and amount of dew b) Diurnal variation of dew c) Association of dew with vegetative wetting d) Probability of dew formation based on the season.
	Hazards and Extreme Events	a) Frost b) Cold wave c) Hail d) Heatwave e) Cyclones f) Floods g) Rare sunshine h) Waterlogging. i) Wind gales
	Weather Forecasts	a) Nowcasting b) Very short-range forecasts c) Short-range forecasts d) Medium-range forecasts e) Long-range forecasts

Area	*Variable(s)*	*Information products and services*
Climate	Recent and historical climate data	Statistics of data Probabilities Extreme value analysis Long-term means and trends Diagnostics of climate variability characteristics f) Diagnostics, assessment, and attribution of current seasonal/sub-seasonal rainfall and temperature patterns, and their anomalies including the associated circulation features;
	Climate extremes	Drought frequencies Drought indices Indices of climate extremes or other, more complexindices that combine several parameters with different thresholds (e.g., temperature with precipitationand humidity) Information on the distribution, frequency andintensity of climate extremes such as forest and grassland fires, droughts, floods and heat waves, including special reports on contemporary and past events.
	Climate Forecasts	Monthly, seasonal and decadal forecasts on rainfall and temperature, adequately incorporating aspects of uncertainty Global climate models Regional climate models Information on the relevance of major drivers of climate variability, e.g. El Niño/La Niña, North Atlantic Oscillation, Indian Ocean Dipole, Madden-Julian Oscillation
	Climate Products	Products (datasets, text, maps, charts, statistics, etc.) that describe the past, present and future climate of different locations and , regions in a country Climate monitoring products such as national State of the Climate reports Climate change projection products including downscaled national projections based on appropriate IPCC scenarios
Land	Soil temperature	a) Mean and standard deviation at standard depth b) Depth of frost penetration c) Probability of occurrence of specified temperatures at standard depths d) Dates when threshold values of temperature (germination, vegetation) are reached.
	Soil water	a) Soil water balance: moisture assessment and forecasts b) Actual evapotranspiration c) Irrigation scheduling

Preparedness is urgently needed to improve the effectiveness of response and recovery, such as establishing early-warning systems to shift from crisis management to risk management for long term planning strategies to cope with climate extremes and climate change in the agriculture sector. Through effective delivery of climate services, NMHSs can help inform decision-making in adaptation planning. Linking climate service development to adaptation planning will therefore be critical.

Agriculture and food security users also have experience with, and need for, functioning and applied weather and climate services that are particularly critical for risk and preparedness management and short-range planning (WMO, 2014c). Common, but not exclusive, decisions that benefit from the use of information about the weather and climate include:

- Identification of extreme weather and climate hazards that pose risks to agriculture and food security;
- Identification of populations vulnerable to weather and climate hazards;
- Plant and animal pest and disease control strategies;
- Regulation and laws;
- Pesticide and herbicide applications, fertilizer management, farm and irrigation management;
- Weather and climate sensitive decisions in the agriculture and food security value chains;
- Decisions on export and import of agricultural inputs and products;
- Decisions related to marketing of agriculture and food security products.

Recent publications in this regard include the following:

- Guidelines for Preparation of the Drought Management Plans

http://www.droughtmanagement.info/literature/GWPCEE_Guidelines_Preparation_Drought_Management_Plans_2015.pdf

- Drought Monitoring and Early Warning (WMO No. 1006)

http://www.wamis.org/agm/pubs/brochures/WMO1006e.pdf

Intra- and inter-seasonal variability has a major impact on agriculture and food security. Seasonal climate outlooks can influence decisions on which varieties to plant and when, or the best timing for spraying where plant disease outbreaks are likely to occur, or perhaps estimate of the quantity of water needed for irrigation or whether to reduce livestock numbers if a drought is forecast. Farmers may be unprepared for expected weather conditions and make decisions based on an understanding of general climate patterns in their regions. Better climate predictions three to six months in advance can help shape appropriate decisions, reduce impact and take advantage of forecasted favourable conditions. Seasonal forecasts provide probability distribution for monthly to seasonal means of climate parameters (in terms of their departures from long-term averages), such as rainfall and temperature, several months in advance that can be used for crop yield estimates. Yet, information about growing season weather beyond the seasonal average is also needed, such as growing degree days, chill days, and changes in the growing season (WMO, 2014c). This approach addresses the activity on comprehensively and iteratively assessing development needs and climate vulnerabilities in the first element of the NAP process ie., laying the groundwork and addressing gaps. The activity on enhancing capacity for planning and implementation of adaptation under the third element (implementation strategies) of NAP process is also addressed by this approach.

Seasonal climate forecasts tend to have more skills during the El Niño-Southern Oscillation (ENSO) events. Although the ENSO phenomenon occurs within the Tropical Pacific, it affects interannual weather variability in many other regions of the world. Good teleconnections with ENSO do exist, for example, with the regional climate during cropping seasons in West Africa, Southern Africa and the October-December “short rains” in East Africa. Seasonal climate outlooks issued by NMHSs in these regions can influence decisions on which varieties to plant and when, or the best timing for spraying where plant disease outbreaks are likely to occur,

or perhaps estimate the quantity of water needed for irrigation or whether to reduce livestock numbers if a drought is forecast. Countries in these regions jointly access forecasts based on such teleconnections through the Regional Climate Outlook Forums (RCOF), and develop a consensus-based seasonal climate outlook. In East Africa, the Food Security Outlook (FSO) process links output from the Greater Horn of Africa COF to deliver early warning of risks that could affect food security in the coming six months. This process uses meteorological and seasonal climate projections based on ENSO, sea surface temperatures of the Indian and Atlantic oceans and other influences of rainfall in the Greater Horn of Africa. The input data comes from a variety of sources including the IGAD ICPAC, NMHSs, and FEWS NET partners including NOAA and the UK Met Office. The data are fed into dynamic and statistical models to produce rainfall forecasts, analysed and interpreted by experts. The rainfall forecasts are then related to food security and vulnerability data provided by WFP, FAO, and NGOs to produce the FSO reports, which provide decision-makers with crucial early insights for food security risk reduction. The FSO and RCOF processes include development of user capacity to understand and use the information.

Numerous projects across the world aim to deliver reliable, timely, locally understandable climate information with response options to farmers, considering inputs, credit, market and financial aspects. They include interdisciplinary training, knowledge building and awareness raising. Examples of existing activities in this category include the World AgroMeteorological Information Service (WAMIS) of WMO which hosts agrometeorological bulletins and advisories issued by NMHSs, aiding user evaluation of various bulletins and sharing insight into improving their own bulletins. Over 50 countries and institutions participate in this service (www.wamis.org). WAMIS also host a tools and resources section, which includes data, information, dissemination, and feedback. Other examples include software, web portals, training resources, and tutorials, climate and agriculture working groups in Africa and Indonesia such as the Farmer Field Schools of Indonesia and resilience building initiatives focused on weather indexed insurance, micro credit and risk reduction activities (WMO, 2014c). WAMIS provides a good example as to what can be learned from international experiences and international cooperation on adaptation planning under the third element (implementation strategies) of the NAP process.

5.1.2 **Disaster Risk Reduction**

Natural hazards involving weather, climate and water are a major source of death, injury and physical destruction. Natural hazards become natural disasters when people's lives and livelihoods are destroyed. Human and material losses caused by natural hazards are a major obstacle to sustainable development as every year, natural hazards cause significant loss of life and erode gains in economic development. Nine in ten of the most commonly reported disasters are directly or indirectly related to weather or climate. During the past five decades, disasters of hydrometeorological origin such as droughts, floods, storms and tropical cyclones and wild land fires have caused major loss of human lives and livelihoods, the destruction of economic and social infrastructure, as well as environmental damages. According to the Centre for Research on the Epidemiology of Disasters (CRED, 2015), 11,938 disasters occurred during 1970 to 2014, leading to a total loss of 3.48 million lives and economic losses amounting to US$ 2.69 trillion.

Among the ten costliest storm events during 1980 to 2014, ordered by overall losses (Munich Re, 2015), Hurricane Katrina which occurred in August 2005 in USA ranked first with overall losses of US $ 125 billions and 1,322 fatalities followed by Hurricane Sandy which occurred in October 2012 in the Bahamas, Cuba, Dominican Republic, Haiti, Jamaica, Puerto Rico, USA, and Canada with overall losses of US $ 68.5 billions and 210 fatalities. Among the ten costliest floods during 1980 to 2014, the floods and landslides which occurred in Thailand in November 2011 ranked first with overall losses of US $ 43 billions and 813 fatalities.

A higher number of disasters that are linked to environmental hazards occur in developing countries and the impacts are greater in these countries. According to Munich Re (2013), the average percentage of direct losses per year with respect to GDP is highest in emerging economies at 2.9%, compared with developing economies (1.3%) and industrialized countries (0.8%).

Tools and Products to provide Climate Services for Farmers

Detailed observations and real-time dissemination of meteorological information, quantification by remote-sensing (radar and satellites), and derived indices and operational services are important for facilitating tactical on-farm operational decisions at different crop growth stages by farmers. The economic value of weather information products is steadily increasing as a result of rising public awareness over the years. Facilities for data quantity and quality control, quick processing and analysis have made this possible. To make information available to assist farmers all the time at the field level, to prepare advisories, and to facilitate long-term planning, it is necessary to combine the agricultural and the meteorological data. The tools and products include the following:

a) Primary tools including data, quantification, statistics, indices and modeling
b) Monitoring and early warning tools for preparedness strategies
c) Forecasting and prediction tools to guide preparedness with probabilities
d) Direct preparedness strategies for crop, forest and livestock protection
e) Determination of crop weather/climate requirements; classification of land into crop suitability zones, integrating both climate and soil factors; and more detailed determination of differences in the impacts of climatic events, particularly recurring events (whether or not related to El Niño–Southern Oscillation (ENSO) phenomena), such as droughts, floods and cyclones, under different preparedness strategies.

The data for agrometeorological applications and their distribution; the database management; the statistical methods of agrometeorological data analysis; weather and climate forecasts for agriculture; climate and weather risk assessment for agricultural planning and agrometeorological services for selected crop production, forestry, livestock, aquaculture and fisheries and for arresting land degradation are described in detail in the WMO Guide for Agricultural Meteorological Practices (WMO, 2010). Two examples of the tools and products for farmers are shown below.

Standardized Precipitation Index (SPI)

Drought is an insidious natural hazard that results from lower levels of precipitations than what is considered normal. Drought means different things to different users such as water managers, agricultural producers, hydroelectric power plant operators and wildlife biologists. Even within sectors, there are many different perspectives of drought because impacts may differ markedly. Over the years, many drought indices were developed and used by meteorologists and climatologists around the world. Experts who participated in the Interregional Workshop on Indices and Early Warning Systems for Drought, held at the University of Nebraska-Lincoln, United States of America, in December 2009, elaborated and approved the Lincoln Declaration on Drought Indices, which recommended that the Standardized Precipitation Index (SPI) be used by all National Meteorological and Hydrological Services (NMHSs) around the world to characterize meteorological droughts, in addition to other drought indices that were in use in their service (WMO, 2012).

- *Standardized Precipitation Index User Guide (WMO No. 1090)*
  http://www.wamis.org/agm/pubs/SPI/WMO_1090_EN.pdf

The SPI (McKee et al. 1993, 1995) is a powerful, flexible index that is simple to calculate. The SPI can be computed for different time scales, provide early warning of drought and help assess drought severity. The SPI calculation for any location is based on the long-term precipitation record for a desired period. This long-term record is fitted to a probability distribution, which is then transformed into a normal distribution so that

the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). Positive SPI values indicate
greater than median precipitation and negative values indicate less than median precipitation. Because the SPI is normalized, wetter and drier climates can be represented in the same way; thus, wet periods can also be monitored using the SPI. McKee et al. (1993) used the classification system shown in the SPI value table below to define drought intensities resulting from the SPI. They also defined the criteria for a drought event for any of the timescales. A drought event occurs any time the SPI is continuously negative and reaches an intensity of -1.0 or less. The event ends when the SPI becomes positive. Each drought event, therefore, has a duration defined by its beginning and end, and an intensity for each month that the event continues. The positive sum of the SPI for all the months within a drought event can be termed the drought's "magnitude".

SPI Value	Category
2.0+	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-.99 to .99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

The latest SPI program (SPI_SL_6.exe) and instructions for Windows/PC use can be found at http://drought.unl.edu/MonitoringTools/DownloadableSPIProgram.aspx.

Agricultural Weather Forecasts

An agricultural weather forecast refers to all weather elements that immediately affect farm planning or operations. The elements will vary from place to place and from season to season. Normally a weather forecast includes the following parameters.

(a) Amount and type of cloud cover;
(b) Rainfall and snow;
(c) Maximum, minimum and dewpoint temperatures;
(d) Relative humidity;
(e) Wind speed and direction;
(f) Extreme events, such as heatwaves and cold waves, fog, frost, hail, thunderstorms, wind squalls and gales, low-pressure areas, different intensities of depressions, cyclones, and tornadoes.

Formats of forecasts for agriculture vary widely in different agricultural contexts due to the high degree of variability among users, crops, agrotechniques, and so on. Specialized forecasts can be tailored for crops, animal husbandry, forestry, fisheries and horticulture.

Detailed information on the considerations related to agricultural weather forecasts including the different elements of the weather forecasts, format of forecasts, specific description of the processing of weather forecasts of single weather variables for agricultural purposes etc., can be found in the in the WMO Guide for Agricultural Meteorological Practices (WMO, 2010).

Natural hazards occur across different time and spatial scales and each is in someway 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 (heatwaves) 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.

Figure 5 shows that the frequency of disasters increased steadily from 1970 with the peak frequencies in the year 2000. Such changes in weather and climate extremes, and their related impacts, pose challenges for national and local disaster risk reduction systems. Better climate services can help meet these challenges, in both the short- and the long-term, by giving decision-makers enhanced tools and systems to analyse and manage risk, under current hydrometeorological conditions and in the face of climatic variability and change (WMO, 2014d). The value of climate services in reducing disaster risk is broadly recognized, given the preponderance of hydrometeorological hazards in shaping disaster risk, and the fundamental role that climate information plays in disaster risk reduction efforts (WMO, 2014d). Disaster risk reduction decisions are taken by a broad group that includes disaster risk managers, as well as government sectors, humanitarian and development agencies and banks, the private sector, nongovernmental organizations, communities and individuals. Multiple consultations, meetings and publications have found that these actors need climate information that is tailored to their specific decision-making needs, and provided in appropriate language and formats that facilitate action (Helmuth et al. 2011).

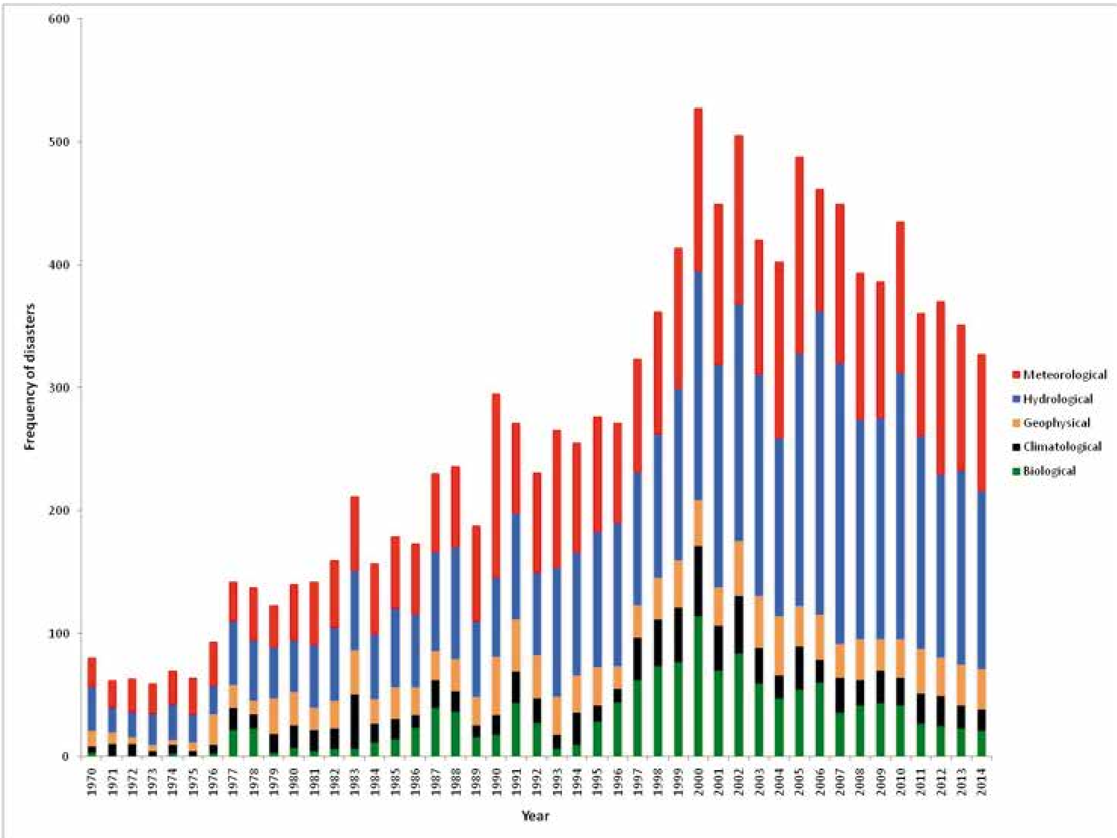

Figure 5. Frequency of natural disasters from 1970 to 2014 (Source of data: CRED, 2015)

To reduce and mitigate disasters, NMHSs provide quick, timely, accurate, broadly disseminated and understandable information as well as high quality services to inform governments and the public to take appropriate actions in response to warnings. Under climate services for disaster risk reduction, there are six priority categories of activities (Fig. 6), that would catalyze provision of related products and services by NMHSs, and promote widespread implementation of programmes and initiatives that incorporate climate information and services (WMO, 2014d). These categories are aligned with existing disaster risk reduction structures, and compatible with other relevant international initiatives, including the Sendai Framework for Disaster Risk Reduction.

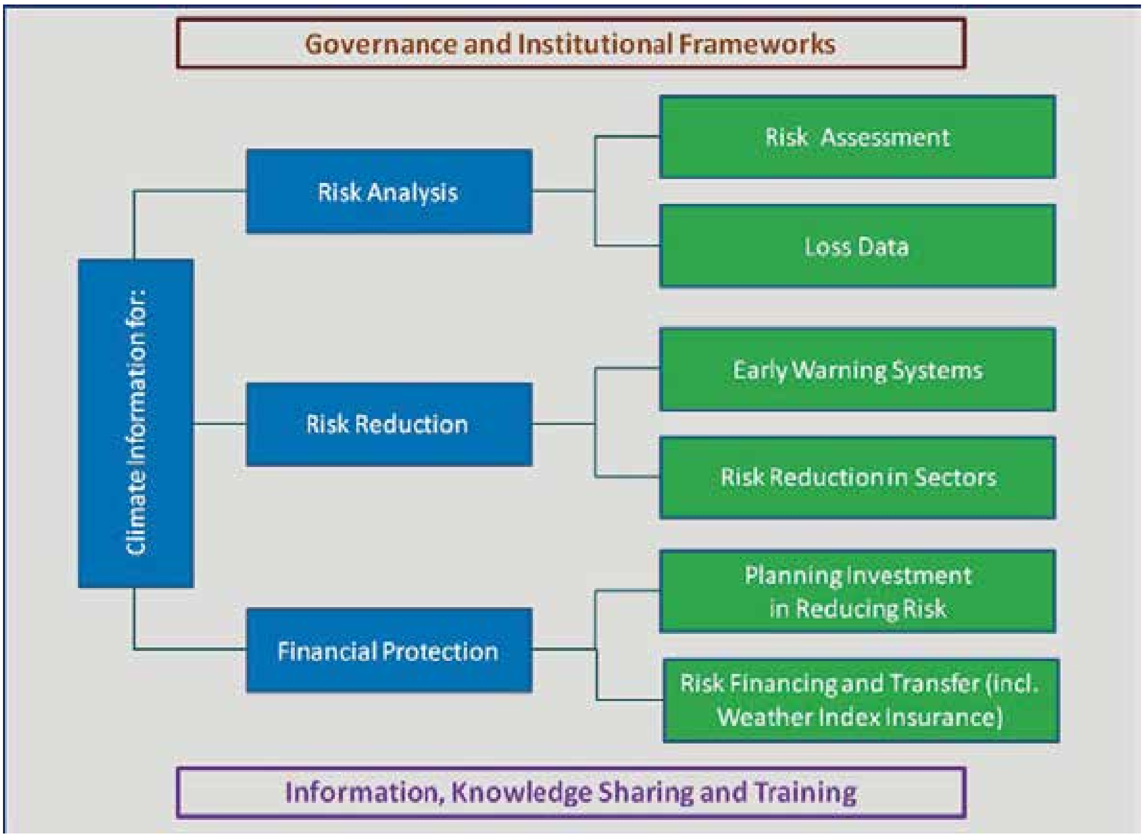

Figure 6. Priority categories of activity under climate services for disaster risk reduction (in green).

These categories include:

a) **Risk Assessment**: Information on weather and climate hazards needs to be complemented with exposure and vulnerability information to develop a complete picture of risk. Climate information is critical for the analysis of hazard patterns and trends.

b) **Loss Data**: Historical and real-time data on loss and damage provide a crucial input for assessing risks of future disasters. Climate services, over time, provide information on historical and ongoing extreme climate events, and help to identify and build processes for integrating this information into loss and damage accounting systems.

c) **Early Warning Systems**: Lessons learned from a number of good national practices in multi-hazard early warning systems indicate that these systems enable decisions to protect lives and livelihoods in short and longer-term timeframes by extending the lead time for contingency planning and preparation. Both short-term weather forecasts and seasonal forecasts can be used to build reliable deterministic or probabilistic risk scenarios and, in turn, to strengthen disaster preparedness.

d) **Risk Reduction in climate-sensitive sectors**: Climate-sensitive sectors include agriculture, health, water, energy, housing, infrastructure, tourism, industry and trade. Multi-sectoral plans to reduce disaster risk and to adapt to climate change consider historical, current and long-term risk in order to avoid investment that locks in future risk or results in mal-adaptation, such as infrastructure that cannot withstand shorter return times for heavy rain.

e) **Planning Investment in Reducing Risk**: Sound financial planning and investment plays a crucial role in reducing the risk of disaster. Climate information is an important component of the evidence base required to guide decisions regarding appropriate levels of investment to minimize potential impacts on the economy, ensuring uninterrupted delivery of critical services and infrastructure, investing in the development of early warning systems and contingency planning, reserving contingency funds for emergency use, and potentially subsidizing vulnerable or impacted sectors to help protect socio-economic welfare.

f) **Risk Financing and Transfer**: Disaster risk financing and transfer can be broadly defined as structured sharing of the potential financial impacts of disasters caused by natural hazards; often, but not strictly, through insurance mechanisms. Risk financing and transfer requires climate services to inform risk assessments and catastrophe risk analysis, ideally based on at least 30 years of hydrometeorological and other asset and vulnerability information. In the case of innovative risk transfer tools, such as weather derivatives or index-insurance, climate information is also needed to determine payout structures, as payouts are not based on actual losses, but triggered by meteorological parameters such as wind, rainfall and temperature. Forecasts of these types of parameters have been used for both portfolio risk management and diversification purposes.

As shown in Figure 6, the six categories of activities are drawn from more general areas of disaster risk reduction practice, which may over time benefit in other ways from enhanced climate services. Risk assessment and loss data are both forms of risk analysis. Early warning systems and sectoral risk reduction fall within the broader heading of risk reduction actions. And finally, both planning investment in reducing risk, and risk financing and transfer, comprise a part of a larger category of financial protection activity aimed at lessening the economic impact of disasters. Clearly there is a great deal of interaction between the areas, as, for instance, risk analysis is the basis for effective risk reduction and financial planning, and planning investment is required to finance both risk analysis and risk reduction.

Figure 6 also includes boxes above and below representing the essential role of "Governance and Institutional Frameworks" and "Information and Knowledge Sharing" in integrating climate services into all these disaster risk reduction activities. These elements are part of all six of the priority categories, and also should be considered priority elements of GFCS for disaster risk reduction.

The above activities and the ones described below under weather and climate data and information products and services for the priority area of Disaster Risk Reduction, are linked to the following activities under the different elements of the NAP process:

Element A (Laying the groundwork and addressing the gaps): Stock-taking: identifying available information on climate change impacts, vulnerability and adaptation and assessing gaps and needs of the enabling environment for the NAP process; addressing capacity gaps and weaknesses in undertaking the NAP process; and comprehensively and iteratively assessing development needs and climate vulnerabilities.

Element B (preparatory elements): Analyzing current climate and future climate change scenarios (What risks does climate change hold for the country? What are major current climate hazards?); Assessing climate vulnerabilities and identifying adaptation options at sector, subnational, national and other appropriate levels; Reviewing adaptation options.

Element C (implementation strategies): Prioritizing climate change adaptation in national planning; Developing a (long-term) national adaptation implementation strategy (What is the

most appropriate strategy for the implementation of adaptation activities including timing, target areas/beneficiaries, responsible authorities and sequencing of activities? How can the implementation build on and complement existing adaptation activities?); Enhancing capacity for planning and implementation of adaptation; Promoting coordination and synergy at the regional level and with other multilateral environmental agreements (How can the cross-sectoral and regional coordination of adaptation planning be promoted and enhanced? How can synergy with other multilateral environmental agreements in the planning and implementation process be identified and promoted?)

Table 2 shows the different weather and climate service data and products that support the different elements of the NAP process.

Table 2.Different weather and climate service data and information products and services for the priority area of Disaster Risk Reduction that support the different elements of the NAP process

Element	*Step*	*Weather and Climate Data and Information Products and Services*
A. Laying the groundwork and addressing the gaps	A.2.Stock-taking: identifying available information on climate change impacts, vulnerability and adaptation and assessing gaps and needs of the enabling environment for the NAP process	a)Historical extreme climate events. b) Archive of past losses. c) In situ and space-based Earth system observing networks for monitoring and detection of hazards, designed with consideration for decision-making spatial and temporal requirements. d) Archives and real-time data records and metadata flagging when events can be expected for dynamic risk assessment. e) Real-time monitoring of hazards and development of historical databases and metadata per standards.
	A.3. Addressing capacity gaps and weaknesses in undertaking the NAP process	a) Identify responsible bodies for developing and implementing appropriate measures, warning communication, and awareness and education activities.
	A.4.Comprehensively and iteratively assessing development needs and climate vulnerabilities.	a)Provide understanding of risk assessment demand and requirements. b) Incorporate relevant climate observations, statistical analysis, forecasts and projections of the weather, hydrological and climate related extremes in risk assessment processes.
B. Preparatory elements	B.1. Analyzing current climate and future climate change scenarios	a) Forward-looking forecasts and trend analysis of hazard characteristics at different temporal and spatial resolutions. b) Risk analysis (multi-hazard, multilevel and multi-sector). c) Identification of information requirements and channels.

Element	*Step*	*Weather and Climate Data and Information Products and Services*
	B.2. Assessing climate vulnerabilities and identifying adaptation options at sector, subnational, national and other appropriate levels	a) Define requirements for climate services and other non-climate inputs for planning investment in reducing climate vulnerabilities. b) Engage stakeholders for implementation – finance and planning ministries, disaster risk management authorities, local authorities and government, private sector etc. c) Establish coordination and information channels for relevant inputs.
	B.3 Reviewing and appraising adaptation options	a) Identify stakeholders and existing processes for hazard loss accounting system implementation b) Identify information channels. c) Coordinate development of relevant climate products and services in relation to specific application to decision making in different sectors.
C. Implementation strategies	C.1. Prioritizing climate change adaptation in national planning	a) Identify priority regions based on analysis of vulnerability to weather and climate extremes and other important factors and future projections
	C.2. Developing a (long-term) national adaptation implementation strategy	a) Identify the areas where current information on weather and climate is inadequate b) Strengthen the meteorological observation networks, data analysis and applications
	C.3. Enhancing capacity for planning and implementation of adaptation	a) Strengthening operational climate services including analysis, forecasts and projection of climatic regimes and probabilities and scenarios related to extreme patterns. b) Promote interoperability of health, socioeconomic and biological data with weather, hydrological and climate extremes and changes in their characteristics.
	C.4. Promoting coordination and synergy at the regional level and with other multilateral environmental agreements	a) Strengthen cooperation with WMO Regional Climate Centers (RCCs)

5.1.2.1 **Weather and Climate Data**

NMHSs can provide past climate data which are essential for quantifying hazard characteristics of a region, in particular the frequency, severity and location of climatic extremes by retrieving and computerizing all available data at the highest temporal and spatial resolution possible in order to capture the characteristic features of particular hazards. While historical climate data remain the prime resource for analyzing 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 have become a 1 in 30-year flood or drought. 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 modeling of the climate system.

As there is a significant difference between a hazard and disaster – with not every hazardous event becoming a disaster – NMHSs can pay special attention 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 insurance group Munich Re and the Centre for Research on the Epidemiology of Disasters (CRED) are useful resources for identifying events for which complementary weather and climate datasets at a national level could be compiled.

5.1.2.2 **Information Products and Services**

An essential starting point for reducing risks from disasters 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. NMHSs can provide information on weather and climate hazards which can be complemented with exposure and vulnerability information to develop a complete picture of risk. Armed with evidence concerning risk, individuals, communities, organizations, businesses and governments can make decisions to protect themselves from loss and adapt to the changing climate. Climate information is critical for the analysis of hazard patterns and trends. NMHSs can also provide information on historical and ongoing extreme climate events which can help to identify and build processes for integrating this information into loss and damage accounting systems.

In the past five decades, mortality rates from disasters have decreased in some regions as a consequence of the development of multi-hazard early warning systems. NMHSs are working together with the public and private sectors to implement multi-hazard early warning systems, which aim to further significantly reduce the number of fatalities caused by weather, water- and climate-related natural disasters. These systems enable decisions to protect lives and livelihoods in short and longer-term timeframes by extending the lead time for contingency planning and preparation. By helping governments and the people to avert potential disasters and maximize opportunities for sustainable development, NMHSs are one of the main components of the risk information management, crisis management and development infrastructure of countries.

NMHSs can also provide climate services for risk financing and transfer to inform risk assessments and catastrophe risk analysis which are ideally based on at least 30 years of hydrometeorological data and other asset and vulnerability information. NMHSs also provide climate information for the innovative risk transfer tools, such as weather derivatives or index-insurance in order to determine payout structures, as payouts are not based on actual losses, but triggered by meteorological parameters such as wind, rainfall and temperature. For example, the weather index-based crop insurance provides financial coverage to protect smallholder farmers against the potential impacts of deficit/erratic rainfall, extreme temperatures and other environmental variables. An index insurance contract pays out on the value of an index; in this case the index is based on measured hydrometeorological variables such as rainfall, temperature or river levels. Forecasts of these types of parameters have been used for both portfolio risk management and diversification purposes.

5.1.3 **Health**

Evidence based decision-making is a fundamental principle for the health sector. The health community relies on appropriate and timely epidemiological, environmental, and climate information at relevant spatial and temporal scale data to make informed decisions. Climate-informed health systems and services can not only save lives but help increase the efficient use of limited resources by identifying and targeting the populations most at risk in vulnerable areas

and developing the capacity of health and other sectors to manage the risks to health. Available, accessible, and useful weather and climate information can help health decision makers improve, inter alia, understanding of the mechanisms of climates impact on disease transmission and occurrence, and estimate populations at risk (e.g. risk mapping). It can help estimate seasonality of disease occurrence and necessary timing of interventions and investments. It can help monitor and predict year-to-year variations in disease incidence (e.g. early warning systems for epidemics), as well as longer term trends of potential impacts (e.g. climate change assessments). Climate information can also improve impact assessments, by removing climate as a confounder of health intervention performance.

The need for collaboration between the NMHSs and the health sector has increased over the past decade, along with the need to better manage health risks associated with climate variability and change. NMHSs can enhance the management of climate-related risks to health by raising awareness of climate risks to health, the availability, uses, and benefits of climate services for health policy and operations. NMHSs can also support research which builds evidence for health policymaking and operations, via both provision of information and engagement in jointly developed health oriented climate service products. They can also 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.

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

a) 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.

b) 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.

c) To facilitate the mainstreaming of climate services into health policy and practice in order to build a health sector that is resilient to climate related pressures.

Under the activity on stock-taking of element A (Laying the groundwork and addressing the gaps) in the NAP Process, the importance of a synthesis of the state of the science on current climate variability and existing vulnerabilities, projected climatic changes, associated impacts and future vulnerabilities, and any outcomes of past adaptation efforts in reducing vulnerability was highlighted as this would develop a basis for further planning and guide efforts to improve this knowledge base. In addition, this activity also calls for conducting a gap analysis to assess capacities and weaknesses, adequacy of available data and information, and resources to effectively engage in the NAP process. The climate services for the health priority area of GFCS addresses these issues and also other important activities highlighted under element B (preparatory elements) of the NAP process such as analysis of current climate to identify trends in variables and indices that could be used to support planning and decision making; assessment of climate vulnerability and identification of adaptation options. The design of implementation strategies of the national adaptation plans with the focus on prioritizing adaptation actions within national planning, identifying synergies and developing and enhancing the country's long-term capacity for planning and implementing adaptation which are important activities under element 3 (implementation strategies) of the NAP process are also addressed under climate services for the health priority area of of GFCS. Some of the details are presented below in the sections on weather and climate data and the information products and services for the health sector.

5.1.3.1 **Weather and Climate Data**

NMHSs can provide climate services to health including those directly related to user needs, such as local measurements of precipitation, soil moisture and surface air temperature, which are needed, for example, to identify malaria risk by correlating health and population information with observations of local ecological conditions conducive or non-conducive for transmission. Observational data from NMHSs are particularly important to establish baselines for historical climate conditions required by health researchers to make correlations and causal linkages between climate and health outcomes. Observations are also needed to enable useful forecasts to be made.

NMHSs can meet the operational needs for weather and climate data in the health sector (WMO, 2014e), which include:

a) Evidence based health risk assessments that are core health decision support processes that require integrated approaches to link historical climate data and observations, with qualitative and quantitative health vulnerability and exposure information. A real need exists to take stock of gaps and needs in: (1) the availability of historical and future hazard data, metadata, tools and methodologies in hazard mapping and human expertise of the technical agencies (on the provider side); but also (2) availability of health sensitivity, impact, vulnerability and weather related hazard exposure information, and user-capacity to incorporate climate information in routine health decisions.

b) Health surveillance that is a core function of the health sector and the backbone of decision making. It is analogous to observations for the climate community. Integrating social indicators from health surveillance with climate and environmental observations will be a core task for most collaborative action. Development of guidance, standards, and tools can assist this process.

Operational research is needed on the temporal, spatial and spectral aspects of meteorological data for healthcare purposes, as well as for the quality, level, and detail of healthcare data required for disease modelling.

5.1.3.2 **Information Products and Services**

Health decisions that can potentially be climate informed are vast and depend upon the type of stakeholder and the time-frame of the decision (i.e. long-term planning or day-to-day emergency management). NMHSs can provide weather and climate information that can help health decision makers improve, inter alia, understanding of the mechanisms of climates impact on disease transmission and occurrence, and estimate populations at risk (e.g. risk mapping). NMHSs can also provide decadal climate projection maps for human vulnerability assessment and adaptation planning. Such tools and methodologies can help the officials in the health sector to incorporate the information generated in routine health decisions. Such information can be particularly helpful to anticipate, prepare for and respond to health risks on both short time scales to address health problems triggered by climate variability (such as an outbreak, or thermal extremes), as well as longer time frame risk changes associated with climate change (i.e. droughts, sea-level rise and health infrastructure protection). In this context, early warning systems of extreme weather events, particularly for heat and cold, that pose health risks can provide very useful information to the health authorities to take preventive action. By working collaboratively and iteratively with the professionals in the health sector, NMHSs can develop and deploy Health - Early Warning Systems (Health-EWS) and other interface tools that help health professionals and community access pertinent weather and climate-related health information that can improve health preparedness and critically extend the lead-time health actors have for decisions and preventive measures.

The health sector currently uses different types of meteorological, hydrological and climate information-products and services. Four categories of climate information and services used by the health sector are shown in Table 3 according to various time frames. Short-term climate

information has a broad range of applications, including adaptation of World Health Organization (WHO)/national response plans based on seasonal information (such as El Niño/La Niña) and development of national/community/health facility response plans for climate-related hazards, including wildfire, flood, storms, landslides, infectious diseases, water shortages, cold weather, heat stress, chemical and radiological hazards and other potential sources of risk, including food security, mass gatherings, population displacement and infrastructure failure. Long-range climate information such as global climate models and climate scenarios anticipate how the conditions of the climate will be decades into the future and is critical for climate adaptation in the health sector. These climate products can provide key information for research, long-range policy, planning, and investment decisions. Collaborative work between the climate service providers and the health sector will be essential to develop the prediction products (monthly, seasonal, decadal) that can be easily used by the health community for their decision needs.

Table 3. Types of climate information relevant for health decision-making

Time Scale	*Example Climate Information Products*	*Example application areas*
Long Range Climate information (decades)	Climate change scenarios Dynamic climate models, Global Circulation Models	Long-term health infrastructure investments, research, demographic/ population models, health systems planning Increase understanding of disease trends, epidemic behaviour on a regional scale
Mid-term Climate information (annual to multiyear)	Status of El Niño Inter-annual forecasts Dynamic climate models	Mid-term policy decisions for disease control, research
Short-term Climate Information (Decadal, Monthly, Seasonal, Annual)	Risk indexes of Cyclones, Floods, Dust Storm, Wind Storms, Extreme Temperature, Fire Temperature/precipitation Outlooks of (6,3, 1 month) average, maximum and Minimum Seasonal trends Tercile forecasts Dynamic and Statistical climate models	Short-term operational investment in preparedness, outbreak prevention, resource needs Example, adaptation of WHO/ national response plans based on El Niño/La Niña forecasts
Weather Information (Hourly, Daily, Weekly)	Daily Weather: temperature, precipitation, humidity, etc. Weather statistics: real-time monitoring, historic time-series, summary statistics	Short-term operational decisions Risk announcements, trigger response plans, staff placement, delivery of supplies

An example is the "explanation note" of La Niña conditions developed for the health community, by IRI and WHO (2010). The note provides regional summaries as well as action points of what health authorities should do next to collaborate with NMHSs to find out national conditions. Through a public service platform, NMHSs with partner institutions can encourage cross-sectoral interaction including cooperation on the establishment of observing and monitoring networks, the development of decision-support tools and systems and the development of 'one stop' advisory services for the health sector that will strengthen health surveillance and response systems. The sharing of data, information and capacity is necessary for improving health monitoring and surveillance systems to achieve "the most elementary public health adaptation" especially for least developed countries. By improving the dialogue with the health sectors on the range, timing, quality and content of climate products and services, NMHSs can ensure that decisions relating to managing climate risks are well informed, more effective and better

targeted. NMHSs can also collaborate in the research efforts on forecasting of health impacts associated with climate variability and climate change and in understanding the role of climate in health outcomes (i.e. studies of correlation and causality), and in development of operational methods and tools (such as climate-health indices for heatwave alerts) including climate enabled decision support systems, such as EWS. Another area of collaboration is the operational research on the temporal, spatial and spectral aspects of meteorological data for healthcare purposes, as well as for the quality, level, and detail of healthcare data required for disease modelling.

An extensive range of collaborative activities between the meteorological and health communities span health policy, research, and practice at global, regional, and national scales. These on-going efforts have built experience, learning, and a community of practice to expand upon and consider for partnership. Notable examples include:

Heat-health and cold-health early warning systems, including development and use of climate indices relevant to health outcomes (municipal/national in Europe, China, Canada);

Health-sector participation in RCOFs/NCOFs (Africa);

Early warning systems for malaria, rift valley fever, plague, water borne diseases and

meningitis (Africa, Indian Ocean, Asia, Pacific);

Health emergency and disaster management programmes across the world to deal with health risks and effects of climate and weather events;

Air quality, pollens and allergens, ultra-violet radiation and their impacts on human health, especially in cities (Americas, Europe, Asia);

Interdisciplinary training, knowledge building and awareness raising (global);

Gathering and managing evidence on the impacts of climate variability and change on the various aspects of the health sector, including vector and water borne diseases, for improved surveillance, evaluation, preparation and response activities (impacts assessment, impacts modelling, etc.) (Africa, Americas, Europe, Asia);

Multi-hazard early warning systems at national and municipal scale (e.g. Shanghai);

Integrated Climate, Health, and Environment Surveillance Systems (Africa);

UNFCCC National Communications and National Adaptation Plans of Action, for health;

Climate and Health Vulnerability and Adaptation Assessments;

Improved public health system management of temperature extremes, most regions;

WHA and Regional Committee work plans for Climate and Health Adaptation Policy;

Safe Hospitals Initiative (global) assesses and improves the safety and preparedness of existing health facilities and ensures building new facilities are designed in relation to local risks, including climate variability and change;

WMO Pilot Projects for Climate and Health Working Groups (Africa).

5.1.4 **Water**

Water management (both surface water and groundwater) is intrinsically linked to climate variability and change. Climate data are critical for the assessment of fluctuations and trends and the risks arising from exposure and vulnerability to natural hazards (floods and droughts) and

WMO-WHO publication on Heatwaves and Health: Guidance on Warning-System Development

Over the past 50 years, hot days, hot nights and heatwaves have become more frequent. The length, frequency and intensity of heatwaves will likely increase over most land areas during this century, according to the Intergovernmental Panel on Climate Change. In addition to the health impact, heatwaves also place an increased strain on infrastructure such as power, water and transport.

Growing concerns over climate change have brought to the fore three important aspects: adaptation, disaster-risk reduction and the need for climate information and services to support these. Heat-Health Warning Systems bring together these three facets and exemplify an effective demonstration of climate-risk management in practice. These provide meteorological and/or climate-prediction-based information on the likelihood of forthcoming hot weather that may have an effect on health. This information is used to alert decision-makers, health services and the general public to trigger timely action to reduce the effects of hot-weather extremes on health.

A number of countries around the world have successfully developed these early warning systems, which necessitates close coordination between meteorological and health services. The WMO-WHO publication *Heatwaves and Health: Guidance on Warning-System Development* promotes more widespread development and implementation of these warning systems (WMO and WHO, 2015). The Guidance considers who is at risk from heat, outlines approaches to assessing heat stress, surveys heat-intervention strategies which are a necessary part of any truly integrated Heat Health Warning System and presents the underpinning science and methodologies..

for the sustainable management of the water resources. There is a wide cross-section of users from the water sector, including for example, hydrological characterization, water supply, flood management and control, irrigation and drainage, power generation, fisheries and conservation, navigation and recreation. These users have a need for a range of climate services (WMO, 2014f) to support decisions relating for a range of uses related to Integrated Water Resource Management (IWRM) planning, which include:
Identification of extreme weather and climate hazards that pose water-related risks;

- Identification of populations vulnerable to weather and climate hazards, including those in the coastal zone;
- Allocation and re-allocation of water resources;
- Design and placement of infrastructure and personnel (i.e. water management organizations, structures and facilities);
- Implementation of risk management and emergency preparedness practices and procedures;
- Dissemination of information to users, including the public, i.e. Public Service forecasts and alerts;
- Development and implementation of water and environmental policy;
- Development and implementation of water and flood management policies and strategies;
- Development and implementation of water management regulations and laws.

Table 4 shows the weather and climate data, information products and services and their applications in the water sector.

5.1.4.1 **Weather and Climate Data**

In the activity on Stock-taking under element 1 (laying the ground work and addressing the gaps) of the NAP process, some important questions are raised: What data and knowledge are available to assess current and future climate risks, vulnerability and adaptation? How can the storage and management of this data and knowledge best be coordinated? What gaps can be identified regarding the capacity, adequacy of data and information, and required resources to engage in the NAP process?

Table 4. Weather and climate data, information products and services and their applications in the water sector.

Area	*Variable(s)*	*Application areas*
Weather	Daily weather: Air temperature, precipitation, wind, solar radiation, humidity, atmospheric pressure	The data are needed for a range of calculations in water budget and energy budget; estimation of stored energy in water; computation of evaporation using different approaches etc., Rainfall depth-duration-frequency datasets are provided as tables or sets of curves, having been obtained from a comprehensive probability analysis of rainfall records. They are required as a basis for drainage design or flood estimation. Irrigation scheduling Hydropower generation Portable water, industrial processing

Area	*Variable(s)*	*Application areas*
	Weather statistics: Historic time series, summary statistics	Pollution control Salinity and sedimentation Modelling hydrological systems
	Open pan evaporation	Needed for information on total amount of evaporation and computations of evaporation from drainage basins and evapotranspiration.
	Quantitative precipitation forecasting (QPF).	The requirement for more definitive information in flood forecasting and warnings has led weather service providers to move away from qualitative statements on rainfall, e.g. light-moderate-heavy, occasional-persistent and localized-widespread to defining numerical or proportional ranges to these descriptors, QPF is now provided in well-defined rainfall ranges, e.g. 30mm-50mm, over geographically defined areas and with definition of likely start and finish times. Medium-range forecasts needed for demand scheduling
Climate	Recent and historical climate data	Floodplain mapping/zoning Diagnostics, assessment, and attribution of current seasonal/sub-seasonal rainfall and temperature patterns, and their anomalies including the associated circulation features Extreme value analysis Long-term means and trends Diagnostics of climate variability characteristics
	Climate extremes	Drought frequencies and drought indices Indices of climate extremes or other, more complex indices that combine several parameters with different thresholds (e.g., temperature with precipitation and humidity)
	Climate Forecasts	Seasonal and long-range forecasts are required by major water management undertakings, where knowledge of forthcoming seasonal water conditions is helpful. Forecasts of rainfall and temperature are most commonly needed, and are presented as probabilities of conditions falling within different categories, expressed in relation to seasonal norms in 3- or 5-step categories, e.g. very low to very high.

Area	*Variable(s)*	*Application areas*
		Seasonal and long-range Information on the relevance of major drivers of climate variability, e.g. El Niño/La Niña, North Atlantic Oscillation, Indian Ocean Dipole, Madden-Julian Oscillation for mid-term policy decisions on water management.
	Decadal Climate Predictions	Hydrological impact modelling and
	Climate Change Projections	Scenario-based impact modelling

These issues are addressed in this section on weather and climate data for the water priority area of the GFCS. NMHSs can provide a wide range of data in different formats, e.g. point or distributed data, instantaneous or averaged over different lengths of time, to serve a number of purposes for water management. Many meteorological and hydrological models are now designed to produce probabilistic output for risk analysis, so the interfacing of climate data feeds with predictive water models is a complex matter. There are frequently gaps and mismatches between the nature and distribution of climate observing systems and those networks devised for water monitoring (WMO, 2014f). An improved climate-water interface will enhance the structure and development of compatible observation networks, by extending them to meet user needs, and ensure quality assurance of data. Recent decades have seen a progressive decline in the size and quality of meteorological and hydrological observing networks, especially in countries at most risk from climate water related impacts. Of relevance from the water perspective is the World Hydrological Cycle Observing System (WHYCOS), a WMO Programme aiming at improving the basic observation activities, strengthening the international cooperation and promoting free exchange of data in the field of hydrology. The programme is implemented through various components (HYCOSs) at the regional and/or basin scale. Improved integration of climate and hydrological networks is seen as a necessary and essential initiative in improving the linkages between the climate and hydrological communities.

Water security in a variable and possibly changing climate continues to be a key concern at national, regional and global scales. In addressing this concern, the critical importance of ongoing climate data for the assessment of fluctuations, and trends in risks arising from exposure and vulnerability to climate variability and related natural hazards is well recognized, in order to assist countries and communities in optimal adaptation efforts. NMHSs can provide long time series of climate data to the water sector in support of hydrological modelling to enable greater understanding of the impacts of climate variability on water resources availability.

NMHSs can also address the need for, use and applications of climate data to address the changes in the demand for water, both through changes in land use and also changes in behaviour of water users. Past weather and water observations have left an enormous legacy of data that now provide the basis of knowledge on climate variability and change. Water management design depends heavily on historical data, whereas use of operational data may depend on rapid data delivery and assimilation into models.

The technology and systems for electronic dissemination and exchanging of data are generally present in most countries, though in many developing countries, the speed, reliability and capacity of systems is far from adequate. At the highest level, a new World Meteorological Information System (WIS) is being developed to serve as the coordinated global infrastructure for the telecommunication and management of weather, climate and water and related data.

5.1.4.2 **Information Products and Services**

The activity on analysing current climate and future climate change scenarios under element 2 (preparatory elements) of the NAP process highlights the importance of appropriate indices of climate trends which could support planning and decision making. Another activity on assessing climate vulnerabilities and identifying adaptation options under this element calls for using approaches such as risk management approaches, ecosystem-based approaches for adaptation etc., The activity on developing an appropriate adaptation implementation strategy under element 3 (implementation strategies) of the NAP process calls for implementation of adaptation activities including timing, target areas/beneficiaries, responsible authorities and sequencing of activities. Also the enhancement of the capacity for planning and implementation of adaptation under element 3 of the NAP process calls for lessons to be learnt from other international experiences and international cooperation on adaptation planning. These issues are addressed in this section on information products and services for the GFCS priority area of water.

The improved and targeted delivery of climate information products and open communications from the NMHSs can enhance the quality of information available to the water community for the assessment of fluctuations, and trends in risks arising from exposure and vulnerability to climate variability and related natural hazards and can assist countries and communities in optimal adaptation efforts. 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 and coastal zone infrastructure. Hence NMHSs can provide improved climate prediction services on time scales from seasons to decades and spatial scales from local to regional to 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. In particular advances made in the area of seasonal climate outlook fora and the establishment of regional climate centres are of interest to the water community, taking specific care of the communication aspects of the scientific content of specific products. Establishment of professional interactions between NMHSs and water managers at scientific and operational levels can make an effective contribution to water-related risk management eg., management of extremes (floods and droughts). Increased dialogue and joint action can help maximize the usefulness of climate services and help develop new and improved applications of climate information for the water sector.

Some examples of development of climate products through feed-back from water sector are as follows:

> *Quantitative precipitation forecasting (QPF).* The requirement for more definitive information in flood forecasting has led NMHSs to move away from qualitative statements on rainfall, e.g. light-moderate-heavy, occasional-persistent and localized-widespread to defining numerical or proportional ranges to these descriptors. QPF is now provided in well-defined rainfall ranges, e.g. 30 mm - 50 mm, over geographically defined areas and with definition of likely start and finish times.
>
> *Seasonal and long-range forecasting.* NMHSs can provide these forecasts which are required by major water management undertakings, where knowledge of forthcoming seasonal water conditions is helpful. Forecasts of rainfall and temperature are most commonly needed, and are presented as probabilities of conditions falling within different categories, expressed in relation to seasonal norms in 3- or 5-step categories, e.g. very low to very high.
>
> *Rainfall depth-duration-frequency datasets.* These are provided as tables or sets of curves, having been obtained from a comprehensive probability analysis of rainfall records. They are required as a basis for drainage design or flood estimation in a standard manner over e.g. a particular country, and so are related to a geographical distribution, either by isolines or as tables or grids.

By working collaboratively and iteratively, NMHSs and the water professionals can develop tools and systems that can effectively forecast and provide information and warnings that improve water security and build resilience. In this context, NMHSs can provide a range of services to

support decisions by water managers that include identification of extreme weather and climate hazards that pose water-related risks; identification of populations vulnerable to weather and climate hazards, including those in the coastal zone; implementation of risk management and emergency preparedness practices and procedures; development and implementation of water and environmental policy; and development and implementation of water and flood management policies and strategies. Through improved and targeted delivery of climate information products and open communications, NMHSs can enhance the quality of information available to the water community to conduct operations, research, impact and risk assessment and planning.

Through appropriate research and modeling activities, NMHSs can improve the available products and services for the water sector in quality and reliability, and thus improve the utility and confidence of the water managers in climate services. Research will also be necessary into methods to improve integration between climate and water science, which must include the identification of the users' needs from the outset. This research approach has to ensure that climate information and services are provided in a timely manner to decision makers and operational organizations.

NMHSs can also provide information from two existing interagency programmes in the areas of flood and drought management based in WMO ie., the Associated Programme on Flood Management (APFM), including the coastal zone, and the Integrated Drought Management Programme (IDMP) which are providing the appropriate products and services to the user communities. The APFM has been jointly developed by the Global Water Partnership and the World Meteorological Organization since 2001. Its mission is to assist countries in the development of Integrated Flood Management policies and strategies within the overall context of national development policy. The successful implementation of the APFM has led the different agencies involved in its creation to initiate the IDMP in 2012/2013. The IDMP promotes an approach that moves drought management practices from reactive, representing crisis management, to more proactive drought management based on risk management principles. It provides global coordination for efforts towards integration of science, policy and implementation by strengthening drought monitoring, drought risk assessment, development of drought prediction; drought early warning services and sharing best practices at the local, national and regional levels.

5.1.5 ***Energy***

Energy is essential to practically all aspects of human welfare, including access to water, agricultural productivity, health care, education, job creation and environmental sustainability (UNDP, 2005). As noted by UN Secretary-General Ban Ki-Moon at the launch of the Decade of Sustainable Energy for All (SE4ALL) in September 2011, the world faces two urgent and interconnected challenges related to energy. One is related to energy access. Nearly one person in five on the planet still lacks access to electricity. More than twice that number, almost three billion people, rely on wood, coal, charcoal or animal waste for cooking and heating. This is a major barrier to eradicating poverty and building shared prosperity. As for the second challenge, where modern energy services are plentiful, the problem is different – waste and pollution. Energy sector emissions such as CO2 account for the largest share of global anthropogenic greenhouse gas (GHG) emissions. In 2010, 35% of direct GHG emissions came from energy production. Emissions reduction targets under the UN Framework Convention on Climate Change are expected to significantly increase demand for energy from renewable sources, which are highly sensitive to climate, as well as energy efficiency measures.

Energy generation and planning of operations are markedly affected by meteorological events and energy systems are increasingly exposed to the vagaries of weather and climate affecting both the availability and energy demand. By taking into account weather and climate information, energy systems can therefore considerably improve their resilience to weather extremes, climate variability and change, as well as their full chain of operations during their entire life-cycle. Energy is essential for the functioning of the four priority areas of the GFCS (agriculture and food security, water, health and disaster risk reduction), while at the same

time energy efficiency and generation of renewable energy are sensitive to weather, climate, and water. Through appropriate partnerships and stakeholder engagement, the application of weather and climate information can provide useful support to energy management decisions and relevant policymaking to achieve optimal balancing of supply and demand as well as to drive behavioral changes in energy saving.

Climate services in the energy sector are needed to support:

- Greater climate resilience and adaptation across the sector, due to its fundamental importance for development;

- The important role of efficiency and reduction of energy consumption with consequent emissions reduction in support to mitigation targets; and

- The growing renewable sub-sector, given the apparent climate sensitivity of renewables on the one hand and the policy priority accorded to them due to their GHG emissions reduction benefits on the other.

The main focus areas in the energy sector for climate services include the following:

(a) Identification & Resource Assessment

(b) Impact assessments (incl. infrastructure and environment)

(c) Site Selection & Financing

(d) Operations & Maintenance

(e) Energy Integration

    - Market trading (incl. supply and demand forecasts) & Insurance

    - Energy efficiency

5.1.5.1 **Weather and Climate Data**

Detailed local assessments are necessary to provide greater confidence in understanding current climate variability and how the climate might change in the future, and therefore which measures are warranted at the level of specific projects. There is a need to improve energy sector (and broader) decision making by improving local weather and climate knowledge, regardless of whether large climate changes are expected; by improving access to existing meteorological and hydrological data; and by developing better mechanisms so that local weather and climate data as well as specialized analyses are archived for the public good (Johnston et al. 2012).

Weather and climate data needs for the five focal areas in the energy sector are shown in Table 5. There are also critical data needs for the different energy sub-sectors ie., wind, solar, hydro and thermal. In the wind power sub-sector, vertical gradients in mean wind speed and wind direction as well as in turbulence intensity above the surface layer are critical to the construction, planning and operations of wind turbines. Increase in current data needs led to a boom in surface-based remote sensing techniques such as wind lidars (Emeis, 2014). For off-shore wind parks, marine boundary-layer weather and climate variables need to be assessed. Accurate measurements of the incoming irradiance are essential to solar power plant project design, implementation and operations.

Table 5. Weather and climate data needs for the five focal areas in the energy sector

Focal Area	*Weather and climate data needs*
a) Identification & Resource Assessment	In situ, and satellite-derived meteorological data for assessment of resources and risks Model-based high-resolution historical meteorological data Climate change projections
b) Impact assessments (incl. infrastructure and environment)	High-grade in situ data Detailed site-specific modelling Historical dataset and analyses of extreme events Projections of potential relevant meteorological and climate trends and changes Observations and monitoring of relevant climate-related variables for identification and mitigation of environmental impacts, e.g. on human health and safety and wildlife Air quality and gas emission database (e.g. carbon-based gases from shale gas extractions) Database on weather/climate risks to hydro-electricity facilities, solar panel risks to buildings, energy transport risks to communities, etc
c) Site Selection & Financing	Very high grade in situ data, both in terms of quality of instrumentation and temporal resolution Detailed site-specific modelling (e.g. wind gust estimation, extreme low and high stream-flows)
d) Operations & Maintenance	Site-specific ground station data Infrastructure specific meteorological data Database and analyses of historical meteorologically-driven problem (forensic) events for operations and maintenance Forecasts at various lead times Communication methodologies for warning systems
e) Energy Integration	Historical datasets of meteorological/climate variables relevant for demand, insurance and energy efficiency Historical datasets of energy demand Model-based data to extend observation records Ancillary datasets such as energy system response to weather variables Forecasts at various lead times Climate projections Site-specific ground station data for triggering of weather index insurance policies

In the absence of surface radiation measurements, estimates of surface radiation can also be made using meteorological ground measurements such as cloud cover, temperature, visibility, and water vapor in a radiative transfer model (Marion and Wilcox 1994). Hydropower is obviously dependent on river flow which depends on the following weather parameters: precipitation and snow amounts; air temperature, which in particular controls the snow melting process in spring in mountain areas; the altitude of the 0°C isotherm is of particular importance; and evaporation, which plays a strong role in controlling the water level in large areas reservoirs, in particular in tropical and sub-tropical regions. Floods and droughts have a strong impact on hydropower generation.

In the area of thermal power, data needs are diverse as the thermal conversion efficiency depends on ambient air temperature. The efficiency of cooling systems depends on several parameters: water temperature (ocean, rivers), river flow (with special emphasis on drought periods, but also in the case of floods), and air temperature and humidity, which control the efficiency of cooling towers. Rising air and water temperature, and lack of water may then lead to reduced power generation or temporary shutdowns.

5.1.5.2 Information Products and Services

Climate information (historical and projected) is required for an initial assessment of the energy resource and the required infrastructure and for management of weather/climate hazards and risks. The energy sector stages, or areas of focus, along with their main requirements for climate information, include the following:

a. Identification & Resource Assessment – Requires climate information (historical and projected) and policy for an initial assessment of the energy resource and the required infrastructure and for management of weather/climate hazards and risks.

b. Impact assessments (incl. infrastructure and environment) – Requires detailed and tailored weather and climate information (historical and projected) for codes, standards, site-specific designs and policy to assist with the construction and maintenance of the energy system infrastructure (e.g. power plants, solar collectors or coal mines), including connecting infrastructure for energy transmission, distribution, and transfers. It also requires detailed site-specific and regional climate information (mainly historical) and policy for assessments and mitigation of impact of energy systems on the surrounding environment (e.g. air quality modifications), on human health (e.g. air particles), on ecosystems (e.g. solar plants, marine turbines) and wildlife as well as potential contributions to GHG reduction.

c. Site Selection & Financing – Requires highly detailed site-specific climate information (mainly historical) and policy for rigorous resource assessment, risk management and financial closure.

d. Operations & Maintenance – Requires highly detailed site-specific weather & climate information (predicted, historical and projected) and policy for an efficient running of the energy system as well as site maintenance (e.g. on/off-shore wind turbines or oil rigs)

e. Energy Integration – Energy supplied by individual generators needs to be dispatched in a balanced/integrated manner to suitably meet energy demand for the following purposes:

Market trading (incl. supply and demand forecasts) & Insurance – Requires highly detailed weather and climate information (predicted and historical) and policy for an efficient use of generated energy via optimal balancing of supply and demand as well as for pricing of insurance structures used to hedge against market volatility and/or risks to assets such as wind farms, oil rigs and transmission infrastructure.

Energy efficiency – Requires highly detailed climate information (predicted, historical and projected) and policy for an efficient use of generated energy via measures such as optimal infrastructure siting or use of shading on hot days to offset air conditioning energy use.

Hydropower generation management requires essentially river flow forecasts at the different time scales at which power systems are operated: yearly, quarterly, monthly, weekly, daily and intra-daily. The current practice in to use weather forecasts, either deterministic or probabilistic depending on the ability and means of each company, up to one or two weeks. For longer time scales, the more advanced energy companies use intra-seasonal to seasonal forecasts but the climatological approach, which uses historical time series of precipitation and/or river flow,

is more widely spread. On longer time scales, for planning purposes, the general rule is to use climatological information as well, even if more and more companies have started to use climate change projections.

6. CONCLUSIONS

In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans. Adapting to climate change is becoming a routine and necessary component of planning at all levels. The UNFCCC established the national adaptation plan (NAP) process as a way to facilitate adaptation planning in least developed countries (LDCs) and other developing countries.

The timely provision of climate services to the user communities in different sectors and at different levels can support climate change adaptation. Climate data, science, information and knowledge are critical components that can facilitate the activities identified under the four key elements that need to be undertaken in the development of national adaptation plans (NAPs).

WMO and the NMHSs of its Members have a vast reservoir of expertise, service capabilities, data and tools that can be delivered through governments, programmes, technical commissions, expert teams and partner organizations. The Global Framework for Climate Services (GFCS), the UN-led initiative spearheaded by WMO to guide the development and application of science-based climate information and services in support of decision-making in climate sensitive sectors, can provide effective support to the NAP Process.

In the context of climate change adaptation, NMHSs are critical actors in national development planning within almost all sectors as they serve as major custodians and providers of data and competencies required to support climate change research and climate services which underpin adaptation at national level. Key services include provision of information and scientific advice on climate variability, trends and change (including at the policy level). NMHSs are encouraged to continue their active role in the UNFCCC Least Developed Countries Expert Group (LEG) process and to provide technical advice to LDCs for preparing and implementing NAPs and other contributions to the LDC's work programme. NAPs are expected to guide the allocation of significant climate finance in the future.

REFERENCES

CRED. 2015. EM-DAT: The International Disaster Database 1970-2014. www.emdat.be. Centre on the Epidemiology of Disasters (CRED), Louvain, Belgium: UniversiteCatholique de Louvain.

Edwards, D. C. and T. B. McKee. 1997. Characteristics of 20th century drought in the United States at multiple time scales. Climatology Report 97-2, Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado, USA.

Emeis, S. 2014. Current issues in wind energy meteorology.Meteorol. Appl. 21: 803–819. DOI: 10.1002/met.1472

George, D.A., Birch, C., Buckley, D, Partridge, I.J. and Clewett, J.F. 2005. Surveying and assessing climate risk to reduce uncertainty and improve farm business management. Extension Farming Systems Journal 1:71-77.

Hallegatte, S., Bangalore, M., Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D. and Vogt-Schilb, A. 2015. Shock Waves: Managing the Impacts of Climate Change on Poverty. Climate Change and Development Series. Washington, DC: World Bank. doi:10.1596/978-1-4648-0673-5.

Hay, J. 2007. Extreme Weather and Climate Events, and Farming Risks. In: Sivakumar MVK, Motha R (Eds.) Managing Weather and Climate Risks in Agriculture. Springer, Berlin Heidelberg.

Hellmuth M.E., Mason S.J., Vaughan C., van Aalst M.K. and Choularton R. (eds.). 2011. A Better Climate for Disaster Risk Management. International Research Institute for Climate and Society (IRI), Columbia University, New York.

IPCC. 2007. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

IPCC. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

IRI and WHO. 2010. Emerging La Niña conditions in the equatorial Pacific: Notes for the Health Community. The International Research Institute for Climate and Society, New York and the World Health Organization, Geneva, Switzerland.

Johnston P.C., Gomez, J.F. and Laplante, B. 2012. Climate risk and adaptation in the electric power sector. Asian Development Bank publication. Available at: http://www.iadb.org/intal/intalcdi/PE/2012/12152.pdf

Least Developed Countries Expert Group. 2012. National Adaptation Plans. Technical guidelines for the national adaptation plan process. Bonn: UNFCCC secretariat. Bonn, Germany. December 2012. Available at <http://unfccc.int/NAP>.

Lim, B, and Spanger-Siegfred, E. (eds). 2005. Adaptation Policy Framework for Climate Change. Developing Strategies, Policies and Measures. Cambridge: Cambridge University Press. Available at <http://www.preventionweb.net/files/7995_APF.pdf>.

Marion, W. and Wilcox, S. 1994. Solar Radiation Data Manual for Flat-Plate and Concentrating Collectors. NREL/TP-463-5607. Golden, CO: National Renewable Energy Laboratory.

McKee, T.B., Doesken, N.J. and Kleist, J. 1993. The relationship of drought frequency and duration to time scale. Pages 179-184. In: Proceedings of the Eighth Conference on Applied Climatology, Anaheim, California,17–22 January1993. American Meteorological Society, Boston.

McKee, T.B., Doesken, N.J. and Kleist, J. 1995. Drought monitoring with multiple timescales. Pages 233-236. In: Proceedings of the Ninth Conference on Applied Climatology, Dallas, Texas, 15–20 January 1995. American Meteorological Society, Boston.

Munich Re. 2013. Topics Geo. Natural Catastrophes 2012: Analyses, assessments, positions 2013 issue. Munich Reinsurance, Munich, Germany.

Munich Re. 2015. NatCatSERVICE. Loss events worldwide 1980-2014. Munich Reinsurance, Munich, Germany.

Rogers, D.P., and Tsirkunov, V.V. 2013. Weather and Climate Resilience: Effective Preparedness through National Meteorological and Hydrological Services. Washington, DC: World Bank.

Schneider, S.H., Semenov, S., Patwardhan, A., Burton, I., Magadza, C.H.D., Oppenheimer, M., Pittock, A.B., Rahman, A., Smith, J.B., Suarez, A., and Yamin, F. (2007). Assessing Key Vulnerabilities and the Risk from Climate Change. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds.). Cambridge University Press, Cambridge, UK.

UNDP. 2005. Energizing the Millennium Development Goals: A Guide to Energy's Role in Reducing Poverty. United Nations Development Programme, New York, USA. Available at: http://www.undp.org/content/undp/en/home/librarypage/environment-energy/sustainable_energy/energizing_the_mdgsaguidetoenergysroleinreducingpoverty.html

UNFCCC. 2012. Report of the Conference of the Parties on its seventeenth session, held in Durban from 28 November to 11 December 2011. Addendum Part Two: Action taken by the Conference of the Parties at its seventeenth session. United Nations Framework Convention on Climate Change, Bonn, Germany.

WMO. 2010. Guide to Agricultural Meteorological Practices. WMO-No. 134, World Meteorological Organization, Geneva, Switzerland. 799 pp.

WMO. 2011a. Climate knowledge for action: A Global Framework for Climate Services–empowering the most vulnerable. The Report of the High-Level Taskforcefor the Global Framework for Climate Services. WMO-No. 1065, World Meteorological Organization, Geneva, Switzerland. 240 pp.

WMO. 2011b. Guide to Climatological Practices. WMO-No. 100, World Meteorological Organization, Geneva, Switzerland.117 pp.

WMO. 2012. Standardized Precipitation Index User Guide. WMO-No. 1090. World Meteorological Organization, Geneva, Switzerland. 24 pp.

WMO. 2014a. The WMO Strategy for Service Delivery and Its Implementation Plan. WMO-No. 1129, World Meteorological Organization, Geneva, Switzerland. 130 pp.

WMO. 2014b. Implementation Plan of the Global Framework for Climate Services. World Meteorological Organization, Geneva, Switzerland.70 pp.

WMO. 2014c. Agriculture and Food Security Exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organization, Geneva, Switzerland.35 pp.

WMO. 2014d. Disaster Risk Reduction Exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organization, Geneva, Switzerland.47 pp.

WMO. 2014e. Health Exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organization, Geneva, Switzerland.35 pp.

WMO. 2014f. Water Exemplar to the User Interface Platform of the Global Framework for Climate Services. World Meteorological Organization, Geneva, Switzerland.35 pp.

WMO. 2015a. Valuing Weather and Climate: Economic Assessment of Meteorological and Hydrological Services. WMO-No. 1153, World Meteorological Organization, Geneva, Switzerland. 308 pp.

WMO. 2015b. The Role and Operation of National Meteorological and Hydrological Services - A Statement by the World Meteorological Organization for Decision-Makers. Annex to paragraph 7.9.2 of the general summary, World Meteorological Congress -17, Geneva, Switzerland.

WMO and WHO. 2015. Heatwaves and Health: Guidance on Warming-System Development (G.R. McGregor, P. Bessemoulin, K. Ebi and B. Menne, Eds.). WMO-No.1142. World Meteorological Organization, Geneva, Switzerland. 96 pp.

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