Climate and Weather Information Services for Humanitarian Agencies

Report

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(prepared by Jennifer Milton, Canada)
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<td>APCC</td>
<td>Asia – Pacific Economic Cooperation Climate Center</td>
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<td>AR</td>
<td>Assessment Report</td>
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<td>BCC</td>
<td>Beijing Climate Center</td>
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<td>CBS</td>
<td>Commission for Basic Systems</td>
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<td>CCI</td>
<td>Commission for Climatology</td>
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<td>CHy</td>
<td>Commission for Hydrology</td>
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<td>CMA</td>
<td>China Meteorological Administration</td>
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<td>CPC</td>
<td>Climate Prediction Center</td>
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<td>CPTEC</td>
<td>Centro de Previsão de Tempo e Estudos Climáticos</td>
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<td>CRU</td>
<td>Climate Research Unit</td>
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<td>CSIS</td>
<td>Climate Services Information System</td>
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<td>DRMCPA</td>
<td>Disaster Risk Management and Civil Protection Agencies</td>
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<td>DOE</td>
<td>Department of Energy</td>
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<td>DRR</td>
<td>Disaster Risk Reduction</td>
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<td>ECMWF</td>
<td>European Centre for Medium Range Weather Forecasts</td>
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<td>EPS</td>
<td>Ensemble Prediction System</td>
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<td>GDPFS</td>
<td>Global Data Processing and Forecasting System</td>
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<td>GFCS</td>
<td>Global Framework for Climate Services</td>
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<td>GPC</td>
<td>Global Producing Centre</td>
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<td>GTS</td>
<td>Global Telecommunication System</td>
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<td>HA</td>
<td>Humanitarian Agencies</td>
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<td>IFRC</td>
<td>International Federation of Red Cross and Red Crescent Societies</td>
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<td>INPE</td>
<td>Instituto Nacional de Pesquisas Espaciais</td>
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<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
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<td>IRI</td>
<td>International Research Institute for Climate and Society</td>
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<td>ITHACA</td>
<td>Information Technology for Humanitarian Assistance, Cooperation and Action</td>
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<td>JMA</td>
<td>Japan Meteorological Agency</td>
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<td>KMA</td>
<td>Korea Meteorological Administration</td>
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<tr>
<td>LC-LRFME</td>
<td>Lead Center for Long-Range Forecasts Multi-Model Ensembles</td>
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<td>MSC</td>
<td>Meteorological Service of Canada</td>
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<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
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<td>NCAR</td>
<td>National Center for Atmospheric Research</td>
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<td>NCDC</td>
<td>National Climate Data Center</td>
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<td>Acronym</td>
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<tr>
<td>NCEP</td>
<td>National Centers for Environmental Prediction</td>
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<td>NMHS</td>
<td>National Meteorological and Hydrological Services</td>
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<td>NOAA</td>
<td>National Oceanographic and Atmospheric Administration</td>
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<td>NWP</td>
<td>Numerical Weather Prediction</td>
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<td>OCHA</td>
<td>Office for the Coordination of Humanitarian Affairs</td>
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<td>PR</td>
<td>Permanent Representative</td>
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<td>RCC</td>
<td>Regional Climate Centre</td>
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<td>RCOF</td>
<td>Regional Climate Outlook Forum</td>
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<td>RSMC</td>
<td>Regional Specialized Meteorological Centre</td>
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<td>SAWS</td>
<td>South African Weather Service</td>
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<td>SST</td>
<td>Sea-Surface Temperature</td>
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<td>SWFDP</td>
<td>Severe Weather Forecast Demonstration Project</td>
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<td>SVSLRF</td>
<td>Standardized Verification System for Long-Range Forecasts</td>
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<td>SWIC</td>
<td>Severe Weather Information centre</td>
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<td>TCC</td>
<td>Tokyo Climate Center</td>
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<td>TT</td>
<td>Task Team</td>
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<tr>
<td>UCAR</td>
<td>University Corporation for Atmospheric Research</td>
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<tr>
<td>UEA</td>
<td>University of East Anglia</td>
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<tr>
<td>UKMO</td>
<td>United Kingdom Met Office</td>
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<td>UN</td>
<td>United Nations</td>
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<td>UNICEF</td>
<td>United Nations Children's Fund</td>
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<td>UNHCR</td>
<td>United Nations High-Commissioner for Refugees</td>
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<td>UNITAR</td>
<td>United Nations Institute for Training and Research</td>
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<td>UNOSAT</td>
<td>UNITAR’s Operational Satellite Programme</td>
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<td>WFP</td>
<td>World Food Programme</td>
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<td>WHO</td>
<td>World Health Organization</td>
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<td>WIS</td>
<td>WMO Information System</td>
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<td>WMO</td>
<td>World Meteorological Organization</td>
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<tr>
<td>WMO Humanitarian TT</td>
<td>Inter-commission ad hoc Task Team on “Meteorological, Hydrological and Climate Services for Improved Humanitarian Planning and Response”</td>
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1. Introduction

1.1. Background

Every year, disasters related to meteorological, hydrological and climate hazards cause significant loss of life, and set back economic and social development by years, if not decades. For example, between 1980 and 2007, nearly 7600 natural disasters worldwide took the lives of over 2 million people and produced economic losses estimated at over 1.2 trillion US dollars. Of this, 90 per cent of the natural disasters, 70 per cent of casualties and 78 per cent of economic losses were caused by weather-, climate- water-related hazards such as droughts, floods, windstorms, tropical cyclones, storm surges, extreme temperatures, landslides and wild fires, or by health epidemics and insect infestations directly linked to meteorological and hydrological conditions.

In 2005, 168 countries adopted the Hyogo Framework for Action 2005-2015 (HFA) adopted at the Second United Nation World Conference on Disaster Risk Reduction (2005, Kobe, Japan), which shifted the paradigm in disaster risk management from emergency response to a comprehensive and strategic approach focusing on preparedness and prevention.

The WMO Disaster Risk Reduction (DRR) Programme was established in 2003 to support HFA through the strengthening and integration of disaster risk reduction processes related to meteorological, hydrological and climate services of its WMO operational and research networks in all countries, particularly those with least resources. The DRR Programme aims to enhance the contributions of National Meteorological and Hydrological Services (NMHS) of the WMO Members, in a more cost-effective, systematic and sustainable manner, towards the protection of lives, livelihoods and property, through enhanced capabilities and cooperation in the field of disaster risk reduction at national to international levels.

To accomplish this, the DRR Programme has adopted a two-tier work plan that includes, (i) development of guidelines, standards and training modules for DRR thematic topics; and (ii) coordinated DRR and climate adaptation national/regional capacity development projects to support capacity development of NMHS (please see Appendix A for a detailed description of the two-tier work plan). A critical aspect of the coordinated DRR national/regional projects is strengthening of cooperation of NMHS, Regional Specialized Meteorological Centres (RSMCs), Regional Climate Centres (RCCs) and DRR users for development of products and services based on user needs and requirements. In this regard, a number of thematic DRR user-interface Expert Advisory Groups (EAG) have been established to guide and support implementation of the DRR Work Plan and related deliverables WMO TCs and programmes, RAs, WMO global operational network.

One of the EAGs, “Task Team on Meteorological, Hydrological and Climate Services for Improved Humanitarian Planning and Response” (hereafter called “EAG on Humanitarian Response”), focuses on the documentation of requirements of the international humanitarian community for meteorological and climate services and the development of products and services to support the humanitarian contingency planning, preparedness and response activities at the national, regional and international levels (See Appendix A for details). This present report is a first step and foundational document that seeks to document meteorological and climate products and services that could be available for the development of operational pilots that would engage NMHSs, RSMCs and RCCs. To date, the EAG on Humanitarian Response has held two meetings of which the first included a brainstorming meteorological services for improved humanitarian emergency contingency
planning and response was held at the WMO headquarters on 17 April 2009 with experts from the HAs and the WMO. The report¹ of the meeting includes some preliminary findings on the needs of HAs for weather and climate information, which has been used to inform the current report. The First Meeting of the Task Team on “Meteorological Services for Improved Humanitarian Planning and Response” was held at the WMO headquarters, from 31 August to 2 September 2010². A number of recommendations were made at this Task Team meeting including:

(i) mapping the WMO network capacities with respect to the provision of meteorological, hydrological and climate products and services,

(ii) mapping the HAs structure, decision making process and requirements for products and services at national to global levels,

(iii) identification of mechanisms for provision of products and services to the Humanitarian community at global, regional and national levels,

(iv) to implement a pilot for development of such capacities.

Following the decision of Congress XVI, these recommendations are to be addressed as one of the high priorities of the DRR Programme in order to establish relevant institutional partnerships and develop guidelines for product and service development and delivery at national to global levels to this user community. Congress requested the Executive Council, in close cooperation with the technical commissions and regional associations, and the relevant United Nations (UN) and international agencies to urgently review the operational arrangements in place between Regional Specialized Meteorological Centres (RSMCs), Regional Climate Centres (RCCs) and NMHSs for preparedness, warning of, and responding to major disasters, focusing particularly on those with an international dimension, taking into account the national accountability for the disaster management and the requirements for regional coordination and support.

The outcomes of the meetings indicated that HAs require meteorological and climate data and information for their humanitarian planning and preparedness as well as response and relief operations as well as for their strategic planning and scenario building. To meet these various needs, the HAs may need historical and real-time data, predictions, advisories, analyses, research, or even just a means to have questions answered. More specifically, the requirements are for information and services that would assist in risk assessment and reduction, disaster management, and risk transfer (IPCC 2012).

1.2. Provision of meteorological and climate products and services

Predictability, Modelling and Forecasting of Meteorological and Climate

Over the last few decades, meteorological, and hydrological forecasts have become increasingly accurate and available as a result of remarkable international co-operation, facilitated by the World Meteorological Organization (WMO) (Figure 1.1).

¹ The final report can be found at: http://www.wmo.int/pages/prog/drr/events/Humanitarian/index.html
² The meeting website URL is: http://www.wmo.int/pages/prog/drr/events/HumanitarianTT/index_en.html
Figure 1.1: Improvements in anomaly correlation of 500 hPa height forecasts of the European Centre for Medium-Range Weather Forecasts (ECMWF) for the northern and southern hemispheres linked to the increase in satellite observations and skill of numerical models (Source: WMO Strategic Plan 2012 – 2015).

These improvements have been made possible in part through improvements in modelling and in understanding of the weather and climate systems through research coordinated by the World Weather and Climate Research Programmes (WWRP and WCRP).

At least as important has been the international cooperation in the collection, generation and distribution of data through an operational network, comprised of the WMO Integrated Global Observing System (WIGOS), Global Telecommunication System (GTS) and Global Data Processing and Forecasting System (GDPFS) for monitoring, detecting, forecasting and exchange of weather, water and climate related information, engaging National Meteorological and Hydrological Services (NMHS) of 189 Members (Chapter 4). Through this coordinated network a wide range of global and regional forecast products and services are provided that support the National Meteorological and Hydrological Services in their development of national products and services such as hazard analysis, and early warnings that support sectoral risk management decision-making (Figure 1.2).

Humanitarian agencies (HAs) respond to and provide relief from many disasters around the world, based on request from the governments. To ensure their preparedness, they have to carry out risk analysis as critical input to their strategic planning, scenario analysis for resource management and preparedness measures, as well as response and relief operations. Disasters are caused by various natural, man-made and technological hazards. Over 90% of the disasters caused by natural hazards are weather- and climate-related. The availability of high quality weather and climate information products and services may provide considerable assistance to HAs to manage these risks ranging from local responses to immediate hazards to global-scale strategic planning (Figure 1.3). However, the information that is needed is not necessarily self-evident, and much of the information may be difficult to access, understand, and use. It is important that information products be
designed based on the understanding of the needs and requirements such that they can be easily accessed and interpreted by the HAs.

Figure 1.2: WMO Coordinated Global/Regional Operational Network (Source: “Institutional Partnerships in Multi-Hazard EWS,” M. Golnaraghi (ed), (2012), Springer Verlag, p 3)

Figure 1.3: Schematic diagram showing the relationship of “seamless” products from weather to climate timeframes and humanitarian applications from response & relief operations to strategic planning & scenario building (Source: WMO DRR Programme adaptation of a schematic in the WMO Strategic Plan 2012 – 2015)
1.3. Challenges for provision of products and services to HAs

In order to avoid confusion in the general population and responders, it is important that HAs receive authoritative information on weather, water and climate from the WMO operational network, specifically from the NMHS and RSMC, RCCs and in some cases, the GPCs. This is especially true for weather bulletins and advisories that are issued by the NMHS which Disaster Risk Management and Civil Protection Agencies (DRMCPA’s) use in their disaster response.

During the 1990s as part of its mandate, WMO facilitated negotiations for data exchange among its Member States and reached two resolutions, WMO Congress XII Resolution 40 (WMO, 1995) and WMO Congress XIII Resolution 25 (WMO, 1999), for exchange of “essential” meteorological data necessary for the provision of services in support of the protection of life, property and well-being of all nations. However weather information from some countries’ NMHSs may be too technical, not always readily accessible or in some cases non-existent due to insufficient capacities. What information exists may be difficult to interpret without expert training.

In many countries the formal infrastructure for managing climate data and for producing climate information such as of statistical analyses and basic climate diagnostics is in relatively good stead. However, the infrastructure and staff training in many countries for implementation of climate watch programmes and development or application of seasonal outlooks have only been partially defined and implemented, and so bulletins, advisories and watches at seasonal or longer timescales may not be available in all countries. In addition, some regions and countries may not be able to provide value-added downscaled information to that available from Global Producing Centres of Long-Range Forecasts. It is intended that the Global Framework for Climate Services (GFCS) will attempt to address such shortfalls, through implementation of its observations and monitoring, research modelling and prediction, Climate Services Information System, User Interface and capacity development pillars.

Because of poor data quality, lack of capacity of many NMHSs, and the inherent difficulties of making predictions, weather and climate information are inevitably imperfect. HAs may be unaware of the quality of the information provided, and thus may not be in a position to interpret the available information appropriately. For some predictions at some timescales, information about the quality may not be available at all.

Differences in terminology among the weather, climate and HAs communities can cause confusion as to the meaning of terms such as early warning and scenario building.

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3 http://www.wmo.int/pages/about/Resolution40_en.html
4 http://www.wmo.int/pages/about/Resolution25_en.html
2. Report Purpose, Scope, Target Users and Methodology

2.1. Purpose

This report aims to be a foundation document to be used in technical discussions with HAs to identify, describe and categorize requests for core as well as customized weather and climate products and services that could satisfy their requirements.

Identification of the needs and requirements of the HAs is an iterative process and as such this report will be a living document as the user’s needs and requirements are further refined through subsequent rounds of consultations with the technical experts of eight HA5. The report will help to converge to the details of the products’ required attributes (content, format, packaging, accessibility, dissemination processes) that will be demonstrated through pilot projects.

The report provides a background on the expressed needs and requirements of HA. It describes what various types of products and services could benefit the humanitarian community, and includes details on the spatial and temporal scales of the information for different hazard types.

This report seeks to fulfil the first recommendation of the WMO Humanitarian TT: to map the WMO network capacities with respect to the provision of meteorological, hydrological and climate products and services. More specifically this report seeks to:

a. Outline the weather and climate monitoring and forecast products and services available to the HA community through the WMO Regional Specialized Meteorological Centres (RSMCs), Regional Climate Centres (RCCs) and the National Meteorological and Hydrological Services (NMHS). These products and services are identified on both the global and regional scales.

b. Map the products and services by categories of major meteorological hazards, and high impact weather- and climate related phenomena (e.g. tropical cyclones, severe thunderstorms, flash floods, protracted dry spells, droughts, heat waves, cold spells, severe winter weather, wild fires) to include availability of information related to:
   (i) The needs of humanitarian planning and operations;
   (ii) Time scale and lead times;
   (iii) Observational networks including surface and in situ data;
   (iv) Sources of technical and metadata information related to these products and services including contact and training information;
   (v) Developing a web site for access to relevant links;
   (vi) Recommending next steps.

5 The eight HA are:
   - International Federation of Red Cross and Red Crescent Societies (IFRC)
   - United Nations Office for the Coordination of Humanitarian Affairs (OCHA)
   - United Nations Children’s Fund (UNICEF)
   - United Nations Development Programme (UNDP)
   - United Nations Institute for Training and Research (UNITAR) Operational Satellite Programme (UNOSAT)
   - United Nations High Commissioner for Refugees (UNHCR)
   - United Nations World Food Programme (WFP)
   - United Nations World Health Organization (WHO)
2.2. Scope

There are numerous reasons why meteorological and climate, data and information, products and services can benefit HAs, but only direct interests are considered in this report, and so the scope is restricted to products and services pertaining to historical and current observations, and forecasts of surface and near-surface meteorological parameters that may be representative of some type of hazard – for example, for weather scale forecasts: precipitation (rain, snow, and hail), wind speed, temperature and for the longer timescale; probabilities of monthly to seasonal precipitation and temperature anomalies. Upper air data and parameters such as sea-level pressure and sea-surface temperatures are not considered in detail because they are likely to be only of indirect interest.

As with most sectors, HAs are especially interested in the occurrence of extreme weather and climate events. “Extreme” can be defined in a variety of ways, but ultimately it is the impact of the event that it is of interest, and the severity, duration, and rarity of the event are only of interest to the extent that those translate into impact. Providing information about impacts requires combining weather and climate data with data on vulnerability. For the purposes of this report, “extreme” conditions are defined purely in meteorological terms: the intent is to provide information only on hazards.

The report discusses information that is available at regional and global scales, and does not provide details of information available in specific countries of for sub-national scales.

2.3. Target Users

The main target users for this report are the technical experts of the HA and technical institutions, including WMO entities such as RCCs, that are supporting HAs to access and analyse weather and climate data and information [e.g., Information Technology for Humanitarian Assistance, Cooperation and Action (ITHACA) for WFP, and the International Research Institute for Climate and Society (IRI) for IFRC]. The report also aims to allow decision-makers without the appropriate technical background to understand how these products will benefit their community. It is aimed that upon completion of this report, a consultant will meet with technical experts from the HAs to develop and document specifications for a set of products and services that can be piloted with RSMCs and RCCs in select regions.

2.4. Methodology and approach for this report

Many of the sources and documents used to develop this report originate from the WMO web site. Additionally, information and documents found from a number of authoritative internet sites around the globe have been utilized and have been referenced in this report. Weather products and experiences with product development from the Severe Weather Forecasting Development Project (SWFDP) and from the Meteorological Service of Canada where also utilized. Various climate documents and publications were utilized for the sections related to climate products and services. These include, the Annex for the Climate Services Information System (CSIS) of the Global Framework for Climate Services (GFCS), early drafts of the Disasters Exemplar of the GFCS were used for background information on the needs for weather and climate information, as were the Intergovernmental Panel on Climate Change (IPCC) Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC 2012), the Third Climate and Society Publication (Hellmuth et al. 2011) and additional technical background was obtained from Troccoli et al. (2008), and Mason (2012).
3. Weather and climate science background

3.1. Definitions

**Weather** is the state of the atmosphere as it is experienced at any given moment and location, and is usually defined in terms of sensible parameters like temperature and humidity, precipitation (a general term that includes rain, snow, sleet, hail – there are other forms of precipitation that are not considered in this report, such as dew?), and wind. Although other parameters, such as air pressure (weight of a vertical column of air extending above a surface of unit area to the outer limit of the atmosphere), are important for describing the weather, these parameters are not directly what constitute a hazard. For example, extremely low air pressure per se does not cause a problem for most practical purposes, but it is almost invariably associated with strong winds, and possibly severe precipitation.

Weather conditions tend to be organized into distinct features known as weather systems. Weather systems can be very localized and short fused such as severe convective activity produced by severe thunderstorms, such as tornadoes, and tower clouds. Weather systems can also be represented by larger scale storms such as tropical cyclones or persisting high pressure systems are easier to forecast than smaller scale convective activity. Yet larger are the large scale low pressure areas – with heavy rain or snow and high winds – and large stationary high pressure areas – which may bring drought conditions. The HAs are primarily interested in the extreme forms of weather.

**Climate** is often described as the average weather conditions over a period of a few weeks or more at a specific location. In fact, the climate is best described not only by the average, but also by other measures describing climate variability, including the extremes. Thus a variety of statistics can be used to describe the climate: the average, standard deviations, percentiles, frequencies of extreme weather events etc.. The long-term climate average for a specific location and time of the year is generally calculated using data from continuous 30-year period, and is used as a reference for computing, ten days, monthly, seasonal and annual variations of the climate conditions. This 30-year average is often referred to as the “climatology” of the region and the period of interest.. In a broader sense, climate is the status of the climate system which comprises the atmosphere, the hydrosphere, the cryosphere, the surface lithosphere and the biosphere. These elements all determine the state and dynamics of the Earth’s climate.

The Standard Climate Normals comprise the reference period for the evaluation of anomalies in climate variability and change monitoring. The current method for calculation of these normals is to average station data over a 30-year period, and update the Normals every 30 years. This might be referred to as the “30/30 model”. The current Standard Normals period is 1961-90, and under current methodology, the next update will be in 2021, when the 1991-2020 period will become the new standard. The question arises about the representativeness of a period such as 1961-90 after 15 or more years in a non-stationary climate. Many climate applications need to base fundamental planning decisions on average and extreme climate conditions, and it is plain that, for instance, an orchardist in 2015 trying to assess whether the climatic conditions in a region suit a particular variety of fruit, is not going to be receiving optimal guidance from 1961-90 Normals when the base climate is

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changing. At the same time, a set of Climate Normals that is stable over a long period is still required to anchor time-series of temperature, rainfall etc for climate monitoring purposes. Recognising these differing needs, the WMO Commission for Climatology (CCl) is working on a new standard of Climate Normals (see additional discussion in Appendix B).

The term “meteorological” is used in this report in a more general sense to include weather and climate timescales.

Weather and climate monitoring involve assessments of current and recent conditions. In the case of climate monitoring, current and recent conditions are compared against a historical background.

Monitoring is an important step in the identification of the early onset of severe conditions, which, in turn can provide advanced warning of potential impacts. Alternatively, in combination with forecasting, monitoring can provide advanced warning of imminent hazardous conditions. In such a case, the NMHS may issue advisories, watches, or warnings, depending upon the expected severity of the anticipated meteorological event, and upon the confidence that can be placed in the forecast. Advisories and warnings are issued only at weather timescales, but watches can be issued for weather and climate timescales.

Advisories are issued to inform the public of a weather event that may cause inconvenience, but not serious threat to life or damage to property.

Watches are used to inform the public of potential severe weather or climate conditions that may have substantial impacts. Examples include watches for flash floods, tornadoes, thunderstorms or droughts that are likely to develop despite the fact that the exact time and location may not yet be determined. They are meant to create awareness, which is very helpful should the threat develop, and a warning has to be issued since they provide time to prepare for evasive action and/or for rapid response. Watches either evolve into warnings, advisories or are cancelled.

Warnings are issued when the threat of severe weather conditions is imminent – the warning should give a specific time, intensity and location of the event.

Warning Authority - Countries, through their policies and legislative processes determine the roles and responsibilities of various agencies at national to local levels and designate the primary warning authority within their jurisdictions. Increasingly as governments are taking ownership in the development of multi-hazard early warning systems, warning authorities could vary from nation-to-nation and in some countries, is shifting from technical agencies such as the National Meteorological and Hydrological Services (NMHS), to multi-hazard warning authorities that incorporate risk information for development of warnings (e.g., disaster risk management agencies, health authorities, etc). In this emerging framework, for example, NMHS are critical providers of “authoritative” science-based hydro-meteorological information, forecasts, alerts, and warning guidance for weather timescales.

Forecasts, predictions, projections and scenarios are all statements about the expected or possible weather or climate conditions in the future. Forecasts and predictions are statements about the expected conditions, and may or may not include some statement about the uncertainty in what is expected. Some scientists prefer to use “prediction” to refer to the output of a model, and “forecast” for the interpreted output that is actually released to the public. However, there is no consistent distinction between a prediction and a forecast,
and in many languages there are no separate terms anyway. Predictions / forecasts can be for conditions in the immediate future and out to two years. **Projections** are statements or model outputs far enough into the future that it is not possible to give a quantitative estimate of the uncertainty in the outcome with any degree of accuracy. “Projections” apply to timescales of the order of a few years to about a decade. **Climate Scenarios** are possible weather or climate conditions that might be expected to occur if some other conditions are met. “Scenarios” apply to multi-decadal (including climate change) timescales. In this case the scenarios involve estimates of weather and climate that would be expected to occur if corresponding assumptions about greenhouse and other gases are met. **Climate Scenarios** are beyond the planning horizons of most if not all HAs, although they can be useful for advocacy around questions of mitigation against climate change. Sometimes “prediction” or “forecast” can be used generically to include “projections” and even “scenarios”, in which case the “prediction” will usually involve some expert interpretation.

For each prediction / forecast / projection /scenario there is an associated timescale and lead-time. The **timescale** is the length of period for which the forecast applies. The **lead-time** is the time between when the forecast is issued, and the beginning of the period for which the forecast is made, regardless of for how long the forecast applies. For example, a one-month forecast issued on 1 May for June has a lead-time of one month, as does a forecast for June – August if issued on the same date. Definitions of different timescales of forecasts as used by the Numerical Weather Prediction (NWP) community are given in Table 3.1. Note that the definitions depend both upon the lead-time, but it is usually implicit that the timescale increases with the lead-time. The **target period** is the actual period for which the forecast applies, and is a function of the lead-time and the timescale. The target period can be specified by specific times and dates (for example, a forecast for tomorrow morning, or a forecast for July – September 2012).

The following are the current forecast terms utilized by the weather community (Table 3.1) and the climate community (Table 3.2). As the tables reveal, there are differences in the forecast terms which points to the need for standardization of terms between the two communities.

**Table 3.1: WMO definitions of forecasts as used by the NWP community (Source: WMO 485 Manual on the GDPFS)**

<table>
<thead>
<tr>
<th>Forecast</th>
<th>Period being forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nowcasting</td>
<td>0 – 2 hours</td>
</tr>
<tr>
<td>Very short-range</td>
<td>0 – 12 hours</td>
</tr>
<tr>
<td>Short-range</td>
<td>12 – 72 hours</td>
</tr>
<tr>
<td>Medium-range</td>
<td>72 – 240 hours</td>
</tr>
<tr>
<td>Extended-range</td>
<td>10 – 30 days</td>
</tr>
<tr>
<td>Long-range</td>
<td>30 days – 2 years</td>
</tr>
<tr>
<td>Climate</td>
<td>More than 2 years</td>
</tr>
</tbody>
</table>
Table 3.2: Definitions of forecasts as used by the climate community

<table>
<thead>
<tr>
<th>Forecast</th>
<th>Period being forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intra-seasonal</td>
<td>&lt;3 months</td>
</tr>
<tr>
<td>Seasonal</td>
<td>3 or 4 months, lead-time of up to 9 months</td>
</tr>
<tr>
<td>Annual</td>
<td>1 year</td>
</tr>
<tr>
<td>Multi-year</td>
<td>&lt;5 years</td>
</tr>
<tr>
<td>Decadal</td>
<td>&lt;10 years</td>
</tr>
<tr>
<td>Short-range</td>
<td>&lt;30 years</td>
</tr>
<tr>
<td>Climate change</td>
<td>10-year timescale, &gt;30-year lead-times</td>
</tr>
</tbody>
</table>

The predictability of the weather and climate is the extent to which they can be predicted with any accuracy and precision. In very general terms, the predictability of the weather and climate decreases as the amount of advanced notice (“lead-time”) increases. For a more detailed discussion of predictability at different timescales and lead-times, see Appendix C.

3.1. Hazard assessment

For long-term planning, it would be beneficial to the HAs to identify areas at greatest risk of specific weather and climate hazards, or to identify which hazards may occur at specific locations. In most cases, the planning horizon is unlikely to extend into the future by more than about 20 or 30 years. Although forecasts are being developed for these timescales (section 6.3.3), the most reliable information is from historical data (section 6.1).

In addition to hazard mapping, historical climate datasets are also essential for use in the design of risk transfer contracts. They are also used for monitoring changes and variability in climate, and for providing a context for understanding forecasts and projections.

Although there is no substitute for free and easy access to historical data, for many purposes there may be little need for HAs to access data per se if data were presented in informative ways. During the consultative process for the observations component of the GFCS, some user groups highlighted the importance of service rather than just data delivery. Nevertheless, at least some HAs may be interested in accessing historical climate data. Unfortunately, there is no single historical climate dataset that is likely to meet all of the requirements of the HAs. Trade-offs usually have to be made amongst length of record, availability in near-real time, numbers of missing values, accuracy, consistency, temporal and spatial resolution etc. The following categorization indicates the pros and cons of different types of climate dataset.

3.1.1. Climatological data:

Meteorological data are collected in a standard way at WMO Synoptic meteorological stations which provide routinely and timely observations, 24 hours a day, for weather analysis and forecasting based on standard procedures and regulations. Other stations collect a predefined set of climatological parameters for local use; mainly temperature and precipitation. These stations are not always part of the WMO standard meteorological observation network. In most cases they are run by institutions which partner with the NMHSs; like institutions linked to ministry of Agriculture, Forestry, Civil protection, Defence, Academia, etc.
Apart from the fact that observational errors can affect meteorological data, meteorological stations are not always representative of a site where the data are needed. Furthermore the data need to be quality controlled and if necessary corrected for changes in instrumentation and site location. In addition, failures to record measurements or instrument malfunctions are more likely to occur in extreme weather and climate conditions, which tend to be of most interest to the humanitarian community. As a result, station data require considerable expertise before they are suitable for analysis for trends, return periods and frequency analysis. Hourly disseminated data from the Synoptic Network are available and accessible on quasi-real time basis through the WMO data processing infrastructure. However historical climate data and data that are not routinely disseminated routinely through the WMO Information System are still difficult to access in many countries either because of technological constraints (Developing and Least Developed Countries) or because of national data policy, which imposes fees on data access. In some cases access to historical climate data can be prohibitively expensive for many HAs.

In recent years the use of Automatic Weather Stations (AWSs) has greatly improved the availability of the data in difficult-to-access areas like remote areas and mountains. AWS also improved time resolution of the data which is helpful to monitor on real time basis extreme and short-lived weather events like high intensity precipitation systems. When AWS are connected to a data management systems it provides a very useful climatological data base for conducting studies and research on climate hazards.

Climatological data are based on all sources of meteorological observations after quality control and adjustment. They are archived on computer based data management systems called Climate Data Management Systems (CDMS), which are also used to retrieve the data and export it into different formats according to user needs. In many countries old and valuable climatological records are still in paper format and facing risk of destruction or degradation. Data recovery and digitisation efforts constitute one of the highest challenges facing developing countries. It will help constitute long term homogenized instrumental data which can help adequate climate hazards analysis and assessment of climate extremes.

3.1.2. Gridded datasets:

Gridded datasets are constructed from at least one of the following sources: station data, remotely sensed data (primarily from satellites), and climate model outputs. They are usually constructed to provide more complete spatial and temporal coverage especially when station data are combined with satellite data (gridded datasets based on station observations only may not interpolate to areas with insufficient stations). Climatologically valid gridded datasets should be based on a good level of quality control and homogenisation. In general, the robustness of the gridded data sets depend on the quality and resolution of the original data that were used to construct the gridded dataset. For example, gridded station data based on very uneven spatial observation distribution can pose a serious problem in the analysis over areas with sparse

**Gridded station datasets** are constructed either by some form of averaging of available station data within each grid, or by interpolating the data to the grids. Station-based datasets usually have the longest records, many extending back to the beginning of the 20th Century, or even earlier. However, there can be problems arising from changing density and location of stations used to construct the dataset. Some of the higher quality datasets attempt to adjust for these problems, but care needs to be taken not to use these data uncritically. For much of the globe these datasets are not suitable for detailed local analyses, even when the
data are available at a fine resolution, and should rather be used to provide regional and global perspectives. Some of the higher resolution datasets are not usually updated in near real-time because of difficulties accessing all the data promptly.

**Gridded satellite datasets** have complete and continuous coverage, and are updated in near real-time. However, even the longest necessarily commence only since the start of the satellite era, in the late 1970s; the higher temporal and spatial resolution products are even more recent. As a result, satellite-based products have not yet reached the level of providing long-term perspectives on climate change. For example, despite the good progress that has been made to construct long term temperature data sets based on satellite data, there is still a need for more research and development in technology and processing algorithms to achieve acceptable temperature datasets to detect long-term trends. Satellite products are most commonly used for estimating precipitation, but estimates of minimum temperatures are also usable – maximum temperature estimates are more problematic. Even for precipitation and minimum temperatures, there are problems with the accuracy of the satellite estimates because they are not measuring these parameters directly. To some extent the inaccuracies can be averaged out by measuring rainfall over larger areas and / or by temporal averaging. Thus the use of satellite data for estimating daily rainfall at fine spatial resolutions is currently unrealistic, unless the data are calibrated using an extensive network of ground-based observations. The precipitation estimates are notably problematic in mountainous regions, where they tend to underestimate heavy rainfall events, and require a high density of station data for proper calibration. As a result, most of the higher quality datasets are based upon a blend of satellite and station observations.

**Model reanalyses** are model estimates of the full structure of the atmosphere, and provide a comprehensive set of meteorological parameters. Although they provide an excellent source of information about the three-dimensional structure of the atmosphere, their estimates of the most commonly considered surface and near-surface parameters, such as precipitation and air temperature, are generally considered of poor quality, and, at least in the case of precipitation, even unusable. There are also problems with consistency of the data because of changes in the observations used in developing the reanalyses. The reanalysis products are generated using a consistent version of the model, which eliminates some, but not all inconsistencies. Some reanalysis products are not updated in real-time because the model may be outdated. Most reanalysis products have high temporal resolution (3-hourly to daily), and reasonably high spatial resolution and global coverage. Some regional reanalyses are available that provide even higher resolution. Reanalysis data are unsuitable for most climate change detection purposes.

**Hybrid datasets** combine two or more of the satellite, remotely sensed and station sources of data. The most common hybrid products combine satellite and station data to combine the advantages of continuous spatial and temporal coverage of satellite observations with the ground-truthing of the station data. The use of the satellite data confines these datasets to begin in the late 1970s at the earliest.

### 3.1.3. Index datasets:

The gridded and station data provide information about the state of the climate at specific locations, but there is additional value in measuring the state of various weather and climate phenomena, such as the Indian monsoon or El Niño – Southern Oscillation. There is a vast array of weather and climate **indices** that are recorded. These are discussed in section 6.1.
3.2. Monitoring hazards

Up-to-date monitoring of the prevailing weather and climate is an essential service for indicating where and whether hydro-meteorological extreme events have occurred, whether they are ongoing, and how intense and extensive they are. Having access to information that can give a reliable impression of the extent and severity of extreme events may help humanitarian agencies in anticipating the possible scale of relief effort that may be required. Since the impacts of some extreme events can occur weeks, or even months after the event itself, good monitoring information can also provide a valuable predictive function. Effective monitoring requires not only thorough and ongoing analyses of high-quality real-time and historical observational data, but also design of monitoring products that are informative to HAs.

3.3. Forecasting hazards

To improve upon the use of historical records of hazards as estimates of future risk, forecasts can be provided. For long-term disaster prevention activities HAs may be inclined to consider the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports (AR). However, as discussed in sections 3.2 and 3.3.2, while the IPCC AR are suitable for estimating what may happen at the end of the Century, the AR, up to and including AR4, are not designed to provide accurate projections for the next few decades. This problem is being addressed for IPCC AR5, which should make the IPCC AR more suitable for long-term planning by HAs.

![Figure 3.1: Risk analysis: From statistical analysis towards forward looking (Source: WMO DRR Programme)](image)

Predictions provide opportunities to HAs to anticipate forthcoming hazards (to become forward looking see Figure 3.1), and thus take action to avoid or minimise any potential damage to lives and livelihoods. The types of action that can be taken depend in part on the amount of advanced warning (lead-time) that is provided, and the certainty in the predictions. As lead-times increase and so certainty about the outcome weakens, HAs can no longer
take definite action in the knowledge that a severe event is likely to occur. However, with careful planning, long lead-time predictions of extreme conditions can enable DRMCPA’s to prepare for possible severe events and for the HAs to plan. The longest lead times do not typically provide indications of the specific events occurring, but indicate only changes in hazard risks. Such information can enable adaptive behaviour. As the lead-time decreases warnings from NMHSs about specific events become possible, and DRMCPAs and the HAs will be galvanized into action and deployed before or when the events occur. In aftermath of the event or during protracted ones, such as large-scale flooding, updates on the weather and the forecasts are required as the weather may affect ongoing operations.

Projections for the next decade or two are still very much in experimental phase, and it still has to be demonstrated that these projections can provide information that might be useful to HAs. Instead, hazard forecasts for disaster preparedness that are likely to be most useful for advanced planning purposes are the seasonal forecasts. For most seasonal forecasts, including the consensus-based products from the Regional Climate Outlook Forums (RCOFs), the lead-time is typically between 0 and 4 months, but some centres provide lead-times of up to 9 months (NCEP). Seasonal forecasts (and all climate forecasts) are unlike weather forecasts. A weather forecast provides information for a specific weather system or condition at a specific place and time. For example, a weather forecast might indicate the track a specific hurricane is expected to take and how much it is expected to intensify or weaken. Another example of a weather forecast is a statement about the expected weather conditions for Geneva tomorrow. In contrast, in a climate forecast, there is no attempt to provide an indication of what the weather will be like at any specific moment. Instead, the most common approach is to indicate how the statistics of the weather for the forecast season are expected to differ from the long-term climate. For example, a seasonal climate forecast is typically about the total rainfall or average temperature over the next three months. However, it is possible to provide a seasonal climate forecast that indicates how the statistics of the weather for the forecast season are expected to differ from those of a specific year. For example, it is possible to indicate whether the coming summer is expected to be hotter or colder than the summer last year.

Weather forecasts at the short- (<3 day) to medium-range (<10 days) are likely to be useful for tactical emergency planning and preparedness, as well as in the response and recovery stages. Like the decadal climate forecasts, extended-range weather forecasts (<30 days) are still largely an area of research. A few centres are issuing experimental extended-range forecasts.

Unfortunately, most forecasts (climate more so than weather) are unlikely to be about hazards conditions per se, and so when planning to use this type of information it is important to be aware of the nature and limitations of what is available. As the predictability decreases the forecasts are likely to become harder to use. Before describing what the implications of this decrease are, it is necessary to describe the different ways in which forecasts can be presented.

3.3.1. Types of forecasts

Weather and climate forecasts typically are issued in one of three formats:

- A specific value: these so-called deterministic forecasts show only one possible outcome with no corresponding information about possible errors in the forecast. For example, the United States National Weather Service indicates specific maximum
and minimum temperatures for the next few days (expressed in Fahrenheit). At medium- and longer-ranges a deterministic value is frequently an average from an ensemble of forecasts (see section 3.3.2).

Deterministic climate forecasts are similar to deterministic weather forecasts, but are averaged or accumulated over long periods of time, and possibly over large areas too. For example, most seasonal climate forecasts are usually for 3- or 4-month periods, and a few forecasts for one-month averages are available. For multi-decadal and climate change time scales, the three-month format is still fairly common, but the projected climate over this period will typically be calculated using data for multiple years. In the case of climate change scenarios, the choice is typically a 10- or a 30-year period.

- A range of values: the range or interval indicates an explicit upper and lower limit between which the actual value is expected to occur. For example, if moderate to heavy rainfall is expected over the next 12 hours, the United States National Weather Service indicates an interval (expressed in inches). Intervals are sometimes used in climate change: for example, the IPCC concludes that the average surface temperature of the Earth is likely to increase by between 1.1 and 6.4°C by the end of the 21st century, relative to 1980-1990 (IPCC 2007).

There may be a probability associated with the interval, which indicates the probability that the observed value will fall within the specified range.

- One or more probabilities: these probabilistic forecasts show the probability(ies) of one or more discrete outcomes occurring. For example, the United States National Weather Service indicates a probability of at least some rainfall occurring over each of the next few days and nights without necessarily specifying how much rainfall is expected. Probabilistic formats are commonly used in seasonal forecasts, including the consensus products from Regional Climate Outlook Forums, where it is standard to define three equi-probable categories (“below-normal”, “normal”, and “above-normal”), but five categories (e.g., UK Met Office), and two categories (e.g., Australian BoM) are not uncommon. Some centres issue three-category seasonal forecast for categories that are not equi-probable: usually the outer categories have climatological probabilities of less than 33% to indicate the chances of extreme climate events occurring. For climate change scenarios, two categories are often used for precipitation – to indicate the probability of an increase or decrease.

Weather and climate forecasts reflect decreasing predictability by indicating increasing uncertainty and / or decreasing the precision. The increasing uncertainty will be shown by widening the interval, or by weakening the shift in the probabilities so that they become closer to the climatological probabilities.

Weather forecasts are usually location specific, but climate forecasts are more typically represented as area-averages. At the seasonal timescale, for example, most seasonal forecasts are presented as area-averages, with areas typically of the order of 10,000s km², or larger. Area-averaging improves precipitation skill more noticeably than temperature. Nevertheless, it is possible to identify skill at specific locations, and there is great demand to downscale climate forecast information to the level of detail that is widely available for weather. In the IPCC Fourth Assessment, information was thought to be meaningful only at sub-continental scales, and so there are considerable efforts to provide more detailed...
information using downscaling techniques. However, in the absence of any clear way of verifying this information, the ability to which climate change projections can be reliably downscaled is an area of some dispute. There is considerable effort being placed into downscaling of climate change projections for input to the Fifth Assessment, and similar downscaling outputs have been considered fairly extensively in some national adaptation planning activities. However, it should be noted that many scientists are concerned about the unreliability of such detailed information: specifically, the range of uncertainty in such information is thought to be underestimated. This question needs urgent research attention since there is a danger of using the climate information too overconfidently.

Unfortunately, it is not entirely clear whether some of the RCOF forecasts are meant as applying to regional averages or if they are location specific. In most cases the accompanying text suggests that RCOF outlooks are meant as area averages, but there are some minor inconsistencies in how each of the regions are defined when producing the maps that create some problems in defining precisely what the forecasts mean. Although these inconsistencies are generally minor problems, there is some resulting ambiguity that needs to be addressed, and in the interim it is best to assume that there is some additional uncertainty not reflected in these products if the interest is in forecasts for specific locations.

Since the first RCOF review meeting, which was held in Pretoria in May 1998, users have been requesting tailored presentation of forecast formats in place of the tercile probabilities and broad regional and three-month averages that were established as the standards at the first ever RCOF. Unfortunately, to date there has been little apparent response to this request in terms of changes to operational products generated at the RCOFs, but there has been considerable research activity to explore the predictability of more tailored information. For example, there is activity to examine the predictability of rainfall frequency, including the predictability of heavy, flood-inducing rainfall events. There has also been some progress in predicting onset dates of the monsoons in parts of West Africa and South-east Asia. However, in all these cases research needs to be consolidated and introduced into operations before the information is likely to become routinely available to the HAs. It is anticipated that the GFCS will help to bring some of these types of research products into operations where there is sufficient interest.

3.3.2. How forecasts are made

In order to make a weather forecast an estimate of the current state of the atmosphere is required. This 3-dimensional analysis describes the winds, temperature, and humidity at the surface and higher up in the atmosphere. In order to make an analysis, observations of the atmosphere are required. Weather and climate observations come in many types: surface observations of temperature, wind speed and direction, dew point, the visibility, precipitation type, cloud type and height and the precipitation amount. Some are automated and some are taken by observers. At sea, observations are taken on ships and automated ones from buoys. To these basic observations are added other methods of detecting conditions at or near the surface. Two or four times a day, weather-balloon-mounted radiosondes take measures aloft of the wind, temperature and humidity as do aircraft and other airborne measurement systems. Remote sensing techniques (radar and polar orbiting and geostationary satellites in many parts of the electromagnetic spectrum) supplement the view of the atmosphere.

The observations are then assimilated into a 3D analysis of the atmosphere using various techniques on grid points in horizontal and in the vertical. These analyses are then fed to a
variety of different NWP models to predict the future state of the atmosphere using the equations of motion and others. If there is one future state of the atmosphere predicted these models are classified as **deterministic** (see section 3.3.1). The resolutions of the models determine the details that one can forecast in future. **Global** models tend to be coarser in resolution and are run to longer projections than **regional** (limited area) models. Finer grid scales are used in **nested meso-scale** models to cover very small areas. Convective activity on a thunderstorm scale is very short fused and only very fine scale models are able to pick up the details. Otherwise models with coarser grids can pick areas of **potential** severe convective activity. Severe local convective activity can only be predicted a few hours in advance.

Numerical Weather Prediction (NWP) is not an exact science, there are errors in forecasting (since NWP uses approximations in the equations) and there are sub grid scale phenomena at work. There are also errors in the initial analysis – due to errors in observations and lack of observations to cover all of the earth. The atmosphere is an unstable system (in places) and these initial errors may grow quickly after several days leaving the forecast without skill. The aforementioned forecasted **details** are sometimes inaccurate because of these errors in forecasting. The current limits of predictability for an individual weather system in a deterministic model are about 7 days depending on the situation. **Ensemble** techniques involve perturbing the initial analysis within the error of observations and then launching a series of forecasts of the future state of the atmosphere which may all differ. Some centres perturb the forecast model simulating forecast error. The results are **ensemble** forecasts. The mean of the ensemble forecast extends predictability to 10 days and is superior to the deterministic model after 3-4 days (see Appendix D). The variability in the forecasts is related to how unstable and therefore how unpredictable the atmosphere is.

Other models include (ocean) **wave** models and ensemble **wave** models based on the surface forecasts from the NWP models. Flood forecasting in certain countries may also be deterministically or ensemble based. There are NWP models specializing in tropical cyclone prediction and some countries may also use the ensemble forecast system. **Air quality** models use pollution sources and forecast air quality at the surface in the short term. With the forecast winds, **Transport** models move airborne particles aloft such as volcanic ash, smoke from large forest fires, radio nuclides, airborne diseases and pests. Precipitation areas cause **wet deposition** of these particles.

Other types of forecasting techniques are: persistence – e.g. tomorrow’s forecast is for a continuation of today’s weather; classical statistical techniques using historical observations (using statistical correlations from a present state to future state); analogue forecasting techniques (finding an analogue among historical analyses); and simple extrapolation for moving systems – these lead to so-called Nowcasting forecasting techniques. Weather systems usually change (and sometimes rapidly) and these techniques have skill for only a few hours. Statistical post-processing may improve NWP – it uses observations and statistical techniques to detect and remove systematic errors in the forecast. As NWP improves it is becoming more difficult to add value with these statistical techniques. Wikipedia provides a basic discussion of NWP\(^7\); more technical (yet elementary) discussions

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on NWP models and statistical post processing may be found at the University of Colorado 
Comet site\textsuperscript{8}.

Monthly forecasts are produced almost exclusively using the same types of models used for 
NWP, and running them a number of times to generate an ensemble of predictions. Similar 
techniques are used for seasonal forecasts, although sometimes these “dynamical” models 
are not started with a realistic representation of the current weather since this representation 
provides minimal predictability after a few weeks. Some of the more powerful seasonal 
forecasting models also have a similarly complex model of the oceans running at the same 
time. These coupled models are run by only a few of the Global Producing Centres (GPCs). 
There are some efforts to try to downscale the predictions from some of the available global 
models using regional models similar to those used in weather forecasting, but these are still 
not widely used in operations. At the other extreme, some of the models used to make 
seasonal forecasts are exceptionally simple, and are based on equations that could literally 
be calculated by hand in a few minutes or less. That is not to say that these models are 
simplistic – on the contrary, they often perform as well as, or even better than the more 
sophisticated models. The simple models are based on identifying statistical relationships 
between various parts of the climate system, and therefore require good historical records of 
the climate. For example, one model might attempt to predict rainfall over a country based 
on previously observed relationships with the strength of El Niño and La Niña. These 
statistical models remain in fairly wide use, and are an important form of input to some of the 
RCOFs. An increasingly common approach is to combine the dynamical and the statistical 
models – the dynamical model predictions are “corrected” using statistical procedures by 
examining how well the dynamical model predictions have performed in the past.

For multi-year forecasts, the possibility of using the dynamical models is still largely a 
research question. A few attempts have been made to use statistical models to project 
“cycles” of climate into the future. Unfortunately skill is very low, and the statistical models 
are best used for descriptive purposes. For example, it may be useful to know that a region 
in the past has experienced approximately decade-long periods of wet years, followed by 
similarly long periods of dry years. While it may not be possible to predict when a switch 
from the wet to dry, or vice versa, is likely to occur, this knowledge may be important for 
ensuring that there is sufficient memory of past climate extremes.

Until the Fifth Assessment Report of the IPCC, the models used for climate change 
scenarios were not initialized with a realistic initial state. As a result it has not been possible 
to assess the quality of the first few years of these model outputs as predictions for the first 
few years. In many parts of the globe the climate can fluctuate on approximately decadal 
timescales, and so it possible for the climate to drift temporarily in the opposite direction to 
any long-term trends. Unless the models are initialized with accurate analyses of the initial 
start dates the projections for the next few years are unlikely to be accurate. For various 
reasons, the models used in IPCC AR4 (IPCC 2007) were not initialized and so cannot 
provide meaningful projections of these temporary fluctuations of climate. Thus, these earlier 
models could not be assessed for the ability to predict the observed global cooling from the 
middle of the last century to the late 1970s, for example, because they were not designed to 
model such variability. However, attempts are being made to initialise the new models that 
are being used for the Fifth Assessment can be investigated in this way, and are at least

\textsuperscript{8} http://comet.ucar.edu/
attempting to make predictions for the next decade as well as for the end of the Twenty-First Century.

3.3.3. Verification methods

A forecast is verified against observations or analyses of the weather. In order to be verifiable a forecast has to describe an observable event with time, location, and intensity. WMO has established programmes for the verification of the public weather forecasts.\(^9\)

The Manual of the Global Data Processing and Forecast System (GDPFS)\(^10\) describes standard WMO verification methods. This allows comparison of the NWP models. Seasonal prediction models are verified using the Standardized Verification System for Long-Range Forecasts (SVSLRF)\(^11\), but there are currently no formally standardized procedures for the verification of RCOF or similar products.

Identification of the most appropriate procedures for verifying forecasts is an area of active research. For deterministic forecasts, the question is reasonably straightforward. There are a number of procedures of summarizing errors in the forecasts, which are defined by some measure of the difference between the forecast and the observed values. Three types of error are possible:

- **A bias**: measures whether the forecasts are systematically too high or too low. For example, many NWP models forecast drizzle too often, and heavy rainfall too infrequently. The effect is that the models indicate rainfall too frequently. (note that forecasters typically will correct for these kinds of model errors.)

- **An amplitude or variance bias**: measures whether the weather or climate implied by the forecasts varies too little or too much. For example, in most models that are used in the IPCC ARs the variability in the equatorial Pacific Ocean is too weak – i.e., the El Niño – Southern Oscillation is not as strong as in the real world.

- **An association**: measures whether the forecasts and the observations increase and decrease together. For example, most weather forecasts give a good indication of whether the tomorrow is likely to be a hot or a cold day – most of the time if the forecast indicates that tomorrow is going to be cold, it is cold, even if the exact temperature may not have been predicted successfully.

The **accuracy** of a set of deterministic forecasts is a measure of the size of the errors in all the forecasts, and depends on the bias, amplitude bias, and association. Forecasts for errors that are typically small are accurate, whereas those that have typically large errors are inaccurate. Forecasts are meaningfully **correct** or **incorrect** only if the forecast and the observation are discrete values. For example, a forecast of at least 10 mm of rain will prove correct or incorrect, but it would be very difficult to predict the exact amount of rainfall that will occur (and impossible if the amount of rainfall were measured with infinite precision).

For probabilistic forecasts, verification is a more difficult concept because such a forecast cannot be described as correct or incorrect (unless the probability is 0% or 100%) or as accurate (because no specific value is being predicted). Instead, probabilistic forecasts are evaluated for their **reliability**: does the forecast appropriately indicate the uncertainty in what

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\(^9\) [http://www.wmo.int/pages/prog/amp/pwsp/qualityassuranceverification_en.htm](http://www.wmo.int/pages/prog/amp/pwsp/qualityassuranceverification_en.htm)


will happen. One helpful way to think of a probabilistic forecast is as a deterministic forecast with a measure of how often that forecast should prove correct. For example, a forecast that says there is a 60% chance of rain has a 60% chance of being right if it is assumed that rain will occur. The reliability of probabilistic forecasts can only be measured over many forecasts. For example, a 60% chance of rain tomorrow does not mean that it will rain for 60% of the day and you thus have a 60% chance of getting wet, it rather means that 60% of days for which such a forecast is issued will receive some rain at some time during the day.

Forecasts are said to have **skill** if their accuracy / correctness / reliability exceeds that of a simple strategy such as persistence (section 3.4.2), or always forecasting the same outcome, or always issuing a constant (typically climatological) probability.
4. WMO Globally Coordinated Operational Network

WMO is the specialized agency of the United Nations responsible for (1) coordination of climate and weather research, (2) development of standards and technical developments, (3) operational cooperation and coordination among its Member States for observing, analysis, data exchange, and forecasting of weather, climate, water and related environmental conditions, and (4) capacity development at national and regional levels for the provision of meteorological, hydrological and climate services to support decision-making for safety of lives, livelihoods and property.\textsuperscript{12}

4.1. WMO Globally Coordinated Operational Meteorological and Climate Network

Building on more than sixty years of international and regional cooperation facilitated through international programmes, WMO coordinates an operational network including:

(i) A coordinated network of the National Meteorological and Hydrological Services (NMHSs) of its 189 Member States and Territories,

(ii) the WMO Global Telecommunication Systems (GTS) which connects all countries through their NMHS,

(iii) WMO Global Data Processing and Forecasting System (GDPFS; Figures 1.1, and 4.1) is comprised of three Global Meteorological Centres (Australia, USA and Russia), over 50 accredited Global and Regional Specialized Meteorological Centres (RSMCs) with thematic or regional specialization, Regional Climate Centres (RCCs) and Drought Management Centres (DMCs);

(iv) The WMO Global Producing Centres (GPCs) for Long-Range Forecasts (LRF) and the supporting Lead Centres, one for Verification, and one for Multi-Model Ensembling (LC-MME).

Figure 4.1: WMO operating centres of the GDPFS including the Regional Specialized Meteorological Centres, Global Producing Centres for Long-Range Forecasts, Regional Climate Centres, as well as Drought Monitoring Centres. (Source: WMO)

\textsuperscript{12} WMO has 183 Member States, who are represented in the Organization through their Permanent Representative (PR), usually the Director of the NMHS.
The WMO global operational network has enabled on-going and sustainable collection, exchange, analysis, forecasting and provision of regional products and services that support the National Meteorological and Hydrological Services (NMHS) of WMO Members. Every day the different national agencies within the WMO network gather and transmit massive amounts of real-time and near real-time data through WMO GTS to the network of RSMCs, who are “mandated” to develop and make accessible various global and regional forecasts and analysis products and outputs based on latest tools and technologies. These are provided to the NMHS of the WMO Members for further processing, analysis and downscaling for national applications. However, this cooperation depends on the national capacities to provide data and to be able to receive and utilize the regional products in their operations.

With the goal to further leverage capacities and resources and improve this network, over the last decade, WMO has been working on the WMO Integrated Global Observing System (WIGOS) to address among many issues, interoperability of meteorological, hydrological, marine and climate related observing networks, which requires agreements on specifications, operational, technical, budgets and mandates of the various operators. Furthermore, given the importance of data availability, accessibility and exchanges within and among countries, WMO is working on the WMO Information System (WIS, Figure 4.2) (building on the WMO GTS) to address accessibility and availability of meteorological, hydrological, marine and climate data and information targeted at sectorial needs and applications. However, this also requires extensive consultations, technical and policy agreements among a large variety of stakeholders and network operators.

Figure 4.2: Diagram showing WIS core components and Information Exchange (Source: WMO)

For example, the WMO global coordinated network has been the foundation of over 30 years of international and regional cooperation, which has led to sustainable provision of regional tropical cyclone and storm surge products and services, based on latest technologies, through six RSMCs to at-risk WMO Members for development of their national warning and
meteorological services. Furthermore, eight RSMCs provide operational meteorological services to WMO Members in case of nuclear and other technological accidents, wild fires and volcanic ash transport. This RSMC network is being further leveraged through the SWFDP for provision of severe weather forecasts and related meteorological services.

WMO has been a leading agency in advancing research and applications in the area of climate variability and change, climate forecasting and modelling, and development of the Global Climate Observing System. WMO has hosted the three World Climate Conferences (1979, 1991 and 2009). These have led to the: (i) establishment of the World Climate Programme (WCP) which included the data and monitoring, applications and services, impacts and assessments and the World Climate Research Programme (WCRP) which underpins the IPCC reports and is co-sponsored by WMO with UNESCO and ICSU; (ii) establishment of the IPCC by WMO and UNEP in 1988; (iii) establishment of the Global Climate Observing System (GCOS), which WMO co-sponsors with UNESCO and its IOC, ICSU and UNEP; (iv) establishment of UNFCCC in 1992; and (v) operationalization of climate information and service for sectorial applications through the Global Framework for Climate Services (GFCS) being established in 2012. At its 16th session in 2011, WMO Congress recognized the WCP, now including the GCOS, the WCRP and the new World Climate Services Programme, as being a key programme for implementation of the GFCS.

Understanding the impacts of climate variability and climate change on the characteristics (frequency, severity, and location) of hydro-meteorological trends and extreme events is key for climate change adaptation and effective risk reduction strategies. The extraordinary progress in climate modelling and forecasting over the last decade provides unprecedented opportunities for the development of climate services that could support informed medium to long-term sectorial planning and risk management.

WMO has begun to implement a climate forecasting infrastructure in which a number of global, regional and national centres run climate prediction systems that adhere to a fixed production cycle, generate a standard set of prediction products, and routinely exchange, and disseminate predictions and related information in an operational environment similar to that operating for weather forecasting, albeit on longer production cycles. Currently this infrastructure applies to only seasonal forecasts (1 to 6 months), although under the Implementation Plan for the Global Framework for Climate Services there are proposals to extend the system to cover all other timescales for which climate prediction information can be supplied, as and when the technical capability to do so allows it. The structure for seasonal timescales involves a network of information providers at global, regional and national scales. These elements are discussed below.

In 2006, WMO began a process of identifying, a network of Global Producing Centres (GPCs) for Long-Range Forecasts13 that make and distribute global seasonal forecasts. The current, officially designated WMO Global Producing Centres (GPCs) are shown in Figure 4.3. The GPCs are expected to adhere to certain well-defined standards that support consistency and functionality across the network.

13 http://www.wmo.int/pages/prog/wcp/wcas/producers_forecasts.html
WMO has also designated two **Lead Centres** among the GPCs, namely the Lead Centre for Long-Range Forecast Multi-model Ensembles (LC-LRFMME)\(^{15}\) hosted by the Korean Meteorological Agency in collaboration with the US National Oceanic and Atmospheric Administration, and the Lead Centre for Standard Verification System for Long-Range Forecasts (SVSLRF)\(^{16}\) hosted by the Australian Bureau of Meteorology in collaboration with the Meteorological Service of Canada. LC-LRFMME collects all the GPC real-time LRF products as well as the available hindcast data, and provides the same to NMHSs and other users in uniform formats and with common graphic displays. LC-SVSLRF is the authoritative source for mandatory verification information for all the GPCs, providing a single source for all information on the skills of the GPC products for any specific region/country in the world. The SVSLRF is a comprehensive set of standard measures for verifying seasonal forecasts and communicating their skill.

At a regional level, WMO is encouraging the establishment of a number of **Regional Climate Centres** (RCCs)\(^{17}\) that, as Centres of Excellence, will generate and deliver more regionally focused, high-resolution predictions, information and products including regional climate watch bulletins,. The aim is for RCCs to assist WMO Members in a given Region or a defined sub-Region to deliver better climate services and products including long-range forecasts, and to strengthen their capacity to meet national climate information needs. A full list of RCC mandatory\(^{18}\) functions and highly recommended\(^{19}\) functions includes the following activities:

- a. Long-range forecasting
- b. Climate monitoring;

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\(^{15}\) [http://www.wmolc.org/](http://www.wmolc.org/)


\(^{17}\) [http://www.wmo.int/pages/prog/wcp/wcasp/RCCs.html](http://www.wmo.int/pages/prog/wcp/wcasp/RCCs.html)


\(^{19}\) [http://www.wmo.int/pages/prog/wcp/wcasp/documents/RCC_Highly_Recommended_Functions.pdf](http://www.wmo.int/pages/prog/wcp/wcasp/documents/RCC_Highly_Recommended_Functions.pdf)
c. Operational data services to support operational seasonal forecasting and climate monitoring; and

d. Training in the use of operational RCC products and services.

WMO RCCs can be implemented within individual institutions providing all the mandatory functions under one roof, or within RCC-Networks comprising one or more nodes with the mandatory functions distributed among the nodes, and each node delivering the assigned function for the entire region of responsibility. Centres or networks of centres having demonstrated all mandatory functions are designated as RCCs or RCC-networks through a formal process established within the WMO Technical Regulations.

In addition to the mandatory functions, highly recommended20 functions of RCCs (i.e. very much encouraged, but not required for WMO designation as RCCs) include, inter alia, climate change projections, non-operational data services, capacity building and research and development activities.

The establishment of RCCs has lagged that of GPCs, and so there are currently only a few RCCs already designated, and several in various stages of that process. However, the WMO is working actively to ensure that all regions are served by one or more RCCs or RCC-networks, and a number of demonstration/pilot initiatives have formally been launched and other initiatives are under discussion. For the latest status on RCCs see the WMOs RCC Implementation Overview21.

The primary ‘clients’ of WMO RCCs are intended to be NMHSs and other RCCs in a region or RCCs in a neighbouring region. RCC responsibilities being regional by nature could by agreement with the countries in question provide services directly to other entities and agencies operating at a regional level, including to HAs. However, such arrangements should not duplicate or unilaterally seek to replace ongoing services provided by the NMHSs of the Region.

A number of the larger WMO member countries use the term regional climate centre’ to apply to centres servicing a region wholly within their respective national borders, for example, the USA and Australia, with the latter using the term Regional Climate Service Centre (RCSC). There are as well a number of regional centres providing climate services in sensitive regions. The term ‘WMO RCC’ is exclusively used, however, for centres or networks designated by WMO in the WMO GDPFS context, and all generate products and services for domains extending beyond a single country, and adhering to specified requirements. Networks of climate centres operating in some of the larger developed countries operate in a similar vein to what is required of WMO RCCs and can also provide a rich source of products and services equivalent to those WMO RCCs are expected to provide.

Since 1997, WMO has facilitated the establishment of the Regional Climate Outlook Forums (RCOF) as multi-stakeholder mechanisms engaging national, regional and international climate experts, sectorial practitioners and policy makers. Regional Climate Outlook Forums seek to reach agreement among participants on current and expected seasonal conditions and to deliver a range of regional climate monitoring and outlook products. Using a predominantly consensus based approach, the RCOFs have an


21 http://www.wmo.int/pages/prog/wcp/wcasp/RCCIplementationOverview.html
overarching responsibility to produce and disseminate a regional assessment of the state of the regional climate for the upcoming season. The forums bring together national, regional, and international climate experts, on an operational basis, to produce regional climate outlooks based on input from NMHSs, regional institutions, RCCs, and GPCs. They also facilitate enhanced feedback from the users to climate scientists, and catalyse the development of user-specific products. They review impediments to the use of climate information, share successful lessons regarding applications of the past products, and enhance sector specific applications. The eleven major RCOFs currently in action are indicated in Figure 4.4. A new forum for North Africa and the Mediterranean was held in January 2012.

Figure 4.4: Current distribution of Regional Climate Outlook Forums. (Source: WMO22)

The Regional Climate Outlook Forum process varies in format from region to region, but typically includes at least the first of the following activities:

a) Presentation of key points for the next (rainy) season,

b) Preparation of national statistical forecasts,

c) Capacity building activities to assist NMHSs in their dealings with specific users,

d) Sharing of experiences in creating new products or improving existing material;

e) A broader forum involving both climate scientists and representatives from user sectors, for presentation of the consensus climate outlooks, discussion, and identification of expected sectoral impacts and implications, and the formulation of response strategies;

f) Training workshops on seasonal climate prediction to strengthen the capacity of national and regional climate scientists;

g) Special outreach sessions involving media experts to develop effective communications strategies.

There are other international climate centres that cooperate closely with WMO structures and programmes, but not formally as GPCs or RCCs, e.g. the International Research Institute for Climate and Society (IRI)\textsuperscript{23} and the APEC Climate Centre (APCC)\textsuperscript{24}. Such centres carry out similar functions to those of WMO GPCs and RCCs and deliver a wide range of climate products and services openly through the Internet.

4.2. WMO Coordination of Verification Procedures

Under the auspices of the WMO's Commission for Basic Systems (CBS) a recommended set of procedures for the verification of "long-range" (seasonal) forecasts has been defined. This so-called Standardized Verification System for Long-Range Forecasts (SVSLRF)\textsuperscript{25} has the specific objective of providing verification information for Global Producing Centre (GPC) products that are used as inputs to seasonal forecasting processes, including RCOFs. These procedures are targeted at providing information about the quality of ensemble prediction systems, and the target audiences of the verification information are model developers, and the immediate users of these products (typically forecasters). A Lead-Centre (LC) for Verification was established in order to assist the GPCs to calculate the verification information through the provision of software and documentation, and to provide a centralized location for posting the results in consistent formats. The Lead-Centre is jointly hosted by GPC-Melbourne, and GPC-Montreal. The GPCs are required to provide their results to the LC.

Because the SVSLRF is targeted at GPC model outputs rather than RCOF products or other similar forecasts intended for end-users, the SVSLRF cannot simply be applied to the forecasts that are intended for use by HAs. There are currently no standardized procedures for the verification of RCOF products but a set of verification guidance materials have been prepared under the auspices of the Commission for Climatology (CCI) XIV Expert Team 3.2 on CLIPS Operations, Verification, and Application Service. The guidance document is still in press, and so has yet to be distributed formally to the RCOFs. It may be necessary, and would certainly be beneficial, to establish a required minimum set of verification procedures for adoption by RCOFs, RCCs, and NMHSs, as is required of GPCs. This required minimum set, and an extended set of recommended procedures could be drawn from the CCI guidance as a starting point.

\begin{itemize}
  \item \textsuperscript{23} http://iri.columbia.edu
  \item \textsuperscript{24} http://www.apcc21.net/en/
  \item \textsuperscript{25} http://www.wmo.int/pages/prog/www/DPS/LRF/ATTACHII-8SVSfrom%20WMO_485_Vol_I.pdf
\end{itemize}
5. Weather products and services

5.1. Linkages to the WMO operational network

There are two main categories of weather products available through the Global Data Processing Forecasting System (GDPFS): Observation or analyses, and prediction products (including numerical weather outputs, and specific forecast bulletins).

The GDPFS is responsible for the production of meteorological analyses and prediction. It is comprised of 1. World Meteorological Centres (WMCs) and 2. National Meteorological and Hydrological Services (NMHSs) that are responsible for forecasts and warnings on a national level, 3. Regional Specialized Meteorological Centres (RSMCs) that specialise in specific products, guidance and services in support to NMHS and severe weather or water events, 4. Regional Climate Centres (RCCs) responsible for providing NMHSs with climatological monitoring and prediction support and 5. Global Producing Centres (GPCs) which provide long range or seasonal forecasts (see fig 4.1).

More recently RSMCs have been designated to provide severe weather guidance as part of the Severe Weather Forecasting and Demonstration Project (SWFDP)\(^{26}\). Through this project, they provide guidance to smaller and less well-resourced NMHSs that do not have the availability of sophisticated tools for severe weather analysis and forecasting.

World Meteorological Centres provide global analysis and prediction based on deterministic and ensemble prediction systems around the world. These global centres produce outputs from high resolution deterministic models initialised by the best analysis available, 4 times a day. Products can be produced up to 15 days in advance. Unfortunately, the atmosphere is not perfectly predictable. In order to ascertain the potential uncertainty into the forecast products, the ensemble prediction system (EPS) produces forecasts that are launched from many analyses that are perturbed within analysis error. The ensemble prediction mean output shows more skill than the high resolution deterministic models after a few days. The products from these ensembles are useful in determining the future state of the atmosphere and uncertainty related to this prediction.

Section 4 of this document presents a comprehensive outline of the WMO and centres that support its activities. Additional information is also available through the WMO survey of numerical weather models and forecast techniques\(^{27}\) used by weather centers across the world.

5.2. Observation data and analysis products

Meteorological data

Real time or near-real time data obtained through weather, hydrological and environmental monitoring networks, are available through the WMO Information Service and through NMHSs, in accordance to observational standards and principles.

For operational purposes, observation data and numerical outputs of weather prediction models can either be integrated within risk and impact modelling capacities or used for planning purposes. Some of these are also displayed through the purview of various WMO linked organisations, for real-time monitoring of hazardous events.

\(^{26}\) http://www.wmo.int/pages/prog/www/CBS-Reports/DPFS-index.html

The following is a subset of available information regarding types and format of data, which can either be available in text (alphanumeric) or binary:

**Observation data:**

Synoptic observations of main weather parameters are available in text format every 6 hours, as of 00GMT, under the heading of SYNOP (synoptic observations).

International hourly observations (24 hours) may viewed from the NOAA NWS site: [http://weather.noaa.gov/](http://weather.noaa.gov/)

Examples of Binary data are GRIB gridded binary for NWP model output and BUFR (Binary Universal Format for Reporting). All data bulletins have a WMO header and for most a defined format that can be decoded. A discussion about WMO Headers may be found at: [http://www.wmo.int/pages/prog/www/ois/Operational_Information/VolC1_en.html](http://www.wmo.int/pages/prog/www/ois/Operational_Information/VolC1_en.html)

The code formats are found at: [http://www.wmo.int/pages/prog/www/WMOCodes.html](http://www.wmo.int/pages/prog/www/WMOCodes.html)

**Data Analysis sets:**


Other analyses over smaller areas are available at: [http://mag.ncep.noaa.gov/NCOMAGWEB/appcontroller](http://mag.ncep.noaa.gov/NCOMAGWEB/appcontroller)

**Display of data:**

Observational and numerical information can be displayed through a Google Earth application (Tokyo Gisc).

For high impact weather, the Severe Weather Information Centre (SWIC)\(^{28}\) monitors winds, precipitation (and type) from a global set of observations and flags those stations with heavy precipitation and high winds and snow.

**Satellite data:**

There are two basic types of satellites: geostationary and polar orbiting which scan the electromagnetic spectrum in many bands including the visible.

*Satellite data with the exception of the United States, are restricted and only some of the data are found on satellite web sites for example Japan Meteorological Agency (JMA) and The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT).*

Sources of satellite imagery on the internet include:

- Satellite imagery with global coverage and archives which includes volcanic ash, forest fires, dispersion modelling, tropical storms can be found at: [http://www.osdpd.noaa.gov/ml/imagery/](http://www.osdpd.noaa.gov/ml/imagery/)
- The following sites have a good global coverage: Satellite imagery and observations \(^{29}\) from the Naval Research Laboratory, Monterey and the NOAA/NESDIS site: [http://www.nesdis.noaa.gov/SatInformation.html](http://www.nesdis.noaa.gov/SatInformation.html)
- Modis imagery may be found at: [http://rapidfire.sci.gsfc.nasa.gov/realtime/2008182/](http://rapidfire.sci.gsfc.nasa.gov/realtime/2008182/)

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\(^{28}\) [http://severe.worldweather.wmo.int/](http://severe.worldweather.wmo.int/)

Climate and Weather Information Services for the Humanitarian Agencies

- Satellite estimates of precipitation are found on a UNESCO sponsored site: Satellite based estimates.\(^{30}\)

- Precipitation data estimates for the tropics is also available through the Tropical Rainfall Measuring Mission (TRMM), a joint venture between NASA and the Japan Aerospace Exploration Agency\(^{31}\).

**Lightning detection** networks data are available from a number of providers (Vaisalla, WSI, UKMO) for a fee or on a subscription basis. The site at the University of Washington displays global near real time lightning data superposed on satellite data: http://webflash.ess.washington.edu/

**Radar data** may be found at NMHSs web sites and some provide radar data feeds. Radar is essential in spotting severe local convective activity (hail, heavy precipitation, microbursts and tornadoes). Radar can also be used to identify phase changes, general heavy precipitation and even (local) bird flock movement.

Short term extrapolation of the radar may give a Nowcast of the precipitation over the next couple hours. These outputs may be available on some NMHS’s web sites.

**Suggested approach for HAs for weather forecasts**

**NHMS warnings:** The HAs should be able to access the NHMS’ warnings however many are currently not on the GTS and/or do not follow a standard format. For now, the HAs can find this information from the for the country of concern or contact the warning authority or the NMHS for the country of concern.

**RSMC:** The HAs could access the severe weather guidance as produced by the RSMC or specialized products that may be applicable to the HAs needs and requirements. The RSMC may use data from a global NWP centre, but may have modelling techniques of their own – regional high-resolution models and regional EPS. The RSMC guidance products should then be a value added one with respect to the products from a global centre. The RSMC products could be pushed to a hosting site. Please note that the use of the RSMC guidance does not obviate the NMHS role because of its relation to the DRMCPAs. The HAs could access the suggested forecast data directly through a RSMC web site or have the data pushed to a hosting agency. These guidance products are not generally available on the public internet as they are used for the GDPFS. The products could be made available to the HAs for interpretation by qualified personnel.

**Global NWP centres:** Outlooks beyond the 4 or 5 day forecasts produced by the RSMCs could be provided by the global centres – to the limits of predictability (~10 days for now). The products could be hosted by a site for the HAs – for example as is done for the US EPS data on the International Research Institute for Climate and Society site.

**Challenges:** Some global centres have restricted or limited access to their products and model outputs and guidance would require interpretation by meteorological professionals.

The lines of communication for weather should respect the lines of authority. This would privilege the direct contact with the NMHS/DRMCPA involved. Should the NMHS/DRMCPA information not be available, guidance information could be available from the responsible

\(^{30}\) http://hydis.eng.uci.edu/gwadi/

\(^{31}\) http://trmm.gsfc.nasa.gov/publications_dir/regional_pacific.html
RSMC. If the RSMC cannot provide the information then the forecasts from a Global NWP centre should be considered. This process then follows a complementary principle for authoritative weather information. If the lines of communication or infrastructure are missing then they should be fixed in some subsequent time. The principle is maintained.

**High-impact weather and climate products and services**

High impact weather products are issued by NMHS for their area of responsibility. For the most part, these alerts or warnings come in the form of a bulletin that is issued from the NMHS to the official warning authority (if the NMHS is not the warning authority) which transmits to the DRMCPA, media public, etc. Some NMHS issue products in graphical form (to be displayed by the media or a web site) or in digital form which may then be automatically displayed by public warning systems. The warnings cover a whole spectrum of high impact weather using criteria that are usually specific to that country. Examples of hazards which warning are issued include heavy rainfall, high winds, heavy snow, freezing rain; severe convective activity (tornado, hail, severe downbursts; strong gusts); flash flooding; heat spells; cold spells; frost; air quality warnings; airborne particulate matter (smoke, dust; radionuclides; diseases), large wave warnings on shore, large waves and gales for the high seas; and tsunamis warnings. In addition, there are Tropical cyclone warnings with rain, wind and surge effects. Flood warnings (flash or widespread) are issued by some NMHS or agencies associated with the NMHS's. RSMC’s provide guidance to day 5 for high impact weather in many areas of the world.

**Services.** The NMHSs and RSMCs could also provide consultation services to the HAs on events. The NMHS are physically nearer to the event and will be apprised of information that does not transit on the GTS. They are also may be contact with the DRMCPAs. Some of the NMHSs and RSMCs have access to a number of other regional and very fine scale specialized NWP models to provide them additional information to make their forecast.

**Forest fires:** Most NMHS’s have an alerting system for forest fires. Information should be available through a country’s web site or through the alerting authority. There is numerical modelling available in a few countries (see: NOAA NWS Fire weather\(^{32}\)). Should the forest fire be extremely large the movement of the particles in the plume may be modelled through the transport models from one of the centres mentioned above.

The following site provides forest fire tracking through satellites: http://www.fire.uni-freiburg.de/current/globalfire.htm

**5.3. Numerical weather prediction outputs**

There are many prediction models in many centres around the world. The WMO regularly surveys the different centres to list the models and forecast techniques they utilize. The survey results, which provides a catalogue of worldwide models and techniques, can be found at: ftp://ftp.wmo.int//Documents/PublicWeb/www/gdpfs/GDPFS-NWP_Annualreports10/STATUSTA2010.doc

Outputs from NWP span varying time intervals and are either deterministic or based on an ensemble prediction system, as explained previously. For most of these products, interpretation skills are required. NWP outputs can be used on their own and ingested within impact based models. They are, however, one of the main tools by which forecasters within

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\(^{32}\) [http://www.spc.noaa.gov/products/fire_wx/]
NMHS, will diagnose and predict the development cycle of meteorological systems. Specific indices may also be calculated from these NWP outputs and be used as predictors in determining the potential for high impact or severe weather or hydrological events.

Various factors explain the variability in the quality of NWP, and a specific section is dedicated to this discussion. The following indicates a subset of available NWP outputs

**Ensemble prediction systems**

The ensemble prediction systems run with models similar to the ones of the deterministic system but at a lower resolution. Many models are run out to 15 days. The results are many different forecasts for the same time. The variability of these models is a measure of the uncertainty in the forecast. The ensemble mean strikes a balanced course though all these uncertainties. The ensemble mean verifies better than the high resolution deterministic model past a few days (see Appendix D).

TIGGE (The Observing System Research and Predictability Experiment (THORPEX) Interactive Global Grand Ensemble) is currently working to better understand the advantages of grouping ensembles together in a grand ensemble. TIGGE has also provides verification of the ensemble mean.

The best ensemble prediction systems as measured by the ensemble means are: are the ECMWF, UKMO, JMA, NCEP and closely followed by the Canadian Meteorological Centre (CMC) and the Korean Meteorological Agency (KMA).

In addition to the aforementioned centres there are many other NWP models. As mentioned above, WMO provides a summary of NWP usage across the many centres around the world.

**Global production centres**

**ECMWF**: *Their EPS is restricted to members only*. HAAs will require special permission to access these products. A limited set is available to non-members see: [http://www.ecmwf.int/products/](http://www.ecmwf.int/products/)

Suggested products EPS products from their web site (see Appendix E and on for examples) for days 1-10 (these are available for members only):

- 50 mm / 24 h rainfall exceedance;
- 1 mm / 24h to view relief for drought stricken areas;
- Surface Wind threshold >25m/s – see surface wind gusts >25m/s – currently available.

Extreme forecast index The EFI is a simple way to spot climatologically significant phenomena (precipitation, wind, waves and temperatures). The climatology (derived from model statistics) depends on location - for example a wind gust to 30 m/s is more significant in the tropics that in mid-latitudes;

Ocean wave heights >4m (currently available) or wave energy. The largest onshore impact is for large long period waves. The wave product should be combined with the period forecast or perhaps a forecast of wave energy.

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33 See: TIGGE Verification: [http://tparc.mri-jma.go.jp/TIGGE/tigge_daily_score.html](http://tparc.mri-jma.go.jp/TIGGE/tigge_daily_score.html)


35 See [http://www.ecmwf.int/products/forecasts/samples/efi.html](http://www.ecmwf.int/products/forecasts/samples/efi.html) and the article that describes the method.
EPS grams for selected cities (for members only). These EPS grams would be used to look at the details of the phenomena being forecast by the other products – for example a heavy rain event – they should only be viewed by qualified personnel.

TCSTRIKE – strike probabilities of a Tropical Cyclone based on the EPS- see example in the Appendix F.

UKMO MOGREPS: The Met Office Global and regional Ensemble Prediction System MOGREPS⁶⁶ is in a high resolution regional mode over Great Britain and lower resolution elsewhere. MOGREPS can be the source of a multitude of products. The UKMO has products that are similar to the ECMWF’s (Appendix G). It too is restricted in its access. Very few products are available on their public web site.

JMA: has similar products based on their EPS and is restricted in access.

NCEP: As was outlined above, the Global Ensemble Forecast System (GEFS) products and GRIB data are freely available. Products from the GEFS and other models are found on the MAGS site ³⁷. The same site also has products from another grand ensemble – the N American Ensemble forecasting System which combines the GEFS and the Canadian ensemble forecasts. 8-14 day outlook from NAEFS are also available³⁸.

TIGGE Multi-model grand ensembles: The TIGGE site³⁹ is perhaps the best web site to provide forecasts that are in near real time and are publicly available. For this reason it should be considered as one stop shop for global forecast data until such time as it could be hosted on a permanent site.

It gives free access to the 4 best models and a grand ensemble. The techniques used to calculate the extremes for the different phenomena (wind, precipitation, temperatures) are described in a brief description (a pdf file).

It should be noted that it is a research site and is not operational: see TIGGE.

The Model Analyses and Guidance (MAG) website showcases the National Weather Service’s observational database and graphical suite of numerical model analysis and guidance. The site is maintained by National Centers for Environmental Prediction Central Operations (NCEP/NCO) and NOAA’s Web Operations Center (WOC). Graphical model guidance for the NAM is available for the following regions:

1) North America
2) Western North Atlantic
3) North Pacific
4) Eastern North Pacific

The website can be found at the following URL:
http://mag.ncep.noaa.gov/NCOMAGWEB/appcontroller?prevpage=index&MainPage=index&cat=MODEL+GUIDANCE&page=MODEL+GUIDANCE

³⁷ http://mag.ncep.noaa.gov/NCOMAGWEB/appcontroller
³⁹ http://tparc.mri-jma.go.jp/TIGGE/tigge_extreme_prob.html
5.4. Other forecasts

The WMO website World Weather Information centre\(^{40}\) displays city forecasts produced and issued by many of the WMO NMHS members.

In addition to these city forecasts many NMHS’s forecast air quality for major cities. NMHS may also provide weather forecasts on a grid. Forecasts are also made for different sectors: agriculture, aviation marine and transportation to name a few.

Forecast periods range from the very short term to generally 7 to 10 days period.

**Deterministic global model quality:** At 120h the best (based on recent 500hPA scores) deterministic global models in the world for medium range forecasts are the European Centre for Medium Range Weather forecasting (ECMWF), The UK Met Office, (UKMO), U.S National Centre for Environmental prediction (NCEP), Japanese Meteorological Agency (JMA) and the Canadian Meteorological Centre (CMC).

For 24 and 120 h verifications scores see: [http://www.weatheroffice.gc.ca/verification/monthly_ts_e.html](http://www.weatheroffice.gc.ca/verification/monthly_ts_e.html)

5.5. High Impact Weather Products and Services

High impact weather products are issued by NMHS for their area of responsibility. The WMO Public Weather Service Programme is currently compiling a register of alerting authorities by country\(^{41}\) which include a list of available warnings and contact information around the world.

For the most part, these alerts or warnings come in the form of a bulletin that is issued from the NMHS to the official warning authority (if the NMHS is not the warning authority) which transmits to the DRMCPA, media public, etc. Some NMHS issue products in graphical form (to be displayed by the media or a web site) or in digital form which may then be automatically displayed by public warning systems. The warnings cover a whole spectrum of high impact weather using criteria that are usually specific to that country. Examples of hazards which warning are issued include heavy rainfall, high winds, heavy snow, freezing rain; severe convective activity (tornado, hail, severe downbursts; strong gusts); flash flooding; heat spells; cold spells; frost; air quality warnings ; airborne particulate matter (smoke, dust; radionuclides; diseases), large wave warnings on shore, large waves and gales for the high seas; and tsunami warnings. In addition, there are Tropical cyclone warnings with rain, wind and surge effects. Flood warnings (flash or widespread) are issued by some NMHS or agencies associated with the NMHS’s. RSMC’s provide guidance to day 5 for high impact weather in many areas of the world.

Warning information is also disseminated and displayed through various methods:

Not all hazard warnings (including flood warnings) follow a machine decodable format. Common Alerting Protocol (CAP) enables warnings to be transmitted in a machine decidable format. This protocol is being implemented in many countries to enable the dissemination and capture of hazard warnings by different dissemination channels. Additional information concerning this protocol is available through the Work Shop report\(^{42}\) of the WIS-CAP.

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\(^{40}\) [http://worldweather.wmo.int/](http://worldweather.wmo.int/)

\(^{41}\) [http://www-db.wmo.int/alerting/authorities.html](http://www-db.wmo.int/alerting/authorities.html)

meeting held in Geneva in April 2011. Subsequent meetings were held recently in April 2012. The individual country reports may viewed through the document plan43.

The Severe Weather Information Centre (SWIC44) could be a source for official warnings – it currently hosts Tropical cyclone alerts45 and has been expanded recently to include observations of, Heavy rain/snow46, gales47 and thunderstorms48.

The Meteoalarm49 website aggregates extreme weather warnings and other hazard information from the NMHSs of many countries in Europe. This site is an example of a weather aggregation portal where HAs could access current weather and forecasts from the NMHSs and warnings from the appropriate warning authorities.

Guidance material from RSMCs may also supplement the warnings from the NMHSs or other specialised centres.

5.5.1. Severe Weather Forecasting Demonstration Project (SWFDP) centres

SWFDP provide severe weather guidance (web sites and products) for smaller, less developed NMHSs within a designated area through RSMCs. At present many of these products are free-form text and are not yet available through the CAP.


![Figure 5.1: Severe Weather Forecasting Demonstration Project SWFDP– Information Flow from the Global Centres to the NMHS (source: WMO- GDPFS Programme). SEE COMMENT](http://www.meteoalarm.eu/)

As was mentioned above, these SWFDP RSMCs provide severe weather guidance for smaller, less developed NMHSs within a designated area. The web sites and products are available only to NMHSs. However, the guidance material could be provided to HAs operations for interpretation.

44 http://severe.worldweather.wmo.int/
45 http://severe.worldweather.wmo.int/rain/
46 http://severe.worldweather.wmo.int/gale/
47 http://severe.worldweather.wmo.int/thunder/
49 http://www.meteoalarm.eu/
The first centre to be designated as a SWFDP RSMC was Pretoria\textsuperscript{50} for Southern Africa, followed by Wellington\textsuperscript{51} for the South Pacific, Nairobi\textsuperscript{52} (jointly with Tanzania) for Eastern Africa and most recently Hanoi for SE Asia. Each RSMC may concentrate on different phenomena. For example Wellington has included large waves in their guidance. See Appendix H for sample products from some of these RSMCs. NMHS’s participating in this project have found the guidance products to be of good quality. It should be noted that the SWFDP is a demonstration project and there are still portions of the globe that are not covered.

5.5.2. Tropical Cyclones Centres (TCC) and products

These centres provide tropical cyclone forecasting for designated areas of the globe (\textbf{Figure 5.2}). Tropical Cyclone warnings and outlooks are available through the SWIC or can be disseminated through a data flow from the GTS. (Sample TC outlooks is available in Annex 1)

Many of the TCC’s, such as Miami, MétéoFrance and the Bureau of Meteorology (Australia) have specialized models for the prediction of tropical cyclones.

\textbf{Figure 5.2: Global Map of Location of and Regions of Responsibilities of the RSMCs for Tropical Cyclones (Source: WMO)}

Tropical cyclone centres:

\textbf{National Hurricane Centre, Miami}\textsuperscript{53} (Caribbean Sea, Gulf of Mexico, North Atlantic and eastern North Pacific oceans east of 140°W)

\textbf{Japan Meteorological Agency, Tokyo}\textsuperscript{54} (Western North Pacific Ocean from Malay peninsula to 180°E)

\textbf{Indian Meteorological Department, New Delhi}\textsuperscript{55} (Bay of Bengal and the Arabian Sea)

\footnotesize{\textsuperscript{50} \texttt{http://rsmc.weathersa.co.za/RSMC/login.php} \textsuperscript{51} \texttt{http://www.metconnect.co.nz/} \textsuperscript{52} \texttt{http://www.meteo.go.ke/rsmc} \textsuperscript{53} \texttt{http://www.nhc.noaa.gov/} \textsuperscript{54} \texttt{http://www.jma.go.jp/en/typh/} \textsuperscript{55} \texttt{http://www.imd.gov.in/section/nhac/dynamic/cyclone.htm}}
Climate and Weather Information Services for the Humanitarian Agencies

The Central Pacific Hurricane Centre, Honolulu, Hawaii\(^{56}\) (North Pacific Ocean 140 – 180°W)

Météo France de La Réunion\(^{57}\) (South Indian Ocean from African coast to 90°E)

Meteorological Service, Nadi, Fiji\(^{58}\) (South Pacific Ocean east of 160°E and north of 25°S)

The Bureau of Meteorology, Australia\(^{59}\) (Southern hemisphere 90 – 160°E)

MetService, Wellington, New Zealand\(^{60}\) (South Pacific Ocean east of 160°E and south of 25°S)

Joint Typhoon Warning Centre, Pearl Harbor, Hawaii\(^{61}\) (West of 180°E)

Canadian Hurricane Centre, Halifax, Canada\(^{62}\) (Canadian Atlantic shores)

For guidance only:

The UKMO Tropical cyclone guidance centre\(^{63}\) : does not provide official forecasts but
guidance for the Pacific, Atlantic and Indian oceans.

The HAs should look at the TC warnings through the SWIC or through one of the other web
sites or through a data flow from the GTS.

Attached in Appendix I are sample TC outlooks from a TCC.

Many of the TCC’s have specialized models- e.g. Miami. See: http://www.nhc.noaa.gov/,
MeteoFrance, and the Bureau of Meteorology, Australia.

5.5.3. Emergency Response Activities (ERA)

WMO’s Emergency Response Activities ERA\(^{64}\) programme involves the application
of specialized atmospheric dispersion-modelling techniques to track and predict the spread of
airborne hazardous substances in the event of an environmental emergency. This kind of
specialized application depends directly on the operational infrastructure of the numerical
weather prediction systems that are implemented and maintained at many of the global,
regional or national meteorological centres within WMO’s World Weather Watch system.

The ERA programme was established to assist NMHS’s, their respective national agencies
and relevant international organizations to respond effectively to environmental emergencies
involving large-scale dispersion of air-borne hazardous substances.

Following the Chernobyl nuclear power plant accident in 1986, the programme has focused
its operational arrangements and support on nuclear facility accidents. In addition, where
possible, the programme has also included emergency response to the dispersion of smoke
from large fires, ash and other emissions from volcanic eruptions, and chemical releases
from industrial accidents.

For disasters from airborne phenomena (dust, volcanic ash, smoke from large fires) the HAs
should be informed of the potential problems. The International Civil Aviation Organisaton

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\(^{56}\) http://www.ph.noaa.gov/hnl/cphc/

\(^{57}\) http://www.meteo.fr/temps/domtom/La_Reunion/webcmrs9.0/anglais/index.html

\(^{58}\) http://www.met.gov.fj/


\(^{60}\) http://www.metservice.co.nz/public/marine/high-seas-forecast-map.html

\(^{61}\) http://www.usno.navy.mil/JTWC

\(^{62}\) http://www.atl.ec.gc.ca/weather/hurricane/index_e.html

\(^{63}\) http://www.metoffice.gov.uk/weather/tropicalcyclone

\(^{64}\) http://www.wmo.ch/pages/prog/www/DPF/EREA/EmergencyResp.html
works closely with these RSMC’s for Volcanic ash, WHO for airborne toxic material, and the
IEAE for radioactive fallout. The HAs should also consult these agencies. The warnings from
the individual NMHS should be heeded and then the guidance material from the ERA
RSMC’s could be looked at.

The ERA RSMC’s usually don’t broadcast data publically –but provide information to the
NMHS’s as well as well governemental authorities. The HAs operations should consult the
contact list65 in the event of some disaster caused by some airborne phenomena.

The ERA RSMCs are:
Beijing, Exeter, Melbourne, Montreal, Obninsk, Offenbach (backtracking only), Tokyo,
Toulouse, Vienna (backtracking only), Washington.
Some of these centres also act as Volcanic Ash Advisory centres (VAAC)66.

Though the products from the VAAC’s are intended for aviation, the HAs operations should
be informed of the movement of volcanic ash plumes and their possible deposition.

5.5.4. Other centres

The African Centre of Meteorological Application for Development (ACMAD67) - NIAMEY,
NIGER: produces principally data for drought analysis and forecasting and other climate
related products for Africa. ACMAD also produces a severe weather bulletin for dust, heavy
rainfall and large waves see: http://www.acmad.ne/en/prevision/SWF.pdf

5.5.5. Flood warnings

Flood warnings are issued by differing authorities in different countries – see Alerting
Authorities68.

The Integrated flood management help desk is at: Flood management helpdesk69

A number of initiatives using ensemble prediction systems may be found at:
http://www.floodrisk.net/.

Current Operational Systems (see Table 5.1) use meteorological ensembles as inputs
(operational and pre-operational) (some of these links are available by permission only)*

http://www.wmo.int/pages/prog/www/DPFSEERA/contacts.html
http://www.ssd.noaa.gov/VAAC/washington.html#
http://www.acmad.ne/
http://www-db.wmo.int/alerting/authorities.html
http://www.apfm.info/helpdesk.htm
Table 5.1 Current flood forecasting systems based on NWP Ensemble

<table>
<thead>
<tr>
<th>Forecast centre</th>
<th>Ensemble NWP input</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>European Flood Alert System</strong>&lt;sup&gt;70&lt;/sup&gt; (EFAS) of the European Commission Joint Research Centre</td>
<td>ECMWF, COSMO-LEPS</td>
</tr>
<tr>
<td>Georgia-Tech/Bangladesh project&lt;sup&gt;71&lt;/sup&gt;</td>
<td>ECMWF</td>
</tr>
<tr>
<td>Finnish Hydrological Service&lt;sup&gt;72&lt;/sup&gt;</td>
<td>ECMWF</td>
</tr>
<tr>
<td>Swedish Hydro-Meteorological Service&lt;sup&gt;73&lt;/sup&gt;</td>
<td>ECMWF</td>
</tr>
<tr>
<td>Advanced Hydrologic Prediction Services&lt;sup&gt;74&lt;/sup&gt; from NOAA</td>
<td>US National Weather Service (NOAA)</td>
</tr>
<tr>
<td>MAP D-PHASE&lt;sup&gt;75&lt;/sup&gt; (Alpine region) / Switzerland</td>
<td>COSMO-LEPS</td>
</tr>
<tr>
<td>Vituki&lt;sup&gt;76&lt;/sup&gt; (Hungary)</td>
<td>ECMWF</td>
</tr>
<tr>
<td>Rijkswaterstaat&lt;sup&gt;77&lt;/sup&gt; (The Netherlands)</td>
<td>ECMWF, COSMO-LEPS</td>
</tr>
<tr>
<td>Royal Meterological Institute of Belgium&lt;sup&gt;78&lt;/sup&gt;</td>
<td>ECMWF</td>
</tr>
<tr>
<td>Vlaamse Milieumaatschappij&lt;sup&gt;79&lt;/sup&gt; (Belgium)</td>
<td>ECMWF</td>
</tr>
<tr>
<td>Météo France&lt;sup&gt;80&lt;/sup&gt;</td>
<td>ECMWF and Arpège EPS</td>
</tr>
<tr>
<td>Land Oberoestereich, Niederoestereich, Salzburg, Tirol (Austria)</td>
<td>Integration of ECMWF into Aladin</td>
</tr>
<tr>
<td>Land Bayern&lt;sup&gt;81&lt;/sup&gt; (Germany)</td>
<td>ECMWF</td>
</tr>
<tr>
<td>Centre d’expertise hydrique du Québec, Meteorological Service of Canada&lt;sup&gt;82&lt;/sup&gt; (Canada)</td>
<td>Meteorological Service of Canada</td>
</tr>
<tr>
<td>Flood Forecasting Centre (UK)&lt;sup&gt;83&lt;/sup&gt;</td>
<td>UKMO</td>
</tr>
<tr>
<td>CSIR&lt;sup&gt;84&lt;/sup&gt;</td>
<td>South Africa</td>
</tr>
</tbody>
</table>

Dartmouth flood observatory<sup>85</sup> is based at the University of Colorado. The observatory has a mission to acquire, publish, and preserve for public access a digital map record of the Earth’s changing surface water, including changes related to floods and droughts. Its products are based on various remote sensing sources.

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<sup>70</sup> http://floods.jrc.ec.europa.eu/
<sup>71</sup> http://cfab.eas.gatech.edu/cfab/cfab.html
<sup>72</sup> http://www.environment.fi/default.asp?contentid=314997&lan=en
<sup>73</sup> http://www.smhi.se/
<sup>74</sup> http://www.nws.noaa.gov/floodsafety/index.shtml
<sup>75</sup> http://www.map.meteoswiss.ch/map-doc/dphase/dphase_info.htm
<sup>76</sup> http://www.vituki.hu/
<sup>77</sup> http://www.rijkswaterstaat.nl/water/
<sup>78</sup> http://www.meteo.be/
<sup>79</sup> http://www.vmm.be/
<sup>80</sup> http://www.vigicrues.ecologie.gouv.fr/
<sup>81</sup> http://www.hnd.bayern.de/
<sup>82</sup> http://direct.sref.org/1607-7938/hess/2009-13-2221
<sup>83</sup> http://wwwffc.environment-agency.metoffice.gov.uk/
<sup>84</sup> http://rava.qsens.net/themes/climate_template/seasonal-forecasts/Streamflow.PDF/view
<sup>85</sup> http://floodobservatory.colorado.edu/index.html
5.6. Availability of weather products and services

WMO Meteorological network: Data for the HAs should be extracted from the WMO operational network which comprises: (i) WMO Global Observing System (GOS) (ii) WMO Global Telecommunication System (GTS) and (iii) WMO Global Data-processing and Forecasting System (GDPFS)

The Manual on the GDPFS may be found at:
http://www.wmo.int/pages/prog/www/DPFS/Manual_GDPFS.html

Annex 1-V of the GDPFS Manual defines the help offered by the NMHS’s and the RSMC’s to the HAs. In essence products from the RSMC’s and the NMHS’s should be made more available to the HAs.

Not all data are available on the GTS. Free data exchange is defined by WMO Resolution 40 (CG XII), which is a WMO policy and practice for the exchange of meteorological and related data and products (see section 1.2). WMO Res 40 defined the free and unrestricted exchange of essential products as essential for the protection of life and property. These and other additional products are listed in Annex I. Provisions 6 and 7 pertain to the free exchange of weather warnings and advisories. Every country may add other free and unrestricted products; these are listed in a series of Notifications.

The free exchange of hydrological data and forecasts is defined by WMO Resolution 25.

Only a small amount of NWP model data is on the GTS. Some Global NWP Centres allow free and unrestricted access to their model data through ftp sites eg. US NWS Gateway – see: http://www.nws.noaa.gov/tg/modfiles.html. Most of the US NWS NCEP (National Centres for Environmental Prediction) NWP models are available as well as some from other countries (some through the GTS). Archived data may be found at: http://nomads.ncdc.noaa.gov/data.php. Environment Canada allows for free access to Canadian model data at: http://www.weatheroffice.gc.ca/grib/index_e.html.

Other Centres (for e.g., ECMWF, UKMO, Meteo-France and JMA) allow access to model data for members only, for commercial clients for a fee, or through special permission (see ECOMET).

Marine warnings including Tsunamis, Tropical Cyclone warnings as well as warnings for aviation are on the GTS (SIGMETS, Volcanic ash warnings and advisories). Some country specific warnings may only be found on the country’s web site (see the WMO list at http://www.wmo.int/pages/members/index_en.html).

Many of these country websites offer a RSS (Really Simple Syndication) subscription service such as:

Australian Bureau of Meteorology (RSS Feeds)
Hong Kong Observatory (RSS feeds)
Macao Meteorological and Geophysical Bureau (RSS feeds)95
Pacific Tsunami Warning Centre (RSS feeds)96
Philippine Atmospheric, Geophysical and Astronomical Services Administration (RSS feed)97
Thai Meteorological Department (RSS feeds)98
The Network of European Meteorological Services (RSS feeds)99
UK Met Office (RSS feeds)100
US National Oceanic and Atmospheric Administration (RSS feeds)101
Japanese Meteorological Agency102
Environment Canada103

5.7. Conclusions and recommendations

5.7.1. Consultation/training:

Much of the work of the HAs is to access and utilize products and services provided by WMO Operational Network. It suggested that trainers that have worked the GDPFS and the PWS should be hired for training/consultations of the responsible personnel in the HAs. For the access to the data – a consultant familiar with WIS should be considered. Should the TIGGE products or products from the ECMWF be sought then consultants from or familiar with the ECMWF should be considered.

5.7.2. Mapping of HAs needs / recommendations

The GTS data could be pushed to a HAs site or a HAs application that processes and displays data. Additional NWP data could be obtained (under WMO Res. 40) from the major NWP sites to provide selected high impact products for the HAs. This will take considerable effort to develop suitable products, displays and graphical user interfaces. The HAs may look at existing meteorological display systems such as those listed on the NOAA NWS Gateway site.

Table 5.2 presents a summary of the mapping of products and services currently available by categories of major meteorological hazards or high impact-related phenomena within the WMO network.
Table 5.2: Suggested mapping of HA needs to the WMO network

<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>monitoring</th>
<th>Alerts –short term</th>
<th>Medium term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsunamis</td>
<td>SWIC\textsuperscript{104}</td>
<td>-NMHS’s web site; -Alerting Authorities\textsuperscript{105}</td>
<td>To be determined</td>
</tr>
<tr>
<td>Severe local convection</td>
<td>- SWIC—thunderstorms and heavy precipitation; -Radar on NMHS' web site; - Lightning data\textsuperscript{106}</td>
<td>-NMHS’s web site; -Alerting Authorities - SWIdget\textsuperscript{107}</td>
<td>No recommendation; -- perhaps guidance of severe stability indices extremes drawn from the EPS?</td>
</tr>
<tr>
<td>Severe local convection Including hail and flash floods</td>
<td>Freeburg U. satellite monitoring\textsuperscript{108} -NMHS’s web site</td>
<td>-Large scale transport of through an ERA model; - medium range forecasts of forest fire indices NOAA NWS Fire weather\textsuperscript{110}</td>
<td></td>
</tr>
<tr>
<td>Forest fire</td>
<td>ICAO, IEAE; WHO; - Alerting Authorities</td>
<td>- NMHS’s web site; -Alerting Authorities</td>
<td>ERA RSMC contact list \textsuperscript{111}</td>
</tr>
<tr>
<td>Volcanic Ash radionuclides, airborne diseases</td>
<td>SWIC – Heavy precipitation Satellite based estimates\textsuperscript{112} TRMM estimates for the tropics\textsuperscript{113}</td>
<td>-NMHS’s web site; -Alerting Authorities</td>
<td>TIGGE EPS forecasts\textsuperscript{115} - Or a site to be developed for the HAs with a grand ensemble extremes; or using ECMWF EFI; -EPSgrams</td>
</tr>
<tr>
<td>Heavy precipitation</td>
<td>Flood management helpdesk\textsuperscript{116} Dartmouth flood observatory</td>
<td>-NMHS’s web site; - Alerting Authorities - SWIdget</td>
<td>European Flood Alert System\textsuperscript{117} -Could be generalized to a global alert system based on EPS output</td>
</tr>
<tr>
<td>Flood</td>
<td>SWIC</td>
<td>-NMHS’s web site; -Alerting Authorities - SWIdget</td>
<td>TIGGE EPS forecasts Or a site to be developed for the HAs; ECMWF wind exceedance or EPSGRAMs</td>
</tr>
<tr>
<td>High winds</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\textsuperscript{104} http://severe.worldweather.wmo.int/
\textsuperscript{105} http://www-db.wmo.int/alerting/authorities.html
\textsuperscript{106} http://webflash.ess.washington.edu/
\textsuperscript{107} http://severe.worldweather.wmo.int/swidget/swidget.html
\textsuperscript{108} http://www.fire.uni-freiburg.de/current/globalfire.htm
\textsuperscript{109} http://www.nesdis.noaa.gov/SatInformation.html
\textsuperscript{110} http://www.wmo.int/pages/prog/www/DPFSERA/contacts.html\textsuperscript{p://www.spc.noaa.gov/products/fire_wx/}
\textsuperscript{111} http://www.wmo.int/pages/prog/www/DPFSERA/contacts.html
\textsuperscript{112} http://hydis.eng.uci.edu/gwadi/
\textsuperscript{113} http://trmm.gsfc.nasa.gov/publications_dir/regional_pacific.html
\textsuperscript{114} http://www-db.wmo.int/alerting/authorities.html
\textsuperscript{115} http://tparc.mri-jma.go.jp/TIGGE/tigge_extreme_prob.html
\textsuperscript{116} http://www.apfm.info/helpdesk.htm
\textsuperscript{117} http://floods.jrc.ec.europa.eu/
<table>
<thead>
<tr>
<th>Phenomenon</th>
<th>monitoring</th>
<th>Alerts –short term</th>
<th>Medium term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremes of cold or warm; heat wave</td>
<td>?</td>
<td>-NMHS’s web site; -Alerting Authorities</td>
<td>TIGGE EPS forecasts Or a site to be developed for the HAs; ECMWF EFI temperature; EPSGrams</td>
</tr>
<tr>
<td>Tropical cyclones</td>
<td>SWIC</td>
<td>-NMHS’s web site; -Alerting Authorities - SWIdget</td>
<td>TCC and tropical warning centres guidance and models</td>
</tr>
<tr>
<td>Phenomenon</td>
<td>monitoring</td>
<td>Alerts –short term</td>
<td>Medium term</td>
</tr>
</tbody>
</table>

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6. Climate products and services

6.1. Historical climate data

Access to “essential” meteorological data is guaranteed by WMO Resolutions 40 and 25 (section 4.1). However, these Resolutions are primarily concerned with the exchange of data in real-time for weather forecasting purposes. In practice, historical data (especially daily data, which essential for mapping of many types of hazards), are not usually easy to obtain, and fees may be levied. Thus, the ease and expense of access to historical climate data varies considerably from country to country, but there are a number of historical global and regional datasets that are freely available for non-commercial purposes, and a few that are available without restriction (Appendix J). The World Data Centre for Meteorology at NOAA-National Climatic Data Centre, the Climatic Research Unit\textsuperscript{118} and the NASA Goddard Institute for Space studies host useful long term instrumental climate datasets, which extend more than a century back and are updated on a monthly basis for operational climate monitoring and long term climate change assessment. The World Data Centre for Paleoclimatology\textsuperscript{119} provides proxy data derived from ice cores, tree rings and other type of data, which are useful for assessing climate conditions over millennia and longer. However, these timescales are likely to be too long for direct interest by HAs, even for providing extended perspectives on the nature and variability of climate hazards in a region.

Figure 6.1: Schematic representation of a modern Climate data Management System

Most historical climate datasets accessible from global centres present information as monthly averages (or totals in the case of precipitation). Monthly data may be useful records of some hazards such as droughts, but for most hazards daily data would be required. Data on temperature and precipitation are reasonably accessible, as are some data on severe storm counts and tracks, but data on wind speeds and humidity (important for defining heat

\textsuperscript{118} http://www.cru.uea.ac.uk/cru/data/paleo/
\textsuperscript{119} http://www.ncdc.noaa.gov/paleo/data.html
waves, for example) are much harder to come by, and data quality can be problematic. In most cases, National Meteorological and Hydrological Services are the repository of a more complete national historical climate datasets with higher time resolution (hourly and daily). Some climate datasets are even of a much higher resolution (few minutes), which are collected from various types of continuous recording devices such as Thermographs, Hygrographs, Rain gauge tipping bucket, AWSs, etc.. Climatological data at NMHS are managed using computer based climate data management systems and advanced quality control and station metadata. Therefore regardless of the hazard of interest, considerable expertise is required to identify and interpret properly climate data. This task is best completed by partnership between the humanitarian and meteorological communities.

The European Climate Assessment and Data set project, ECA&D, provides a web oriented database and is the result of a collaboration between 58 European meteorological institutes and universities. Each partner provides daily time series for a number of elements for inclusion in a central database, although some partners had to digitize the old parts of the daily series first. One of the partners is the MEDARE initiative which aims at developing, consolidating and progressing climate data and metadata rescue activities across the Greater Mediterranean Region\textsuperscript{120}. The ECA&D website\textsuperscript{121} offers a data portal and climate monitoring tool for information on changes in climate and climate extremes. The system has an operational status, which means that the series and derived products such as the number of cold days, the number of days with heavy precipitation and the potential evapo-transpiration, are updated monthly. Due to differences in national data policies, not all daily series are available for public download. ECA&D is being scaled up to cover other regions like South Asia (SACA&D), Latin America (LACA&D) and West Africa (WACA&D).

\subsection*{6.1.1. Droughts and floods}

For many countries, precipitation data are the best archived of all meteorological parameters. Some of the more commonly used precipitation datasets are listed in Appendix J. For a number of reasons, these datasets are best suited as records of droughts rather than floods. Since floods are essentially a hydrological rather than a meteorological phenomenon, heavy rainfall per se is not necessarily a problem. For example, some of the major flooding events are associated with snowmelt, and the snow is likely to have occurred weeks, or even months before the flooding, and some distance away from the flooded area. Of course, rainfall often does directly cause flooding problems and so historical precipitation data will be useful to HAs, but daily datasets will provide much more useful records of hazardous conditions than will monthly data. Historical records of extreme precipitation events and major storms are discussed separately in sections 6.1.3 and 6.1.4, respectively.

\subsection*{6.1.2. Heat-waves and cold spells}

Because it is more the combination of unusually high temperatures with high humidity that constitutes a health threat rather than high temperatures alone, heat waves are best measured using a measure that combines both variables. Unfortunately, historical records of such heat-stress indices are not widely available, and there is not even any universal definition of how to calculate such an index. Similarly, for cold spells, it is the combination of low temperatures with blizzard conditions that are likely to prove of greatest interest to HAs. Despite these limitations, daily maximum and minimum temperature data can be useful in

\textsuperscript{120} http://www.omm.urv.cat/MEDARE
\textsuperscript{121} http://www.ecad.eu
characterising heat waves and cold spells, and are relatively well archived. Some of the more commonly used temperature datasets are listed in Appendix J. As with heavy precipitation, daily data are likely to prove much more valuable in identifying hazardous conditions than are monthly means.

Figure 6.2: Example Heat wave monitoring product over Europe. Summer 2003, (Source: Royal Netherlands Meteorological Institute (KNMI)

<table>
<thead>
<tr>
<th>Year</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1890</td>
<td>-7.7°C</td>
</tr>
<tr>
<td>1900</td>
<td>-7.0°C</td>
</tr>
<tr>
<td>1940</td>
<td>-10.0°C</td>
</tr>
<tr>
<td>1947</td>
<td>-7.7°C</td>
</tr>
<tr>
<td>2012</td>
<td>-7.0°C</td>
</tr>
<tr>
<td>1940: -10.0°C</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6.3: Example of monitoring the winter 2012 cold wave in Europe Mean temperature for the 10-day periods 01-10 February of the years 1891-2012 in Hamburg, Germany. Source: Deutscher Wetterdienst, Germany

6.1.3 Analysis of climate extremes
Since many disasters are associated with extreme weather events that may be only weakly evident in monthly means, datasets of monthly means may be unsuitable for detecting variability and changes in the extreme events that are of interest to HAs. The monitoring, detection and attribution of changes in climate extremes usually require daily resolution data, but the compilation, provision, and update of a globally complete and readily available full resolution daily dataset is a very difficult task because not all NNMHSs have the capacity or mandate to freely distribute the daily data that they collect. Consequently, the WMO CCI / CLIVAR / JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) and its predecessor, the CCI/CLIVAR Working Group on Climate Change Detection have been coordinating an international effort to develop, calculate, and analysis a suite of indices so that individuals, countries, and regions can calculate the indices in exactly the same way such that their analyses will fit seamlessly into the global picture. A core set of 27 indices of extreme temperature and precipitation has been developed as means of monitoring changes in extremes as a result of climate change. These indices attempt to measure parameters hazards such as heat waves, cold spells, dry spells and intense precipitation events. These indices have constituted important inputs to the IPCC. The indices represent seasonal and/or annual values derived from daily station data. Further details about these data are provided in Appendix J. More detailed and up-to-date regional datasets on extremes do exist. Such datasets may arguably be some of the most useful climate data products for HAs. The Commission for Climatology has recently launched a parallel initiative through the new expert team on Climate Risk and Sector-Specific Climate Indices (ET-CRSCI) to develop sector-specific climate indices, particularly those associated with Agriculture (e.g. droughts, frosts and freezes) and health (a new approach on heatwaves in particular through more complex indices). The work is based on, and is conducted in collaboration with ETCCDI, and with sector experts.

WMO/TD No 1500\(^1\) provides guidelines on the Analysis of extremes in a changing climate in support of informed decision for adaptation.\(^{122}\)

**6.1.4. The monsoons, storms, and other important potential hazards**

Variability in rainfall in the major monsoon regions can be associated with severe flooding or drought problems, while long-term changes may result in significant migration patterns, such as in the African Sahel during the 1980s. The Sahel experienced a substantial decrease in rainfall during the 1970s and 1980s, amounting to about a 30% decline over most of the region, and contributing to widespread famine and migration to urban areas. The rainfall has recovered somewhat in the 1990s and 2000s. The causes of the trend and the recent reversal are an ongoing and active area of research. In the other major monsoon regions there have been no similar long-term changes. Data on the Indian monsoon from 1813 to date provide one of the longest monitored climate phenomena (Appendix J).

Tropical cyclones constitute one of the most severe hazards, and are of considerable interest to HAs. Increases in tropical cyclone frequency in the North Atlantic Basin have been reported, but it is not clear whether this is a result of global warming, or whether it is a temporary upward trend. The current consensus is that frequencies are likely to decrease globally, but that the most intense cyclones will become more frequent. Historical records of tropical cyclone frequency are useful for hazard mapping, and for providing a baseline for monitoring and forecasting purposes. The US National Hurricane Centre provides extensive

resources on North Atlantic and East Pacific (see Appendix J)\(^\text{123}\). North Atlantic tropical storm tracks are presented by the Coastal Services Centre in a useful online mapping tool\(^\text{124}\) that provides a visual indication of risk for user-specified locations.

### 6.1.5. El Niño and La Niña

The state of the El Niño – Southern Oscillation phenomenon is measured by a range of atmospheric and oceanic indices. Perhaps the simplest is the Southern Oscillation Index (SOI), which is a measure of sea-level pressure difference between Darwin and Tahiti. The SOI has a number of advantages as a measure of the ENSO, not least of which is that it is been possible to reconstruct the index back to the mid-nineteenth century. In addition, the index is fairly simple to calculate and understand, and as a measure of sea-level pressure, it indicates the extent to which the atmosphere is responding to El Niño / La Niña, and thus is more directly a measure of potential impacts than is an oceanic measure. However, the SOI can be noisy (it fluctuates quite markedly), and so there is a danger of over-interpreting trends over the last few days. There are also some slight differences in how the index is calculated at different centres, so it is important to note that it may not be possible to update historical values from one centre using real-time values from another centre.

Other commonly used ENSO indices are calculated as area-averages of sea-surface temperatures in various parts of the near-equatorial Pacific Ocean. Numerous areas have been suggested, each of which has different purposes, but the most commonly used one for measuring the phase and strength of the current ENSO state, is the Niño3.4 index, which has the strongest correlation with the SOI. The Niño3.4 index is a more direct measure of the El Niño / La Niña than is the SOI, and is much less noisy. The Niño3.4 index is commonly used for defining whether El Niño or La Niña conditions are occurring. For HAs it would be preferable to use an index of the phase and strength of the ENSO state that is consistent with official declarations.

A list of the most commonly used ENSO indices and data sources is provided in Appendix J.

#### 6.1.6. Data analysis tools

In addition to simply providing access to the data, some centres provide visualization and analysis tools. Examples include:

- a) Climate Explorer\(^\text{125}\) (Koninklijk Nederlands Meteorologisch Instituut)
- b) Data Library\(^\text{126}\) (International Research Institute for Climate and Society)

Although there are a large number of accessible datasets available and that could be accessed by HAs, a simple principle with all of these is that considerable expertise is required to convert the data into meaningful products that can be used to inform decisions, whether because of a need to understand the limitations of the data, or to interpret the data correctly, or to understand how to convert the data into useful information products.

### 6.2. Hazard monitoring

There are a number of centres that provide important services (see Table 6.1), and most National Meteorological Services provide a variety of climate monitoring information with

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\(^{123}\) [http://www.nhc.noaa.gov/climo/](http://www.nhc.noaa.gov/climo/)

\(^{124}\) [http://www.csc.noaa.gov/hurricanes/](http://www.csc.noaa.gov/hurricanes/)

\(^{125}\) [http://climexp.knmi.nl/](http://climexp.knmi.nl/)

varying level of sophistication depending of the local human and technological capacities. The World Data Centres (section 1.2.2) also generally carry out analysis and monitoring of their respective climate-related domains of interest. Under the Global Framework for Climate Services (GFCS) it is likely that there will be a setup of a formal designation process of global climate monitoring centres. WMO coordinates international efforts in global climate monitoring through the World Climate Programme under the advisory role of the Commission for Climatology. At regional level climate monitoring is a mandatory function of Regional Climate Centres (RCCs; for further details on RCCs see section 4.1).

A number of these centres collaborate with WMO and make available their products for global, regional and national use.

Table 6.1: Examples of current global-scale climate monitoring centres

<table>
<thead>
<tr>
<th>Centre</th>
<th>Principal Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Climate Data Centre, USA</td>
<td>Analysis and state of the global climate</td>
</tr>
<tr>
<td>Meteorological Office, UK</td>
<td>Global monthly monitoring</td>
</tr>
<tr>
<td>National Snow and Ice Data Centre, USA</td>
<td>Cryosphere (snow and ice)</td>
</tr>
<tr>
<td>National Centres for Environmental Prediction, USA</td>
<td>Monthly global climate diagnostics</td>
</tr>
<tr>
<td></td>
<td>Global reanalysis</td>
</tr>
<tr>
<td>European Centre for Medium-Range Weather Forecasts, UK</td>
<td>Global climate system monitoring</td>
</tr>
<tr>
<td></td>
<td>Global reanalysis</td>
</tr>
<tr>
<td>Global Precipitation Climatology Centre, Germany</td>
<td>Global precipitation</td>
</tr>
<tr>
<td>Bureau of Meteorology, Australia</td>
<td>Global climate and its variability</td>
</tr>
<tr>
<td>Beijing Climate Centre, China</td>
<td>Global climate system monitoring</td>
</tr>
<tr>
<td>Aristotle University, Greece</td>
<td>Ozone Mapping Centre (Satellite)</td>
</tr>
</tbody>
</table>

6.2.1. Climate Watches

Climate variations and change can affect global and regional atmospheric and oceanic circulations. Significant variations and change, where the system deviates dramatically from the mean state of the climate, are correlated to extreme weather and climate events on various time scales including, monthly, seasonal and annual time scales. Such events can lead directly or indirectly to negative consequences on lives, goods, properties, and the well-being of societies. Droughts, heat waves, cold waves, flooding, extreme wind storms, landslides, bush and forest fires, costal erosions and tropical cyclones are some of the impacts that can be triggered by variations and changes in circulation. Many of these

http://www.wmo.int/pages/prog/wcp/wcdmp/index_en.php
variations are actually recurrent and associated with well-known climatic patterns such as the El Niño Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), warming/cooling of Sea Surface Temperatures (SST) in the tropical oceans, strengthening/weakening of the upper level Jets, etc. This means that many of the extreme weather and climate events can, to a certain extent be predicted, and therefore prepared for.

The 14th session of the WMO Congress recognized that climate system monitoring and climate change detection are increasingly important inputs to high priority activities such as early warning and disaster prevention planning. The Congress stressed the critical importance of eliminating confusion and of minimizing duplication in the provision of operational products and services related to warning services. Guidelines were drafted to promote the implementation of Climate Watches (section 3.1). For further details about the content and operation of Climate Watches, see WMO/TD-No.1269. Because of their focus on high-impact, extreme climate conditions, Climate Watches are likely to constitute an essential service for Has.

The WMO Commission for Climatology during its fifteenth session, CCl-XIV, Beijing, 3-10 November 2005 clarified the definition and aspects of Climate Watch (WMO No 996, final abridged report with resolution)

Climate Watch is a system (Figure xx), i.e. a set of functions and responsibilities, providing information on the status of climate, and foremost on its possible negative impacts; Climate Watch System does not imply or require creation of new entities to run climate watch activities; Climate watch advisories were to be issued by NMHSs to their users; Regional climate entities would assist NMHSs by providing regional climate products to NMHSs. Congress XV, Geneva, 7 - 25 May 2007 adopted Resolution 12 (Cg-XV) on future climate monitoring priorities including the enhancement of climate monitoring capabilities for the generation of higher quality and new types of products and services and the implementation of climate watches particularly in developing countries (WMO No. 1026). Executive Council LX, Geneva, 18 - 27 June 2008 noted the urgent need for NMHSs and regional climate institutions to make use of best practices in delivery, provision and evaluation of a Climate Watch System and in managing efficiently and seamlessly the interaction among the involved parties (WMO No. 1032).

It is important that Climate Watches are issued by recognized authoritative organizations. In most cases this organization is likely to be the NMHS, but in some countries there is no currently designated organization with such a mandate. Where the NMHS lacks capacity to issue Watches, regional and global organizations could play an important role. The WMO-coordinated Global Climate Hazards Monitoring and Climate Watch Systems, are some notable examples of operational monitoring activities that identify, document and provide an alerting service on current and incipient climate anomalies (early detection).

6.2.2. International climate products

The National Oceanic and Atmospheric Administration (NOAA) provides a comprehensive set of freely available global monthly and seasonal climate information. The Climate Monitoring Pages\(^{129}\) contain an extensive array of global and national products, including “Climate at a Glance” overviews, Monthly State of the Climate Reports, and extremes monitoring. Global products include teleconnection indices, ENSO, and more. National products include drought monitoring, snow and ice monitoring and impacts indices for crop moisture stress, residential energy demand temperature and air stagnation. Some of these impacts indices may be of direct interest to HAs. NOAA’s Earth System Research Laboratory (ESRL) Physical Science Division Maproom\(^{130}\) includes a wide range of detailed information about the global circulation, state of the ocean, and various indices monitoring phenomena such as ENSO and the MJO. Products are available at daily, weekly, monthly and seasonal scales.

Additional monitoring centres provide information on precipitation and temperature at global and regional scale. Some centres monitor a wider range of meteorological variables, including extremes and climate impacts, for example, flooding. Some examples are provided in Appendix K. Many of these products are fairly technical, and HAs may need assistance in interpreting them correctly. In addition, with a large array of variables available, it may be hard to identify which ones are relevant to humanitarian interests. Some attempts to provide climate monitoring information to specific target audiences have been undertaken by the International Research Institute for Climate and Society (IRI), including for infectious disease and desert locust control.\(^{131}\)

\(^{129}\)http://www.ncdc.noaa.gov/climate-monitoring/index.php

\(^{130}\)http://www.esrl.noaa.gov/psd/map/

\(^{131}\)http://iridl.ldeo.columbia.edu/maproom/index.html
Most climate monitoring sites include at least some information about the state of the El Niño–Southern Oscillation (ENSO) phenomenon. The more comprehensive sites provide monthly and seasonal monitoring and diagnostics in combination with outlooks for the upcoming season. These sites are described in Appendix K. Given the multitude of service providers issuing products and drafting statements about the ENSO, there is inevitably some cause for confusion amongst users who may not understand why there is not always full agreement. The WMO has taken a lead role in coordinating attempts to reach consensus amongst scientists on the state of the ENSO phenomenon, and on its expected evolution. The “El Niño/La Niña Update” is a collaborative effort between WMO and several major climate research and operational climate centres round the world. It is a statement issued approximately once every three to four months on current and expected evolution of the ENSO phenomenon. This product was initiated during the major El Niño event of 1997 in response to a demand for information on what was to become one of the most significant global climate events of the 20th century.

Another set of climate phenomena that are monitored closely because of their importance to large segments of the human population are the monsoon systems. Typically these are monitored daily during, and leading up to, the monsoon season, and then reviewed after the season is over. Thus monsoon monitoring is both a weather- and a climate-question. A monsoon email discussion forum exists to exchange information and ideas. Some monsoon monitoring products are described in Appendix K.

Although many of the climate monitoring products described above do contain specific information on extreme events that may be of interest to humanitarian agencies, their broader objective is to provide a comprehensive assessment of the state of the global and/or regional climate system, including the ENSO phenomenon. However, a number of more specialized climate monitoring products have been developed, perhaps most notably a set of Drought Watches, which are primarily available at national scale. Several of these providers also monitor soil moisture. Some of the main drought-monitoring products are described in Appendix K.

Global scale information about other hazards is available from NOAA NCDC’s monthly Global Hazards Reports. These reports cover drought, wildfire, extreme temperature, flooding and storms, although the information provided may not be comprehensive. The Hungarian National Association of Radio Distress-Signalling and Infocommunications (RSOE) hosts a map showing current weather and climate hazards. Although this information is presented rather misleadingly as climate change monitoring, the site provides detailed information on the impacts of each event. Information is also available on other ongoing geophysical hazards. Several International climate monitoring centres collaborate through the WMO climate data and monitoring projects and initiatives.

6.2.3. WMO annual climate statements

One of the functions of monitoring products that are issued at least every few months is to provide indications of extreme events that are in process or have recently occurred and whose impacts may still to be felt. Annual climate reports, on the other hand, are generally

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133 [http://cc.rsoe.hu/?pageid=alertmap_index](http://cc.rsoe.hu/?pageid=alertmap_index)
more retrospective, and may serve a function of monitoring for climate change. For example, the WMO’s Annual Statement on the Status of the Global Climate reports (http://www.wmo.int/pages/prog/wcp/wcdmp/CA_2.php) provide a global summary of a past year’s major climate events. The series aims to document the climate as it evolves and to explain the factors and processes involved in its evolution. The WMO Statements on the Status of the Global Climate and the more detailed NOAA-NCDC State of the Climate report, which is published as an article in the Bulletin of the American Meteorological Society¹³⁶, include information on the global climate, global oceans, tropics, arctic, Antarctic and regional climates, as well as seasonal global summaries. The preparation of the Annual WMO climate statements is coordinated by WMO Secretariat in collaboration with the Commission for Climatology, several leading climate centres and organizations at global and regional levels as well with the WMO Members which provide inputs directly. Before the final publication of the Statement, a preliminary press release is made each December based on data available for the year to date, and the final report is released each March of the following year. The annual summary is a valuable source of ongoing information about the evolving climate between the IPCC global assessments of climate change that are issued every 5 to 7 years. Although the Annual State of the Climate reports contain detailed technical information, they are also intended to meet the needs of user communities, and for this reason have been evolving to include analyses of new user-relevant indices that integrate climate, water, soil and socio-economic indicators to better characterize climate events and the extent of their impacts.

Several countries produce their own annual reports. In addition to their value as a reference for a wide range of in-country users, they provide a baseline for documenting ongoing climate variability and change for national reporting. Some examples of national annual climate reports are provided in Appendix K.

In response to some of the most significant climate events special reports may be generated so that they can be discussed in more detail than might be possible in an annual report, for example the assessment of observed extreme conditions during the 2009/2010 boreal winter was peer-reviewed and published by WMO WMO/TD-No1550.¹³⁷

Many of these reports appear in the scientific literature as research articles concerned with questions of attribution and/or diagnosis of relevant predictions. Examples include the 1997 El Niño, the 2010 Pakistan floods, and the 2011 Somali drought (other examples are provided in Appendix K). These debates are often picked up by the popular media, which can provide a valuable service in translating the results into language accessible beyond the scientific community. There is, of course, a danger of the popular media misrepresenting the science. The WMO may also play an important role in informing other UN agencies and the broader community about significant climat e events through press releases and the publication of brochures.

¹³⁶ http://www.ncdc.noaa.gov/bams-state-of-the-climate/

6.2.4. Air quality monitoring

Air quality monitoring is largely a meteorological question, and so is discussed more extensively in section 5 of this report. However, there is some climate interest in issues such as smoke haze because of its association with the ENSO phenomenon in some parts of the globe. For example, under the ASEAN Regional Haze Action Plan endorsed by the ASEAN Ministers of the Environment and implemented in 1997, the ASEAN Specialized Meteorological Centre (ASMC) was designated to monitor and assess land and forest fires and the occurrence of transboundary smoke haze affecting the ASEAN region. The countries monitored initially covered Brunei Darussalam, Indonesia, Malaysia and Singapore, and later extended in 2003 to cover the whole ASEAN region (Cambodia, Lao PDR, Myanmar, the Philippines, Thailand and Vietnam)\(^{138}\). Similarly, the development of climatologies of mineral dust in West Africa is of interest because of health-related issues. These climatologies are under development by the Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) of the Northern Africa-Middle East-Europe (NA-ME-E) Regional Centre\(^{139}\).

Depletions of stratospheric ozone have significant health implications. Daily updates are provided by the NASA Ozone Hole Watch\(^{140}\). Image and video files of the ozone layer are available daily from 1979 to the present. Tropospheric ozone concentrations also have health implications, and are monitored by EUMETSAT\(^{141}\), and data are distributed via EUMETCast and the WMO GTS. Local ozone concentrations are made at numerous sites,

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\(^{138}\) http://www.weather.gov.sg/wip/web/ASMC/Haze\textunderscore Information

\(^{139}\) http://sds-was.aemet.es/forecast-products/dust-observations

\(^{140}\) http://ozonewatch.gsfc.nasa.gov/

\(^{141}\) http://o3msaf.fmi.fi/products.html
the NOAA ERSL Global Monitoring Division (GMD)\(^{142}\) collates many of these measurements, as well as for other gases, including greenhouse gases. More generally, the GMD “conducts sustained observations and research related to source and sink strengths, trends and global distributions of atmospheric constituents that are capable of forcing change in the climate of Earth through modification of the atmospheric radiative environment, those that may cause depletion of the global ozone layer, and those that affect baseline air quality”.

As discussed above, annual climate reports generally make an important contribution to the monitoring of climate change, but the most comprehensive analyses are provided by the IPCC Assessment Reports\(^ {143}\). The Assessment Reports provide scientific, technical and socio-economic information relevant for the understanding of human induced climate change, potential impacts of climate change and options for mitigation and adaptation. They include reviews of analyses of available evidence for (or against) climate change. Additional special reports and supporting documents provide further information. The Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)\(^ {144}\) is likely to be of particular interest to humanitarian agencies. Amongst other matters, the report reviews evidence for changes in extremes, and considers the extent to which any changes may be attributable to global warming. The full version of this report is to be published in February 2012.

The United Nations Development Programme (UNDP) has published a set of Climate Change Country Profile\(^ {145}\) reports for each of the 52 developing countries profiled. The reports contain a set of maps and diagrams demonstrating the observed and projected climates of the respective country as country average time-series as well as maps depicting changes on a 2.5° grid. Summary tables of the data are provided. A narrative summarises the data in the figures, placing it in the context of the country's general climate. The report, and data (observed, and modelled) are available to download for each country.

6.3. Predictions, projections, and scenarios

6.3.1. One-month forecasts

In general, there is a significant gap between routinely available weather information that may extend to medium ranges (see Table 3.1) in many countries, and climate forecast information, which, in most cases, is available only for seasonal timescales. Thus, intra-seasonal information is generally not easily accessible. However, many of the GPCs do issue forecasts for the coming month (see Appendix L) – these have to be generated to produce the seasonal forecasts anyway. In most cases it is acknowledged that nearly all the skill of these one-month forecasts comes from the first two weeks of the forecast anyway. There are some experimental initiatives to provide forecasts of the MJO, but this remains largely an area of research. Improvements in some of the general circulation models used to make seasonal predictions have demonstrated notable improvements in their ability to reproduce MJO-like activity, and prospects for improved forecast products at this timescale look promising.

\(^{142}\) http://www.esrl.noaa.gov/gmd/ccgg/

\(^{143}\) http://www.ipcc.ch/publications_and_data/publications_and_data.shtml#1

\(^{144}\) http://www.ipcc-wg2.gov/SREX/

\(^{145}\) http://country-profiles.geog.ox.ac.uk/
6.3.2 Seasonal forecasts

Standard products

The following products are currently set down as the minimum requirement for any designated GPC issuing seasonal time-scale products:

- Predictions for averages, accumulations, or frequencies over 1-month periods or longer - typically, anomalies in 3-month-averaged quantities is the standard format for seasonal forecasts. Forecasts are usually expressed probabilistically;
- Lead time: between 0 and 4 months;
- Issue frequency: monthly or at least quarterly;
- Delivery: graphical images on GPC website and/or digital data for download;
- Variables: 2m temperature, precipitation, sea-surface temperature (SST), MSLP, 500 hPa height, 850 hPa temperature;
- Long-term forecast skill assessments, using measures defined by the WMO Standardized Verification System for Long-Range Forecasts (SVSLRF).

Additional data or products to the minimum list above may also be provided by GPCs on request by regional or national centres. These centres would be required to adhere to any conditions attached by the GPCs to these data and products. The current list of recommended products is being reviewed by WMO to extend the range of information available – for many of the RCOFs, for example, GPC products are currently unavailable because of limited lead-times.

At seasonal timescales forecasts are not produced by all countries, generally because of lack of predictability rather than lack of capacity (as mentioned above, seasonal forecasts are only possible for certain locations and at certain times of the year). Forecasts are usually for 3-month periods, but some RCOFs issue 4-month averages. Lead-times can vary from 0 up to 9 months (NCEP) (see section 3.4.1 for details on standard formats). There is no central repository of national forecasts, but the Lead-Centre for Multi-Model Ensembling combines all the predictions from the GPCs, while the IRI provides a multi-model product specifically for the HAs. Both sites provide verification information.

Forecasts from the Regional Climate Outlook Forums are not collected centrally, and archives are inconsistently available from the hosting regional climate centres. There is little if any verification information. See Appendix M for details.

WMO Cg-XVI has endorsed a CCI initiative to extend the El Niño/La Niña Update into a full Global Seasonal Climate Update (GSCU)\(^\text{146}\) to encompass information on other factors that drive climate variations and extremes, such as the North Atlantic Oscillation in Europe, and the Indian Ocean Dipole in East Africa, Asia and Australia. The GSCU is currently in its pilot phase. Only the executive summary is to be released to the general public, but a more detailed scientific statement is made available to NMHSs. The full product will be updated every three months, but an automated product will be developed by the LCMME for release each month.

Specialized and tailored products

\(^{146}\) http://www.wmo.int/pages/prog/wcp/wcaspl/GSCU.html
Tropical cyclone frequencies are one example of a specialized product available at the seasonal scale, for example the Australia Bureau of Meteorology (BoM) Tropical Cyclone Outlooks\textsuperscript{147}. In most cases, however, specialized and tailored products would have to be obtained by special request from the GPCs. Access to these products may require a fee to be paid.

\textit{Research-based products}

Since the first RCOF review meeting, which was held in Pretoria in May 1998, users have been requesting tailored presentation of forecast formats in place of the tercile probabilities and broad regional averages that were established as the standards at the first ever RCOF. Unfortunately, to date there has been little apparent response to this request in terms of changes to operational products generated at the RCOFs, but there has been considerable research activity to explore the predictability of more tailored information.

In many areas, rainfall frequencies, for example, are more predictable than rainfall totals, and can be seen as an important contribution to requests for information about the characteristics of rainfall during the season. The agricultural community has been active in making such requests. For humanitarian agencies, however, light rainfall events are generally of interest only in the context of causing problems in the immediate aftermath of a disaster; there is more concern about the risk of heavy rainfall events. Unfortunately, partly because of sample size problems, and partly because of the unpredictability of weather noise at seasonal timescales, it is unlikely to be viable to provide skillful forecasts of heavy rainfall totals at specific locations, but there may be some useful predictability of changes in heavy rainfall risks over large areas. These prospects need to be explored further.

Another high priority request for tailored information that has come from numerous user communities is for forecasts of onset and cessation dates. Onset date prediction of the Asian and West African monsoons has been an area of active research for decades. Recent success has been achieved in identifying predictability at least of the West Africa and South-east Asian monsoons. This research needs to be consolidated and introduced into operations.

6.3.3 \textit{Decadal projections}

Experimental monthly and decadal-scale products may become more widely available in time. It will be important, however, to develop and make accessible appropriate verification measures for all forecast time scales, noting that such measures have only been generated at this stage for climate forecasts at the seasonal scale. Products will typically be provided as maps and tables of expected anomalies, e.g. for temperature or precipitation, and most likely in probabilistic formats. Information related to the predictions will include consensus summary assessments of key features and, at national levels, may include advisories and warnings.

Formal WMO mechanisms for the provision of operational climate prediction services have been developed for seasonal timescales and similar mechanisms, including verification standards, need to be established for forecast activities on monthly as well as multi-annual to decadal timescales. Close links between the CSIS and R&MP components are needed to ensure that the capabilities and limitations of monthly and multi-annual to decadal predictions are clearly communicated to all users.

\textsuperscript{147} http://www.bom.gov.au/wa/cyclone/seasonal/
6.3.4. Climate change scenarios

The NMHS is the authoritative centre for issuing forecasts at national level. Most NMHSs now issue some type of seasonal forecast information, but far fewer have been involved in provision of climate change scenarios. Under the GFCS, countries will be encouraged to define the roles of different organizations in the provision of national climate services.

The Intergovernmental Panel on Climate Change (IPCC)\(^{148}\) is a scientific intergovernmental body that provides comprehensive assessments of current scientific, technical and socio-economic information worldwide about the risk of climate change caused by human activity, its potential environmental and socio-economic consequences, and possible options for adapting to these consequences or mitigating the effects. The IPCC does not carry out its own original research, nor does it do the work of monitoring climate or related phenomena itself. A main activity of the IPCC is publishing special reports on topics relevant to the implementation of the UN Framework Convention on Climate Change (UNFCCC). One of the main outputs of the IPCC is the series of Assessment Reports (ARs; published in 1990, 1995, 2001, 2007), which are intended to assess scientific, technical and socio-economic information concerning climate change, its potential effects, and options for adaptation and mitigation. The reports contain useful information on past and expected climate change. The Fifth Assessment Report (AR5) is due to be published in 2014.

The IPCC also publishes Special Reports, of which the Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)\(^{149}\) is likely to be of interest to HAs. The SREX report contains information on observed and expected changes in climate extremes, as well as discussions about early warning systems.

The Coupled Model Intercomparison Project (CMIP) (and PCMDI archive)\(^{150}\) provides the IPCC with model outputs used to draw up the Assessment Reports. The current intercomparison CMIP5 for IPCC 5AR experiment design has been finalized with the following suites of experiments:

CMIP5 will notably provide a multi-model context for:

a) assessing the mechanisms responsible for model differences in poorly understood feedbacks associated with the carbon cycle and with clouds;

b) examining climate “predictability” and exploring the ability of models to predict climate on decadal time scales, and, more generally;

c) determining why similarly forced models produce a range of responses.

d) CMIP5 promotes a standard set of model simulations in order to:

e) evaluate how realistic the models are in simulating the recent past,

f) provide projections of future climate change on two time scales, near term (out to about 2035) and long term (out to 2100 and beyond), and

g) understand some of the factors responsible for differences in model projections, including quantifying some key feedbacks such as those involving clouds and the carbon cycle.


The PCMDI Software Portal\textsuperscript{151} provides access to the IPCC AR4 Model Data as well as several software packages specifically tailored to the climate community - the Climate Data Analysis Tools (CDAT) and the Climate Model Output Rewriter (CMOR). CMIP AR5 data are available here upon registration with Earth System Grid Federation (ESGF)\textsuperscript{152}.

World Data Centre for Climate (WDCC; Hamburg, Germany\textsuperscript{153}) provides access to a wide range of model outputs including those used in the IPCC Assessment Reports, the Coupled Model Intercomparison Projects, outputs from the ENSEMBLES project, etc.

The Coordinated Regional climate Downscaling Experiment (CORDEX)\textsuperscript{154} of the World Climate Research Program (WCRP) involves dynamical and statistical regional climate downscaling of the recent past and future climate projections. This project emphasizes increased interaction between modelling and user communities to enable improved understanding of potentials, limitations and uncertainty of the data for impact and adaptation studies. Project goals include provision of a quality-controlled data set of information for the recent historical past and 21st century projections, covering the majority of populated land regions on the globe. The information will sample uncertainties in Regional Climate Change associated with (i) varying Global Climate Model (GCM) simulations; (ii) varying greenhouse gas (GHG) concentration scenarios; (iii) natural climate variability; and (iv) different downscaling methods. The CORDEX downscaling activities will be based on the latest set of GCM climate scenarios and predictions produced within CMIP5.

A first data portal has been set up at http://cordex.dmi.dk/.

6.3.5. Verification information

RCOF verification

Although it is standard practice in most of the RCOFs to verify the forecast product(s) from the previous forum, there is little to any systematic tracking of these verification results, and none of the results seem to be available online. In addition, the forecasts are verified as if they were deterministic: some form of “percentage correct” is calculated taking the category with the highest forecast probability as the category predicted (and making adjustments for tied highest probabilities). While such a score is informative, the actual probabilities are ignored in this procedure.

Detailed diagnostics (which consider the reliability of the probabilities) of the performance of the RCOF forecasts over time is only possible once a reasonable number of forecasts have been produced. Only some preliminary results are currently available, but all indicate that the RCOFs forecasts have had some skill, but in general the reliability of the forecasts has been poor (the probabilities do not give an accurate indication of the uncertainty in the forecasts). Unfortunately, the poor reliability means that it is difficult for the users of the RCOF forecasts to realize benefit from the information provided.

Decadal forecasts and climate change scenarios

For forecasts at decadal and longer timescales there are at best too few realizations to verify forecasts. For similar reasons, it is not possible to correct the models sufficiently for their

\begin{itemize}
\item[151] http://www2-pcmdi.llnl.gov/
\item[153] http://www.mad.zmaw.de/wdc-for-climate/index.html
\item[154] http://wcrp.ipsl.jussieu.fr/SF_RCD_CORDEX.html
\end{itemize}
systematic errors, and so the uncertainties in the projections are likely to be underestimated. This problem requires careful attention by the research and climate services communities.

6.4. Conclusions

While historical climate data are essential for a wide range of HAs needs, by far the majority of these datasets are for monthly records, which provide only an indirect indication of hazards. Another problem is that most meteorological hazards are complex phenomena, involving combinations of high temperature and humidity as can be in the case of heat waves, for example, or strong winds and heavy rain in the case in severe storms, but most climate datasets are about individual meteorological parameters measured at discrete times. However, with expert tailoring through partnerships between the humanitarian and climate community climate data can assist HAs in hazard mapping, identification of trends, and can be used as a basis for designing risk transfer policies. Historical data are also important for making sense of current conditions, and thus for the monitoring of emerging slow-onset hazards, or for interpreting the severity of imminent hazards, for example.

Monitoring and/or State of the Climate reviews should play a more prominent role in RCOFs. The climate conditions (present, and over the recent past) should be reviewed in ways that are understandable to HAs, and should include discussions about the occurrences of extremes. Climatological periods that are meaningful to HAs should be identified, and used for monitoring and forecast products, which may require using short and frequently updated periods. Anomalies should be expressed understandably – in a way that does not required knowledge of climatology. Preferred formats should be identified in discussion with HAs.

Forecasts beyond anything more than a few days are considerably less skilful than weather forecasts are, and so, climate forecasts cannot be used to predict the occurrence of any specific rapid-onset events. However, especially at the seasonal scale, forecasts can be useful for disaster preparedness and planning. In most cases climate forecasts are not directly about hazardous events, and so some expertise may be required to interpret these for the HAs, and tailoring of products for their use would be desirable. It needs to be emphasized that seasonal forecasts are only possible for some locations and for limited seasons, and may not be possible every year. It is also important to identify appropriate preparedness actions that account for the large uncertainties in seasonal forecasts even where and when they are possible. It is therefore important to have information about how well the forecasts verify.

The importance of verification needs to be taken more seriously by the RCOFs, and by seasonal forecasting centres more generally, especially given the poor reliability of some of these forecasts to date. Rigorous verification should be implemented not only so that systematic errors in the forecast production can be corrected, but also to help build confidence amongst forecast users, and provide clearer indications of how the information can be best used. The HAs need to be engaged to discuss how best to present verification information for their purposes.

For multi-annual forecasting, despite strong demand for information at this timescale, usable skill has yet to be demonstrated convincingly, and it would be premature at this time to move any such experimental forecasts into the mainstream for routine uptake or application. That does not preclude their application, however, within a controlled, research-driven context; nor does it preclude the possibility that improvements in skill in the future might be realized.
**Suggested approach for HAs for climate forecasts**

For most long-term planning purposes, historical climate data are likely to be more useful than forecasts, but use of past climate information could be dangerous in places where rapid changes have been observed (the past is no longer always an accurate basis for estimating the future). However, for disaster preparedness, the HAs could make use of Climate Watch Bulletins issued by the NMHSs. As with Weather Watches, Climate Watches are by nature episodic, being issued only in response to emerging/imminent hazards, and the HA should not expect these to be released on a regular schedule. At the national level the NMHS could be contacted directly, but broader access could be enabled through a site that could be established under the GFCS, or displayed by a HAs site through a data push. The HAs could then access a NMHS’s web site directly for additional information or contact the DRMCPAs or NHMSs directly through contact info. Should a NMHS not produce watches, the HAs could use the RCC extreme climate guidance.

The HAs could access the extreme climate guidance as produced by the RCC or specialized products as produced by the RCCs for the use of HAs. The data could be pushed to a hosting site. Again the RCC guidance does not obviate the NMHS role – a crucial one because of its relation to the DRMCPAs. The HAs could access the suggested forecast data directly through a RCC web site or have the data pushed to a hosting agency e.g. IRI.

The HAs could access seasonal forecasts generated by GPCs or the Lead Centre for Multi-Model Ensembles. However, given that most seasonal and longer-term forecasts are not directly about hazards, specialized products for the use of HAs may be preferable. The products could be hosted by a site for the HAs – eg. IRI.
7. Conclusions

Weather and climate information and services of potential (direct or indirect) interest to HAs may take a variety of forms. Information products range from historical and current or recent observations, to predictions about the future, to diagnostic analyses providing a detailed description and / or explanation of events of interest. However, simply providing any available information is insufficient: weather and climate services are also required. Services can include the customizing of information products (including possibly their design, information content, and modes and timing of dissemination) based on understanding of HAs’ needs and requirements such that they can be easily accessed and interpreted by these agencies. Services can also include the provision of support systems for the information products, which may take the form of explanatory online, printed or recorded materials, training opportunities, and help desks.

Since there are many sources of weather and climate data, in a time of crisis it is crucial that the HAs get the best, most complete and authoritative view(s) of the weather and climate. For operations within countries the HAs should work with the NMHSs and DRMCPAs. The HAs should use the forecasts (though the WWIC) and warnings from the NMHS’s as much as possible. For the warnings, the HAs could drill down to the NHMS’s site. The alerting authority for the country could be contacted. If the warnings were standardized and available on the GTS they could be displayed on a site such as the SWIC which could be used for these products. Alternatively the NMHS data could be displayed on a HA’s portal or server. The severe weather can be monitored through the SWIC site for heavy precipitation, snow and winds.

The NMHSs may offer consultation to the HAs during all phases of the humanitarian operations. These linkages must be strengthened as was pointed out in the Report of the Humanitarian TT, in the DRR strategic goals (see Annex A) and the WMO strategic goals.

These forecasts should be supplemented by the forecasts from RSMC’s – SWFDP, geographic, Tropical Cyclones Centres. The HAs should also be aware of airborne phenomena (radiation, ash, smoke etc.) through the ERA RSMC’s and the VAAC’s and through the IEAE, WHO.

Ensemble forecasts from the best global centres such as ECMWF, UKMO, JMA and NCEP should be used to ascertain severe phenomena beyond the range found in 5.1 and 5.2 above and to complement the products from the NMHSs and RSMC. These forecasts should be made available under the auspices of WMO Res 40 on a WMO site. Alternatively it could be on a site for HAs purposes to house tailor-made products required by the HAs.

These products should be interpreted by a HAs operations centre with qualified (meteorological) personnel to assemble and interpret the varied and disparate products. In order to help with the assessment of the products, the HAs should encourage verification activities of all of the products and access to existing NWP verification.
8. Next Steps

The precise audience for this report needs to be identified. In a few cases the technical staff of the HAs may be interested to use this report as a resource for identifying sources of information. In most cases, however, it is likely that even the technical staff will find the report does not address their concerns. In many cases the technical experts of the HAs want the relevant weather and climate information identified, formatted and provided to them without them so that they do not have to address the questions that this report attempts to answer. The first important question, then, is not to get feedback from all the HAs, but to identify the process and actors for the provision of services, and to get feedback from those actors.

Important questions that the service providers can help to answer through consultation with the HAs include: Should data be pushed to the HAs through the WIS or should the HAs pull data? Do the HAs use existing Web sites? Do these sites meet their needs? Are all of the data available? Are the data available in a form suitable for the HAs? Should a site specific to HAs needs be developed? This will lead to more specific needs and the development of a plan whose feasibility could be demonstrated in a regional project.

Meanwhile, given some of the shortcomings of weather and climate information for HAs needs that have been discussed in this report, the WMO should:

- Coordinate the provision of verification information for all forecast timescales. The HAs should be consulted to determine verification procedures that would be informative to them.
- Enable NMHSs to present historical, current, and forecast information in formats that are more understandable to HAs (and to other users), and to develop the capacity of the NMHSs to build partnerships with user communities, for example through encouraging the participation of user groups in regional and national Climate Outlook Forums.
- Assist in the coordination of weather and climate information for regional and global scale planning and operations.
9. References

Global Framework for Climate Services (2012), Implementation Plan, Annex for the Climate Services Information System (CSIS) and Disasters Exemplar.


Appendix A: WMO DRR Work plan:

Disaster Risk Reduction (DRR) is a priority for the World Meteorological Organization (WMO) because the protection of lives, property and livelihoods are at the core of the priorities of the WMO Members and the National Meteorological and Hydrological Services (NMHS). Furthermore, the implementation of the Hyogo Framework for Action (HFA) by national governments is leading to changes in national DRR policies, legal and institutional frameworks, with implications on the role, responsibilities and new working arrangements for the NMHS. These changes provide opportunities such as increased recognition of the NMHS by their governments and stakeholders, which could result in strengthened partnerships and increased resources. However, NMHS face new challenges and liabilities related to the provision of products and services to a larger and more diverse group of DRR stakeholders (e.g. government authorities, public and private sectors, Non-Governmental Organizations (NGOs), general public and media, etc) who have direct responsibilities for DRR decision-making. To meet these new challenges, as illustrated in Figure 1, the crosscutting DRR Programme two-tier Work Plan (hereafter referred to as the DRR Work Plan) aims to facilitate better alignment of the activities of WMO constituent bodies and global operational network as well as strategic partners to assist the NMHS to:

- Engage as relevant in the National DRR and Adaptation governance and institutional frameworks;
- Identify, prioritize, establish partnerships and service delivery agreements with national DRR user community (users);
- Establish partnership agreements with other national technical agencies (e.g. hydrological services, ocean services, etc) as well as global and regional specialized centers (e.g. Global Producing Centers (GPC), Regional Specialized Meteorological Centers (RSMCs), Regional Climate Centers (RCC), Tsunami Watch Centers, etc);
- Develop and deliver core and specialized products and services for DRR decision support (e.g. hazard/risk analysis, Multi-Hazard Early Warning Systems (MHEWS), sectoral risk management and disaster risk financing and risk transfer) in a cost-effective, systematic and sustainable manner;
- Ensure that core operational capacities (e.g. observing network, operational forecasting systems, telecommunication systems, data management systems, human resources, etc) are built upon the principles of Quality Management Systems (QMS) to support product and service development and delivery; and
- Engage in regional and global efforts for development of risk information for large scale and trans-boundary hazards, through strengthened regional and global cooperation

The DRR Work Plan (Figure 2) includes, (i) development of guidelines, standards and training modules for DRR thematic topics based on documentation and synthesis of good practices; and (ii) coordinated DRR and climate adaptation national/regional capacity development projects to support capacity development of NMHS as per paragraph 1 (a—f). A critical aspect of the coordinated DRR national/regional projects is strengthening of
cooperation of NMHS, RSMCs, RCCs and DRR users for development of products and services based on user needs and requirements.

Figure 1: Schematic representation of linkages between meteorological services and DRR stakeholders

Figure 2: Two-Tier Schematic of the Implementation Approach of the DRR Programme

DRR thematic guidelines, standards and related training modules:
WMO thematic priorities are underpinned by the Hyogo Framework for Action 2005-2015 (HFA), and include: Risk Identification, Risk Reduction and Risk Transfer. The thematic areas of the Disaster Risk Reduction (DRR) Programme include provision of meteorological,
hydrological and climate services to support: (1) Hazard/Risk Analysis; (2) Governance and institutional frameworks at the national to local levels; (3) Multi-Hazard Early Warning Systems (MHEWS); (4) Sectoral risk management through improved planning in land zoning, infrastructure and urban planning, agriculture, health, transport, water resource management, and (5) disaster risk financing and weather indexed financial risk transfer mechanisms, (6) Information and knowledge sharing, education and training (Figure 3).

![Figure 3](image)

**Figure 3: Building capacities of NMHS to serve different components of DRR in their national DRR decision making context.**

**Thematic DRR User-Interface Expert Advisory Groups**

Four thematic DRR user-interface expert advisory groups have been established to guide and support implementation of the DRR Work Plan and related deliverables. These user-interface expert advisory groups involve leading experts from the diverse DRR user community (public and private sectors), United Nations and international partner agencies, academia as well as NMHS. These advisory groups are established to: (i) guide documentation of good practices and development of user needs and requirements for products and services to support thematic topics; (ii) support development of and provide feedback on the WMO DRR knowledge products (guidelines, standards, training modules, etc.); and (iii) support the implementation of the national/regional DRR projects. The four DRR user-interface expert advisory groups established, include:

a) Expert Advisory Group on Hazard/Risk Analysis (EAG-HRA) (First meeting in September 2012) with focus on issues related to standards and guidelines for hazard definition, standardization of hazard databases, metadata and statistical analysis and forecasting techniques of hazard characteristics to support risk modelling.

b) Expert Advisory on MHEWS: Building on the work carried out during the previous inter-sessional period on the documentation of good practices on MHEWS WMO Guidelines on DRR and Institutional Partnerships in MHEWS are under preparation. Furthermore, WMO Guidelines on the operational aspects of MHEWS building on the principles of QMS, are to be implemented during the 2012-2015 inter-sessional period.
c) Expert Advisory Group on Climate Services for Disaster Risk Financing (EAG-CSDRF): was established to provide requirements for climate services for disaster risk financing in order to develop WMO guidelines for NMHS based on documentation of good practices in this area. A concrete work plan has been developed to identify, document and synthesize good practices in this area and develop relevant requirements and guidelines for climate services to support different sectors in this area (see the final report of the first meeting and list of deliverables associated with the EAG can be downloaded at: http://www.wmo.int/pages/prog/drr/events/EAG-FRT/FRT1/Documents/EAG-FRT-Finalreport.pdf.

d) Inter-commission ad hoc “Task Team on Meteorological, Hydrological and Climate Services for Improved Humanitarian Planning and Response”, including the WMO Technical CoMmissions, (i) Commission for Basic Systems (CBS), (ii) Commission for Climatology (CCl), and the (iii) Commission for Hydrology (Chy), and in cooperation with eight United Nations and international humanitarian agencies.

Coordinated DRR and Adaptation national/regional capacity development projects

The WMO Congress XVI endorsed the (i) DRR and Adaptation DRR national/regional capacity development projects in South East Europe, the Caribbean, and Southeast Asia, and (ii) the national Costa Rica Early Warning System Project funded by the World Bank. These projects are designed to demonstrate the benefits of leveraging WMO’s programmes, constituent bodies, global operational network and partners to address capacity development needs of NMHS. To date, efforts have been undertaken to strengthen coordination and cooperation among TCs and Programmes, RAs, and strategic partners at regional and international levels to support these projects (Figure 3 and Table 2). Specifically, the developments of these projects are based on the following considerations:

a) Government interest, engagement and commitment to DRR and climate adaptation

b) Multi-stakeholder and multi-sectoral engagement and development of strategic alliances (national, regional, global)

c) Engagement of WMO Members, RAs and WMO Operational Network

d) Partners and donors engagement from early stage

e) Leverage existing projects and their outcomes

f) User-driven assessment of gaps, needs, prioritization and requirements

g) National/regional development component

  • National: DRR policies, institutional roles, partnerships, capacity development
  • Regional: Strengthening of RSMCs and RCCs and cooperation with NMHS

h) Integrated Service Delivery for development of meteorological, hydrological and climate services

  • National: Strengthening of NMHS, technical cooperation and development of products and services as per requirements of target users
  • Regional: Engagement and strengthening of RSMCs and RCCs and their cooperation with NMHS

i) Sustainability
Appendix B: Presentation of meteorological data

Current and recent weather and climate conditions can be presented in a multitude of formats, some of which are likely to be more informative to HA than are others. For example, if the last few months have been apparently dry, reporting the total rainfall over that period would indicate precisely how dry it has been, but would only be understandable by somebody who has a good knowledge of the climatology of the area in question. Comparing the recent rainfall with historical data can indicate how unusual the dryness has been. Again there are numerous options for communicating how anomalous the current conditions are: the most common methods of displaying the anomalies are: as differences from average; as percentages of average; as percentiles (for example, “this season was in the driest 10% of all years”); as exceedance probabilities (“nine out of every ten years receives more rainfall than this year”); or as a return period. Alternatively, the climate conditions in question could be expressed in comparison with earlier events (for example, “this was the warmest year for 60 years”; “last month had 20% more rain than during the floods of 2000”). Some of these formats still require some knowledge of the climatology: for example, anomalies that are presented in mm/day can be difficult to interpret if one does not know what the mean and variance are. A good example of the presentation of climate anomalies in different formats is provided by the Australian Bureau of Meteorology155 (BoM; Figure B.1).

The “average”, or “climatological normal” is an important reference against which conditions for a specific location and period can be compared, and are generally widely available in the form of “atlases”. The “average” is typically defined using a recent 30-year period, and is updated once every ten years. In defining the climatology, 30 years was selected as an appropriate period for providing a reasonably stable estimate of the conditions that might be experienced in a given location; in most cases it should not be overly sensitive to short-term variability, or insensitive to climate change.

Because of persistent and widespread increases in temperature over the last few decades, the use of a 30-year climatology that is updated only once every ten years has led to reconsiderations of the appropriateness of current practices for defining temperature normals. For example, until early in 2011, the standard climatological normal period was 1971 – 2000. Operational seasonal temperature forecasts over the last decade have almost always indicated high probabilities of “above-normal” conditions. These high probabilities indicate an expectation that the strong warming observed in much of the globe during the 1980s and 1990s is not expected to reverse suddenly, but provides less clear information about whether the coming season is likely to be warmer or colder than in more recent years. For many users, a forecast which compares the coming season with more recent years, compared to whatever is the current 30-year standard, is likely to be most useful. As a result, the WMO Commission for Climatology (CCI) has proposed a number of new guidelines for how often climatological normals should be re-calculated and how they should be used. These proposals have not yet been adopted, but are under consideration. In some cases, even the standard recommendation to update the 30-year period once every ten years has not been heeded. For example, the African Regional Climate Outlook Forums continue to use a 1961 – 1990 climatological period. For precipitation it may be argued that there is less need to update the climatology because trends are supposedly not as marked as for

temperature. However, that argument may be disputable in some cases: the recent "greening" of the Sahel, and the drying trend in East Africa are cases in point. Retaining the old precipitation climatologies in theory should help to reinforce the message of the greening in the Sahel or drying in East Africa when seasonal forecasts are presented; in practice, however, as discussed below, the forecasts have not been very successful in predicting these trends anyway.

Figure B.1: Example climate monitoring product from the Australian Bureau of Meteorology indicating how recent climate conditions can be expressed as anomalies in numerous ways. Although these options provide the user with the ability to view the information in the format that is most suitable for their purposes, some users may need assistance in identifying which format is preferable.

Another argument for retaining the old climatologies is that it does simplify operational procedures and verification analyses. A sudden change in a monitoring product that is a result of the adoption of a new climatology, for example, could cause undue confusion. However, rather than making arguments for or against an updated climatology from climatological perspectives, it is worth considering what the humanitarian agencies would prefer once they have been presented with and considered the pros and cons. There are strong reasons why humanitarian agencies may prefer a short, recent and frequently updated climatological period to align closely with their respective institutional memories. Some of the arguments for using a long and infrequently updated climatological period that form the basis for the standard WMO definitions, may not be relevant criteria for humanitarian agencies. However, their needs do have to be determined, and it is possible, and even likely, that their preferences will differ from representatives from other sectors, and even from one humanitarian agency to the next.
Appendix C: Predictability of weather and climate

Most weather forecast errors that become typical after a few days are primarily a result of inaccuracies in the timing or intensity of specific weather systems. For example, a rain storm may arrive a few hours earlier, and may be a little heavier, than initially anticipated. With careful planning and reliable indications of the uncertainty in the forecasts, these types of errors should not prohibit effective planning by the HA. However, beyond about a week or two weather forecasts become so inaccurate that they are essentially useless for most practical purposes (see Table C.1). A possible exception is some large-scale weather patterns that occur near the equator, whose approximate locations the best models can now predict about two or three weeks into the future. This new capability does not yet enable scientists to make accurate predictions for any specific day, but it may provide some indication of whether there may be a dry or wet spell on the way, for example. These forecasts, which extend out to about one month, are still largely in research mode, but experimental forecasts are becoming increasingly available. Some centres are already producing operational forecasts one month into the future.

Table C.1: Sources of predictability at different timescales

<table>
<thead>
<tr>
<th>Timescale and phenomena</th>
<th>Source of predictability</th>
<th>Scale of predictability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe local convection (up to 1 day)</td>
<td>Current weather</td>
<td>Very localized: 10’s of KM eg. tornadoes; downbursts; microbursts and flash flooding</td>
</tr>
<tr>
<td>Tropical cyclones (up to 07 days)</td>
<td>Current /very recent weather</td>
<td>Larger areas (100’s KM’s); coastal flooding; storm surge effects; inland flooding</td>
</tr>
<tr>
<td>Weather systems (0-14 days)</td>
<td>Current / very recent weather</td>
<td>Specific locations (100-1000KM), and specific timing; some patterns more predictable than others; flooding over widespread areas;</td>
</tr>
<tr>
<td>Monthly (2 – 4 weeks)</td>
<td>Large scale weather patterns</td>
<td>TBD; likely to be predominantly tropical areas only, and weekly summaries</td>
</tr>
<tr>
<td>Seasonal (1-6 months)</td>
<td>Sea-surface temperatures (and other surface features such as snow cover, and soil moisture)</td>
<td>Some parts of the tropics, and a few areas beyond, for a few months of the year only; three-month summaries</td>
</tr>
<tr>
<td>Multi-annual to decadal (6 months – 10? years)</td>
<td>Sub-surface oceanic conditions</td>
<td>TBD; likely to be sub-continental scale, multi-year summaries</td>
</tr>
<tr>
<td>Century (&gt;100 years)</td>
<td>Atmospheric composition</td>
<td>Sub-continental scale, multi-decadal summaries</td>
</tr>
<tr>
<td>Millennial (1000s years)</td>
<td>Orbital parameters</td>
<td>Sub-continental scale, millennial summary</td>
</tr>
</tbody>
</table>
To forecast beyond a few weeks it is no longer possible to predict specific weather systems, and instead forecasts are based on whether certain weather patterns are likely to be unusually frequent, or persistent, or intense – no pretence is made to predict the timing of any such events. This ability is based on how the atmosphere is affected by the sea – primarily its temperature. The best known examples of the atmosphere being affected by sea temperatures are the effects of El Niño and La Niña. The influence of sea temperatures on the atmosphere is rather tenuous, and so even a strong El Niño or La Niña does not guarantee an unusually wet or dry season. However, the influence is generally much stronger in the tropics than in the mid-latitudes. As a result, whereas weather forecasts are more accurate in the mid-latitudes than in the tropics (in part, because it is easier to predict frontal systems than convective systems), the opposite is true of seasonal forecasts (because the sea temperatures have a stronger effect in areas where the sea is relatively hot).

Typically, unusually hot or cold areas at the sea surface will not last more than a few months, and so longer range predictions are dependent upon successful forecasts of changing sea-surface temperatures. These predictions require an understanding of how the oceans are currently circulating and what conditions are like beneath the surface of the ocean. With the El Niño phenomenon, the ocean circulation and how it affects, and is affected by, the atmosphere is reasonably well understood, but only allows for accuracy in predictions for about a year in advance at the most. In other areas, scientists’ understanding of the oceanic circulation is limited, largely because of a lack of data. However, recent deployment of thousands of small buoys is providing data that may enable improvements in the prediction of the global oceans, and thus in sea-surface temperatures, a year or more into the future. As with the forecasts for the coming month, this is an active area of research, and is likely to result in increasing availability of experimental forecasts in the next few years.

Even a detailed understanding of the current state of the oceans would not enable accurate climate predictions beyond the next few years. To predict what may happen over the coming century scientists consider instead what the effects of possible changes in the chemistry of the atmosphere might be. Unfortunately, these changes cannot be predicted since they depend upon the extent to which humans decide to cut back on emitting greenhouse gases and other pollutants into the atmosphere. All that scientists can do is to make projections under different assumptions about the rate of this on-going pollution, and then model the effects of the changed atmospheric composition on the climate. The different assumptions are called scenarios, and projections based on these scenarios are coordinated by the Intergovernmental Panel for Climate Change (IPCC).

Projections even further into the future are possible, and are based on changes in the Earth’s orbit around the sun. Millennial-scale model runs are important for testing the ability to simulate past climates, but are not used much for predicting the future because of the minimal interest in planning questions at such long timescales.
Appendix D: Ensemble mean vs. the deterministic model

The Ensemble mean is superior (see Figure D.1) to the deterministic model at day 4 – the deterministic model deteriorates more rapidly than the Ensemble mean thereafter.

Figure D.1: Anomaly correlations of the deterministic model versus the ensemble mean. Anomaly correlation correlates the forecast anomalies with analyzed ones. The higher the correlation the better is the forecast. These are 2007 results from the ECMWF. The bright red curve is the high resolution operational deterministic model. The blue curve is the Ensemble mean. (Source ECMWF)
Appendix E: ECMWF products:

Suggested products from the ECMWF are EPSgram. EPSgrams provide a lot of information about the deterministic and ensemble forecasts at a location. They should be used in conjunction with other products showing the extreme conditions (eg. EFI, heavy rainfall exceedance etc.) . Figure E.1 describes the major components of the EPSgram.

Figure E.1: EPSgram structure. The blue box indicate the values of the 10, 25,50(median) 75, and 90% percentile values. The whiskers indicate the max and min. An elongated box indicates a wide spread in the ensembles. Also plotted are the EPS control in red and the high resolution deterministic model in blue. There can be wide differences between the median value and the high resolution deterministic model. Typically forecast total cloud cover, 6 hour precipitation, 10 m wind speed and 2m temperature are plotted. (source ECMWF).
Sample EPSgram

**EPS Meteogram**
Apia 13.91°S 171.84°W (EPS land point) 1 m
Deterministic Forecast and EPS Distribution Friday 11 November 2011 00 UTC

- **Total Cloud Cover (okta)**
- **Total Precipitation (mm/h)**
- **10m Wind Speed (m/s)**
- **2m Temperature (°C) reduced to the station height from 201 m (T1279) and 91 m (T539)**

*Figure E.2: EPSgram structure*
Sample ECMWF charts:

Probability of Precipitation exceedance greater than 50MM/24
Appendix F: Tropical Cyclone strike products based on EPS

Forecasts of the track of a tropical cyclone: The black curve is the operational model track, the green the control, and the blue individual EPS members.
Appendix G: UKMO products:
Many of the EPS models of the world provide EPSgrams. The following is a EPSgram from the UKMO MOGREPS model. As in the ECMWF EPSgram it allows the user to view details of the forecast at a location.

MOGREPS (THORPEX) EPS Meteogram
HONIARA (91517) 9.4° S 160.0° E
RAW - EPS Forecasts : 11 November 2011 00 UTC

Total Precipitation (mm/12hr)

10m Wind Speed (Knots)

2m Temperature (deg C)

FRI SAT SUN MON TUE WED THU FRI SAT
11 12 13 14 15 16 17 18 19
NOVEMBER 2011

Note: All times in UTC. Met Office, Crown Copyright
Sample 10m wind exceedance chart from the UKMO. MOGREPS

(c) British Crown copyright. Material supplied by the Met Office.
Appendix H: Guidance from SWFDP RSMC

The following are Severe guidance charts from SWFDP RSMC. The samples are intended to demonstrate the forecast domains and the hazards being forecast. The guidance charts should be used in conjunction with the forecasts the NMHS’s and from the global centres.

South Pacific Guidance from Wellington RSMC:

Issued at: 12:46 11 Nov 2011 UTC
Valid at: 12:00 14 Nov 2011 UTC

An active trough is expected to extend from the Solomon Islands through Fiji to Tonga. A low may lie northwest of Fiji.
Day 1 Southern Africa Guidance from RSMC Pretoria:

Day 1 Severe weather guidance chart from RSMC Nairobi
Appendix I: Tropical Cyclone Center (TCC) outlook

The TCC outlooks are available on the GTS or from the individual centres. The graphical outlook below is from NHC Miami.

**Graphical Tropical Weather Outlook**

National Hurricane Center  Miami, Florida

ZCZC MIATWOAT ALL
TTAA00 KNHC DDHHMM

TROPICAL WEATHER OUTLOOK
NWS NATIONAL HURRICANE CENTER MIAMI FL
700 PM EST WED NOV 30 2011

FOR THE NORTH ATLANTIC...CARIBBEAN SEA AND THE GULF OF MEXICO...

1. A LOW PRESSURE SYSTEM LOCATED ABOUT 500 MILES SOUTH-SOUTHEAST OF BERMUDA IS PRODUCING AN AREA OF GALE-FORCE WINDS NORTH AND EAST OF THE CENTER. WHILE THE ASSOCIATED SHOWER ACTIVITY HAS BECOME A LITTLE MORE CONCENTRATED DURING THE PAST FEW HOURS...UPPER-LEVEL WINDS ARE NOT FAVORABLE FOR SIGNIFICANT DEVELOPMENT... AND THE LOW IS EXPECTED TO MERGE WITH A COLD FRONT DURING THE NEXT DAY OR TWO. THIS SYSTEM HAS A LOW CHANCE...20 PERCENT...OF BECOMING A SUBTROPICAL CYCLONE DURING THE NEXT 48 HOURS AS IT MOVES NORTHWARD AT 15-20 MPH. ADDITIONAL INFORMATION ON THIS SYSTEM CAN BE FOUND IN HIGH SEAS FORECASTS ISSUED BY THE NATIONAL WEATHER SERVICE...
UNDER AWIPS HEADER NFDHSFAT1 AND WMO HEADER F2NT01 KWBC.

ELSEWHERE... TROPICAL CYCLONE FORMATION IS NOT EXPECTED DURING THE NEXT 48 HOURS.

THIS IS THE LAST TROPICAL WEATHER OUTLOOK OF THE 2011 ATLANTIC HURRICANE SEASON. THE NEXT REGULAR TROPICAL WEATHER OUTLOOK WILL BE ISSUED ON JUNE 1 2012. SPECIAL TROPICAL WEATHER OUTLOOKS WILL BE ISSUED AS NEEDED IF A SIGNIFICANT WEATHER SYSTEM FORMS DURING THE OFF-SEASON.

$$
FORECASTER BEVEN

TC Outlook for the S pacific from RSMC Nadi:

FKPS20 NFFN 092100
TROPICAL CYCLONE 3-DAY OUTLOOK FOR AREA : EQUATOR TO 25S BETWEEN 160E AND 120W ISSUED BY RSMC NADI AT 2100UTC TUESDAY 9TH MARCH 2010.
EXISTING TROPICAL CYCLONE: NIL.
POTENTIAL FOR TROPICAL CYCLONE FORMATION TO 1200 UTC SATURDAY 13TH MARCH 2010:
TROPICAL DISTURBANCE 13F NEAR 12S 167E AT 092100UTC, POSITION POOR, IS SLOW MOVING. THE GLOBAL MODELS EXPECT 13F TO REMAIN SLOW MOVING OVER THE NEXT FEW DAYS, WITH SOME INTENSIFICATION ON SATURDAY.
POTENTIAL FOR 13F TO DEVELOP INTO A TROPICAL CYCLONE:
THURSDAY 11/03 - LOW
FRIDAY 12/03 - LOW
SATURDAY 13/03 - MODERATE
TROPICAL DISTURBANCE 14F NEAR 13.5S 171W AT 092100UTC, POSITION POOR, IS SLOW MOVING. THE GLOBAL MODELS EXPECT 14F TO MOVE SOUTHWEST OVER THE NEXT FEW DAYS AND INTENSIFY THE SYSTEM.
POTENTIAL FOR 14F TO DEVELOP INTO A TROPICAL CYCLONE:
THURSDAY 11/03 - LOW
FRIDAY 12/03 - MODERATE
SATURDAY 13/03 - HIGH
NO OTHER SIGNIFICANT TROPICAL DISTURBANCE ANALYSED OR FORECAST IN THE AREA.
THE NEXT BULLETIN WILL BE ISSUED BY 0400 UTC THURSDAY 11TH MARCH 2010.
© Fiji Meteorological Services | 2010
## Appendix J: Historical climate data sources

### Table J.1: List of important historical climate datasets

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Source</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Core Research for Evolutional Science and Technology of Japan Science and Technology Agency (JST-CREST), Global Satellite Mapping of Precipitation (GSMaP)</td>
<td>Gridded hourly satellite data, 0.25° × 0.25°, global 1998 – 2006</td>
</tr>
<tr>
<td></td>
<td>NASA, Global Precipitation Climatology Project (GPCP)</td>
<td>Gridded monthly satellite – station blended data, 1.0° × 1.0°, 1979 – date</td>
</tr>
<tr>
<td></td>
<td>NASA, Tropical Rainfall Measuring Mission (TRMM)</td>
<td>Gridded 3-hourly satellite data, 0.25° × 0.25°, 50°S – 50°N, 01 Jan 1998 – date</td>
</tr>
<tr>
<td></td>
<td>NCEP, CPC, Merged Analysis of Precipitation (CMAP)</td>
<td>Gridded 5-day satellite – station blended data, 2.5° × 2.5°, 1979 – date</td>
</tr>
<tr>
<td></td>
<td>NCEP, CPC, Climate Anomaly Monitoring System and OLR Precipitation Index (CAMS OPI)</td>
<td>Gridded monthly satellite – station blended data, 2.5° × 2.5°, 1979 – date</td>
</tr>
<tr>
<td></td>
<td>NOAA, CPC, Unified Precipitation Analysis 1.0</td>
<td>Gridded daily station data, 0.5° × 0.5°, global land only, 01 Jan 1979 – date</td>
</tr>
<tr>
<td></td>
<td>NOAA, CPC, Precipitation Reconstructed Over Land (PREC/L)</td>
<td>Gridded monthly station data, 0.5° × 0.5°, global land only, Jan 1948 – date</td>
</tr>
<tr>
<td></td>
<td>NOAA, CPC, Global MORPHed Precipitation (CMORPH)</td>
<td>Gridded 3-hourly satellite data, 0.25° × 0.25°, global, 03 Dec 2002 – date</td>
</tr>
<tr>
<td></td>
<td>NOAA, CPC, Famine Early Warning System (FEWS) Afghanistan Rainfall Estimate (RFE) version 2</td>
<td>Gridded daily satellite – station blended data, 0.1° × 0.1°, 18.0° – 50.0°N, 48.0° – 86.0°E, 01 May 2001 – date</td>
</tr>
</tbody>
</table>

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159 [http://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html](http://www.esrl.noaa.gov/psd/data/gridded/data.cmap.html)
162 [http://www.esrl.noaa.gov/psd/data/gridded/data.precl.html](http://www.esrl.noaa.gov/psd/data/gridded/data.precl.html)
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<th>Hazard</th>
<th>Source</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>NOAA, CPC, Famine Early Warning System (FEWS) Africa Rainfall Estimate (RFE) version 2(^\text{165})</td>
<td>Gridded daily satellite – station blended data, 0.1° × 0.1°, 40.0°S – 40.0°N, 20.0°W – 55.0°E, 01 May 2001 – date</td>
</tr>
<tr>
<td></td>
<td>NOAA, CPC, Famine Early Warning System (FEWS) South Asia Rainfall Estimate (RFE) version 2(^\text{166})</td>
<td>Gridded daily satellite – station blended data, 0.1° × 0.1°, 5.0° – 35.0°N, 70.0° – 110.0°E, 01 May 2001 – date</td>
</tr>
<tr>
<td></td>
<td>NOAA, NCDC, Global Historical Climatology Network-Monthly (GHCN-M) version 3(^\text{167})</td>
<td>Gridded monthly station data, 5.0° × 5.0°, global land only, Jan 1900 – date</td>
</tr>
<tr>
<td></td>
<td>NOAA, NCDC, Global Historical Climate Network (GHCN)(^\text{168})</td>
<td>Daily station data, Jan 1835 – date</td>
</tr>
<tr>
<td></td>
<td>UEA, CRU, Time Series 3.1 (TS3.1)(^\text{169})</td>
<td>Gridded monthly station data, 0.5° × 0.5°, global land only, Jan 1901 – Dec 2009; includes total and frequency</td>
</tr>
<tr>
<td></td>
<td>University of California, Irvine, Center for Hydrometeorology and Remote Sensing (CHRS), Precipitation Estimation from Remote Sensing Information using Artificial Neural Network (PERSIANN)(^\text{170})</td>
<td>Gridded 6-hourly satellite data, 0.25° × 0.25°, global, 01 Mar 2002 – date</td>
</tr>
<tr>
<td></td>
<td>WCRP, Global Precipitation Climatology Centre (GPCC) Product(^\text{171})</td>
<td>Gridded monthly station data, 0.5° × 0.5°, global land only, Jan 1901 – date</td>
</tr>
<tr>
<td></td>
<td>European Observations version 5 (E-OBS 5)(^\text{172})</td>
<td>Gridded daily station data, 0.1° × 0.1° (others available for RCM validation), Europe only, 01 Jan 1950 – 30 Jun 2011</td>
</tr>
<tr>
<td></td>
<td>NOAA, CPC, US Unified Precipitation Analysis</td>
<td>Gridded daily station data, 0.25° × 0.25°, 20.0° –</td>
</tr>
</tbody>
</table>


\(^{168}\) [http://www.ncdc.noaa.gov/ghcnm/](http://www.ncdc.noaa.gov/ghcnm/)

\(^{169}\) [http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_12562237773328276](http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_12562237773328276)


\(^{171}\) [http://gpcc.dwd.de](http://gpcc.dwd.de)

\(^{172}\) [http://eca.knmi.nl/download/ensembles/ensembles.php](http://eca.knmi.nl/download/ensembles/ensembles.php)
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<th>Hazard</th>
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<th>Details</th>
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<tbody>
<tr>
<td></td>
<td><strong>Temperature</strong></td>
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</tr>
<tr>
<td></td>
<td>GISS Surface Temperature Analysis (GISTEMP)</td>
<td>Monthly zonal, hemispheric and global averages, Jan 1880 – date</td>
</tr>
<tr>
<td></td>
<td>Hadley Centre – CRU, Temperature version 3 (HadCRUT3)</td>
<td>Gridded monthly station data, 5.0° × 5.0°, global land only, Jan 1850 – date</td>
</tr>
<tr>
<td></td>
<td>NASA, Moderate Resolution Imaging Spectroradiometer (MODIS) Products</td>
<td>Gridded daily satellite data, 250 m × 250 m, global, 01 Mar 2002 – date</td>
</tr>
<tr>
<td></td>
<td>NOAA, CPC, Global Historical Climate Network (GHCN) Climate Anomaly Monitoring System (CAMS)</td>
<td>Gridded monthly station data, 0.5° × 0.5°, global land only, Jan 1948 – date</td>
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<tr>
<td></td>
<td>NOAA, NCDC</td>
<td>Gridded monthly station data, 5.0° × 5.0°, global land only, Jan 1880 – date</td>
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<td></td>
<td>NOAA, NCDC, Global Historical Climatology Network-Monthly (GHCN-M) version 3</td>
<td>Daily station data, Jan 1835 – date</td>
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<tr>
<td></td>
<td>NOAA, NCDC, Global Historical Climate Network (GHCN)</td>
<td>Gridded monthly station data, 0.5° × 0.5°, global land only, Jan 1901 – Dec 2009; includes maximum, minimum, diurnal range, and frost frequency</td>
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<td></td>
<td>UEA, CRU, Time Series 3.1 (TS3.1)</td>
<td>Gridded daily station data, 0.1° × 0.1° (others available for RCM validation), Europe only, 01 Jan 1950 – 30 Jun 2011</td>
</tr>
<tr>
<td></td>
<td>European Observations version 5 (E-OBS 5)</td>
<td></td>
</tr>
</tbody>
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173 http://www.esrl.noaa.gov/psd/data/gridded/data.unified.html#detail  
174 http://data.giss.nasa.gov/gistemp/  
175 http://www.metoffice.gov.uk/hadobs/  
177 ftp://ftp.cpc.ncep.noaa.gov/wd51yf/GHCN_CAMS/  
178 http://www.ncdc.noaa.gov/cmb-faq/anomalies.php#grid  
180 http://www.ncdc.noaa.gov/ghcnm/  
181 http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_1256223773328276  
182 http://eca.knmi.nl/download/ensembles/ensembles.php
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<th>Hazard</th>
<th>Source</th>
<th>Details</th>
</tr>
</thead>
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<td>Multi-hazards</td>
<td>European Climate Assessment and Datasets (ECA-D)¹⁸³</td>
<td>Monthly station data, Europe, 61 indices on cloudiness, cold, combined temperature and precipitation metrics, drought, heat, humidity, pressure, rain, snow, sunshine, temperature</td>
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<td>IRI Data Library²⁸⁴</td>
<td>Various</td>
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<td>Monsoon indices</td>
<td>Asia-Pacific Disaster Research Center (APDRC) Monsoon Indices¹⁸⁵</td>
<td>Daily (during the monsoon season), Indian, Western North Pacific, and Australian monsoons, 1948 – 2010</td>
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<td>Indian Institute of Tropical Meteorology (IITM), Monsoon On-Line (MOL)¹⁸⁶</td>
<td>Daily (during the monsoon season), Indian monsoon, 1871 – date</td>
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<td>Institute of Global Environment and Society (IGES)¹⁸⁷</td>
<td>Seasonal data, 1871 – 2000</td>
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<td>Tropical cyclones</td>
<td>India Meteorological Department (IMD), Best Track Data¹⁸⁸</td>
<td>3- or 6-hourly best track data, North Indian Ocean, 1990 – 2010</td>
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<td>India Meteorological Department (IMD), Cyclone Data¹⁸⁹</td>
<td>Annual counts, North Indian Ocean, 1891 – 2010</td>
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<td></td>
<td>Joint Typhoon Warning Center (JTWC) Best Track Data¹⁹⁰</td>
<td>6-hourly best track data, Southern Hemisphere, North Indian Ocean, Western North Pacific Ocean, 1945 – 2010</td>
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<td>NOAA, Hurricane Research Division¹⁹¹</td>
<td>Annual counts, North Atlantic, 1851 – date</td>
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<td></td>
<td>NOAA, National Hurricane Centre¹⁹²</td>
<td>Tracks and reports, North</td>
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¹⁸³ http://www.ncdc.noaa.gov/ghcnm/
¹⁸⁴ http://iridl.ldeo.columbia.edu/
¹⁸⁶ http://www.tropmet.res.in/~kolli/MOL/
¹⁸⁷ http://www.iges.org/india/allindia.html
¹⁸⁸ http://www.imd.gov.in/section/nhac/dynamic/bestrack.htm
¹⁸⁹ http://www.imd.gov.in/section/nhac/dynamic/bestrack.htm
¹⁹¹ http://www.aoml.noaa.gov/hrd/tcfaq/E11.html
¹⁹² http://www.aoml.noaa.gov/hrd/tcfaq/E11.html
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<td><strong>Hazard</strong></td>
<td><strong>Source</strong></td>
<td><strong>Details</strong></td>
</tr>
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<td>NOAA, Central Pacific Hurricane Centre</td>
<td>Atlantic and Eastern Pacific, 1851 – date</td>
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<td>RSMC Tokyo – Typhoon Center, Best Track Data</td>
<td>Tracks and reports, North Atlantic and Eastern Pacific, 1800s – date</td>
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<td>Unisys, Best Track Data</td>
<td>6-hourly best track data, annual counts, Western North Pacific Ocean, 1951 – 2011</td>
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<td>Extremes</td>
<td>Best track data, all basins, 1851 (depending on the basin) – 2010</td>
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<td>Expert Team on Climate Change Detection and Indices (ETCCDI)</td>
<td>Monthly, seasonal, annual (depending on index definition), by country, or 2.5° × 3.75°, 1951 – 2003</td>
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<td>Australia Bureau of Meteorology</td>
<td>Monthly SOI, Jan 1876 – date</td>
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<td>JMA, Tokyo Climate Center (TCC)</td>
<td>Monthly SOI, Niño1+2, Niño3, Niño4, and others, Jan 1946 – date</td>
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<td>UEA, CRU</td>
<td>Monthly SOI, Jan 1866 – date</td>
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<tr>
<td></td>
<td>North Atlantic Oscillation</td>
<td>Monthly, Jan 2950 – date</td>
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<td></td>
<td>NCEP, CPC</td>
<td>Monthly, Jan 1865 – date</td>
</tr>
<tr>
<td></td>
<td>UCAR, NCAR</td>
<td></td>
</tr>
</tbody>
</table>

193 http://www.prh.noaa.gov/cphc/summaries/
195 http://weather.unisys.com/hurricane/
196 http://cccma.seos.uvic.ca/ETCCDI/data.shtml
198 http://ds.data.jma.go.jp/tcc/tcc/products/elinino/index/
199 http://www.cpc.ncep.noaa.gov/data/indices/soi
200 http://www.cru.uea.ac.uk/cru/data/soi/
201 http://www.cpc.ncep.noaa.gov/data/teledoc/nao.shtml
202 http://www.cgd.ucar.edu/cas/jhurrell/indices.html
### Climate and Weather Information Services for the Humanitarian Agencies

The following table contains a list of important reanalysis products. Reanalyses.org provides links to a wide range of reanalysis products.

**Table J.2: List of important reanalysis datasets**

<table>
<thead>
<tr>
<th>Source</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECMWF 40 Year Reanalysis (ERA-40)</td>
<td>Global, 6-hourly, 125 km × 125 km, 01 Sep 1957 – 31 Aug 2002</td>
</tr>
<tr>
<td>ECMWF Interim Reanalysis (ERA-Interim)</td>
<td>Global, 12-hourly, 80 km × 80 km, 01 Jan 1979 – date</td>
</tr>
<tr>
<td>JMA Japanese 25-year Reanalysis (JRA-25) and JMA Climate Data Assimilation System (JCDAS) since 2005</td>
<td>Global, 6-hourly, 110 km × 110 km, 01 Jan 1979 – date</td>
</tr>
<tr>
<td>NASA Modern Era Reanalysis for Research and Applications (MERRA)</td>
<td>Global, daily, 1/2° × 1/3°, 01 Jan 1979 – date</td>
</tr>
<tr>
<td>NCEP, CPC North American Regional Reanalysis (NARR)</td>
<td>North America, 3-hourly, 32km × 32km, 1979 – date</td>
</tr>
<tr>
<td>NCEP Climate Forecast System Reanalysis (CFSR)</td>
<td>Global, hourly, 0.5° × 0.5°, 01 Jan 1979 – Jan 2010</td>
</tr>
<tr>
<td>NCEP / DOE Reanalysis I</td>
<td>Global, 6-hourly, 0.5° × 0.5°, 01 Jan 1979 – date</td>
</tr>
<tr>
<td>NCEP / NCAR Reanalysis I</td>
<td>Global, 6-hourly, 2.5° × 2.5°, 01 Jan 1949 – date</td>
</tr>
<tr>
<td>NOAA-CIRES 20th Century Reanalysis V2 (20CR)</td>
<td>Global, 6-hourly, 2.0° × 2.0°, 1871</td>
</tr>
</tbody>
</table>

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203 [http://www.cru.uea.ac.uk/cru/data/nao/](http://www.cru.uea.ac.uk/cru/data/nao/)
204 [http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_mjo_index/pentad.html](http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_mjo_index/pentad.html)
205 [http://reanalyses.org/atmosphere/overview-current-reanalyses](http://reanalyses.org/atmosphere/overview-current-reanalyses)
206 [http://data.ecmwf.int/data/](http://data.ecmwf.int/data/)
207 [http://data.ecmwf.int/data/](http://data.ecmwf.int/data/)
211 [http://nomads.ncdc.noaa.gov/data.php?name=access#cfsr](http://nomads.ncdc.noaa.gov/data.php?name=access#cfsr)
214 [http://www.esrl.noaa.gov/psd/data/20thC_Rean/](http://www.esrl.noaa.gov/psd/data/20thC_Rean/)
<table>
<thead>
<tr>
<th>Source</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Institute for Humanity and Nature (RIHN) and Nature and Meteorological Research Institute (NMRI) of Japan Meteorological Agency (JMA) Asian Precipitation – Highly-Resolved Observational Data Integration Towards Evaluation of the Water Resources (APHRODITE)(^{215})</td>
<td>– 2008 Monsoon Asia, Russia and Middle East, daily, 0.25° × 0.25°, 1900 – 2009</td>
</tr>
<tr>
<td>WCRP CoOrdinated Regional climate Downscaling EXperiment (CORDEX)(^{216})</td>
<td>South America, Central America, North America, Europe, Africa, West Asia, East Asia, Central Asia, Australasia, Arctic, Mediterranean, 3-hourly, 0.5° × 0.5°, 01 Dec 1949 – date</td>
</tr>
</tbody>
</table>


\(^{216}\) [http://cordex.dmi.dk/joomla/](http://cordex.dmi.dk/joomla/)
Appendix K: Examples of climate monitoring products

1. GLOBAL MONITORING

1.1. The United Kingdom Met Office’s climate monitoring includes global land, atmosphere, ocean and sea ice data, in addition to comprehensive national monitoring products. Data are available through the Hadley Centre, and Quarterly Monitoring Reports\(^{217}\) are available.

1.2. The Tokyo Climate Center publishes a monthly Climate System Monitoring Bulletin\(^{218}\), which “monitors the present state of the global atmospheric, oceanic and terrestrial climate system focusing on atmospheric circulation, convection, ocean conditions and snow/ice coverage based on numerical objective analyses and satellite observations. These monitoring results provide useful information for interpretation of the present climate including extreme events and long-term trends, and for long-range forecasts and scientific research.” The quarterly TCC News\(^{219}\) provides similar information with a greater regional and national focus.

1.3. The monthly Climate System Monitoring Bulletin of the Beijing Climate Center\(^{220}\) includes a wide range of monitoring products at national, hemispheric and global scales. Various climate impact assessments are provided, and extreme climate events are mapped.\(^{221}\) An example of the national mapping is shown in Figure 1.

![Figure K.1: Example of monthly extreme weather and climate events map from the Beijing Climate Center.](http://ncc.cma.gov.cn/upload/upload2/jdjc/ehsj_m110800.bmp)

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\(^{221}\) [http://ncc.cma.gov.cn/upload/upload2/jdjc/ehsj_m110800.bmp](http://ncc.cma.gov.cn/upload/upload2/jdjc/ehsj_m110800.bmp)
1.4. CPTEC provides monitoring information at national, regional, and global scales.\(^{222}\) Online streaming videos of CPTEC’s monthly Climate Meetings\(^ {223}\) provide additional discussion of their monthly summaries and other products.

1.5. The Hydrometeorological Centre of Russia provides maps of monthly meteorological variables over the northern hemisphere.\(^ {224}\)

1.6. The Deutscher Wetterdienst (DWD) hosts the Regional Climate Centre—Climate Monitoring (RCC-CM)\(^ {225}\), which provides monthly climate bulletins, and performs monitoring of extreme events for the WMO Region Association VI (Europe – Middle East).

1.7. Some regional climate centres in Africa (ICPAC\(^ {226}\)), also provide monthly bulletins, which provide information on the rainfall and temperature for the last month over their respective domains, and include forecast information.

1.8. As an example of national products, the Australian Bureau of Meteorology has comprehensive monthly and seasonal maps and statements of precipitation and temperature, including information about the occurrence of extreme weather and climate conditions. Data can be interactively selected and downloaded from their Climate Data Online\(^ {227}\) page. The interface for their extremes monitoring site is shown in Figure 2.

![Example weather extremes monitoring system from the Australian Bureau of Meteorology](http://www.bom.gov.au/climate/data/)

**Figure K.2:** Example weather extremes monitoring system from the Australian Bureau of Meteorology indicating how recent conditions compare to previous extremes. Although these options provide the user with the ability to view the information in the format that is most suitable for their purposes, some users may need assistance in identifying which format is preferable.

\(^{222}\) [http://clima1.cptec.inpe.br/](http://clima1.cptec.inpe.br/)


\(^{224}\) [http://wmc.meteoinfo.ru/monthly_maps](http://wmc.meteoinfo.ru/monthly_maps)

\(^{225}\) [http://www.gcmp.dwd.de/](http://www.gcmp.dwd.de/)

\(^{226}\) [http://www.icpac.net/Products/products.html](http://www.icpac.net/Products/products.html)

2. ENSO MONITORING

2.1. Tropical Atmosphere Ocean project (TAO)/TRITON\(^{228}\) displays real-time ocean buoy data, providing surface and sub-surface ocean measurements, and near-surface atmospheric measurements such as wind.

2.2. Australian Bureau of Meteorology (BoM) ENSO Wrap Up\(^{229}\) includes a comprehensive range of data, plus a summary of conditions and outlook information, which is updated every two to three weeks.

2.3. NOAA Climate Prediction Center’s (CPC) ENSO Page\(^{230}\) also provides a comprehensive range of data, as well as expert discussions and assessments that are available as weekly and monthly diagnostic discussion documents, and diagnostic and attribution tools.

2.4. The Japanese Meteorological Agency provides the latest analysis of oceanic and atmospheric conditions in the equatorial Pacific together with an ENSO Outlook.

2.5. The International Research Institute for Climate and Society (IRI)\(^{231}\) provides expert discussions and assessments that are updated monthly, and provides a summary of a comprehensive set of model predictions.

3. MONSOON AND TROPICAL CONVECTION MONITORING

3.1. The Indian Institute of Tropical Meteorology (IITM) Monsoon Online (MOL)\(^{232}\) is arguably one of the most developed monsoon monitoring sites. It includes monsoon circulation and indices, monsoon advance maps, rainfall (including all-India summer monsoon rainfall), temperature and annual summary reports (Figure 3).

3.2. NOAA’s Climate Prediction Center (CPC) monsoon monitoring\(^{233}\) includes global monthly and seasonal sea-surface temperatures, winds, soil moisture, precipitation, outgoing longwave radiation, and temperature. There are separate African, American, and Asian-Australian Monsoon regional pages.

3.3. Japan Meteorological Agency (JMA) Tokyo Climate Center (TCC)\(^{234}\) provides monthly circulation and convection variables for the Asian Monsoon.

3.4. Beijing Climate Center (BCC) produces monthly East Asia Monsoon bulletins\(^{235}\) including circulation, precipitation and monsoon intensity indices.

\(^{228}\) http://www.pmel.noaa.gov/tao/jsdisplay/


\(^{230}\) http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml

\(^{231}\) http://portal.iri.columbia.edu/portal/server.pt?open=512&objID=491&mode=2&cached=true

\(^{232}\) http://www.tropmet.res.in/~kolli/MOL/Monsoon/frameindex.html


\(^{234}\) http://ds.data.jma.go.jp/tcc/tcc/products/clisys/index.html#AMS

\(^{235}\) http://bcc.cma.gov.cn/Website/index.php?ChannelID=27&show_product=1
3.5. The Australian Bureau of Meteorology (BoM) Darwin Regional Specialised Meteorological Centre (RSMC)\textsuperscript{236} provides “a near real-time monthly diagnostic summary of the major tropical circulations” within the domain 40°S-40°N, 70-180°E. They include discussions of the state of ENSO, key features of the tropical atmosphere, and diagnoses of any tropical storms in the region.

![Monsoon On Line](http://www.tropmet.res.in/~kolli/MOL/Monsoon/frameindex.html)

**Figure K.3:** Home page of the Monsoon On Line monitoring site\textsuperscript{237}.

3.6. The Center for Australian Weather and Climate Research (CAWCR) provides an All-season Real-time Multivariate MJO Index monitoring page\textsuperscript{238}, which includes phase diagrams, time-longitude plots of monitoring fields, and time series.

4. **HAZARD MONITORING**

4.1. NOAA Climate Prediction Center (CPC), National Drought Monitor\textsuperscript{239}, which is produced weekly, includes PDSI and Crop Moisture Index information.

4.2. Beijing Climate Center (BCC) Drought Monitoring\textsuperscript{240} resources include soil moisture, monthly drought monitoring, satellite drought monitoring products and regional drought monitoring.

\textsuperscript{237} http://www.tropmet.res.in/~kolli/MOL/Monsoon/frameindex.html
\textsuperscript{238} http://www.cawcr.gov.au/staff/mwheeler/maproom/RMM/index.htm
\textsuperscript{239} http://www.cpc.ncep.noaa.gov/products/expert_assessment/drought_assessment.shtml
\textsuperscript{240} http://bcc.cma.gov.cn/Website/index.php?ChannelID=62&show_product=1
4.3. Australian Bureau of Meteorology’s (BoM) Drought Statements\(^{241}\) are issued monthly. Other rainfall deficiency information products also available.


4.5. Unisys\(^{243}\) provides hurricane information for all basins, including charts on the track of the storm plus a text based table of tracking information. The table of “best tracks” includes position in latitude and longitude, maximum sustained winds in knots, and central pressure in millibars.

5. **ANNUAL REPORTS**

5.1. BoM Annual Climate Summary\(^{244}\) includes precipitation, temperature, ocean conditions and significant events (e.g. flooding, drought, extreme heat).

5.2. JMA annual report on the climate system\(^{245}\) includes an annual summary of each climate system component, monthly highlights and special topics such as ENSO conditions, heat waves, etc.

5.3. BCC annual climate highlights (temperature, precipitation along Yangtze River), is included in their monthly climate system monitoring bulletin every February\(^{246}\).

6. **SPECIAL REPORTS**

6.1. BoM Special Climate Statements\(^{247}\) provide a detailed summary of significant weather and climate events. They are produced on an occasional basis for weather/climate events which are unusual in the context of the climatology of the affected region.

6.2. NCDC Special Reports\(^{248}\) include hurricanes, heat/cold waves, floods, wildfires, and other extreme weather.


\(^{242}\) [http://www.weathersa.co.za/web/Content.asp?contentId=12](http://www.weathersa.co.za/web/Content.asp?contentId=12)


\(^{248}\) [http://www.ncdc.noaa.gov/special-reports/](http://www.ncdc.noaa.gov/special-reports/)
## Appendix L: Global-Producing Centres

### Table L.1: Contact details for Global Producing Centres (GPCs) and other global seasonal forecasting centres

<table>
<thead>
<tr>
<th>Centers</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOAA CPC</td>
<td><a href="http://www.cpc.ncep.noaa.gov/">http://www.cpc.ncep.noaa.gov/</a></td>
</tr>
<tr>
<td>ECMWF</td>
<td><a href="http://www.ecmwf.int/products/forecasts/seasonal/">http://www.ecmwf.int/products/forecasts/seasonal/</a></td>
</tr>
<tr>
<td>KMA</td>
<td><a href="http://www.kma.go.kr/">http://www.kma.go.kr/</a></td>
</tr>
<tr>
<td>Météo-France</td>
<td><a href="http://www.meteo.fr">http://www.meteo.fr</a></td>
</tr>
<tr>
<td>Met Office</td>
<td><a href="http://www.metoffice.gov.uk/research/seasonal/">http://www.metoffice.gov.uk/research/seasonal/</a></td>
</tr>
<tr>
<td>MSC</td>
<td><a href="http://www.weatheroffice.gc.ca/saisons/GPC_Montreal_e.html">http://www.weatheroffice.gc.ca/saisons/GPC_Montreal_e.html</a></td>
</tr>
<tr>
<td>SAWS</td>
<td><a href="http://www.weathersa.co.za/">http://www.weathersa.co.za/</a></td>
</tr>
<tr>
<td>Hydrometeorological Centre of Russia</td>
<td><a href="http://wmc.meteoinfo.ru/season">http://wmc.meteoinfo.ru/season</a></td>
</tr>
<tr>
<td>INPE CPTEC</td>
<td><a href="http://clima1.cptec.inpe.br/gpc/">http://clima1.cptec.inpe.br/gpc/</a></td>
</tr>
</tbody>
</table>

### Table L.2: Contact details for Lead-Centres of Global Producing Centres

<table>
<thead>
<tr>
<th>Centers</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC-MME</td>
<td><a href="http://www.wmolc.org/">http://www.wmolc.org/</a></td>
</tr>
</tbody>
</table>

### Table L.3: Contact details for other centres producing global seasonal forecast information

<table>
<thead>
<tr>
<th>Centers</th>
<th>Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRI</td>
<td><a href="http://portal.iri.columbia.edu/">http://portal.iri.columbia.edu/</a></td>
</tr>
<tr>
<td>APCC</td>
<td><a href="http://www.apcc21.net/en/services/forecasts/3mon/latest_monthly">http://www.apcc21.net/en/services/forecasts/3mon/latest_monthly</a></td>
</tr>
</tbody>
</table>
### Appendix M: Regional Climate Outlook Forums

Table M.1: Contact details and availability of products from the Regional Climate Outlook Forums

<table>
<thead>
<tr>
<th>FORUM</th>
<th>Acronym</th>
<th>LCOP Full Name</th>
<th>Coordinating Organization</th>
<th>URL</th>
<th>Contact Details</th>
<th>Approx Forum Date and Target Season</th>
<th>Variables Forecast</th>
<th>Availability Online</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCOF</td>
<td>RCOF</td>
<td>Climate Monitoring, Assessment and Prediction for Regional Association</td>
<td>Beijing Climate Center (BCC) of China Meteorological Administration (CMA)</td>
<td><a href="http://www.bcc.cma.gov.cn/Website/index.php?WCHID=6&amp;ChannelID=70">http://www.bcc.cma.gov.cn/Website/index.php?WCHID=6&amp;ChannelID=70</a></td>
<td>SUN Yuan (<a href="mailto:sunyuan@cma.gov.cn">sunyuan@cma.gov.cn</a>)</td>
<td>early April: JJA 2005 - present</td>
<td>total seasonal precipitation and mean seasonal temperature</td>
<td>PDF only, not available online</td>
</tr>
<tr>
<td>SASCOF</td>
<td>SASCOF</td>
<td>South Asian Climate Outlook Forum</td>
<td>IMD (India Meteorological Department)</td>
<td><a href="http://www.impdune.gov.in">http://www.impdune.gov.in</a></td>
<td>Dr. D. S. Pai (<a href="mailto:srp@imdpune.gov.in">srp@imdpune.gov.in</a>)</td>
<td>mid-April: IAS 2010 - present</td>
<td>total seasonal precipitation</td>
<td>All available (2)</td>
</tr>
<tr>
<td>SEACOF</td>
<td>SEACOF</td>
<td>South-East Asia Climate Outlook Forum</td>
<td>No COF activity currently. Initiated in 1997/1998 but could not be sustained</td>
<td>None</td>
<td>Mr. Eren Malik (<a href="mailto:mer.nak@bmkg.go.id">mer.nak@bmkg.go.id</a>)</td>
<td>97-98 only</td>
<td>Not available</td>
<td></td>
</tr>
<tr>
<td>PACIFIC</td>
<td>PACIFIC</td>
<td>Australian Bureau of Meteorology as part of the Pacific Islands - Climate Prediction Project (PI-CPP), funded by the Australian Agency for Meteorology, Climatology and Geophysics (BMKG), and funded by the New Zealand Agency for International Development (NZAID)</td>
<td>New Zealand's National Institute of Water and Atmospheric Research (NIWA), funded by the New Zealand Agency for International Development (NZAID)</td>
<td><a href="http://www.niwa.co.nz/our-science/climate/publications/climate-publications/climate-update">http://www.niwa.co.nz/our-science/climate/publications/climate-publications/climate-update</a></td>
<td>Andrew Loney (<a href="mailto:a.lorrey@niwa.co.nz">a.lorrey@niwa.co.nz</a>)</td>
<td>Oct 2007 - present</td>
<td>total seasonal precipitation</td>
<td>Only latest available</td>
</tr>
<tr>
<td>Country</td>
<td>Region</td>
<td>Contact Person</td>
<td>Organization</td>
<td>Address</td>
<td>Email</td>
<td>Website</td>
<td>Contact Information</td>
<td>Notes</td>
</tr>
<tr>
<td>---------</td>
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<td>---------</td>
<td>-------</td>
<td>---------</td>
<td>---------------------</td>
<td>-------</td>
</tr>
</tbody>
</table>
| WCACOF  | Caribbean | Fausten Dominique | Caribbean Climate and Agriculture Outlook Forum | Private address | fausten.dominique@wmo.int | [Website](http://www.caribbeanclimateoutlook.com) | fausten.dominique@wmo.int |ipi member
| SCSACOF | South America | Giovanni Marseglia | South America Climate and Agriculture Outlook Forum | Private address | giovanni.marseglia@wmo.int | [Website](http://www.southamericacfo.org) | giovanni.marseglia@wmo.int |ipi member
| VAACOF  | Central America | Sincey de los Reyes | Central American Climate and Agriculture Outlook Forum | Private address | sincey.delosreyes@wmo.int | [Website](http://www.centralamericanclimateoutlook.com) | sincey.delosreyes@wmo.int |ipi member
| CBACOF  | Central America | Raquel Rodriguez | Caribbean Basin Agricultural & Climate Outlook Forum | Private address | raquel.rodriguez@wmo.int | [Website](http://www.caribbeanbasinclimateoutlook.com) | raquel.rodriguez@wmo.int |ipi member
| CAACOF  | Northeast Caribbean (Sub-national CCO) | Fabrice Michel | CARICAR | Private address | fabrice.michel@caricar.org | [Website](http://www.caricar.org) | fabrice.michel@caricar.org |ipi member
| LACOF   | South America | Rodrigue Vernet | Latin American Climate and Agriculture Outlook Forum | Private address | rodrigue.vernet@wmo.int | [Website](http://www.latinamericancfo.org) | rodrigue.vernet@wmo.int |ipi member
| NACOF   | South-East Asia | B. Ramesh | South-East Asia Climate and Agriculture Outlook Forum | Private address | ramesh.b@wmo.int | [Website](http://www.southeastasiacfo.org) | ramesh.b@wmo.int |ipi member
| NDACOF  | North America | William M. Newlin | North America Climate and Agriculture Outlook Forum | Private address | newlin.wm@wmo.int | [Website](http://www.northamericancfo.org) | newlin.wm@wmo.int |ipi member
| MLPACOF | Malaysia | Meenakshi Pandey | Malaysia Climate and Agriculture Outlook Forum | Private address | meenakshi.pandey@wmo.int | [Website](http://www.malaysiacfo.org) | meenakshi.pandey@wmo.int |ipi member
| APAACOF | Australia | M. Mehta | Australia Climate and Agriculture Outlook Forum | Private address | m.mehta@wmo.int | [Website](http://www.australiancfo.org) | m.mehta@wmo.int |ipi member

**Notes:**
- **ipi member:** Indicates membership in the International Integrated Public Information System (Ipi).
- **ipi:** Information on Integrated Public Information
- **ipi member:** Indicates membership in the International Integrated Public Information System (Ipi).