Weather, Climate and Water Services for everyone

World Meteorological Organization
Weather • Climate • Water

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FOREWORD

Weather, climate and water information contributes to the safety and welfare of the public, and has the potential to provide immense social and economic benefits to society. It is for this reason that WMO established its Public Weather Services Programme and strengthened its various application programmes. These programmes aim at strengthening the capabilities of WMO Members to meet the needs of society through provision of comprehensive weather services. They also strive to foster a better understanding, by the public, of the capabilities of National Meteorological and Hydrological Services (NMHSs) and how best to use their services.

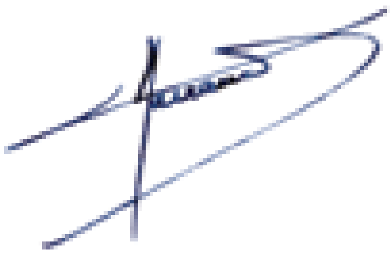
M. Jarraud, Secretary-General

In order to fulfil this purpose, WMO carries out various activities aimed at building the capability of the NMHSs to provide warnings and forecasts in a timely, reliable and comprehensive manner. These activities include the production and distribution of publications that provide the NMHSs easy access to vital information, enabling them to contribute effectively to the mitigation of adverse effects of high impact weather, including drought, floods, heavy snow and excessively strong winds, as well as to demonstrate the social, environmental and economic benefits of products and services for a full range of user communities.

The present publication, which is intended to update NMHSs on the evolution, advances and scope of service delivery, within the framework of the WMO Strategic Plan, carries examples of such delivery that may serve as desirable benchmarks.

This publication is also a resource that NMHSs may use for education and for raising awareness of their service delivery activities, by sharing it with policy- and decision-makers; disaster management authorities; and social and economic sectors including agriculture, health, fisheries, energy management, water resources, recreation and sports, banking and insurance, and construction, since many of these sectors can derive significant benefits from weather services.

This publication is based on a draft prepared by Mr William James Burroughs. It also reflects input from many other experts. It is hoped that readers, whether stakeholders or users, will benefit from, and enjoy perusing it and will obtain insight into the progress made in the last decade in service provision, and how these services contribute to sustainable development and preservation of the environment.



(M. Jarraud)
Secretary-General
World Meteorological Organization

INTRODUCTION

The basic function of NHMSs is to provide weather forecasts, warnings and other information for public welfare and for the protection of life and property. NMHSs deliver such services through a variety of activities, which in some cases include establishing an office to coordinate with the media and other users. Increasingly it is appreciated that the public require information about the state of the atmosphere over periods ranging from hours to decades for a wide range of decision-making needs. Ordinary people rarely distinguish between weather, climate or water services but, rather, expect to be able to gather meteorological and hydrological services from a common source. Some NMHSs deliver a full suite of services including information on weather, climate and water to users from a common source popularly called Public Weather Services (PWS).

The basic function of an NMHS is to provide weather forecasts, warnings and other information for public welfare and for the protection of life and property.

This publication gives a detailed account of the functions of an NMHS in delivering a range of services. Various activities that NMHSs engage in and which contribute to service delivery include public education, awareness raising and encouraging the integration of weather and climate information in decision-making. Also discussed are the products and services available from NMHSs, from warnings of severe weather to short-term and long-term forecasts. Insight into the process of making weather forecasts is also provided. Some of the high impact weather events that have occurred in recent years, which are shaping user expectations, are also mentioned.

The needs and expectations of both public and private sectors served by the NMHSs are addressed. In addition, in discussing how these sectors receive information, the challenges of communicating uncertainty and confidence in forecasts are also highlighted.

The publication brings out the importance of partnering and collaborating with stakeholders, showing how such partnerships result in the best and most effective applications of NMHS products and services.

Finally, the challenges of how NMHSs deliver their products and services and their future role, given the ease with which the public can access weather forecasts and warnings from a variety of sources is considered. This aspect is examined particularly in the context of developing and least developed countries (LDCs).

The tourism industry benefits significantly from high quality and reliable weather and climate forecasts

JULIE TIJERINA

UNDERLYING PRINCIPLES OF SERVICE DELIVERY

Within the NMHSs, it is normally the function of the PWS to deliver and communicate high quality, relevant, useful and timely, weather and related information (past, present and future) in order to assist users in making informed decisions. The service delivery function is carried out in two ways: by collaborating with other programmes within the NMHS to ensure production of appropriate user products, and by acting as the interface between the NMHS and the users in the dissemination and utilization of products. Traditionally, NMHSs have focused on providing information on prevailing conditions and short-term forecasts of the atmosphere to the public, via television, radio and print media. However, society's needs have evolved and today the public require information covering wide timescales, from hours to decades, from a one-stop source.

The goal of the service delivery function is to enable users to make informed decisions based upon the information provided.

Another vital role of programmes involved in service delivery is to educate users and the public about important issues such as the sensitivity of environmental systems to human activities, climate variability and change, the greenhouse effect, global warming, destruction of the ozone layer, vulnerability to natural hazards, protection of land and water resources and renewable energy. Providing the public and policymakers with the necessary appreciation of issues, informing the role people can play to alleviate adverse effects and the steps they can take in order to adapt to future climate scenarios is critically important work.

In order to be effective, the PWS perform this function through building and maintaining the position of the NMHSs as the key providers of high quality weather and climate services by:

- Applying excellence in science and technology to ensure continuous improvement of products, e.g. appropriate presentation of products;
- Disseminating products in a timely manner and in formats that users can easily understand and apply;
- Seeking to understand and respond to users' needs;
- Carrying out public awareness and education;
- Ensuring socio-economic applications of weather and climate information; and
- Establishing credibility in weather products and services through performance assessment.

The NMHSs provide accurate, official information and without access to this information, via PWS, users could turn to a variety of less reliable sources.

With these functions fulfilled, the PWS make a great contribution to many countries, especially developing and LDCs, by encouraging the alleviation of poverty through the mitigation of the effects of extreme weather events and by enabling effective application of weather and climate information as a resource for the creation of wealth.

UNDERSTANDING USERS' NEEDS

The development and evolution of NMHSs have been driven by user needs and requirements for services. NMHSs aspire to deliver service to the public based on a complete understanding of, and response to user requirements in order to retain validity, credibility and public and political support.

This entails an external focus on the part of the NMHS to provide an understanding and insight of user needs and how those needs are changing. In turn, this understanding informs and directs the internal focus of programmes, activities and resources needed to meet those needs.

Service to users represents the main purpose for the existence of national public weather services and activities. Service guided by user-focus is a tangible return to the national community who, as taxpayers, expect to benefit from government investment in the NMHS. It also provides the opportunity to analyse prevailing perceptions of NMHS performance and to use the results of the analysis to improve products and services thereby creating positive user perceptions.

To ascertain the requirements of users is an on-going task requiring continuous communication and consultation, since these requirements change over time. The managers of programmes that provide services are tasked with ensuring regular meetings with stakeholders. Major stakeholders include government agencies (agricultural, health, transport, environment, tourism, energy, etc.) and the natural hazards community.

In recent years Climate Outlook Forums (COFs), held before all major rainfall seasons, with the participation of several countries in Africa, Asia, the Pacific Islands, South America, Central America and the Caribbean Islands, have provided a very good opportunity for users to participate with climate scientists in the development of forecasts. In these forums, users of weather and climate services can obtain clarifications and explanations regarding seasonal climate outlooks.

One very important stakeholder is the public. To understand the needs of the public, NMHSs utilize a variety of fact-finding approaches including questionnaires, open public forums such as are held during World Meteorological Day celebrations, and public phone-ins on television and radio.

In assessing user needs, NMHSs normally, through their public weather services programmes and activities, seek insight into:

- User requirements: whether the products issued fully meet the needs of users;
- User satisfaction: whether the users are satisfied with the format and means of dissemination of the products; and
- User perception: whether the users understand the content and think that NMHS products are credible.

PUBLIC AWARENESS AND EDUCATION

It is not sufficient for NMHSs to employ good science and provide accurate forecasts; they also need to educate and inform the public, and more specialized users, about services available from NMHSs, how to access them and how to make effective use of them. Public knowledge of this ever evolving science is limited and it is clear that public education and outreach are important aspects of the work of the PWS.

Specialized users of weather information—traditionally people involved in agriculture, fisheries, maritime and air transport—have now grown to encompass those concerned with the management of energy and water resources, banking and insurance, construction and urban design. All of these users can derive significant benefits from weather services. Good weather information contributes to the safety and welfare of the public, and is potentially of immense social and economic benefit.

Extreme events can have a catastrophic impact on society, and they are of particular concern. Events such as tropical cyclones, floods, droughts, cold spells and heat waves, have the potential to cause enormous destruction and loss of life. Regarding longer time scales, climate change, ozone depletion, dwindling freshwater resources and increased pollution have an impact on the global environment. Educating the public, specialized users and policymakers in understanding these issues and in developing strategies to deal with them is a key mandate of NMHS and in particular their public weather service programmes.

Public education and outreach programmes aim to strengthen links between the providers and users of PWS so that individuals, communities and organizations can make effective use of the available products and services. While the initiative to develop such public education and outreach programmes should normally come from the NMHS, it is preferable that these activities be undertaken together with partners such as educational authorities, emergency management agencies and the media.

As well as providing direct benefit to the users of services—the general public, policy- and decision makers and the economic sector—public education and outreach campaigns also contribute to enhancing the credibility of NMHSs. An informed and educated public will have a better appreciation of the information provided, and will be better equipped to make use of high-quality services.

There is a broad spectrum of people who use weather, climate and water services and careful thought is given to the needs of various groups within that spectrum. However, the target audiences for public education and outreach programmes can be divided into two main categories:

CHRISTOPHE PAREL (IRD)

Students visiting a weather exhibition: an effective way to foster better understanding and awareness of service delivery functions

Schools and academic institutions

Public education programmes can be designed to assist schools and academic institutions in developing an awareness of the environment among both students and educators. In such programmes particular emphasis is placed on understanding the physical processes associated with weather, climate and water.

Users of weather, climate and water services

Fostering a better understanding and awareness of available weather, climate and water services, explaining the terminology, the socio-economic benefits provided and effective applications—is a key goal.

Target audiences include:

- The general public, with its diverse needs and interests;
- People involved in economic activities, such as farming, fishing, energy supply, transport, building and construction, and recreational activities;
- Reporters, presenters and editors in the media;
- The natural hazards community, including people involved in managing, mitigating and handling hazards (e.g. media, governmental bodies, emergency managers, and non-governmental and volunteer organizations); and
- Governmental authorities (e.g. high-level policy and decision makers).

Fostering such understanding is done through outreach programmes, with the material used and approach taken tailored to each specific group of users targeted (WMO/TD-No. 1354, 2006).

Rescue operations require accurate weather forecasts

NIKO ROMBERG

CONTRIBUTIONS OF METEOROLOGICAL AND HYDROLOGICAL SERVICES TO SOCIETY

SAVING OF LIFE AND PROPERTY

The meteorological and hydrological information disseminated through various communication channels contributes to disaster preparedness and mitigation when life and property are threatened by hazardous weather.

HAZARDOUS WEATHER

Examples of hazards that could be a threat to life and property (from WMO-No. 834, p. 46).

Storms and consequent phenomena

Tropical cyclones, typhoons, hurricanes
Winter storms
Thunderstorms, thundersqualls
Tornadoes
Strong winds and gales
Lightning
Blizzards, snow squalls
Waves, storm surges, storm tide
Waterspouts
Sand storms, dust storms

Precipitation and fog

Heavy rainfall, heavy snowfall
Freezing rain, freezing drizzle, sleet
Hail
Blowing snow
Freeze, frost, glazed frost
Icy roads
High humidity
Fog, dense fog

Heat and cold

Intense cold, cold wave, intense temperature decrease
Wind chill
Excessive heat, heatwave

Other weather-related hazards

Drought
Floods, flash floods
Avalanches, landslides
Forest and grass fires
Agricultural plant diseases
Increased ozone levels
High pollen count

Tropical cyclones, drought and floods present the highest threats to life and property. These phenomena are discussed below.

Tropical cyclones

A tropical cyclone is a low pressure system, characterized by destructive strong winds, heavy precipitation and even tornadoes. Cyclones develop over the tropical or subtropical waters. Depending upon location, tropical cyclones have different names around the world. In the Atlantic and the eastern Pacific oceans

Tropical cyclones threaten life and damage property due to the storm surges, heavy rain and strong winds associated with them.

NIGER DROUGHT IN 2005

Abundant rainfall in the northern Sahara, south of the Atlas Mountains in late 2003 and early 2004 created favourable climatic conditions for increased locust breeding levels in Sahelian West Africa. Consequently, the United Nations Food and Agriculture Organization (FAO) warned that desert locusts risked invading and causing damage in Niger. The locusts did eventually get to Niger, resulting in the biggest locust invasion in 15 years. This event coincided with an unfavourable weather occurrence: the rainy season, which occurs between June and September in Niger, performed particularly poorly. When planting was well under way, the rains stopped in June for a long period, with very harmful consequences for the seeds in many agricultural zones. Water stress on crops and pastures was severe in several places, especially those where the rain had stopped too early, towards the end of August. There was, therefore, a drought situation as well as a locust invasion. The two combined hazards had a strong negative impact on both pasture and cereal production. They cut the average cereal production by 11 per cent, compared to the five-year rolling average. Pasture availability also fell by 40% (Mousseau, Mittal and Rose, 2006). This resulted in food deficits in parts of Niger, which necessitated concerted international efforts to keep under control.

they are known as hurricanes; in the western Pacific, typhoons; and in the Indian Ocean, cyclones. There are several favourable environmental conditions that must be in place before a tropical cyclone can form. These include warm ocean waters of at least 27°C, up to a depth of about 46 m.

One of the most damaging features of tropical cyclones as they move onshore is the associated storm surge. This is a measure of how much the sea level rises during the passage of a cyclone. It depends on such factors as how low the pressure is at the centre of the cyclone, the speed of movement of the cyclone, wind speed, the depth of the sea and whether or not there is a high tide. Strong onshore winds combined with high tides can cause a lot of damage. The regions most vulnerable to storm surges from tropical cyclones are the Bay of Bengal, Gulf of Mexico and the Yellow Sea.

In the southeast corner of the North Sea a one-in-50-year surge may exceed 5 m. Around the Bay of Bengal the combination of shallow seas and tropical cyclones leads to great human disasters. Here the maximum surge can exceed 12 m around the Ganges Delta.

Many damaging storm surges can now be predicted more accurately using increasingly sophisticated storm surge models. Storm surge models are an essential part of hurricane warning in the USA. The National Hurricane Centre in Miami, Florida, provides predictions of surge height. Because flooding is a serious cause of mortality when hurricanes make landfall, emergency plans rely heavily on forecasts of how rapidly and how much water levels will rise to ensure effective evacuation of low-lying areas. Similar warnings are an essential part of the emergency arrangements in Bangladesh.

Here, local volunteers are instructed to disseminate cyclone warnings and guide people to local cyclone shelters, which have been constructed to provide a haven during storms.

Drought

Since the 1970s, drought associated famines have killed more people than the combination of all other weather-related disasters. The drought in sub-Saharan Africa in the early 1970s killed over 200,000 people. The Ethiopian famine of 1984 had even greater mortality, estimated at one million (WMO, 2003, p. 126).

The benefits of increased skill in seasonal forecasting are becoming evident in some countries that hitherto used to be confronted by drought conditions without any warning, but which presently factor climate outlooks in decision-making. In the countries of the Greater Horn of Africa, for example, seasonal outlook information is integrated into food security and early warnings.

Research shows that there is prospect of producing useful long-range forecasts of rainfall patterns in the future.


PATRICK BLANCHON (IRD)

Drought ravaged landscape

The users of these forecasts range from government ministries and departments and international aid organizations to farmers, pastoralists and freshwater fishermen, who are greatly affected by rainfall fluctuations. For instance, without irrigation, the success of agriculture depends on the difference between water input (rainfall) and water loss (evapotranspiration). It is this water balance that sustains the crop throughout the growing season. Decisions on ploughing, sowing, weeding, fertilizer application and so on are dependent on water balance considerations.

Seasonal rainfall forecasts are of increased usefulness to farmers when they include an indication of the likely behaviour of the rains in terms of the seasonal rainfall onset and cessation dates, likely dates of particularly heavy downpours and dry spells. Furthermore, to meet the farmers' needs, rainfall forecasts need to be packaged in a form which can be broadcast on radio and other media. In addition, they must be worded in terms that reflect the perceptions of drought and what drought means in the lives of local communities.

Current seasonal forecasts using statistical methods are making attempts at providing this information with varying degrees of success.

Floods

The inexorable nature of widespread flooding following heavy rainfall over an extensive catchment area makes certain features of the event predictable. There are features of flooding that involve a wide variety of planning authorities that bring into play all four aspects of disaster management namely: prevention, preparedness, response and recovery. This is discussed below in the section on disaster risk reduction.

For example, in Bangladesh, frequent inundation is a fact of life. Some 80 per cent of the country, with no point higher than 30 m, is in the flood plains of the Brahmaputra, Ganges and Meghina rivers. In

MOZAMBIQUE FLOODS IN 2000

Massive flooding struck Mozambique in early 2000, particularly along the Limpopo, Save and Zambezi valleys. About 544,000 people were displaced and 5 million were affected. In addition, 699 people lost their lives (UN, 2000). The floods destroyed crops and overwhelmed water and sanitation infrastructure in many areas. Many people had to escape the floodwaters by retreating to the roofs of their houses or small patches of high ground.

Flooding was at previously unknown levels, inundating areas that people normally treated as safe high ground. The Limpopo, at its widest point, was 60 km wide, flooding areas that had never been under water. People in the Limpopo, Save and Buzi river valleys were forced to take refuge in trees and on the roofs of buildings.

The impact of the floods on all sectors of the economy was enormous: 10 per cent of the cultivated land was destroyed, while 90 per cent of the irrigation structure in the affected areas was damaged. More than 600 primary schools were either destroyed or severely damaged, as were health posts and hospitals. The World Bank estimates that direct losses amounted to US$ 273 million, while lost production amounted to US$ 247 million.

Despite its very limited means, the Government of Mozambique responded in a remarkable way to the emergency. Within the National Institute for Disaster Management (INGC), the operational arm of the government in emergencies, a coordination structure was set up with support from the United Nations. The INGC organized regular press briefings and sectoral planning meetings, which greatly helped the response phase of the management of the disaster (UN, 2000).

heavy monsoon years such as 1987, 1988 and 1993, virtually all of this land was flooded but in almost any year with above average rainfall, widespread flooding can be expected.

There has, however, been a marked increase in flooding. This appears to have much to do with deforestation and more rapid runoff in the foothills of the Himalayas. The rate of clearance of the forests of Nepal, Bhutan and Assam for cultivation, timber and firewood in recent decades may be a major factor. It causes more rapid runoff and also greatly increased topsoil erosion. Human-induced changes such as these have contributed to increase the frequency and magnitude of flooding. The absence of reliable long-term data makes it difficult to identify which particular aspect of the land and water use changes upstream is most adverse and how best to address it.

The challenges of flooding are also placing massive demands on developed countries. Flooding in recent years in central Europe and along the Mississippi in 1993 provide useful lessons on how even well-established flood control schemes have to undergo subtle changes in order to respond sufficiently to repeated flooding. As the economic impact of flooding has

E. H. AL-MAJED

Serious flooding in Bangladesh

JIM READ

A roof blown off a building by violent wind. Mitigation, preparedness, response and recovery phases are applied in the management of disasters.

grown in many countries, serious questions are being asked about the strategy of flood control. Building bigger and better defences may not be the answer. Maybe, it would be better to accept the inevitability of occasional floods and plan accordingly. This might prove more economical and manage heavy rainfall better by controlled inundation of the flood plain.

In the case of the 1993 Mississippi floods, the scale of federal disaster aid led, however, to prompt action. The US Government decided to finance a scheme to "retire" the most vulnerable riverside properties. Local towns were funded to purchase and demolish the most frequently flooded properties and turn the areas into parks or recreational land. In the case of Valmeyer, Illinois, it was decided to abandon the original site of the town and rebuild on higher ground away from the river. In the state of Missouri alone US$ 100 million was used to purchase 2000 residential properties for demolition. It was estimated that this measure alone would save US$ 200 million over 20 years even without exceptional flooding (WMO, 2003, p. 134).

DISASTER RISK REDUCTION

The generic features of disaster risk reduction activities can be defined as follows:

Disaster prevention

In this phase long-term activities prior to an event aim to reduce the occurrence of a disaster or its impact. This includes using climatological records to map potential hazards and the provision of advice to planners on the probability of occurrence, frequency, duration and speed of onset of severe phenomena.

Emergency planning and preparedness

These are the long-term activities that increase the effectiveness of the emergency response during the disaster. Action plans are designed to sustain consistent delivery of service during the emergency. This includes ensuring the critical hydrometeorological information will be maintained even if the NMHS is severely impacted by the disaster or cannot function at all. At the same time, citizens must understand the hazards that may affect them and learn how to respond in a predetermined and learned manner.

Response

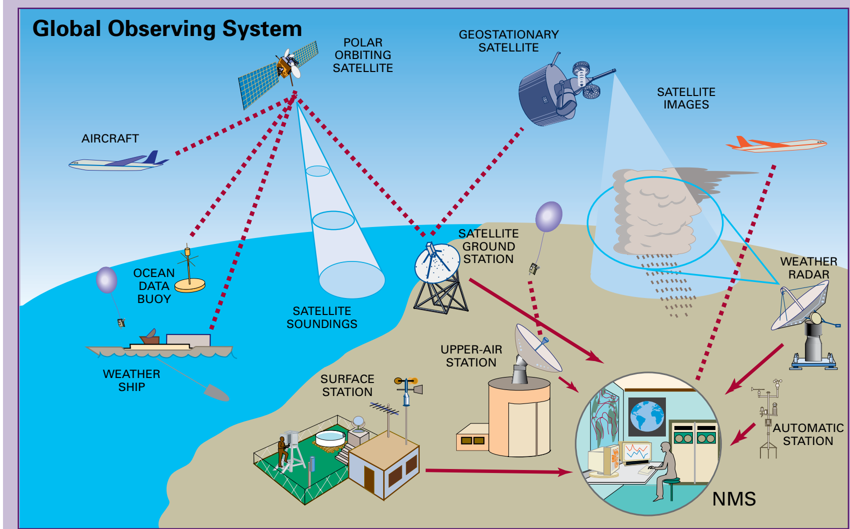
In this stage activities are undertaken to protect lives and property prior to and during an event. This involves the actual warning process, including keeping the hazard under observation, disseminating warnings, forecasts and communications of essential information. The goal of any warning system is to maximize the number of people who take appropriate actions for the safety of life and property.

Recovery

Post-impact activities are performed to return affected communities to a more normal condition during the recovery phase. Apart from the immediate requirement of providing forecasts to assist in post-disaster

GLOBAL OBSERVING SYSTEM

Instruments deployed on the land, at sea, in the air and in near-earth outer space make up the Global Observing System (GOS). The backbone of the surface-based subsystem continues to be some 11,000 stations on land, making observations at or near the earth's surface every three hours, of which over 3000 are automated. More than 900 stations make observations of the upper air using radiosondes while 3000 commercial aircraft automatically provide in flight observations at regular intervals. Over the oceans around 6000 ships, 1000 drifting buoys, 300 moored buoys and 600 fixed platforms are instrumented to provide meteorological and some oceanographic observations. The space-based subsystem is made up of 5 near-polar orbiting and 6 geostationary environmental observation satellites that augment the observations of the surface-based systems to provide global coverage. This system is continually being modernized to meet the observational requirements of NMHSs through the development of the WMO programmes (WMO-No. 986).



A representation of the GOS depicting weather data observation from land, sea air and space.

JACOB APPELBAUM

The aftermath of a storm in a coastal area

support, the other role of the NMHS is to conduct assessments of the warning system to improve early warning capabilities.

How this series of activities are used to good effect is more easily considered by dividing events in terms of the speed at which they develop. The handling of what can be defined as "rapid onset" hazards (e.g. severe thunderstorms, tornadoes, lightning, hail and flash flooding) relies heavily on nowcasting techniques.

Other hazards develop more slowly (e.g. tropical cyclones and drought) allowing more time for decision-making. This does, however, present other challenges. In particular, in issuing warnings there is a difficult balance between accuracy and lead time. For example, the time taken to evacuate vulnerable coastal areas in the USA, when a hurricane is approaching, is more than 40 hours and considerably longer for the larger cities, such as New Orleans. In these situations, emergency managers and local government officials must make preparations well before a warning or a watch is issued. At the same time they must recognize that, depending on the past performance of forecasts, where false alarms have occurred, the local populace may be reluctant to leave their homes until the reality of the hazard is unquestionable: by which time it may be too late to escape. So, local emergency services can pay a high price for past inadequate forecasts.

Hence, it is essential that warnings be timely, clear and unambiguous. Wherever possible, these must be combined with guidance of what action to take in terms of evacuation, using refuges or finding the safest place to shelter from fast-moving systems.

WEATHER FORECASTING PROCESS

Data collection

Making weather forecasts and warnings, depends on observed weather data. To meet data requirements, the NMHSs establish, maintain and operate national weather observing networks which form part of the GOS. This is the networked system of weather observation from the ground, the sea and from near-earth outer space. These data are exchanged rapidly to enable processing and forecasting. Weather observation involves both high standards of maintenance of the equipment and proper observing methods. This scrupulous effort is what allows the build up a reliable picture of the many physical processes that control the world's weather and climate.

Surface observations

The first requirement in the provision of the PWS is local, regional and global surface observations. Weather measurements, including air temperature, wind speed, wind direction, precipitation, cloud cover, humidity, sunshine hours and visibility, are taken regularly over the globe. These observations are collected from all around the world by both weather observers

RE-ANALYSIS WORK

Since the earliest days of using computers for weather analysis the charts have been archived and used as the basis for building regional and global climatologies. However, as a result in delays in communication many observations were not included in weather analyses at the time or in the subsequent climatology. Also, over time, great improvements in the automatic data analysis systems were introduced. By the late 1980s it was recognized that "missing data" and changed methods contributed to significant deficiencies, particularly in the early years of analysis, that had the effect of altering the apparent "climate".

A major development in recent years has been the re-analysis of data obtained in the production of weather forecasts since around 1950. This work has been conducted by the National Centers for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR) in the United States and the European Centre for Medium-Range Weather Forecasts (ECMWF). It has produced improved global analyses of atmospheric fields.

These measurements are of particular value in defining the conditions around the globe at any given time of the year. When it comes to interpreting the trends observed in various climatic parameters much greater care is needed as the changes in the measurement techniques may have been a significant factor in subtle changes in the observed climate.

These three centres have been working closely with PWS in developing countries to establish practical ways of using the climatological data to improve the provision of advice to users. In many of these countries gaps in their databases can only be filled with the re-analysis data.

and automatic weather stations (AWS), which take measurements and transmit them every few minutes. Some of the AWS are very useful as they record weather observations from remote localities.

Radiosondes and aircraft

The backbone of the system to measure conditions throughout the atmosphere is the worldwide network of weather balloon (radiosonde) observations. This is supported by aircraft measurements at upper atmospheric levels. Automation has led to a substantial increase in observations from aircraft over recent years, providing wind and temperature profiles at airports during take-off and landing as well as at flight level.

Satellite data

Satellite pictures give a good overview of current weather and are essential for nowcasting and warnings. They are especially important in tropical areas where they are often the only means of monitoring the development of severe weather and the formation of storms. In addition, measurements by satellites are an essential component of numerical weather prediction. The latest computational systems can combine the continuous stream of data from these sources with

A satellite image of a tropical cyclone.

other data to construct more accurate estimates of the initial conditions for numerical weather forecasts.

Radar data

Radar images of severe weather systems have become an essential part of storm and tornado warnings. Radars track cloud systems, storms, hurricanes and typhoons. They are also used for rainfall estimations and wind speed and direction in severe thunderstorms. An immediate benefit of radar is to provide better warnings of tornadoes.

A tornado is a violently rotating and potentially destructive column of air, from a cumulonimbus cloud. Here, a tornado on water causes a water spout.

Climate data

It is important that accurate climatic analyses are carried out since they form a basis upon which climate variability and change may be discerned. Re-analysis of old data records for this purpose becomes necessary from time to time.

Data transmission

After collection, weather data are rapidly transmitted to forecasting centres in the NMHSs for quality control, plotting on weather charts and analysis. Following this work weather forecasting is then done.

Making the forecasts

There are several techniques employed by the NMHSs in making weather forecasts but the following are the two main ones:

Trends method

Many NMHSs use the trends method to make weather forecasts. This method involves using weather maps to determine the speed and direction of movement for air masses, fronts, pressure systems, and areas of clouds and precipitation. Using this information, the forecaster can predict where these weather features are likely to be in the near future. Differences

Powerful main-frame computers are necessary for numerical weather prediction due to the large volumes of data and enormous calculations necessary to the prediction process.

in latitude, possible acceleration or deceleration of weather systems, local effects such as topography, water bodies and heat islands affect the forecasting, so these factors are taken into consideration when making a forecast.

Numerical weather prediction techniques

Numerical weather prediction (NWP) uses the power of computers to make forecasts. Complex computer programs, also known as forecast models, run on supercomputers and provide predictions about many atmospheric parameters such as temperature, humidity, pressure, wind speed, wind direction and rainfall.

REGIONAL FORECASTING MODELS

Global NWP exploits the most advanced computer systems to the full. However, even with powerful computing the relatively coarse data do not allow for a detailed regional picture to be produced. For regional forecasts it is necessary to combine the low resolution of global models with a more detailed computation for a specific region. Often termed "nested modelling", this technique involves the linking of models of different scales within a global model to provide increasingly detailed analysis of local conditions within the context of the global output. Results for a particular region from the global model are used as initial and boundary conditions for the regional calculations, which operate at a much higher spatial resolution and go into much finer detail. This procedure is particularly attractive for mountain regions and coastal zones, whose complexity is unresolved in global models. Current models are capable of producing local forecasts with a grid spacing of 4 km, which is very fine. The technique also provides more detail as to when and where the weather is prone to develop "high impact" events, such as tornadoes or flash flooding.

Spatial coverage of forecasts

Forecasts are issued at almost every scale in terms of space (spatial coverage). They range from local predictions at the scale of a town through defined areas of several thousand square kilometres, up to global analyses. As the area becomes larger the forecasts become more general, whereas local forecasts have to be far more precise in their content. Most NMHSs have their own spatial scale definitions. Often these are defined in terms of state boundaries, or reflect geographical features of the

NUMERICAL WEATHER PREDICTIONS

Standard numerical weather forecasting models simulate the weather on a global scale. They calculate the formation, growth, movement and decay of large-scale systems across the face of the planet. The models incorporate the principles of conservation of atmospheric momentum, mass, energy and water in all its phases; the equations of motion applied to air masses; the physical laws of heat energy transfer and radiation for incoming energy from the sun and outgoing radiated energy from the earth (infrared); and the equations of state for atmospheric gases. In the NWP models, parameters which are specified in advance include the size, rotation, geography and topography of the earth, the incoming solar radiation and its daily and seasonal variations, the radiative and heat conductive properties of the land surface according to the nature of the soil, vegetation and snow and ice cover, and the surface temperature of the oceans.

The physical state of the atmosphere is updated continually, drawing on observations from around the world. Just assimilating the data to establish the starting point for the model prediction is a very important part of the whole exercise. Errors in the initial representation, through deficiencies in the global observing networks, will expand as errors in the forecast, so the observations are fundamentally important. The model atmosphere is divided into 30 or more layers between the ground and an altitude of 30 km, and, in the most advanced models, each level is divided up into a network of points about 50 km apart—some four million points in all. Each of these points is assigned new values of temperature, pressure, wind and humidity with each step forward of the model, repeated in 15-minute steps at each point to provide forecasts up to ten days ahead. Each new set of forecasts involves many tens of trillion calculations. The output is predictions of pressure, temperature, wind, humidity, vertical motion, rainfall and other meteorological parameters, which are used to provide a variety of products for different users. Although weather forecasts have shown significant improvements in recent decades, they only provide consistently useful forecasts to around six days ahead. This slow progress stems from the chaotic nature of the atmosphere that limits how far ahead its detailed evolution can be predicted. Currently, there is a WMO initiative to accelerate improvements in the accuracy of one-day to two-week high impact weather forecasts that is aimed at application in the PWS. It is named The Observing-system Research and Predictability Experiment (THORPEX)

There are times when the atmosphere appears to be less stable. Standard weather forecasts do not predict sudden switches between stable circulation patterns (regime changes) well. But, by running the models from slightly different starting points and seeing whether the different forecasts stick together or diverge rapidly, it is possible to identify those aspects of the forecast that are most stable and those for which there is a lot of uncertainty. This ensemble approach is now a central part of weather forecasting.

Forecasters using various data and information in the preparation of forecasts

country, such as mountains, river valleys or deltas. The essential feature of the spatial definitions is that they must be well-known to the public, so there is no risk of confusion about what is being forecast and for where.

TYPES OF FORECASTS

In our daily lives we want to know how the weather may affect decisions we have to make. It may be as simple as whether we need to take a raincoat or umbrella, or whether there is a risk of encountering ice on the road when driving to work. What really matters is to know how conditions will impact on us. For all sorts of reasons, people want to know what weather they are going to experience. In particular, they want warnings of high impact weather that will cause serious inconvenience or pose a risk to them or their possessions. Moreover, high impact conditions are defined entirely by the local weather: snowfall that, in southern England, can produce widespread chaos is regarded as a trivial matter in Montreal or Moscow. Similarly, a heavy storm in well drained countryside may be a welcome event but it may cause serious damage to property in an adjacent poorly-drained highly populated area. So, the essential skill of local forecasters is to be able to present accurately to the general public and public services authorities, just how disruptive predicted events are likely to be.

The NMHSs provide a wide range of forecasts. These rely on an abundance of data and require supercomputers to produce different products for different users. In many cases this diversity may imply that there is a difference between the various products. However, despite these differences, the products present a "seamless" transition in timescale. This seamless nature becomes evident when we examine the various forecasts in a little more detail.

Nowcasts

The shortest-range forecasts are termed nowcasts. These are of immense value to people in their day-to-day lives. For instance, they enable people to anticipate a variety of hazards associated with severe then respond to the risk and occurrence of tornadoes and flash flooding.

These examples show that users of nowcasting require a relatively "quantitative" product, which enables emergency organizations and the public to make decisions on the precautionary measures to be taken. These have a huge impact on public safety as well as economic development. The ability to answer questions about the location, timing and severity of weather conditions requires both the monitoring of current weather systems and a good understanding of how the current weather situation is developing. This depends on exploiting fully short-range forecasts.

A SAMPLE NOWCAST

NATIONAL WEATHER SERVICE ALBANY NY 758 AM EST MON JAN 8 2007

NYZ041>043-083-084-081500-NORTHERN SARATOGA-NORTHERN WARREN-NORTHERN WASHINGTON-SOUTHEAST WARREN-SOUTHERN WASHINGTON – INCLUDING THE CITIES OF... SARATOGA SPRINGS... WARRENSBURG... WHITEHALL...GRANVILLE...GLENS FALLS...WEST GLENS FALLS...HUDSON FALLS...FORT EDWARD... CAMBRIDGE...GREENWICH 758 AM EST MON JAN 8 2007

.NOW...

POCKETS OF NEAR 32 DEGREE AIR REMAIN TRAPPED AT VALLEY LOCATIONS IN THE UPPER HUDSON VALLEY...NORTH OF SARATOGA SPRINGS. THEREFORE, PRECIPITATION WILL BE A MIX OF RAIN AND SOME SNOW PELLETS AND POSSIBLY FREEZING RAIN...THROUGH 10 AM. AS SOUTHEAST WINDS PUSH WARMER AIR INTO THE REGION THROUGH MID MORNING TEMPERATURES WILL RISE INTO THE MID 30°F (0°C) S AND THE PRECIPITATION WILL CHANGE TO ALL RAIN. SMALL STREAMS AND CREEKS WILL CONTINUE TO RUN HIGH AND FAST. ADDITIONAL PRECIPITATION OF UP TO A QUARTER INCH WILL BE POSSIBLE.

thunderstorms. These range from avoiding torrential rain, through warning managers of outdoor work (e.g. agriculture and construction) and recreation (e.g. golf courses) that there is a high risk of lightning, to emergency services taking action to anticipate and

Short-range forecasts

Short-range forecasting has become the popular product for daily planning of outdoor activities, such as sports and social events, as well as special purpose activities such as filming, tourism and construction. They have a direct link to nowcasting in that they can be produced on a much more detailed scale for regional forecasts. In the NMHSs, to monitor emerging weather situations, forecasters exploit the products of global analysis, augmented by more detailed predictions that often draw on real-time observations from national weather observatories, radar and satellite pictures. Using the nested modelling technique within standard forecasts it is possible to run forecasts with a resolution of a few kilometres. When combined with radar and satellite measurements and a dense network of automatic weather stations and rain gauges, it is possible to get a more accurate prediction of the position and intensity of severe weather events. The detection of lightning is also used to locate thunderstorms and measure their severity.

The seamless nature of short-term forecasts is evident in the way in which nowcasting techniques flow into

HOW FAR AHEAD?

Weather forecasts are produced to cover a wide variety of timescales. Broadly speaking they can be divided into the following categories:

- **Nowcasting:** a description of current weather conditions and a zero to two-hour forecast of their likely behaviour (most often used to describe current severe weather events such as heavy rain, severe thunderstorms, tornadoes and hurricanes);
- **Short-range forecasting:** descriptions of weather conditions up to 72 hours ahead (often divided into very short-range, out to 12 hours and short-range from 12 to 72 hours);
- **Medium-range forecasting:** descriptions of weather conditions from three days up to ten days ahead;
- **Extended-range forecasting:** beyond ten days and up to 30 days, description of weather conditions, usually described as a departure from climate values for that period;
- **Long-range forecasting:** a description of average weather conditions as a departure from climate values for a defined period, often presented in the forms of monthly, three-month or seasonal outlooks;
- **Climate forecasting (beyond two years):** predictions of either climatic variability, which describe expected climatic conditions associated with inter-annual, decadal or multi-decadal climate anomalies, or climate prediction, which describes the expected future climate including the effects of both natural and human influence (WMO-No. 834, p. 72).

forecasts of up to 72 hours ahead. These developments are particularly important in providing updates in rapidly developing situations (e.g. severe thunderstorms or tornadoes, landfall of tropical storms and developing snowstorms).

Medium-range forecasts

Medium range weather forecasts cover three to ten days. They may be presented in either deterministic or probabilistic form.

The deterministic and probabilistic forecasts are two different ways of presenting the forecast information. The deterministic forecasts show the predicted forecast category as either above, near or below normal. This is useful but unfortunately, the presentations do not provide information on the confidence that might be attributed to a particular forecast. This is where the probabilistic forecasts add important information to the deterministic forecasts by giving an indication of the specificity of the forecast. For example, a deterministic forecast of above normal conditions that is accompanied by probabilities of 45, 30 and 25 per cent for the above normal, normal and below normal categories respectively, would be less clear than a forecast with probabilities of 60, 25 and 15 per cent

EXAMPLE OF A CLIMATE OUTLOOK EXTRACT FROM THE INTERGOVERNMENTAL AUTHORITY ON DEVELOPMENT (IGAD) CLIMATE PREDICTION AND APPLICATION CENTRE (ICPAC)

September to December 2006 constitutes an important rainfall season over much of the Greater Horn of Africa subregion. The rainfall outlook for each zone within this subregion is given below:

Zone I: Increased likelihood of above to near normal rainfall over southern coast of Somalia, Kenyan coast and northern coast of the United Republic of Tanzania.

Zone II: Increased likelihood of near to below normal rainfall over southern, parts of central and north-eastern United Republic of Tanzania; southern, eastern and parts of western Kenya; northern and extreme western Uganda; extreme parts of western Rwanda; extreme north-western Burundi; much of Somalia and eastern Ethiopia.

Zone III: Increased likelihood of above to near normal rainfall over western and Lake Victoria basin parts of United Republic of Tanzania; much of Rwanda and Burundi as well as much of southern and central Uganda.

Zone IV: Increased likelihood of above to near normal rainfall over northern Kenya; south-eastern and north-eastern Sudan; south-western, central and parts of northern Ethiopia; extreme north-western Somalia; eastern and southern Djibouti as well as southern, central and parts of northern Eritrea.

Zone V: Increased likelihood of near to below-normal rainfall over western Ethiopia, central and south-western Sudan.

Zone VI: Climatology is indicated over northern and western Djibouti; north-eastern Ethiopia as well as southern and eastern Eritrea.

Zone VII: Climatology is indicated over northern Sudan and western Eritrea.

Note:
The numbers for each zone indicate the probabilities (chances of occurrence) of rainfall in each of the three categories: above, near and below normal. The top number indicates the probability of rainfall occurring in the above normal category; the middle number is for the near normal and the bottom number for the below normal category.

respectively. In the latter case, the forecast is that there are better than even odds of above average conditions, accompanied by relatively small odds of below average conditions.

Both deterministic and probabilistic techniques are used to extend forecasts to the medium-range. Deterministic forecasts using numerical weather forecasts are inevitably limited by the predictability of the atmosphere. So, while they work reasonably well out to around a week, beyond this it becomes increasingly important to assess and quantify the uncertainty in the forecast, hence the adoption of probabilistic techniques.

Medium-range forecasts covering ten days and beyond are routinely produced by some specialized centres and NMHSs. In many cases the forecasts beyond a few days are used as an extension of the short-range predictions. There are, however, instances when decisions have to be made for periods of well over a week ahead (e.g. routing of ocean-going ships).

Forecasts of up to 14 days are now available from some NMHSs. Relying on the ensemble approach, they extend the range of forecasting and bridge the gap with seasonal forecasting by running models out to a month. This extension has been enabled by progress in data assimilation and modelling techniques and improvements in the GOS, notably in the form of high-resolution satellite data. The potential value of this work is considerable. In terms of a week or two ahead, the ability to identify a regime change that could produce a severe winter cold wave or summer heatwave is of great value to decision makers.

Seasonal forecasts

Many of the users of day-to-day forecasts have equally critical requirements for longer-term forecasts. So, monthly and seasonal forecasts have become part of the operations of the NMHSs. But, forecasting on the timescale of one to three months ahead cannot rely on the standard NWP output. Instead, these forecasts depend on the fact that longer-term atmospheric weather patterns are strongly influenced by surface conditions (e.g. sea surface temperatures [SSTs], soil moisture and snow cover). These parameters are fairly predictable on a timescale of weeks to months because the ocean, moist ground and snow cover have a considerably longer "memory" than that of the atmosphere. So, by building up rules about how certain patterns of surface conditions lead to given atmospheric patterns, it is possible to produce useful seasonal forecasts.

The benefits of seasonal forecasts are not restricted to the tropics, but extend to higher latitudes. The prospect of forecasts on seasonal and longer timescales, for example about whether rainfall or temperature will be above or below average and by how much, has huge potential benefits. Cumulative climate events, such as snowmelt floods, extreme (high or low) reservoir levels and sea-ice concentrations (the amount of ice in a given area) are based on recent and current conditions and are reasonably predictable some time in advance. Climate forecasts (or outlooks for a month, season or year ahead) are eagerly sought for longer-term decision-making and early warning of potential hazards. Their credibility will depend on the quality of their track record. To retain the confidence of users, NMHSs are always trying to improve the level of skill and accuracy of these predictions further and further beyond the climatological experience.

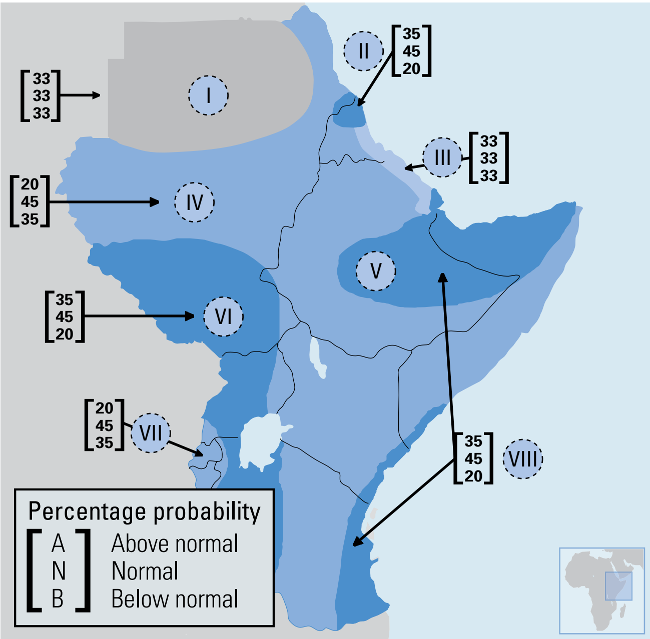
How developing countries are using global weather forecasts

Today NMHSs in developing countries benefit from increased access to global weather forecasts produced by a number of NMHSs in developed countries and by specialized centres.

An essential link in this process of realization of NWP forecasts is effective use of specialist services that have been established by developing countries to coordinate cooperative action. One example is the Agricultural, Hydrological and Meteorological Centre (AGRHYMET) Regional Centre (ARC), an institute of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) composed of eight member states. Its objectives are to contribute to achieving food security, increasing agricultural production, and improving natural resource management in the Sahelian region. Another important organization is the African Centre of Meteorological Applications for Development (ACMAD). It is supported by African

Member States and staffed mainly by meteorologists seconded from these Member States. Its mission is the provision of weather and climate information for the promotion of sustainable development of Africa, in the fields of agriculture, water resources, health, public safety and renewable energy.

Longer-term forecasts are also issued by the Intergovernmental Authority on Development (IGAD) Climate Prediction and Application Centre (ICPAC) in Nairobi, the Drought Monitoring Centre in Harare and also by some NMHSs themselves. Ten-day weather advisories include a climatological summary, analysis of drought severity conditions, and socio-economic conditions and impacts, plus a synoptic review and weather outlook. Monthly drought monitoring bulletins include monthly and three-monthly climatological summaries and drought severity conditions, monthly dominant synoptic systems and three-monthly and seasonal weather outlooks. In addition, these bulletins provide an assessment of socio-economic conditions and their impacts.



Climate outlook for the Greater Horn of Africa, March to May 2006.

Intra-seasonal Oscillation

The ability to predict several weeks in advance the early or late onset of the rainy season, together with anticipating interruptions in rainfall during the season is of great value to farmers. In this respect, the discovery of roughly periodic variations in tropical convection has opened up the prospects of intra-seasonal forecasting in the tropics. These variations were observed in surface and radiosonde data, and in satellite images. Over the Indian and Pacific oceans, in particular, tropical convection was often active for about a week or so and then there was a relatively quiet period of a month or so. The active regions of convection travel from west to east close to the equator within a period of somewhere between 30 and 70 days. A significant percentage of the rainfall in the tropics occurs during the active convection phases of this cycle, as does the formation of most tropical cyclones. This cycle is now known as the Madden–Julian Oscillation (MJO) after the scientists who first observed it. It is also termed the Intra-seasonal Oscillation.

The trigger factors for the MJO are not fully understood and they are largely chaotic like other aspects of atmospheric behaviour.

Climate predictions

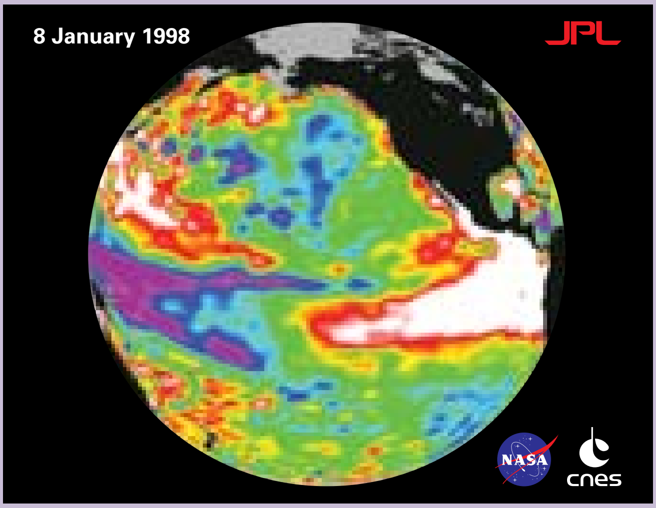
Modern climate services support many aspects of PWS. This entails collection, storage, processing and publishing of climate records. The statistical and geographic presentations produced define the national climate, its year-to-year variability and any changes over time.

The success of these services depends on their ability to meet the many demands of the communities they serve. There is hardly a human activity

EL NIÑO-SOUTHERN OSCILLATION (ENSO)

The dramatic changes that occur from year to year beyond the expectations of seasons have been the source of fascination to meteorologists for more than two centuries. Finding out what causes these fluctuations has centred on how the atmosphere and the oceans interact in the longer term.

Foremost in this process was the discovery of the atmospheric Southern Oscillation at the beginning of the 20th century. It is now defined in terms of the monthly or seasonal fluctuations in the air pressure difference between Tahiti and Darwin (the Southern Oscillation Index [SOI]). The large-scale surface air pressure pattern see-saws between one extreme, with above normal sea level pressure being over Indonesia and northern Australia and below normal over much of the eastern Pacific. At the same time the SSTs across the equatorial Pacific swing back and forth. When there is an extensive warming of the ocean surface across the eastern equatorial Pacific lasting three or more seasons it is known as an El Niño event. When this oceanic region switches to below normal temperatures, it is called a La Niña event.



NASA

Illustration of El Niño showing warming of the eastern and central Pacific Ocean and cooling of the western Pacific.

The link between the Southern Oscillation and El Niño is collectively known as the El Niño-Southern Oscillation (ENSO) phenomenon. This oscillation swings between El Niño and cold La Niña conditions every two to seven years. In between these extremes the SOI is often close to zero and the system is neutral. Over the 20th century there were 23 El Niño events and 22 La Niña events. The behaviour of ENSO is linked to the monsoon rains of Australasia and India. The net effect of this complex set of interactions resembles large quantities of warm water slowly flowing back and forth across the equatorial Pacific and a large east-west oscillation in the heat supply to the atmosphere from the Pacific Ocean. At the peak of an El Niño event, the tropical Pacific Ocean overall is warmer than normal and the global surface temperature warms up as the ocean gives up heat to the atmosphere.

Essentially, the ocean is a source of moisture and its enormous heat capacity acts as the flywheel that drives the atmosphere.

The ENSO has a profound effect on weather patterns throughout the tropics and at higher latitudes.

The scale of these influences is such that any seasonal forecast of the weather around the world has to include a prediction of the likely behaviour of ENSO. A number of NMHSs have developed both computer models and statistical techniques to predict the swings back and forth between El Niño and La Niña events.

that is not climate sensitive to some extent, despite our technological adaptation capabilities that have enabled communities to exist in climate regimes from the equator to the poles. These services contribute to the safety of life and property in the event of extreme meteorological and hydrological events. A strong foundation of climate science is essential to ensure that development policies adequately reflect climatic realities.

Climate science supports food and fibre production, safe housing and public infrastructure, planning and utilization of freshwater resources and the enjoyment of many leisure activities. Future policies for the generation and utilization of energy must be made in full knowledge of climate information. Effective services must bridge disciplines and combine the expertise needed to ensure sensible planning decisions. This requires frequent contact between the

EXAMPLE OF A FIRE WEATHER OUTLOOK FROM THE NWS OF NOAA (SOURCE: NOAA)

DAY 1 FIRE WEATHER OUTLOOK
NWS STORM PREDICTION CENTER NORMAN
0207 AM CST TUE DEC 19 2006

VALID 191200Z - 201200Z

...No critical areas...

SYNOPSIS

Fire weather concerns will remain low today across the country. The colder upper low air pressure system moving across the south-western states is expected to be turning north-eastward toward the southern and central high plains region by tonight. In its wake, locally gusty north-eastern winds below canyons and passes can be expected early today in south eastern California where fairly widespread rain/snow occurred during the weekend. The gusty winds will be short-lived as ridging aloft spreads eastward later today.

Elsewhere, a large warm ridge of high pressure aloft will dominate the eastern parts of the country. Though temperatures will be seasonably warm from the lower Mississippi valley into the mid-Atlantic region and the south-eastern coastal states, surface wind speeds will remain low and humidity sufficiently high to preclude widespread fire weather concerns.

providers of climate services and the people who use this information. It also requires information to be readily accessible.

ISSUING OF WEATHER OUTLOOKS, ADVISORIES, WATCHES AND WARNINGS

Issuing weather warnings, watches, outlooks and advisories is a key function of NMHSs. On behalf of the NMHSs, PWS programmes play a pivotal role ensuring that the information issued is in accordance with the severity of the threat. This enables appropriate action to be taken and may involve evacuation of people, moving possessions to higher ground, deploying security personnel, reallocation of resources or closing down operations.

Outlooks

Outlooks are used to inform the public of expected prevailing weather, for example, the likelihood of frost, drought or even fire occurring. These outlooks are issued to the public and to communities that require considerable a lead-time to prepare for the event.

Weather advisories

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.

Weather watches

Watches are used to alert the public of severe weather such as flash floods, tornadoes or thunderstorms that are likely to develop despite the fact that the exact time and location may not yet be determined. They are meant to alert the public and create awareness, which is very helpful should the threat develop and a warning has to be issued since it reduces the response time. Watches either evolve into warnings, advisories or are cancelled.

EXAMPLE OF A SEVERE WEATHER WATCH (NEW ZEALAND)

SEVERE WEATHER WATCH FOR FIORDLAND GISBORNE ISSUED BY METSERVICE AT 2050hrs 19-Dec-2006
WATCH FOR HEAVY RAIN MAINTAINED FOR FIORDLAND AND GISBORNE

A front currently crossing Fiordland is bringing some heavy falls to the fiords, but should clear the area by the early hours of Wednesday morning. Rainfalls totals should remain just below warning levels. Meanwhile, a period of heavy rain is expected about the Gisborne ranges and north of Ruatoria from late Wednesday morning through to late afternoon. This rain could contain some thunderstorms, but at this stage, rainfall totals look likely to fall just below warning criteria.

Met Service forecasters will maintain a watch for these areas for the time being and advise people there to remain up-to-date with the latest forecasts in case the situation changes.

This watch will be reviewed by 9am Wednesday 20th December 2006.

Weather warnings

The greatest challenge for NMHSs occurs in the face of likely extreme weather. In presenting potentially hazardous conditions in terms of probabilities, they

EXAMPLE OF A WEATHER ADVISORY (USA)

URGENT – WEATHER MESSAGE
NATIONAL WEATHER SERVICE SAN DIEGO CA, 319 AM PST TUE DEC 19 2006

FROST ADVISORY WILL AGAIN BE IN EFFECT TONIGHT FOR THE VALLEYS AND LOWER DESERTS

A cold air mass over southern California will result in areas of frost in wind sheltered valleys and lower deserts this morning and again tonight into early Wednesday. Low temperatures will be in the upper 20° Fahrenheit (-7°C) to lower 30°F (0°C), and a few spots could fall into the mid-20s (-7°C). Patchy frost is also likely in the coldest coastal locations such as Oceanside and San Juan Capistrano. Areas below passes and canyons will be breezy and frost will be much less likely in those areas, at least this morning, though winds are expected to be lighter tonight. People should prepare for frost by protecting sensitive plants or, if possible, bring them indoors.

JEAN-PIERRE RAFFAILLAC (IRD)

must make the uncertainties understandable to the emergency services and the general public.

This is not an easy process, as it requires the transfer of complicated information from highly specialized scientists through emergency managers, local politicians and the media, to every member of society. The NMHSs have therefore to employ skill in communicating to ensure that warnings are understood. This is essential since warnings are issued for the purpose of protecting life and property when a severe event occurs.

CONTRIBUTION TO SOCIAL AND ECONOMIC WELL-BEING OF COMMUNITIES

Assessment of socio-economic applications of meteorological and hydrological services

The overriding challenge for all NMHSs is that the provision of a wide variety of services costs a great deal of money. This must either be provided from government budgets or obtained from customers requiring specific services. To justify the funding NMHSs must demonstrate that their products and services are good value for money.

To effectively demonstrate the importance of the services the NMHSs provide, assessment of social, environmental and economic benefits of weather, climate and water information for the full range of users served by an NMHS has to be carried out continuously. While some NMHSs have been carrying out assessments, there are many who have not yet instituted this function in their operations.

This is a complex undertaking in that the contribution of NMHSs to the safety and well-being of the public is not simply a matter of economic gain. More important is the major reduction in loss of life and disruption to society due to natural disasters in vulnerable regions of the globe. At the macroeconomic level, cost-benefit studies invariably demonstrate high rates of return to national economies from investments made in hydrometeorological services. On a smaller scale, the same holds true for many enterprises in weather sensitive sectors of the economy such as agriculture, fishing, forestry, construction, transportation and power generation.

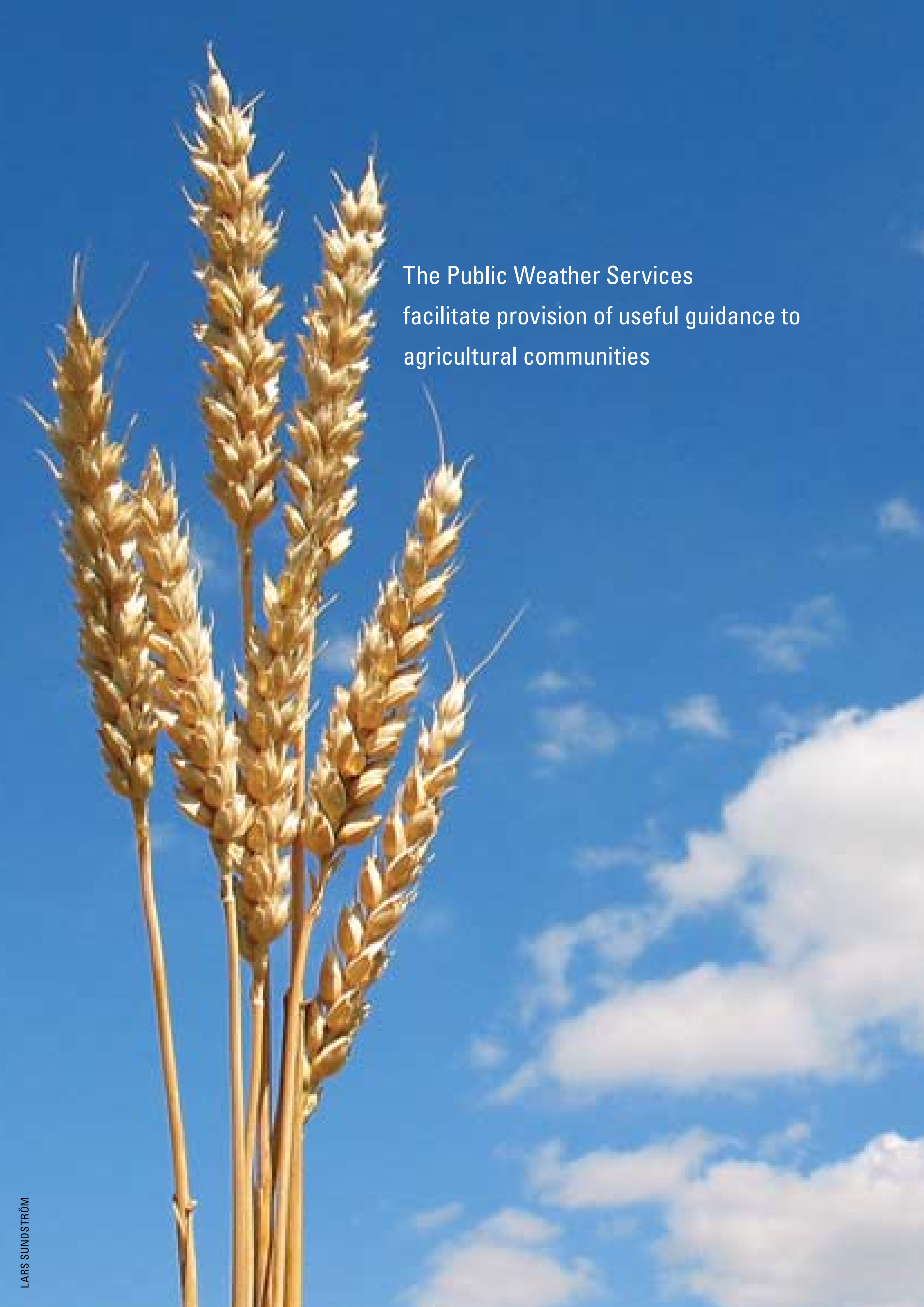
GEORGE TARBAY (NIU)

Provision of meteorological advice to weather sensitive sectors such as agriculture

EXAMPLE OF A WEATHER WARNING ISSUED BY THE METEOROLOGICAL SERVICE OF CANADA

Warning
Central Coast - coastal sections
8:32 PM PST Sunday 7 January 2007
Wind warning for Central Coast – coastal sections continued.

Southeast winds rising to up to 90 km/h Monday morning along the central coast. This is a warning that damaging winds are imminent or occurring in these regions. Monitor weather conditions. Listen for updated statements. The next frontal system approaching from the Pacific will bring some strong southeast winds to most of the British Columbia coast on Monday. Winds are expected to reach up to 90 km/h off the Central Coast by around noon on Monday. The wind warning may need to be extended to North Vancouver Island and to parts of the Inner South coast as well.



LARS SUNDSTRÖM

METEOROLOGICAL AND HYDROLOGICAL SERVICES IN SUPPORT OF DECISION-MAKING

The NMHSs have a responsibility to deliver weather and climate related services to the public and all socio-economic sectors of a country for the protection of the public from impacts of hazardous weather events as well as for the application of weather and climate as a resource for creation of wealth and for personal comfort and convenience. This task is carried out within their PWS programmes. The key sectors served by NMHSs include: health, agriculture, water resources, disaster management, transport, energy production, tourism, environmental conservation and construction. In all these sectors, PWS contribute to decision-making in matters related to weather and climate.

Mainstreaming of weather and climate information into the decision-making processes of various sectors is of paramount importance if climate variability and change issues are to be taken on board for long-term planning. The PWS programmes of NMHSs are normally responsible for guiding the process of collaboration with users and ensuring that their needs are met and that weather forecasts and climate outlooks are readily included into relevant decision-making processes.

The mere availability of weather and climate information does not guarantee that societies will be able to respond proactively to risks. To benefit societies better, weather and climate forecasts are normally supported by resources that enable sound decision-making for an adequate response. They are also tied in with existing socio-economic settings and institutional policy contexts.

In many sectors of our society decision-making is enhanced by quantified and specifically tailored climate services. Often these applications require the development of special information that recognizes critical times in the user's activity cycle or critical values of the climate variables. For example, the performance of power stations is improved when the management of generating capacity takes into account the weather sensitivity of the community power usage. Decisions made regarding the cost of power generation against the demand for power include incorporating temperature forecasts into a complex power station management decision model.

Evidence of a warming trend in the last 100 years shows the climate is changing. So, the premise that "the past is the key to the future" is no longer adequate. In recent years it has become clear that what will happen in the future is not necessarily limited to what has happened in the past. Given the uncertainties inherent in forecasting how various extremes may change in the future, any advice must address the nature of risk, and the probabilities of certain extremes occurring.

It may be relatively straightforward to give advice on harbour installations or sea-wall defences in connection with the likely sea-level rise over the next 100 years.

The real issue here is, given the range of possible figures for the rise by 2100, what is the right level of investment to provide a reasonable level of protection for the lifetime of the project? By comparison, providing figures, which can be used to make decisions about whether offshore installations should be designed to withstand more severe storms and bigger waves in the future, requires judicious use of the output of global climate models, which have been developed to predict the likely scale of regional climate change during the 21st century.

HEALTH

There are close links between human health and weather and climate. In recent years much effort has gone into incorporating these links into PWS. Services include identifying the health risks associated with predicted excess rainfall, cold spells or heatwaves. They also include warnings about the hazards that come with certain environmental conditions (e.g. poor air quality and high ultraviolet levels), high pollen levels at certain times of the year and the multiplication of parasites that cause disease such as malaria.

Malaria

Of all the climate-related health hazards in tropical and sub-tropical developing countries, malaria is by far the most damaging. Globally, malaria causes in the order of 1.3 million deaths annually. Approximately 90 per cent of these deaths occur in sub-Saharan Africa (WHO, 2004).

Regional climate influences both the development of the malaria parasite and the behaviour of the carrier mosquito. Climatic variability from year to year is particularly important. The incidence of the disease is affected by periods of drought or heavy rainfall. Transmission often ceases when there is a drought (because of a lack of mosquito breeding sites), so immunity in the human population drops. When the rains return, carrier mosquitoes appear in large numbers and transmission increases. As population immunity is low, this can lead to rapid transmission, and high rates of illness and death. So, understanding the causes of variability in seasonal rainfall throughout the tropics is an essential part of responding to the scourge of malaria.

Climate influences both the development of the malaria parasite and the behaviour of the carrier mosquito.

Climate prediction models have recently enabled research scientists to provide more accurate forecasts of when and where outbreaks of malaria are likely to occur. Central to these forecasts is a better understanding of ENSO and how it interacts with SST patterns in the Indian and Atlantic oceans. The NMHSs are working closely together with WMO, the World Health Organization (WHO), health services and international research and service organizations to develop a multi-hazard early warning and response system in West Africa. Parallel work involving the 14 countries of the Southern African Development Community (SADC) within the Malaria Outlook Forum aims to develop a system to fight malaria in southern Africa.

Heatwaves

A heatwave is not easy to define in precise terms. What constitutes a heatwave in London or Stockholm is mild in St Louis or Sydney, and is distinctly cool in New Delhi or Riyadh. So, although heatwaves will almost inevitably involve maximum temperatures well above 30°C the important aspect of any definition is to emphasise how much above normal the temperature is and for how long. It is only after several days of exceptional warmth that the heat has the greatest impact on people. Furthermore, the impact is heightened by relatively high humidity levels, which increase discomfort and keep temperatures high at night. Conversely, discomfort is somewhat alleviated by dry atmospheric conditions with radiative cooling overnight.

Part of the problem with defining the danger of heatwaves is that humans are capable of adapting remarkably well to hot conditions. Even people who

CHRIS BESSLER

Children seek relief from unusually high temperatures on a summer day.

EUROPEAN HEATWAVE IN 2003

Just how dangerous severe heatwaves can be was seen in Europe in the summer of 2003. Many places had record-breaking temperatures that were around 10–15°C above average. In Rome the temperature maxima exceeded 35°C for 42 days during June to August. Night time minima were also exceptionally high. Perhaps the most dramatic measure of the exceptional nature of the summer emerged from an analysis of the Burgundy Pinot Noir wine harvest extending back to the 14th century. The analysis concluded that the summer of 2003 was an unprecedented event. It was nearly 6°C warmer than the average for the period 1960–89, whereas the next highest anomaly during the whole period was just over 4°C in 1523 (Chuine *et al.*, 2004).

Over 52,000 Europeans died from heat in the summer of 2003, making the series of heatwaves one of the deadliest climate-related disasters in Western history (Larsen, 2006; Schoer and Jendritzky, 2004).

have lived all their lives in temperate regions can largely acclimatize to tropical conditions within a week or two. So it is the sudden increase in temperature that matters most. For instance, in the USA, the most vulnerable cities for heat-related mortality are in the north-eastern quadrant of the country, whereas southern cities are far less sensitive. This suggests that the population of these more southern cities are better acclimatized to hot weather. Moreover, it is usually the most vulnerable members of the population—the poor and the elderly—who suffer in heatwaves, as their homes or apartments not only often lack air conditioning or other cooling devices, but often are constructed such that heat is retained and the buildings get hotter and hotter.

In India, heatwaves are most likely to occur in the dry season before the monsoon (March to July), with over half of them occurring in June. A severe heatwave in India is defined as when the prevailing maximum temperature remains 7°C or more above the long-term normal for the location, where the normal maximum temperature is less than 40°C. But, where the normal maximum is greater than 40°C,

SUNBURN AND ULTRAVIOLET (UV) RADIATION

Hot summer weather increases exposure to ultraviolet (UV) radiation. Voluntary exposure through sunbathing or involuntary exposure both involve health hazards. These include sunburn, the increased risk of skin cancer and eye cataracts. The monitoring of UV levels and the incorporation of the measurements into a simplified UV-index can alert people to protect themselves during critical periods of elevated UV intensity by avoiding outdoor activities, wearing protective clothing and using chemical sunblocks. In Europe, the simple index ranges from 0 or 1 (low) in winter to 5 to 7 (high) in summer at high latitudes, whereas in the southernmost parts of the continent the figure can be a high as 9 to 11 (very high to extreme). In addition extreme levels can be experienced high in the mountains in spring and summer, which means that mountaineers and skiers need to take particular measures to protect exposed skin with sunblock creams.

NWS, NOAA

A UV index map.

a severe heatwave is declared when the prevailing temperature is 5°C above the normal, because at 45°C everybody suffers from heat. But, as in the USA, the impact of heatwaves is not as serious in the hottest parts of the country (e.g. Rajasthan) as the less hot areas (e.g. Orissa, West Bengal and Bihar).

These events have increased the awareness in NMHSs that the links between human health and weather and climate should be incorporated in weather forecasts and warnings. They also resulted in increased sensitivity and lead to new products and services and better-heeded warnings. In terms of summer heat, a wide variety of thermal indices have been developed to reflect the fact that comfort levels are defined principally by the temperature and humidity of the air, although wind speed and exposure to sunshine can alter comfort levels appreciably. These indices usually consist of some form of effective temperature, which has a set of defined levels at which an increasing proportion of people feel discomfort. These increasing levels are found to tally closely with increased mortality during heatwaves. The use of a heat index is a common feature of day-to-day forecasts and the numbers are widely recognized by the public as being a useful measure of how hot it feels outdoors.

Cold spells

Mortality figures for countries in the temperate latitudes, especially in the northern hemisphere, show a dramatic rise in every winter. The largest rises in

JAN ZABRODA

The combination of cold and wind result in human discomfort or even injury.

cold-related mortality are not in the coldest countries, but in those that are relatively mild but have occasional cold spells. For example, in Europe the highest proportion of winter deaths are in Ireland and Portugal, while the lowest figures are in colder countries such as Norway and Finland. Approximately half of excess winter deaths are due to a complication termed coronary thrombosis. Mortality is highest around two days after the peak of a cold spell. The rise in coronary deaths is due mainly to the thickening of the blood during exposure to the cold; some coronary deaths are secondary to respiratory disease. About half the remaining winter deaths are caused by respiratory diseases, and this figure peaks around two days after the peak of a cold spell but the health effects may continue beyond this for seven to ten days. In the UK, it is estimated that cold spells account for between 20,000 to 50,000 excess deaths a year (Keatinge *et al.*, 1997).

By comparison, in the UK, hot spells in summer account for around 1000 deaths a year.

Air quality

Another aspect of abnormal spells of weather is a decline in air quality. This is principally an urban problem, but can extend to rural areas. Timely forecasts and advisories from NMHSs assist the public in coping with the dangers of ground-level ozone, sulphur dioxide, nitrous oxide and particulate matter.

Air quality advisories issued when predetermined pollutant thresholds are exceeded enables authorities to take action to reduce pollution levels and encourage people to avoid polluted areas, thereby alleviating the adverse effect on health. This can involve asking people to use public transportation, staggering work hours or even staying indoors. Industry and regulatory agencies may decide on the temporary shutdown of polluting factories, thermal power plants, banning some categories of vehicles from urban centres and closing government offices.

WIND CHILL

The cooling effect of low temperatures on exposed skin increases sharply with rising wind speeds. This can be reflected in the use of the concept of wind chill, which is usually expressed in terms of an effective temperature. Although a wind chill index is expressed as a temperature, it is not a temperature: it is an expression of a human sensation. The index likens the way the human skin feels to the temperature on a calm day. For example, if the outside temperature is -10°C and the wind chill figure is -20, it means that the exposed face will feel as cold as it would on a calm day when the temperature is -20°C. In addition, it is possible to provide a measure of the risk of exposed skin suffering frostbite within a given number of minutes. Armed with these figures, NMHSs are able to issue warnings about the risks of suffering discomfort or even injury when the combination of cold and wind is potentially dangerous.

In many countries longer-term action over the last 50 years has had a significant impact on urban air pollution. The "Great Smog" in December 1952 in London, caused by smoke pollution from industrial and domestic smokestacks and chimneys, was responsible for at least 4000 deaths, and led the UK Government to pass the Clean Air Act in 1956. The transformation was dramatic. By the 1970s winter sunshine levels had nearly doubled, and the incidence of fog in the city, which had been much higher, dropped below that of the surrounding countryside (WMO, 2003, p. 146).

Example of an air quality summary for Greater London:

Forecast valid until 08:00 to 15:00 on 20/12/2006

In towns and cities near busier roads

Currently: **LOW**

1 2 3

Forecast: **MODERATE**

1 2 3 4

Elsewhere in towns and cities

Currently: **LOW**

1 2 3

Forecast: **LOW**

1 2 3

A similar story emerged in Los Angeles where the cause of pollution was vehicle emissions. A combination of climate and geography means that for much of the year pollutants are trapped in the Los Angeles basin by stable air as a result of a temperature inversion in the lower layers of the atmosphere. (A temperature inversion occurs when a relatively warm layer of air is present in the atmosphere, breaking the continuous gradual reduction of temperature with gradually increasing height). Combined with high UV levels in the frequent sunny conditions, the region was an ideal place to generate photochemical smog. Since the 1970s, when federal legislation was introduced requiring cars sold in the US to meet increasingly strict emission standards, the change has been dramatic. In the Los Angeles basin the number of days when the ozone level exceeded the federal one-hour standard fell from nearly 200 in the late 1970s to 41 in 1999. Other measures of unhealthy levels of air pollution showed equally striking falls during the same period.

GERLA BRAKKEE

Decline in air quality is principally an urban problem but can extend to rural areas.

Agriculture

The PWS facilitate provision of useful guidance to agricultural communities by informing them of expected weather conditions in time for them to schedule farming and animal husbandry operations. These include:

- Planting: Information on expected dates of onset of rainfall, expected rainfall amounts, field drying potential and soil temperatures;
- Scheduling irrigation: Information on Potential Evapotranspiration (PET), (a measure of the ability of the atmosphere to remove water from plants and soils through the processes of evaporation and transpiration), past rainfall, probability of precipitation (PoP) maps and forecasts of rainfall amounts;
- Application of pesticides: Data on wind speed and direction are needed for deciding on the best times for the application of pesticides especially when using aircraft. This is useful in the prevention of many plant diseases including potato blight, wheat rust, and coffee berry disease;
- Monitoring crop development and scheduling field work: This is done through the computation of degree days, agricultural weather forecasts, chilling hours, etc.;
- Harvesting: Rainfall forecasts are used in the preparation of harvest guides for crops such as cotton, maize and peanuts, for use especially in mechanized agriculture;
- Managing animals: Forecasts of heat and cold conditions are useful in protecting livestock from heat and cold stress; and

AIR POLLUTION PROBLEMS AND ECONOMIC DEVELOPMENT

In many parts of the world, where economies are booming, the major cities are facing increasing problems with air pollution. The historical evidence from the developed world is that this is a feature of rapid growth and as economic structures mature, air quality improves dramatically. As a general rule, developing countries have been able to draw on past experiences of developed countries to avoid the worst extremes of air pollution that were experienced in the early stages of the industrialization of the developed world. Nevertheless, the WHO estimates that the excess mortality worldwide attributable to air pollution could be as high as 800,000 people each year (Cohen *et al.*, 2005). Combined outdoor and indoor pollution has been estimated to cause excess deaths in the order of 2 million per year worldwide.

Around the world, local authorities have used a wide variety of strategies to modify public behaviour and reduce the impact of air pollution episodes. Because of improved weather forecasting methods and better predictions of likely pollution levels a few days ahead, it is possible to anticipate the worst conditions and take action. Some cities, including Athens, Paris and Singapore, have used various forms of traffic control such as only letting cars with odd and even licence plates have access to city centres on alternate days during emergency situations. Clearly, strategies that work need to be extended to developing countries.

ALFRED SCHWARZ (IRD)

Information about expected weather conditions is necessary for all stages of farming operations.

- Seasonal rainfall forecasts: These forecasts carry information for a cross-section of crops in different zones of a country during a rainy growing season.

Forestry

The NMHSs serve forestry and animal park departments by providing information on the likelihood of forest fires. This entails forecasting on temperature, humidity, rainfall and wind during the fire season.

Another service that some NMHSs provide is the forecasting of calm conditions for aerial spraying to control insect pests.

ENERGY PRODUCTION

The energy sector covers a wide range of activities, from energy resources exploration, extraction, storage and transport, to electricity production, transport and distribution. Optimal and cost effective management of the energy sector is crucial for nations and the world's economy and development.

Over the next 30 years, global electricity demand is expected to double and the global demand for energy, including non-renewable energy, to expand by about 60 per cent, with two-thirds of this increase in the developing world, particularly India and China.

The energy sector depends highly on climate conditions and water resources. Moreover, the rising use of renewable energy in the future, desirable to mitigate climate change effects, will make energy production and distribution more and more dependent on climate conditions (Dubus, 2006).

Weather, climate and water information are very important in short- and medium-term energy management processes. Extreme events such as heat or cold waves, wind storms or floods can have severe impacts on production means and electrical grids.

But “normal” day-to-day weather variations also have impacts on load level, production capacity, transport and distribution. For example, a -1°C extra temperature anomaly in winter in France corresponds to an extra production of 1400 MW, the capacity of one nuclear reactor or that of about 1500 windmills. In the USA, electricity generators save US$ 166 million annually using 24-hour temperature forecasts to improve the mix of generating units that are available to meet electricity demand.

In developing countries, the vital issues are energy access and reliability, with efficient energy management being a secondary issue. Many of these countries are located in areas where climate variability and risks are important, and weather, climate and water information therefore are, and will continue to be, crucial for the development and safety of their energy systems. The main concern for NMHSs is first to provide databases that could help in siting future grids and electric energy production units (especially those based on renewable sources). The second issue is to provide services for the short- to medium-term management of the energy systems, and warnings to minimize the impacts of hazardous weather events.

In developed countries, the energy sector is already one of the most important users of observation products and weather forecasts. The main concern in the next few years is to promote a better and shared use of existing data and forecast information, and to prepare the industry to use the new products that will be available in the coming decade. These will include improved short- to medium-term weather predictions (notably ensemble predictions) and atmospheric environment monitoring products.

Optimize information delivery to users

Due to the high complexity of energy systems management, it is important that energy companies and NMHSs collaborate closely in an interactive mode. The level of weather, climate and water information that is needed in the energy sector can be high, and requires a mastery of complex information such as ensemble forecasting. Personnel in the energy sector may not have the necessary level of skill in this field and it is therefore desirable to have an intermediate between the users and NMHSs, be it a specific service of the energy company, or of the NMHS.

Regular training and information for users is also important, to ensure an up-to-date knowledge of products and services, and identify potential future developments of interest to the sector. A provider/user coordination team should be formally established, and regular meetings with feedback and event review mechanisms planned, in order to maintain good communication.

TRANSPORT

There are two groups served by the PWS within the transport sector. The first group is the general public. This group gets weather information from the media (television, radio, print, the Internet) to plan their journeys, avoid hazardous weather and to decide on the


HELMUT GEVERT

Public Weather Services provide vital forecasts and warnings for hazardous conditions on roads.

Extract of a real-time road and weather traveller information, Colorado, USA

Report last updated Dec 21, 2006 06:43:54 AM

HIGHWAY	CITY/AREA	CONDITIONS	COMMENTS
I-70	Denver	(snow)(icy)(snow-packed)	Restricted Denver metro area interstates and freeways Chains all commercial vehicles, including buses, vans 16+ capacity.
I-70	Mt Vernon Canyon	(snow)(icy)(snow-packed)	Restricted Mt. Vernon Canyon/Floyd Hill, MM 258-244
I-70	Idaho Springs	(snow)(icy)(snow-packed)	
I-70	Georgetown	(snow)(icy)(snow-packed)	
US 6	Loveland Pass	(Blowing snow) (snow)(icy)(snow-packed)	Restricted CLOSED. Adverse conditions
US 40	Berthoud Pass	(Blowing snow) (snow)(icy)(snow-packed)	Restricted CLOSED. Adverse conditions

Updates were last made to this report on 12/21/2006 06:43:54 AM. Information will be posted as it becomes available.
Current forecast: Blizzard warning east until noon Thursday. Snow, blowing snow, wind gusts to 45 MPH. Mostly cloudy in the mountains with isolated snow. Highs in the 20s and 30s degrees Fahrenheit.

mode of transport. The second group is composed of transport providers. They require information to plan operations, draw up schedules and organize backup plans. These include the aviation industry, marine transport, rail and road transport systems.

WATER RESOURCES

The provision of weather forecasts by the PWS that cover relevant aspects of the management of water resources is vital to all societies around the world.

These services range from the immediate needs of people for safe drinking water, through irrigation for agricultural production, inland water transport and cooling for power stations. Longer-term planning of water resources requires climatological information for the building of dams, bridges, aqueducts, wells, pumps, runways, water and sewage plants, drainage works and recreational facilities, which are designed on the basis of a region's climate.

Once built, the efficient operation of water supplies relies on up-to-date information on temperature, precipitation, humidity and wind speeds, and forecasts of these variables. Accurate predictions of periods of extreme weather, both drought and flooding, are vital to ensure that adequate emergency plans are developed and put into effect in good time when disaster threatens. These range from operation and maintenance of water supplies during floods and droughts to the safety of lives and property in areas at risk of inundation.

MARINE SERVICES

Apart from providing tailored forecasts for ocean-going vessels, the NMHSs provide marine information for other marine activities by the public. The forecasts include information on gale and strong wind warnings, the general situation, wind speed and direction, probability and strength of gusts, developing weather conditions, visibility and sea state. This service enhances safety and convenience for the public engaged in near-shore recreational or economic activities such as fishing.

TOURISM, RECREATION AND SPORTS

Risks associated with weather and climate conditions may seriously impact the financial situation and viability of businesses in the tourism, recreation and sports sectors. For example, the impact of adverse weather conditions on the tourism industry ranges from a reduction in visitor numbers to property damage and putting lives at risk, which result in varying degrees of revenue loss, claims for compensation, damage repair costs and possible exposure to litigation.

The NMHS programmes delivering weather and climate information may partner with destination planners, resort developers and tourism business managers in developing weather and climate information tools for use in planning activities such as hang-gliding, hot-air ballooning, camping, game drives, skiing, sea surfing and golfing.

This involves the incorporation of weather information such as temperature, rainfall, humidity, wind speed and direction, snow, etc., into planning events. Likewise, climatological information may be used in developing tools for risk mitigation and management, vulnerability assessment, and emergency preparedness.


MARCUS ÖSTERBERG

Weather information is very important to businesses in the tourism, recreation and sports sectors.

CONSTRUCTION

Bad weather can complicate outdoor building projects while severe weather can make roofing, paving or planting projects difficult and dangerous, and can cost a construction company time and money. NMHSs support construction activities through the provision of comprehensive weather information necessary for planning and knowing when to pull crews away from hazardous weather. This involves the use of radar data for pinpointing the construction location under threat with sufficient accuracy. Forecasts include thunderstorms, likelihood of lightning strikes, hail, destructive winds, tornadoes, heavy snow fall, flooding etc.


JOZEPH KLINGER

Forecasts for thunderstorms, likelihood of lightning strikes, hail, destructive winds, tornadoes, heavy snowfall and flooding are applied in reducing risk in the construction industry.

SERVICES ADDRESSING CLIMATE CHANGE

Projections of global warming for the 21st century bring in a new dimension to the role of the NMHSs, in terms of the need to provide services that inform about the consequences of shifting weather patterns. Analyses of climate data collected by the NMHSs show the changes that have already occurred during the 20th century, and also provide a clear indication of how things may change in the future. With mounting evidence of impending changes in various aspects of the climate, it is imperative that the users of climate services obtain help to understand and anticipate the future.

Detailed climatic studies have concluded that there was a significant warming throughout the 20th century, especially since the 1970s.

The most significant temperature changes have been the decline in frequency of frost days (days with a minimum temperature less than 0°C), the lengthening of the growing season in the extra-tropics, decrease of the intra-annual temperature range, and an increase in the incidence of warmer night-time temperatures. The annual occurrence of cold spells significantly decreased while the annual occurrence of warm spells significantly increased. The trend in warm spells is, however, greater in magnitude and is related to a dramatic rise since the early 1990s. As far as rainfall is concerned, there has been a significant increase in particularly wet days and periods of wet weather, and a decline in dry periods. Nevertheless, droughts have increased, which is consistent with the accelerated water cycle in a warmer world. More importantly, there has been less rainfall between 10–30°N latitudes since around 1970.

Some NMHSs are actively involved in the worldwide efforts to understand past climate change and predict changes in the 21st century. Under the auspices of the UN (supported by WMO and

PATRICK SWAN

Reduction of snow and glaciers on mountains, as a result of climate change, could negatively impact river water volumes and the tourism industry.

CLIMATE CHANGE

According to the Intergovernmental Panel on Climate Change (IPCC), global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those in methane and nitrous oxide are primarily due to agriculture.

As a result, most of the observed increase in global average temperatures since the mid-twentieth century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations. Discernible human influences now extend to other aspects of climate, including ocean warming, continental average temperatures, temperature extremes and wind patterns. (IPCC, 2007).

UNEP), since 1990, the Intergovernmental Panel on Climate Change (IPCC) has produced a series of major assessment reports. The NMHSs, together with other scientific and commercial organizations, have played a central role in the providing scientific advice to the IPCC and in the production of the reports. In addition, they have had responsibilities for briefing national governments for negotiations on international agreements on action to reduce the impact of human activities on the climate. The NMHSs also have a significant role in the preparation of "National Communications" to the United Nations Framework Convention on Climate Change (UNFCCC), in terms of vulnerability assessments of regional aspects of climate change. Much of this scientific expertise has been built through international collaboration on meteorological matters.

A central pillar of climate change assessment is numerical modelling of the global climate. Climate models work on the same principles as are used for weather forecasting. To include all aspects of the climate system, however, they must contain more complicated representations of the atmosphere, oceans, the cryosphere (portions of the earth's surface where water is in a solid form including sea ice, lake ice and frozen ground), the biosphere and the properties of the land. When simulating the general

CONSEQUENCES OF RISING SEA LEVELS

One of the most immediate challenges of global climate change is the expected rise in sea level. If global temperatures continue to rise as predicted, sea levels are expected to rise.

There is debate within the meteorological community as to whether global warming will lead to more intense hurricanes in the future. This stems from the interpretation of the consequences of the tropical oceans becoming warmer in the next century. Whatever the true nature of future trends in tropical cyclones, governments will still have to make difficult decisions about investments in defences to enable people to live in attractive, but inherently risky places.

Rising sea levels have a much more profound impact on low-lying developing countries (e.g. Bangladesh, the Maldives and many islands in the tropical Pacific, where much of the land is less than a metre above normal high-water level). Where these countries are vulnerable to tropical cyclones, the prospects are catastrophic and may lead to some areas becoming uninhabitable during the 21st century.

PHOTODISC

behaviour of the climate system over decades and centuries, it is essential to use models that represent the physical coupling of all the components of the climate. These are usually known as coupled general circulation models (CGCMs).

The output of these models can explore many aspects of the climate, the presentation of which pose formidable challenges for NMHSs in providing guidance on what predicted climate change means on a regional and local level. Because there are considerable differences in the predictions made by the various models, this will require developing an expertise in reconciling the differences between the models and their implications for national policy decisions. Combined with the fact that these decisions on how to minimize and alleviate climate change are rising up the political agenda, the NMHSs will need to make an increasing contribution in assisting the political debate about climate change.

Climate change and developing countries

The impacts of climate change are not evenly distributed—the poorest countries and people will suffer earliest and most. And if and when the damages appear it will be too late to reverse the process. Thus we are forced to look a long way ahead. Many developing countries are already struggling to cope with their current climate.

Global average surface warming following a doubling of carbon dioxide concentrations is likely to be in the range 2°C to 4.5°C with a best estimate of about 3°C, and is very unlikely to be less than 1.5°C. Values substantially higher than 4.5°C cannot be excluded, but agreement of models with observations is not as good for those values, (IPCC 2007).

The most damaging change has been the decline in rainfall in the latitude zone 10 to 30°N, notably in sub-Saharan Africa (Morel, 1992). In addition, more generally for Africa south of the Sahara, there have been significant increases in dry spell length, average rainfall intensity and annual one-day maximum rainfall, which produce the contradictory results of both more droughts and more floods. Additionally, the effect of rainfall becoming more variable, especially from year to year, could also lead to worse malaria epidemics in rainy years.

The consequences of these trends would, if continued, spell disaster for many of the poor countries. The latest CGCMs predict, however, that during the 21st century the South Asian monsoon will strengthen and move northwards. Over Africa, the monsoon would strengthen and move north with an increase in rainfall in the tropics and a decrease in the subtropics. This could lead to a northward movement of the Sahara and the Sahel. As for changes in variability, the models do not provide any clear message.

Disseminating weather forecasts and warnings to the general public and to specialized users

PHOTODISC

DISSEMINATION OF WEATHER FORECASTS

PACKAGING OF WEATHER PRODUCTS

National public weather services programmes and activities are at the forefront in using the latest technological tools and methods of packaging weather forecasts and warnings for different users. In so doing, they aim to present weather information in the most informative, educational, attractive and entertaining format in order to impart information and motivate users to recognize the value of the service.

Resources available to a particular NMHS dictate, to a large degree, the level of sophistication of technological application for packaging of weather information. However, in both developed and developing countries, technology is advancing and becoming more affordable and accessible. Constantly improving science and technology enables the realization of better products and the ability to offer them to more and more users.

In order to assist NMHSs to have the necessary knowledge base for keeping up with scientific, technological and methodological advances in this area, WMO works closely with experts to produce guidance materials on different aspects of PWS for use by NMHSs. Additionally WMO equips NMHSs with the necessary skills through holding of training seminars and workshops for PWS practitioners.

DISSEMINATION MEDIA

Dissemination of weather forecasts and warnings to the general public and to specialized users is a primary function of an NMHS. To be effective, this function has to be done efficiently since weather forecasts and warnings are highly perishable products which have to be disseminated to the intended user in an understandable form and in time for their application. An excellent forecast that reaches a user late or in a format or language the user cannot understand serves no useful purpose. The task of effecting dissemination is normally handled by the PWS programme of an NMHS.

In order to carry out this function effectively, the staff responsible for service delivery need to be equipped with skills not normally associated with mainstream functions of an NMHS. They have to be well trained in aspects of weather packaging for presentation in various types of media, including radio, television, print and the Internet, and in the actual dissemination itself. They have to make the weather product not only understandable, but also attractive so as to encourage user uptake. This requires the staff to have effective communication skills, which they gain through specialized training. They are skilled in interacting with and rendering services to the media—writing press releases, holding press interviews, press conferences, press briefings, etc. Hence, in pursuit of excellence in dissemination of weather forecasts and warnings, the NMHSs train some meteorologists in broadcasting skills, now known as broadcast meteorologists.

Radio

Radio is a common and very effective means of disseminating weather forecasts and warnings, not only for daily weather forecasts for public convenience and comfort, but also as a handy mass medium in the event of severe weather disasters. Most radio stations, including commercial FM stations, have a weather segment while some stations include weather forecasts in their news programmes and some even schedule comprehensive weather programmes. Some NMHSs operate a weather radio that provides continuous 24-hour broadcasts while others have found it a useful tool for reaching rural communities, in local languages using a radio and Internet system called the RANET system.

THE RANET INITIATIVE FOR DISSEMINATION OF WEATHER AND CLIMATE INFORMATION TO RURAL COMMUNITIES

One of the challenges faced by NMHSs is to ensure that PWS products, such as weather warnings and forecasts, reach all the intended users in a timely manner and in formats they readily understand. The challenge is even greater when the targeted users are communities living in remote rural areas with limited resources and having no such amenities as main-grid electricity supply or even radio or television broadcasts that address their social needs.

In response to this challenge the African Centre of Meteorological Applications for Development (ACMAD), in collaboration with the University of Oklahoma (USA), NOAA, the WorldSpace Foundation and some NMHSs established an innovative and cost-effective methodology known as the RANET (RAdio and InterNET) initiative. Through the RANET initiative, digital radio technology, the Internet, community radio stations, wind-up radio receivers and solar power technology are combined to produce systems allowing communities living in remote rural areas to receive regular weather and climate information. Information is received in a format similar to Internet websites or via radios from community radio stations run independently or in collaboration with NMHSs and broadcasting in the appropriate local languages.

RANET has been established in some countries in Africa and also in the Pacific.

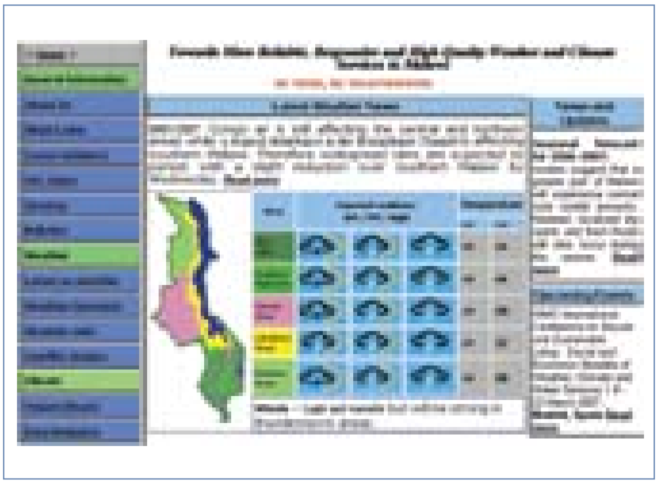

RANET-KENYA

Television

Television, as a medium for dissemination of weather information, is very popular because it is a versatile tool for entertaining, educating and informing viewers. Its extensive graphics capabilities and powerful visual impact is very adaptable to weather presentation, enabling viewers to directly align their outdoor activities to the expected weather and to assess the severity of any imminent high impact weather events. Many television stations carry weather forecasts and related information as part of their news programmes and several have meteorologists broadcasting regularly scheduled weathercasts. A few countries also have 24-hour weather channels that are quite successful and attract large viewing audiences. In some

ZDF GERMANY

The combined ability to use graphics and sound has made television a versatile and popular tool for weather presentation.



WWW.METMALAWI.COM

The Internet is providing increasingly easy access to weather forecasts and information.

developing countries, NMHSs have set up weather television studios within their services from where weather presentations are recorded and provided to television stations for airing. This allows a lot of flexibility in the way an NMHS wishes to package weather information and it has proven very popular.

National and international television weather broadcasts cover large geographical areas, but the broader the area, the more forecasts become generalized. However, international television broadcasts provide a useful service to vacationers, travellers and even local populations because they are widely available in hotels and on cable television channels.

The use of television crawlers across the top or bottom of the screen is an effective way of capturing viewer attention regarding severe weather information, without interrupting regular programming.

The Internet

The NMHSs use the Internet as a dissemination medium for weather forecasts. This is a versatile dissemination tool in that a meteorological service can display large amounts of information which can be easily updated. The information may include raw data, forecasts and warnings, satellite and radar pictures and educational information. The Internet allows an NMHS to display its information in an attractive format including highly visual graphics and animation, which attract users and motivate them to consult it regularly. Where required, information is targeted to specific or specialized users who request specific forecasts by using a password.

Video-streaming

Some NMHSs use the Internet to transmit information on video. The content normally comprises forecasts prepared for television, which are made available on the Internet following TV transmission, allowing the public to access the information at their convenience.

Newspapers

Newspapers provide routine weather forecasts and information through the use of text and graphics.

KAY PAT

Newspapers are most suited to more detailed description of weather conditions or weather stories aimed at educating the public.

They are very useful in disseminating long-range forecasts and climate outlooks. Newspapers also play an important role in public education of more complicated concepts, such as explaining probability forecasts, the El Niño phenomenon and topical issues including climate variability and change. They are, however, less useful for the short-lived, fast-breaking weather events such as flash floods, tornadoes and severe thunderstorms. Many newspapers are available online and provide a wider range of products, sometimes with very high quality graphics.

Some NMHSs produce ready-to-print weather pages for newspapers, sometimes even paying for space to ensure that important forecasts such as seasonal climate outlooks, explanations and associated advisories have sufficient space for the benefit of the public.

Telephone

In some NMHSs, the public can call and speak directly to staff but this may result in overloading of service lines at critical times. Restricted-use, unlisted, hotline numbers are normally available which permit urgent communication between the NMHS and government authorities and emergency management to take place. Additionally, weather messages recorded on automatic telephone answering devices are effective in reducing the number of telephone calls to office personnel. This service is very popular and in some countries access attracts a fee.

Mobile and wireless

The telephone paging system is another method that enables quick, simple messages or alarms about time-critical weather information, to be sent to a

BILL DAVENPORT

Mobile phones provide weather information when and where it is most needed.

list of individuals including emergency managers. Weather information can also be accessed through arrangements between NMHSs and mobile telephone providers who disseminate it to individuals who subscribe to the service. This may take the form of Wireless Application Protocol (WAP), which is a standard means of transmitting interactive content over mobile phone networks. The subscriber receives web pages on their mobile. Short Messaging System (SMS) is also another popular way of receiving weather information.

Bulletins and newsletters

The NMHSs use bulletins and newsletters to provide non-real-time information such as weather summaries, rainfall amounts and distribution, temperature values, hydrological and agrometeorological data and so on. Such media are useful for featuring interesting research findings and upcoming events. The design and printing is usually done in-house by PWS and may also be hosted on the NMHS's website.

Press conferences and briefings

The NMHSs use press conferences or briefings to obtain wide coverage of important events, such as high impact weather ranging from expected droughts to flood forecasts. In some regions, where climate outlook events involving many countries are held, press conferences and briefings are particularly useful in getting wide publicity for the agreed climate prediction, known as the climate outlook statement.

ICPAC, NAIROBI

A health expert briefing the press on the implications of the regional consensus climate outlook on malaria epidemics in the GHA subregion.

Press conferences are effective in that they ensure that NMHSs do not get overwhelmed by requests for information from the media, during severe weather.

Building public weather services

ANATOLI STYF

BUILDING PARTNERSHIPS

WMO has, over the years, encouraged partnership building between NMHSs and users of their services for effective delivery of service. In so doing, one of the major activities of WMO is to promote training in aspects of partnership development with key users. This strategy has proved beneficial to the development of public weather services.

PARTNERSHIP WITH PUBLIC AND USERS

Successful response to warnings is most likely to occur when the people receiving the warning messages have been educated about the particular characteristics of the hazard. If they are familiar with the likely extent of damage that could result and have personalized appreciation of the risk, they are more willing to take protective action. The willingness and ability of the population to respond effectively to warnings is largely dependent on how successful public education campaigns have been and how well the people receiving the warnings are prepared. In order to effectively serve the users, NMHSs normally seek to develop partnerships with users such as people in farming, fishing, energy supply, transport, building and construction and recreational activities. These partnerships sometimes involve drawing up a memorandum of understanding, which becomes the instrument to guide the way the different organizations will relate with the NMHS.

Building partnerships with the user commity is essential for effective service provision and delivery.

The other important community is the natural hazards community—people involved in managing, mitigating and handling hazards (e.g. media, governmental bodies, emergency managers and non-governmental and volunteer organizations). An effective partnership requires a number of tasks to have been achieved:

- The role of the NMHS, during a hazardous weather occurrence, to have been clearly defined;
- Members of the natural hazards community to have gained a healthy understanding of the meaning of weather watches, alerts and warnings; and
- Contingency measures defining actions to take while under the threat of high impact weather, such as the evacuation of communities, to have been agreed upon.

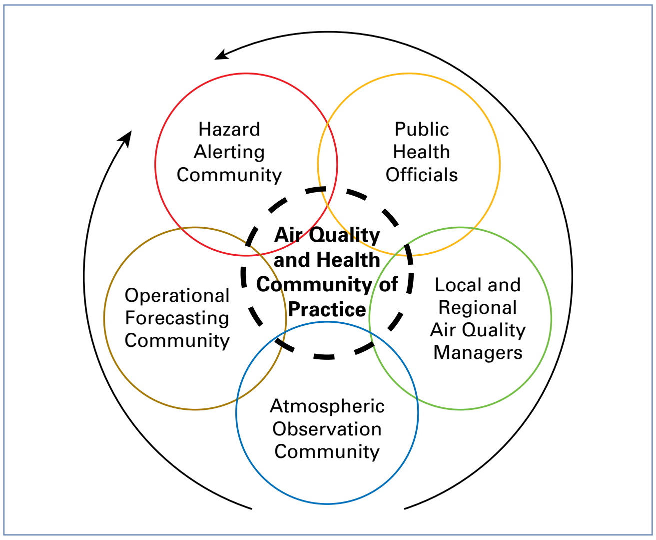
Partnership with the media

In order to reach the public, NMHSs have to use the mass media. It is imperative, therefore, that a healthy and operational collaborative relationship with the media exists. On the one hand, the media need weather information from the NMHSs. On the other hand, the NMHSs need to use the media to pass information to the public. Hence the media may be viewed as both a client and a partner of an NMHS.

The NMHSs encourage and cultivate close working relationships with the media during periods of "normal" weather. This is so that during periods of severe or emergency weather there is a close and effective understanding thus ensuring that the public are kept correctly informed. Good relations with the media result in more accurate stories on weather and climate in the media, which contribute to the education of the general public. This is achieved through maintaining good contacts with science journalists.

In order to effect a sustainable and healthy cooperation with the media, some NMHSs have formed media networks to enhance their interactions. Network activities include holding workshops at which journalists learn the terminology and formats of weather forecasts, climate outlooks and warnings, especially focussing on the aspect of reporting uncertainty. This helps to clarify concepts such as deterministic as opposed to probabilistic forecasts, which require great care in translating into everyday language. To aid more accurate reporting, they also seek to impart an understanding of the concepts behind the processes that drive weather and climate.

Within such a partnership, NMHS staff get to learn how to originate press releases and information notes for use by journalists. Press releases to journalists, when properly done, reduce the chances of inaccurate reporting in the mass media.



An example of an "air quality and health community of practice" structure.

Another benefit is that meteorologists get to appreciate the time constraints that people in the media work under.

The establishment of the media network for the countries of the Greater Horn of Africa has resulted in an increase in the number of weather-related stories featuring in newspapers. This is because the media finds it easier to access information from the staff of NMHSs with whom they have a good working relationship.

PARTNERSHIP WITH POLICYMAKERS

In order to establish an effective policy in dealing with weather and climate issues, whether for creation of wealth or for mitigation of effects of high impact weather, NMHSs have to work closely with governmental authorities (e.g. high-level policy and decision makers). This is important as it affects the allocation of resources by a government responding to the possible effects of an expected high impact weather such as a severe drought. An NMHS also gets to contribute to policies that the government may want to put in place with respect to climate change issues, with possible far reaching effects. It is thus essential to build effective links between PWS and other public services to provide better support for making decisions.

"Communities of practice" approach in partnership building

Despite efforts to have weather and climate information integrated into decision-making processes of key sectors, there is still a long way to go before this is achieved on a wide scale. For this reason, WMO is engaging its own community and user communities at national, regional and local levels to develop "communities of practice" working together to remove gaps between provision and understanding and use of information. For example, an "air quality and health community of practice" in a particular country could comprise the weather forecasting community, the atmospheric observation community, the hazard alerting community, public health officials and local and regional air quality managers.

This structure recognizes that all the participants in the information chain are part of the decision-making process. The sharing of best practice, especially from developing countries, is encouraged in this approach. The community of practice effects the necessary local training and education, effective translation of environmental information into informed decisions and facilitates effective decision-making by individuals as well as agencies.

Ensuring high quality products for users

GEORGE TARBAY (NIU)

ASSESSMENT OF QUALITY OF SERVICES

The work of NMHSs is not complete without assessing the overall quality of services provided and the impact of these services on society. The PWS programme of an NMHS is normally responsible for evaluating the quality of services available to users; specifically:

- Product quality—the accuracy and completeness of the content;
- Scope of products—the set of products being provided by an NMHS;
- Timeliness—to determine whether users are getting forecasts, warnings or information on time;
- Presentation—to assess whether the products are presented in a format and language that is easily understood.

The aim of the evaluation is twofold:

- Firstly, to ensure that products are accurate and skilful from a technical viewpoint and secondly, that they meet user requirements; and
- That users have a positive perception of, and are satisfied with the products.

The main goal of a verification process is to constantly improve the quality (skill and accuracy) of the services. This includes:

- Establishment of a skill and accuracy reference against which subsequent changes in forecast procedures or the introduction of new technology can be measured;
- Identification of specific strengths and weaknesses in a forecaster's skills and the need for forecaster training, and similar identification of a model's particular strengths and the need for model improvement; and
- Provision of information to management about a forecast programme's past and current quality to plan future improvements. The information is used in making decisions concerning the organizational structure, modernization and restructuring of the NMHS.

Verification carried out by a PWS programme benefits the NMHS in various ways:

- It enables NMHSs to verify and track the accuracy, skill and timeliness of their forecasts and to make the appropriate improvements as required;
- It identifies improvements in prediction skills resulting from investments in training, or new equipment such as radar, satellite ground stations or computer capacity;
- It assists in making rational decisions concerning priority target areas for increased emphasis;
- It provides answers to questions concerning forecast accuracy from the public, media, major clients and decision-makers and has the effect of promoting the credibility of the NMHS among these groups;
- It supplies ready answers to funding agencies to justify proposed investments in NMHS infrastructure, or as proof that investments have indeed yielded improvements in skill and accuracy.

There is no guarantee that the verification results will match people's perceptions of how good the forecasts are. Indeed, it is probably true to say that, while professional users of specific weather forecasts are impressed by the progress made in the predictions they receive, the public may believe that the forecasts are often "wrong". Convincing them otherwise requires a combination of improved methodology and better understanding of how the product is used. User-relevant verification methods are developed to address this problem.

It is important to NMHSs that the verification scheme truly reflects the perception of both the public and specific customers about the accuracy of forecasts. Surveys show that the public believe that a temperature forecast is "correct" if it is within 3°C, and verification can then be made on those terms. An electricity supplier, whose operational requirements are better met by a forecast to within 1°C, requires a higher level of accuracy.

In the assessment of services related to high impact weather such as severe thunderstorms, heavy snow, or the track of a hurricane, PWS take great care bearing in mind that the proportion of false alarms, especially when a high impact event happens infrequently is important to consider. In this case, the capacity of issuing reliable warnings becomes all the more important. For example, in a place that rarely gets frost, a constant forecast of "no frost" may be right 99 per cent of the time, but is of no tangible value in itself. What really matters is to pick out, reliably, those rare instances when frost presents a major hazard to users, such as farmers and horticulturists. Similarly, there is little value in verifying maximum temperatures in a region where they rarely ever vary appreciably from day to day.

User-based assessments require far more effort to establish what customers want. They involve a variety of direct methods such as surveys, focus groups, public opinion monitoring, feedback and response mechanisms, consultations such as users' meetings and workshops, and the collection of anecdotal information. On their own, each of these methods may produce information that is subjective and of questionable reliability. Overall, however, a consistent picture emerges which is credible. Moreover, they are the only effective means by which information can be gathered on needs, expectations and satisfaction of users. They have also been demonstrated as effective means of getting at estimates of the economic value of weather information and forecasts.

Verification results are normally presented to users so that they can have a realistic view of the worth of the forecast products.


SANDRA PORRAS

User-based assesments such as surveys and public opinion monitoring serve to establish customer needs and satisfaction levels with products and services.

EXAMPLE OF ASSESSMENT OF A WARNING

Extract from the
Service Assessment Report of the
Tornado in Rogers, Minnesota
September 16, 2006

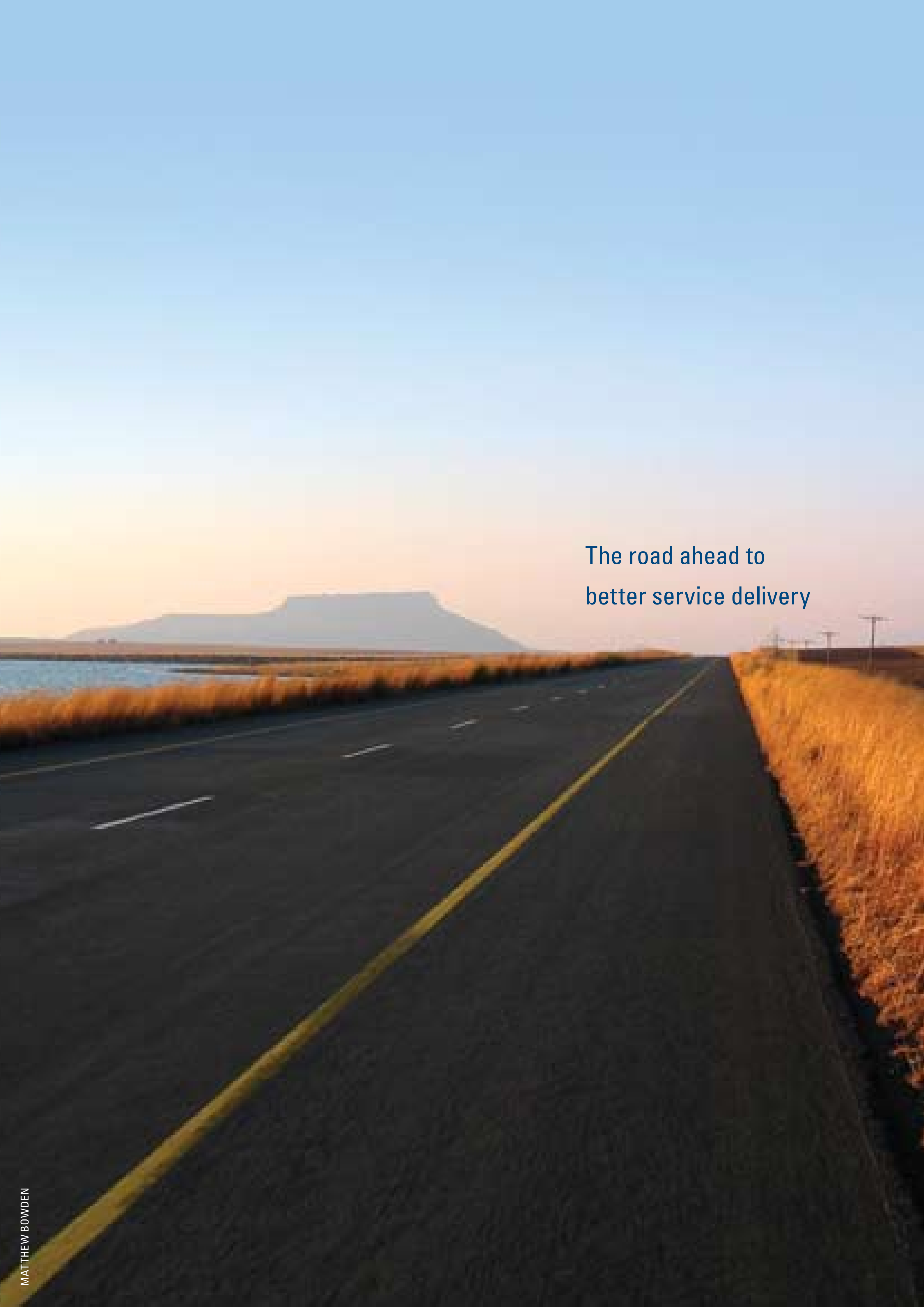
On September 16, 2006, a tornado, rated F2 on the Fujita Scale (Appendix A), touched down three miles west of Rogers, MN, at 9:52 p.m. The tornado had an eight-mile path and was on the ground for 12 minutes, first striking the city of Rogers at 9:54 p.m. Central Daylight Time (all times hereafter in CDT unless noted). The tornado crossed the Mississippi River into Anoka County and dissipated in the west section of Ramsey at 10:04 p.m. The tornado caused one fatality and injured six. In response to the event, the NWS' Central Region Headquarters formed a team to evaluate the warning service from the NWS, in particular the Minneapolis Weather Forecast Office (WFO) at Chanhassen, MN, which has warning responsibility for the area.

Residents of the area were provided with a heightened sense of awareness to the threat of severe weather as the Storm Prediction Center (SPC) in Norman, OK, issued a Tornado Watch for the Rogers area at 5:10 p.m. and indicated this was a "particularly dangerous situation." WFO Chanhassen issued several warnings and statements as the storms were approaching the Rogers area and a Severe Thunderstorm Warning for the Rogers area (Hennepin County) was issued at 9:43 p.m. This warning included a statement that a Tornado Watch was in effect for the warned area. A Tornado Warning was issued for Anoka County at 10:04 p.m. WFO Chanhassen received the first report of damage in Rogers at 10:13 p.m. Local officials from Rogers and Hennepin County, and the three television station meteorologists from the Twin Cities area who were interviewed by the assessment team said the meteorological staff provided adequate products and services from WFO Chanhassen during this event. Severe weather information was being broadcast on the air and local emergency officials were alert to the approaching storms.

Issuing a timely Tornado Warning for the Rogers area was difficult, as the first definitive indicators on Doppler radar signatures of strong rotation became evident at the same time the tornado struck Rogers. In addition, there were no real-time reports of the tornado. The WFO used proven scientific methods in their radar analysis and issued a Severe Thunderstorm Warning for the Rogers area 11 minutes before the tornado hit the community. A number of enhancements currently planned for NWS WSR-88Ds will provide more timely radar information which will assist forecasters in detecting tornadoes earlier in their life cycle.

The assessment team evaluated all aspects of WFO Chanhassen's products and services and identified areas for improvement. Specifically, the team focused on the process and timing of sectorizing WFO warning operations; the Tornado Warning product preparation process; and the call-to-action statement in the 9:43 p.m. Severe Thunderstorm Warning. The team has offered three findings and provided four recommendations to address these areas of the NWS warning service. All equipment functioned properly during the event.

Full report on:
http://www.weather.gov/os/assessments/pdfs/RogersAssessment.pdf



The road ahead to better service delivery

MATTHEW BOWDEN

SERVICE DELIVERY: CHALLENGES AND FUTURE PERSPECTIVE

CHALLENGES FACING PUBLIC WEATHER SERVICES

Weather events in recent decades have resulted in NMHSs around the world having to assume a growing role in current affairs. Confronted with a variety of challenges arising from a mixture of rapidly advancing technology, the rising cost of weather-related disasters and growing concern over climate change NMHSs have been moved more and more into the limelight. The NMHSs have an opportunity to use this increased attention as PWS providers to show what they do and that their services matter. Criticisms of NMHS performance reflect growing public expectations regarding the quality and accuracy of weather forecasting, which is a positive outcome. So, rising to the challenge of meeting users expectations provides NMHSs with a measure of what they must achieve in their quest for more accurate and useful forecasts and analyses on all timescales—from days to seasons and beyond.

Challenges and opportunities facing NMHSs in their service delivery are many, but adopting a balanced approach to all aspects of their operations will enable them to meet society's needs.

Special challenges to service delivery in developing countries

In developing countries, external pressure for economic reform has driven many to seek significant reductions in public expenditure and where possible to offset the cost of some services via cost recovery mechanisms. The absence of a compelling reason to support an NMHS as an essential service provider has left many to recover costs through fee-for-service mechanisms and to seek the recovery of costs associated with the provision of observational data. This has resulted in the exclusion of these data from regional and international databases and undermined the potential development of new decision-support tools for social sectors, such as health and agriculture. As a result many governments are not receiving the full benefit that their NMHS could provide.

Many governments in developing countries are faced with multiple developmental issues. Given the problems facing these countries, it is difficult for them to accord the establishment and maintenance of costly meteorological and hydrological observation networks the high priority they merit as a critical component of a national development strategy. This has translated into the current situation where some meteorological and hydrological services are under-funded. However, development in regions where pest borne diseases, droughts and floods, and human health are closely linked requires a full understanding of the sensitivity of the population to climate. By developing tools to assess and ultimately forecast the impact of the environment on agriculture, water security and health, it will be possible to mitigate adverse consequences, averting natural disasters that otherwise undermine national poverty reduction efforts.

Challenges to NMHSs in developing countries, therefore, include:

- The extension of services from weather to climate on all relevant timescales;
- The need to convince central governments of the NMHSs' role as an essential service requiring increased national or donor investment in national observing infrastructure;
- Effecting free and open exchange of data between countries and the international community; and
- Strengthening partnerships with institutional users—the natural hazards community, media, health sector, agriculture and water resources—to provide better services.

Challenges posed by easy access to information

The challenge posed by the ease with which users and the general public can access weather information became clear with the increasing popularity of the Internet.

In order to ensure that the public are served with authentic and official information from NMHSs through the Internet, the PWSP of WMO launched two websites giving access to official warnings and forecasts.

The first website, the Severe Weather Information Centre (SWIC), issues information on tropical cyclones, heavy rain, heavy snow and thunderstorms.

The second website, the World Weather Information Service (WWIS) supplies official weather forecasts for cities as provided by NMHSs. The information is available in Arabic, Chinese, English, French, Portuguese and Spanish.

The Hong Kong Observatory developed, and has continued to maintain, the websites for WMO. The two websites can be accessed on: http://severe.worldweather.wmo.int/ and http://www.worldweather.int.

FUTURE ROLE OF NMHSs IN SERVING THE PUBLIC

As the applications of weather and climate information continue to increase, especially as more and more sectors start factoring climate risk management into their decision-making processes, the need for better and more effective service delivery will grow. This will require NMHSs to ensure that their capabilities to deliver the required services and products not only keep pace with users' demands but that they anticipate, and are prepared to respond to, such demands. Public requirements for products and services have undergone considerable change in the past decade and it is very likely that they will continue to evolve.

Therefore, in the coming decade the NMHSs will have to play to their strengths, which include:

- The authority of government in providing advice and issuing warnings;
- Access to global data and products; and
- Highly professional staff, often internationally trained and helped through a global support network through WMO.

The challenges facing NMHSs in this task include:

- The low priority, in some countries, given to NMHS functions in setting national development agendas, although the consequences of global warming may change this situation;

- The poor capacity of NMHSs in many countries to take advantage of global information and provide an effective PWS; and

- Requirements for cost recovery that curb user demand and inhibit the development of an effective PWS function.

So, it is essential that NMHSs make the fullest use of the opportunities that will arise in the coming decade. Among these will be:

- The growing sensitivity of society to the environment and the political pressures that will develop, notably in respect of air and water pollution, climate change and sustainable economic development; and

- The scope for increasing alliances between users and service providers.

In spite of the opportunities that will open up in the coming years, NMHSs must recognize that they are vulnerable to various competitive pressures:

- Some users can bypass NMHS services by exploiting data directly from Internet and international partners; and

- Inadequate investment in NMHS infrastructure might limit capacity to take advantage of global developments, and compete with commercial services.

Only by adopting a balanced approach to all aspects of their operations can NMHSs contribute to society's needs fully. At a time of growing international concern about climate change, sustainable development and environmental degradation, the public is relying on NMHSs to provide the support it needs through effective and efficient dissemination of information via national public weather services.

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