World Meteorological Organization

GUIDELINES ON CAPACITY BUILDING STRATEGIES IN PUBLIC WEATHER SERVICES

PWS-15

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Chapter 1
INTRODUCTION

Weather affects virtually every person on the planet, every day of the year. Consequently information on past, present and future weather conditions plays an important part in planning our daily lives. Although the provision of weather and climate information to the community at large has long been one of the main responsibilities of the National Meteorological Services (NMHSs) of the now 188 Member States and Territories of the World Meteorological Organization (WMO), it is only during the past decade that most NMHSs have begun to focus their efforts on the provision of the highest possible quality public weather services (PWS) to their national communities.

This dramatic increase in concern with the scope, quality and utility of weather and climate information for use by society at large was, to some extent, responsible for, and has in turn been reinforced by, the establishment of the WMO Public Weather Services Programme (PWSP) in 1991. But it has also presented a major challenge to the NMHSs of both the developing and the developed countries as they strive to make the best use of the remarkable advances taking place in the science, technology and public policy for weather service provision. The purpose of the WMO PWSP is to help ensure that every country is enabled to draw on all the relevant knowledge and expertise within the WMO system to build its capacity to provide the best possible PWS to its national communities.

1.1 PURPOSE OF THE GUIDELINES

Capacity building requires significant investment so it is important that use is made of the experience of others to guide the development of the infrastructure and expertise necessary for the provision of first-rate PWS at the national level. The purpose of these guidelines is to equip NMHSs with information and knowledge on how to build their capacities in order to deliver the highest standard of PWS possible with the available resources and the contemporary state of meteorological science and technology.

While they cannot be exhaustive in addressing all the scientific, technological and policy issues involved in meteorological service provision, these guidelines do attempt to provide a reasonably comprehensive view of what is possible, and how that might be achieved.

Throughout the guidelines emphasis is placed on the areas where PWS can contribute to public safety and welfare. Also consideration is given to strategies for meeting the needs and requirements of users, and narrowing the gap between their expectations and the service outcomes. After providing some introductory information about Public Weather Services and the associated socio-economic benefits, the two main areas covered by these guidelines are:

- The skills, competencies and tools needed by NMHS staff to satisfy ever-changing user requirements.
- The mechanisms by which NMHSs and their staff can develop the required capacities.

1.2 CAPACITY BUILDING AND ITS STRATEGIC IMPORTANCE

Capacity building is a generic concept that embraces all those activities that need to be undertaken to strengthen the capacity of an institution, or all the relevant institutions, in a country to undertake, effectively, its full range of responsibilities. It has been interpreted in the meteorological context (WMO-No.908, 2000) to embrace the creation of an appropriate policy, legal and management framework for the operation of an NMHS, its human resource development and training, and the acquisition and use of appropriate technologies including instrumentation, computing and communication systems, buildings and other facilities necessary for it to carry out its mission. In the context of PWS, capacity building entails equipping an NMHS with the necessary scientific, technological, policy, management, communication and community liaison expertise to ensure the highest possible quality, utility and societal benefit from the basic meteorological services provided to the community at large.

The importance of capacity building is emphasized by it being one of the five strategic thrusts in the "WMO Strategic Plan 2008–2011 and Beyond". The other four strategic thrusts are science and technology development and implementation, service delivery, partnership, and efficient management and good governance. Indeed capacity building can make a contribution to supporting all components of the Strategic Plan.

According to the Strategic Plan there are five capacity-building strategic initiatives.

- Improve the capacity of developing and least developed countries to provide user-relevant services with targeted improvements in communication, client relations and service delivery.
- Increase the capacity of Members' NMHSs in developing and least developed countries to align their services with the particular needs of development in their countries.
- Increase the scientific and technical capacity of developing and least developed countries.
- Increase governmental and public education in Member countries to create a more environmentally literate populace.
- Increase the capacity of Members to address the different needs and experiences of men and women in the development of environmental products and services.

It is expected that these guidelines will support these strategic initiatives and lead to enhanced capabilities of Members in developing countries, particularly least developed countries, to fulfil their mandates.

1.3 ROLE OF NATIONAL METEOROLOGICAL SERVICES

The overall role of the NMHS at the national level has been described by Zillman (1999). In addition a definitive statement on the contemporary role and operation of NMHSs was issued by the WMO Executive Council (WMO, 2003). According to this statement the NMHS is usually the primary (in many cases the only) institution within a country which is responsible for acquiring and providing data, information, products and services relating to weather and climate and their application to those human activities which are influenced by atmospheric and related phenomena.. The role of the NMHS may be conveniently defined in terms of its mission and the national goals to which it contributes.

Mission and goals of an NMHS

The basic mission of an NMHS is to (a) observe and study national weather and climate conditions in the global context and (b) use the resulting meteorological and related knowledge, data and products to fulfil national requirements and satisfy international obligations.

Usually the NMHS takes the leading role, at the national level, on matters relating to weather observation, analysis and prediction. It provides weather forecasts, warnings and current information and a range of climatological services as well as air pollution data and other environmental services for the general public and for various sectors of the economy. In particular, the mission of the NMHS involves the discharge of the government's responsibilities to provide its national community with the meteorological and related information that is essential for the safety, security and general welfare of the community as a whole – in other words, for the provision of the nation's PWS.

The fulfilment of the mission of the NMHS in the provision of services, especially its PWS, is ultimately achieved through the contribution of those services to the following national goals:

- Protection of life and property;
- Safeguarding the environment;
- Contributing to sustainable development, making effective use of national resources, enhancing the performance of national economies and improving quality of life;
- Ensuring continuity of the observations of meteorological and related data, including climatological data;
- Contributing assessments which serve as a basis for policy-making;
- Promoting capacity building;
- Meeting international commitments;
- Contributing to international cooperation.

Role of the NMHS in integrated service provision

Increasingly in recent years, governments have looked to their national meteorological, hydrological, oceanographic and related environmental service agencies to adopt a more integrated approach in the provision of essential information, including forecasts and warnings, to the community at large.

In particular, there is a growing tendency for NMHSs to work together, either in partnership or as a single governmental agency, to provide a consolidated set of weather, climate and water services in forms that are best suited to their diverse user communities. The following are some other bodies that can help an NMHS deliver the PWS.

- ***Government agencies***. In some countries there are other government agencies which play a significant part in the delivery of the total PWS (broadly defined) to the national community. The most important complementary agency for the NMHS, in its provision of PWS, will usually be the national broadcasting organization which is responsible for ensuring that the official forecasts and warnings are delivered to the community at large in a timely, accurate and useful way.
- ***Private meteorological service providers***. In some countries where the NMHS role is seen as largely restricted to the provision of the basic national meteorological infrastructure and essential warning services, the formulation and delivery of the non-warning element of the PWS is entrusted to the private (commercial) sector.
- ***The media***. The role of the mass media is critical to PWS provision in virtually every country. In particular, in those countries where the NMHS is essentially the sole provider of PWS, the establishment of an effective partnership between the NMHS and the media is essential to the quality and effectiveness of the service in meeting community needs.

More information about the role of these various bodies can be found in Annex A along with a discussion of the role of information science and technology.

1.4 CONCEPT OF A NATIONAL METEOROLOGICAL SERVICE SYSTEM

It is useful, in the context of PWS, to characterise service provision in terms of the operation of a total national meteorological service system involving end-to-end arrangements from basic data collection, through to service delivery to end users by single or multiple provider mechanisms and delivery channels. A model illustrating the concept of a national meteorological service system is shown in Figure 1.

A particularly important recent trend is to view PWS as the essential core of an increasingly diverse suite of environmental services needed by users in a wide range of socio-economic sectors in addition to the traditional users of weather services. The services involved will need to draw on observing and data collection systems beyond the traditional meteorological observation networks – essentially the evolving concept of a Global Earth Observation System of Systems (GEOSS) – to enhance delivery of benefits to society in the following areas (GEO, 2005):

- ***Disasters***. Reducing loss of life and property from natural and human-induced disasters.

- ***Health***. Understanding environmental factors affecting human health and well-being.
- ***Energy***. Improving management of energy resources.
- ***Climate***. Understanding, assessing, predicting, mitigating the effects of, and adapting to climate variability and change.
- ***Water***. Improving water resource management through better understanding of the water cycle.
- ***Weather***. Improving weather information, forecasting and warning.
- ***Ecosystems***. Improving the management and protection of terrestrial, coastal and marine resources.
- ***Agriculture***. Supporting sustainable agriculture and combating desertification.
- ***Biodiversity***. Understanding, monitoring and conserving biodiversity.

Just as the established concept of the Global (meteorological) Observing System (GOS) is beginning to evolve into GEOSS, the essential suite of PWS must also expand to include a wide range of publicly accessible environmental services serving the needs of the community at large.

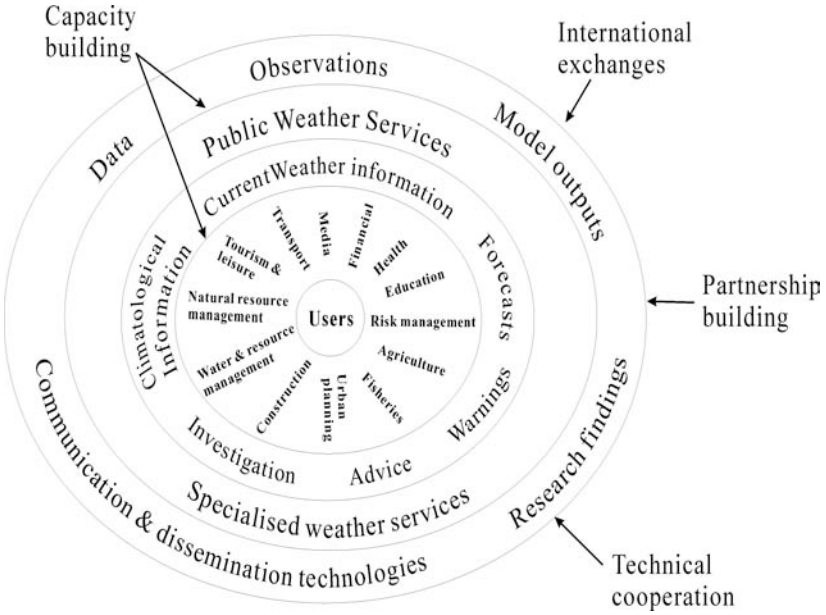

Figure 1: A model illustrating the concept of a national meteorological service system.

1.5 MISSION OF PUBLIC WEATHER SERVICES

PWS comprise the provision of weather information, forecasting and warning services in the public interest and supporting to government agencies in their weather-related decisions for the benefit of public safety and welfare. The basic missions of PWS are:

- to minimise loss of life, livelihoods and property due to severe and high impact weather;
- to reduce weather-related adverse socio-economic impacts;
- to assist communities exploit opportunities created by prevailing weather in their day-to-day weather-related activities;
- to contribute to the sustainable development of society and the earth's system as a whole.

It is important for NMHS staff to share the mission of enhancing the well-being of the community so that the products and services provided by an NMHS are those actually required by the users and not those the NMHS thinks the users require. It is only through effective communication and consultation with users that an NMHS can ascertain the user needs and requirements for products and services. Doing this allows the proper planning of the end-to-end forecast process, from observations to the production of forecasts, warnings and decision-support tools, through to the dissemination and communication of these products. The levels of accuracy, reliability and relevance, as well as the degree of timeliness of the forecast and warning products, are important elements for measuring the usefulness of these products to the users.

For the PWS to be successful, in addition to their accuracy, the products have to be disseminated and presented in a way that allows the intended users to actually receive, understand, believe and act upon the information. An effective PWS programme will always aim to enhance:

- ***User awareness*** – to receive the information the users must be aware of the services available and the means by which they can be accessed.
- ***User understanding*** – to understand the information the product must be presented in plain, concise language and the users must know the meaning of the meteorological terms used.
- ***User faith*** – for users to act upon the information received, it is essential that they believe in it; this requires the NMHS to have a public image of credibility and a

reputation for providing reliable, accurate and timely services.

Transformation of weather information to information directly comprehensible and applicable by users will increase the cost effectiveness of the PWS and may significantly reduce the response time of users in critical situations. In particular, translation of weather warnings to disaster response/management information will enhance the effectiveness of weather warnings and help people to respond appropriately. To this end, multi-disciplinary efforts by social scientists, environmental scientists and disaster managers as well as meteorologists will be required. In addition, active engagement of an NMHS in public education, awareness and preparedness activities can help the communities make best use of warnings and forecasts, understand the potential impacts of severe and high impact weather, and take appropriate mitigating actions. It would be useful for an NMHS to develop its PWS mission so that there is clarity about its purpose. Examples of PWS missions from NMHSs in Australia, Canada, Hong Kong, China, and United Kingdom can be found in Table 1.

Table 1: Examples of NMHS missions for PWS.

Bureau of Meteorology, Australia Contribute to the comfort, convenience and general welfare of the public and major community user groups through the provision of relevant, accurate and timely weather information and forecasts through the mass media and the Internet. *Bureau of Meteorology, 2003*
Environment Canada, Canada Through the weather and environment prediction business line, Environment Canada helps Canadians adapt to their environment in ways that safeguard their health and safety, optimize economic activity and enhance environmental quality. *Environmental Canada's 2003-04 Estimates: Report on Plans and Priorities (http://www.ec.gc.ca/rpp/2003/en/toc.htm)*
Hong Kong Observatory, Hong Kong, China Provide weather forecasts and issue warnings to the public, special users, the shipping community, aircraft and aviation groups in order to reduce loss of life and damage to property, and minimise disruption to economic and social activities during hazardous weather. *Hong Kong Observatory Controlling Officer's Report, The 2005-06 Budget, The Government of the Hong Kong Special Administrative Region (http://www.budget.gov.hk/2005/eng/head168.pdf)*
UK Meteorological Office, United Kingdom Create value for taxpayers, customers and stakeholders by using Met Office's assets and capabilities to deliver benefits to the public, the Government, the economy and the environment. *Met Office Annual Report and Accounts 2004/5 (http://www.metoffice.gov.uk/corporate/annualreport0405/index.html)*

1.6 SCOPE OF PUBLIC WEATHER SERVICES

Decisions on what is to be included within the PWS of an individual NMHS will vary according to the geographical and socio-economic circumstances of each individual country, as well as the public policy environment set by its government. However, the WMO community now has access to a well-developed intellectual framework and a substantial body of international experience to guide NMHSs in defining the scope of their PWS. It is particularly useful, in this context, to consider separately the three different dimensions of the concept of 'public . . . . weather . . . . services'.

Public

The term 'public' or 'general public' is usually taken to refer to the community at large, as opposed to the separate individuals who make up the community. For meteorological purposes, the definition of public is usefully linked to the economic concept of 'public goods' (Stiglitz, 2000) which are defined (Samuelson, 1954) as those which satisfy two requirements: non-rivalry of consumption (one person's consumption does not reduce the amount available to others) and non-excludability (it is impossible, or extremely expensive, to exclude from benefit a person who refuses to contribute to the cost). However, there are some other considerations.

- There are many different 'publics', in which one distinguishes the interests of the collective from those of the individual within any of a number of major subsets of the entire community (e.g. the travelling public from the individual traveller or the informed public from the individually expert citizen).
- There are important distinctions to make on a hierarchical basis between the public and private interests, and needs and benefits at the international,

national, regional and local levels (e.g. at the national level, a service provided for the benefit of fishermen may seem narrowly directed to sectional interests rather than those of the whole community, but within a fishing village the same service will clearly be seen as directed 'at the public interest').

Weather

The scope of what 'weather' is considered to embrace ranges widely from country to country, language to language, and discipline to discipline. It seems appropriate to regard 'weather' as embracing all those physical (and, to some extent, also chemical) processes and phenomena that are manifested in the atmosphere on time scales from seconds up to days and weeks, and including also selected information on longer time scales into the past and future, traditionally thought of as 'climate'. It is also worth noting that in recent years the concept of 'weather' has been expanded to embrace the variability of the ionosphere and space environment on 'weather' time scales under the title of 'space weather'.

Services

The broadest definition of 'service' derives from the economic concept of 'goods and services' and thus embraces almost anything used or consumed by society that is not a material good. In meteorological usage, one common characterisation of the scope of services provided by an NMHS recognises five broad groups of service as follows (Zillman, 1999).

- ***Past information***: Provision of information on past conditions from the historical record.
- ***Current information***: Provision of information on the current state of the atmosphere, oceans or surface water.
- ***Future information***: Provision of forecasts (or 'predictions') of future conditions, especially warnings of severe weather and climate events.
- ***Advice***: Provision of advice on meteorological and related science and its application to community needs.
- ***Investigation***: Conduct of investigations into specific scientific problems of the atmosphere and the atmospheric environment.

A distinction is often made between weather information (taken to mean current and historical information), forecasts and warnings. Information includes unprocessed data, analysis products such as synoptic charts, visualisation products such as radar or satellite imagery and even advice on the actions that should be taken in particular situations to make best use of the information.

Definition of PWS

From these three separate perspectives on the elements of the concept of PWS emerges the useful working definition that PWS embraces all the atmospheric and related information and products made available for the benefit of the community at large with emphasis on, but not limited to, information on processes and phenomena that impact on society.

1.7 BASIC AND SPECIALIZED SERVICES

In recent years, WMO has introduced a very important distinction between what are referred to as 'basic' and 'specialised' services which is useful in delineating the scope of PWS in individual socio-economic structures and systems. Both are built upon the long-established WMO concept of the 'basic systems', which underpin both the public and private provision of meteorological services in all countries. According to WMO (2003) basic systems, basic services and specialised services can be described as follows.

- ***Basic systems***. These consist of the basic data collection and processing infrastructure of an NMHS which underpins the full range of services provided at the national level and which may be regarded as a basic service to present and future generations.
- ***Basic services***. These are services provided by an NMHS in discharging its government's sovereign responsibility to protect the life and property of its citizens, to contribute to their general welfare and the quality of their environment, and to meet its international obligations under the Convention of the World Meteorological Organization and other relevant international treaties and agreements.
- ***Specialised services***. These are services beyond, and complementary to, the basic services which are provided to meet the special needs of individual users or user groups and which may include the provision of special data and products, their interpretation, distribution and dissemination along with special purpose investigations and consultative advice.

1.8 SERVICES OF SPECIAL RELEVANCE TO PUBLIC NEEDS

Among all of the environmental sciences, meteorology has probably the most immediate impact on a society. Relevant meteorological information can help users develop adaptive strategies in response to changes in weather, climate and the environment. With appropriate knowledge, good communications and reliable forecasts, different weather-dependent sectors of the community can benefit from the use of meteorological services and products in enhancing the security and economic value of their activities.

When designing specific weather products or services for a community sector, it is recommended that NMHSs adopt a bottom-up approach with user involvement in the design and testing phases. NMHSs can obtain user requirements and feedbacks through regular liaisons between a designated liaison officer and representatives from the community sector. In such a way, NMHSs can be aware of the changing user needs and requirements in an evolving society, and at the same time users can derive the greatest benefit from using the new services or products.

Timeliness in delivering the weather information and warnings to users is a crucial factor for determining the usefulness of the information. NMHSs need to formulate strategies for disseminating weather information to the intended users of different sectors in addition to the community at large. Use of Geographical Information Systems (GIS) and other spatial modelling tools can

integrate biological, physical and socio-economic factors in a holistic manner. The opportunity exists, more than ever before, to obtain and provide information to users from a variety of sources.

The following identifies the key services that can be provided as part of the PWS.

- Warning Services for Disaster Prevention.
- Climatological Services.
- Agrometeorological Services.
- Hydrometeorological Services.
- Marine Weather Services.
- Aviation Weather Services.
- Road Weather Services.
- Urban Weather and Air Quality Services.
- Biometeorological and Human Health Services.

1.9 SOCIO-ECONOMIC SECTORS THAT BENEFIT FROM WEATHER, CLIMATE AND WATER SERVICES

Various weather-sensitive socio-economic sectors utilize weather and climate information to assist their decision-making in response to the changes in weather and climate. An overview of the societal and economic benefits from meteorological and hydrological services is given by Rogers et al. (2007).

It is of utmost importance for NMHSs to ensure that their staff involved in service delivery possesses a good understanding of the requirements of each sector and to include this requirement as part of their training programmes.

- ***Decision Makers and Policy Makers within Government***. Weather information helps decision makers within the government formulate contingency plans for natural disasters and develop policies about environmental issues.
- ***Risk and Disaster Management Authorities***. Climate and real-time information helps emergency managers determine the appropriate vulnerability reduction, prevention and mitigation, preparedness and response strategies in terms of socio-economic impacts.
- ***Marine Transportation and Offshore Operations***. Use of marine weather information assists mariners in choosing a cost-effective sea route and oil drilling operators in optimizing their operational schedules. Also warnings of extreme weather and sea conditions are crucial to the safety of mariners and seafaring passengers.
- ***Aviation***. Weather impacts the safety of aircraft, its passengers and crews, and adverse weather conditions affect the costs of aviation operations and the efficiency of air traffic management.
- ***Land Transportation***. Use of reliable road weather information and forecasts assists road transport operators in taking prompt actions to ensure effective traffic management, cost reduction in road maintenance, and risk reduction of weather-related road accidents.
- ***Agricultural Community***. Provision of weather and climate information helps develop sustainable and economically viable agricultural systems, improve production and quality, increase efficiency in the use of water, labour and energy, conserve natural resources, and decrease pollution by agricultural chemicals or other agents..
- ***Fisheries***. To promote sustainable development of the fishing industry and to conserve fisheries resources, use of weather and climate information assists government agencies in the pursuit of fisheries resources, conservation management and policy making.
- ***Education Sector***. Education and outreach programmes stimulate student's interest in meteorology and hydrology, and promote their awareness of hazardous weather, appropriate precautionary measures and response actions.
- ***Energy***. Energy efficiency and effective long-term energy planning can be achieved by using observations, weather forecasts and climatological data.
- ***Water Resources Management***. Weather forecasts and information about climate change support the sustainable management of water and the effectiveness of flood control services.
- ***Health***. The public benefits from the results of research on the relationships between weather and human health, and the use of climate data to formulate healthy policy and improve epidemic preparedness and response.
- ***Natural Resources Management***. Climate and weather information facilitates the development of natural resources management tools and conservation planning to protect the security of the community and to ensure sustainable development.
- ***Tourism***, Leisure and Sport. Providing weather forecasts and warnings helps ensure the safety of people engaged in outdoor activities and assists the public in making choices on the locations and timing of outdoor recreational activities.
- ***Financial Sector***. Though severe weather imposes negative impacts on the financial sector, such as increasing inventory costs and socio-economic costs, provision of weather information also provides new opportunities in the financial sector (e.g. development of insurance and derivatives markets).
- ***Construction Industry***. Weather and climatological information assists in the design, planning and construction of structures.
- ***Management of the Urban Environment***. Provision of information about weather and air quality can enable the public to take appropriate actions to minimise the weather impacts to human life in urban areas, and support government agencies in formulating policies and strategies in relation to urban weather.
- ***Land and Urban Planning***. Climate information contributes to land and urban planning in the aspects of safety, human comfort and energy conservation.
- ***General Public***. Weather information helps decision making and planning by members of the public in the face of day-to-day weather changes, as well as from the standpoint of responding to severe weather events.

More information about the socio-economic benefits from the PWS is given in Annex B.

Chapter 2
REQUIRED EXPERTISE AND TOOLS

In order for the staff of NMHSs to ensure that their national communities receive the full benefits made possible through advances in meteorological science, technology and public policy, it is essential that PWS staff have the opportunity to undertake more broadly based training programmes and general capacity building than was considered necessary in the past. The expertise they must acquire and the tools they must use are now far more diverse and challenging. This is partly due to the need for continual improvement in the delivery of services. A schematic diagram illustrating the improvement cycle of service delivery is shown in Figure 2.

Some of the significant new areas of expertise and tools required to deliver the PWS which meet the ever increasing expectations of users are summarised in this chapter.

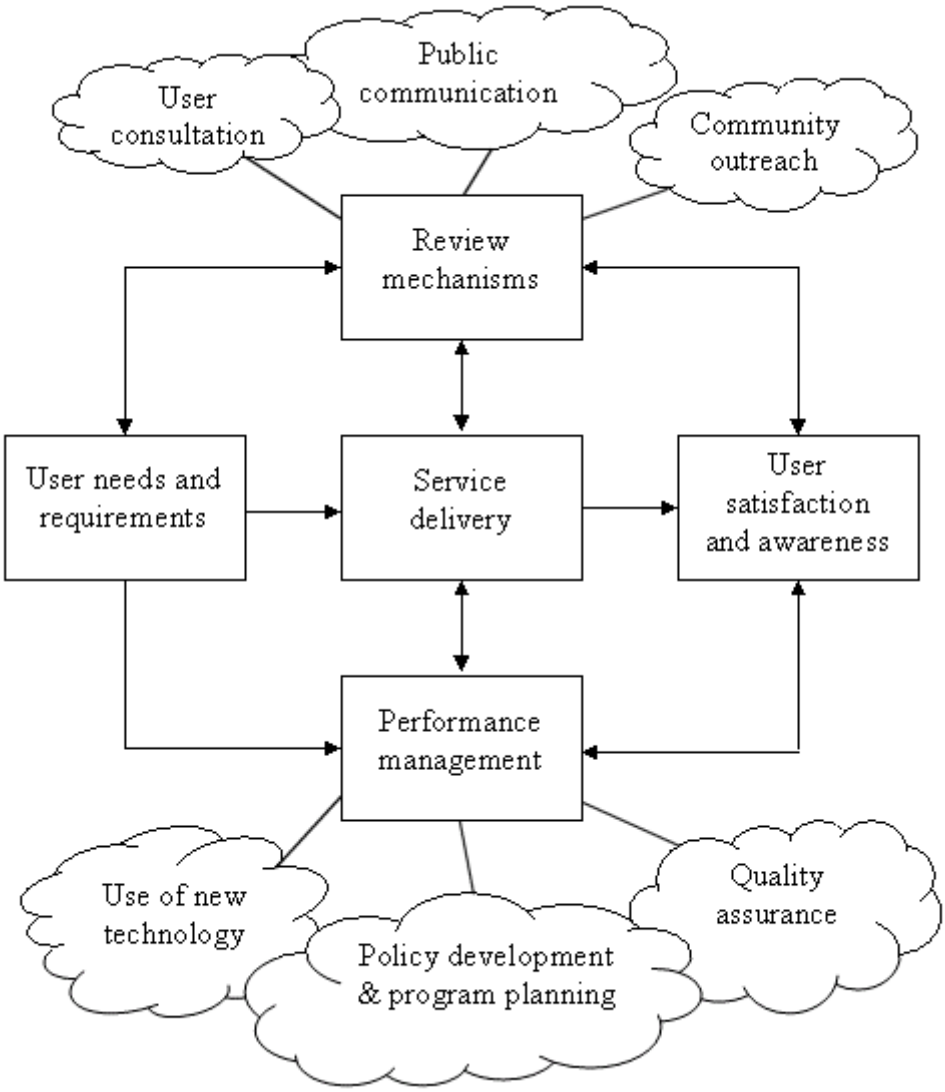

Figure 2: A schematic diagram showing the improvement cycle of service delivery.

2.1 PUBLIC POLICY DEVELOPMENT

Over the past decade, there has been a strong shift in emphasis within governments in many countries towards the abandonment of the rigid 'silos' that characterised traditional public sector bureaucracies. There is now expected to be a much more networked, holistic, whole-of-government approach to the solutions of problems from safety of transportation to natural resource management and natural disaster reduction.

It is no longer possible, in this changed administrative environment, for NMHS staff to stand aside from the cut and thrust of public policy debate within the government system. It is important, therefore, for NMHS staff (particularly those concerned with the design and delivery of services which impact across the spectrum of government and community needs) to become competent and fully engaged in the public policy process. This requires at least basic capacity building in legal and environmental affairs, social sciences and modern approaches to public administration and business management.

2.2 PROGRAMME PLANNING AND MANAGEMENT

Historically, most meteorological staff tended to advance to senior management positions in their NMHS through the established chains of professional career progression based on their meteorological expertise. But the past few decades have seen a major shift to a situation in which senior staff must expect to develop expertise in many facets of the management of resources, staff and programmes. This is particularly important for those NMHSs that have adopted, or plan to adopt, any of the many outcomes-based approaches to programme management that are now in vogue in both the public and private sectors around the world.

It is necessary, therefore, that the PWS staff of NMHSs are given the opportunity for the development of expertise in areas such as the following.

- Programme definition and formulation.
- Objective setting and task formulation.
- Prioritisation and resource allocation.
- Performance evaluation and quality control.
- Programme evaluation and reporting.

It is also necessary that staff are familiar with contemporary management systems and techniques. Many management models can be found in Have et al. (2003) and some of the most widely used are given in Table 2.

Table 2: Some widely used management systems and techniques.

Management systems and techniques	Description
Management by Objectives (MBO)	A systematic and organised approach that allows management to focus on achievable goals and to attain the best results from available resources.
Continuous Improvement	Continual improvement is an important component of quality management, for example using Plan-Do-Check-Act (PDCA) cycle to drive continuing improvement.
Planning Programming Budgeting System (PPBS)	A budgeting system that enables incorporation of planning aspects in the budget process and development of plans and programmes in concert with the resources. The steps in doing a PPBS may include preparation of a comprehensive list of services/products that reflect the accomplishment of goals and objectives, using previously collected data on costs of these services/products and determine the cost of each for a budget year, and presentations to management as a series of programmes for funding in priority order along with statements of implications if not funded.
Results Based Budgeting (RBB)	Emphasis is on the outputs to be produced and consequent outcomes as opposed to input budgeting where the defining feature is an emphasis on the inputs. The financial management focus in RBB would be on controlling the overall (as opposed to individual) expenditures and on ensuring that outputs are delivered within the agreed budget.
Balanced Scorecard	A performance measurement system that considers not only financial measures, but also customer, business process and learning measures. The balanced scorecard translates the organisation's strategy into four perspectives, with a balance between internal and external measures, between objective measures and subjective measures, and between performance results and the drivers of future results.
Benchmarking	Systematic comparison of organizational processes and performances that provides new insights into strengths and weaknesses of an organization. It illustrates possible improvement, objective norms, new guidelines and innovative ideas so as to create new standards and/or improve processes. Benchmarking can be internal (between different units within an organization), competitive (with competitors), functional (within the broader range of the business with similar processes), and generic (between unrelated businesses).
Business Process Redesign (BPR)	A fundamental reconsideration and radical redesign of organizational processes to achieve drastic improvement of current performance in cost, quality, service and speed. Value creation for the customer is the leading factor for process redesign, in which information technology often plays an important role.

Change Quadrants	The change quadrants model helps management to define an approach for successfully managing organizational change. It can be useful in determining the change agents, identifying active participants in the change process, and establishing the scope of the change and the timing in order to maximise the success of change efforts. Four possible change strategies are intervention, implementation, transformation and innovation.
Core Competencies	Managers are encouraged to think inside-out as well as outside-in. The outside-in approach to strategic management places the customer and the competition at the centre; core competencies refer to a combination of specific, inherent, integrated and applied knowledge, skills and attitudes of an organization that should be used as the basis for strategic intent.

2.3 METEOROLOGICAL ECONOMICS

It is becoming increasingly necessary in the design, funding, management and evaluation of publicly-funded programmes, such as the PWS provided by NMHSs, that those involved are familiar with the economic basis for:

- Determining the total and marginal costs and benefits of publicly funded programmes.
- Understanding the essential distinction between public, private and mixed goods and the relative roles of the public and private sectors in their production and provision.
- Assessing the societal benefits of non-market public goods.
- Determining the most economically efficient approaches to funding, pricing and charging for the provision of public, private and mixed goods.
- Performing standard benefit/cost analysis for programmes and projects.

The need for appropriate expertise in meteorological economics is based not only on the requirements for a coherent overall rationale for the definition and design of PWS as part of the total operation of the NMHSs, but also to provide an economically rigorous rationale for supporting proposals for public funding for an economically and socially optimum standard of PWS at the national level.

It is important, therefore, for PWS staff are provided with a foundation in the following.

- Basic concepts of public sector economics.
- Interpretation of supply and demand curves for public goods.
- Economic characterisation of meteorological services.
- Costing and pricing of goods and services.
- Overall economic framework for meteorological service provision.

For further information about economic aspects of providing meteorological services see Stiglitz (2000), Zillman and Freebairn (2001), Freebairn and Zillman (2002 a, b) and Gunasekera (2004).

2.4 SOCIO-ECONOMIC ASSESSMENT

The societal value of the weather and climate information available from NMHSs is often under-appreciated by government as is the role these resources could play in sustainable development, the alleviation of poverty, and the mitigation of the impacts associated with natural disasters. Governments may not recognise the inherent societal value of the information that can be provided by NMHSs. Consequently NMHSs need to proactively demonstrate the socio-economic benefits of meteorological and hydrological products and services.

Economic losses from hydrological or meteorological natural hazards are increasingly significant and these disasters gain the attention of governments and policy makers. This provides an opportunity for NMHSs to demonstrate the vital contribution they make to reducing loss of life, property, and productive capacity. In addition the case can be made for further developing a timely and reliable warning and delivery systems which can lead to improvements in mitigation actions and preparedness planning (e.g. in the areas of water management, agriculture, health and energy).

Various studies have been performed to assess the economic value of meteorological information. A key concept in measuring the economic value is the crucial relationship between the economic value of meteorological information and its impact on decision-making by users engaged in weather- or climate-sensitive activities. There is a range of analytic tools available for the valuation of meteorological information such as those given in Table 3.

A study by Gunasekera (2003) demonstrated that the estimated benefits of key public good meteorological services to users far exceed the costs associated with the provision of those services.

2.5 UNDERSTANDING THE IMPACT OF FORECASTS

Weather forecasts aid decision making, from as simple a decision as taking an umbrella when going out to a massive community response such as an evacuation. In severe weather situations, the desired response to weather forecasts and warnings is a structured response in which effective and prompt actions are taken to minimise the impact of weather on human lives and property. The key factors leading to desirable outcomes depend on how effectively the forecast and warning information is translated to risk-based decisions by users (including government agencies, emergency managers, socio-economic sectors and the public at large) so as to combat threats posed by weather hazards.

The challenge to NMHSs is to change the behavioural pattern of users (ranging from policy makers to the person in the street) in response to weather and climate information. A good understanding of the needs and social behaviour of users of weather information and services is required in the adjustment process. However, different user sectors have their own agenda and needs so the applicability of forecast.

***Table 3: Some analytic tools available for the valuation of meteorological information* (Gunasekera, 2003).**

Analytical tool	Description
Market-based approaches	Market prices are used as a measure of the marginal benefits to users of meteorological information.
Normative or prescriptive decision-making models	Meteorological information is viewed as a factor in the decision-making process that can be used by decision-makers to reduce uncertainty. The model is based on the Bayesian decision theory (Johnson and Holt, 1997) which takes explicit account of how forecast information is utilized.
Descriptive behavioural response methods	Based on the notion that the value of meteorological information is dependent on their influence on the decisions of users engaged in meteorologically sensitive activities.
Contingent valuation method	A non-market valuation method used by some analysts in relation to public good meteorological information and is based on survey techniques and hypothetical situations to elicit users "willingness to pay" or their "willingness to accept" for hypothetical changes in the quantity or quality of a non-market good such as public weather information.
Conjoint analysis	Similar to contingent valuation in using hypothetical survey format but requires survey respondents to rank or rate multiple alternatives where each alternative is characterized by multiple attributes.

information depends on the characteristics and roles of the users, their understanding of what is provided, and the extent to which the information meets their real needs. Consequently the service providers need to know the users requirements in terms of the key parameters and their desired spatial and temporal resolution, regions of interest and accuracy limits. In addition there needs to be an understanding of how the services are used and the level of expertise of the users. With all this information it should be possible to maximise the usability of the services.

The capability of integrating weather forecasts into other tools is essential to maximising the effectiveness of forecasts in decision-making processes. For example, rainfall forecast information integrated into a flood model can be used to predict the possibility of flood, its severity and time of occurrence. Advisories on flood risk can then be produced to trigger user response. In this case, the users may include government agencies, flood managers and people living in flood-prone areas. For the agricultural sector, integration of climate model forecast information with remote-sensing data and soil information as input to a crop model to predict crop production can produce useful guidance. In essence, the weather warning services should be risk-oriented.

Forecasts sometimes need to compete with indigenous knowledge of the users. Regular interactions with targeted user sectors, for example through training, are useful for improving their understanding and usability of forecast products, avoiding misconception, obtaining feedbacks, building trust and common language, and most importantly managing their expectations and perceptions. The ultimate aim is to influence people and their behaviour so that they can make full use of the weather services provided.

Uncertainty information about forecasts can facilitate risk management, but it has to be conveyed in a format applicable to the users through appropriate communication channels. Users need to know how uncertainties in forecasts propagate into uncertainties in the parameters of their interest. The uncertainty information about forecasts can be transformed into probability forecast of the change in the warning status if user reactions are solely based on the warning status. However, users with higher competencies need to be encouraged to make intelligent use of weather information and dynamic strategies, taking into account their own social and business factors as well as level of acceptance of risk in their decision making processes, instead of merely acting upon the warning signals.

2.6 RESOURCE MOBILIZATION

Resource mobilization deals with engaging in preparatory and implementation activities to secure funds, equipment, personnel, training, and any other means to produce data, products and services to meet the needs and priorities of an organization.

There are three levels of resource mobilization, namely local, regional and global. It is worthwhile having strategies for resource mobilization in place in order to fulfil the role of an NMHS and its baseline activity of providing quality PWS.

At the local level, the PWS can be viewed as the tangible service output of NMHSs along with measures and targets for the PWS to ensure the service delivers value for money from the viewpoints of government funding authorities and the public. Justifications are required for securing funds to continue with existing activities as well as to support the development of new projects. In doing so, NMHSs could prepare annual reports about their weather services detailing their goals, service descriptions, deliverables and achievements, use of financial resources, performance measures (showing whether the past year's

target has been met, and evaluation of results according to a set of performance indicators), as well as plans and targets for the coming year. The targets might relate to the reliability, timeliness, availability, popularity and usefulness of weather information and warnings.

To develop and enhance PWS, NMHSs need to formulate a strategic plan for the development of weather data, products and services with well-defined objectives, targets and deliverables, and a clear set of priorities. Mechanisms are then required to review expenditure against the budget and assess whether the service is developing in an efficient, structured and co-ordinated fashion, especially when several parties are involved in the development and implementation processes. Roles and responsibilities of different parties in mobilizing the funds need to be spelt out clearly to ensure rationalization and efficiency in resource mobilization. Also attaining flexibility in fund re-allocation would allow for further development across a range of products and services, thereby maximising the effectiveness of resource mobilization.

At the regional and global levels, resources can be mobilized from various sources of funding such as Trust Funds, United Nations Development Programme (UNDP), Global Environment Facility (GEF), United Nations Fund for International Partnership (UNFIP), UN Foundations, Banks (e.g. World Bank) and the private sector. They may provide support, individually and collectively, to enhance the capabilities of NMHSs and related regional and international institutions. The funds could be used to support priority programmes such as those related to poverty alleviation, capacity building, modernization, environment protection and regeneration, climate change adaptation, water resources management and natural disaster mitigation.

Getting cooperation with regional groupings that are typically structured according to economic benefits, common heritage or geographical proximity is an advantage when bidding for resources from external bodies. The likelihood of success is higher if the priorities of the NMHSs match those of the funding associations. It would be of value if NMHSs developed their own multi-year development plans in concert with national, regional and international priorities. The plans should emphasise the benefits to users of the products and services, and the activities that could be undertaken to ensure that users' needs and requirements are met. Such strategic planning requires interaction with the users, development of effective communication for providing products and services, and feedback mechanisms about the usefulness and timeliness of the products. The timing of submitting the proposal is also a factor in successful application of funds. Plans for improving services when a devastating weather event occurs usually have a better chance of success.

Almost every example of success with securing resources or support in kind for capacity building has an element of strong personal contacts (Yerg, 2002). Dedicated staff with motivation can earn the respect and trust of users and funding organisations through frequent and consistent contacts. In essence, a well thought out plan, the right people (NMHS staff engaging in resource mobilization activities) and good timing are key factors to successful resource mobilization.

2.7 ADVANCES IN OBSERVATIONS, FORECASTS AND PRODUCT GENERATION

The improvement in the availability, density, quality and types of weather observations is vital to the monitoring of weather and climate as well as the provision of quality initial data to run numerical weather prediction (NWP) models. In the context of PWS, the observational data is used to generate "current weather" for the public. Use of network cameras in capturing the real-time picture of the place and displaying the "current weather" arouses people's interest in utilising weather information in their daily lives.

The use of surface observations from a dense network of automatic weather stations together with the application of radar and satellite data is critical for issuing weather warnings and nowcasting. They are also useful for television and Internet broadcast particularly in severe weather situations when they can help people "visualize" the weather situation over a large area and the way the weather will evolve.

The increasing availability of ensemble prediction system (EPS) products from major NWP centres has opened up new possibilities in probabilistic forecasting, especially for risk assessment of potential inclement weather. Other techniques such as time-lag model ensemble forecasting (combined prognoses for the same valid time from model runs with different initial times) and multi-model ensemble forecasting (combined prognoses from different models for the same valid time) are "poor-man" ensemble forecasting techniques that can be employed by NMHSs with much less computer resources. Time series of EPS outputs for various critical weather elements such as temperature, wind, relative humidity, precipitation and cloud cover in the form of EPS Meteogram (EPSgram) can be generated for different parts of the world (Figure 3). The availability of EPSgrams is a valuable tool for producing site-specific products and services, particularly for the medium range.

Probability forecasts are useful to those user sectors that are competent in the use of such information in assessing the costs and benefits of making weather-related decisions. However, for applications of probability forecasts in PWS, public education initiatives are required in order to realize the potential benefits.

The advancement in nowcasting benefits most from the development of remote-sensing technologies such as Doppler radars and satellites. These provide moisture and wind data which can be used in mesoscale models to generate reliable forecasts of precipitation. These developments provide opportunities for making nowcasting products available to the public to facilitate their evaluation and reaction to a rapidly evolving weather situation.

In order to maximise the benefits from ever-improving forecasts in the reduction and mitigation of natural disasters, it is necessary to transform timely and accurate weather forecasts into specific and definite information or in the form of decision-support tools that produce the desired societal and economic outcomes. In response to the weather related challenges of the 21st century, a ten-year World Weather Research Programme, The Observing system Research and Predictability EXperiment (THORPEX), was established in 2003 by the Fourteenth World Meteorological

Congress under the auspices of the WMO Commission for Atmospheric Sciences (CAS) to accelerate improvements in the accuracy and the socio-economic and environmental benefits of one-day to two-week high-impact weather forecasts. THORPEX creates a contemporary organisational framework to address global weather research and forecast problems whose solutions will be based on the collaborative efforts of operational forecast centres, academic institutions and users of forecasts (see the THORPEX Research Implementation Plan, WMO/TD-No. 1258). The outcomes of THORPEX will provide enormous opportunities and new initiatives for NMHSs to enhance their PWS.

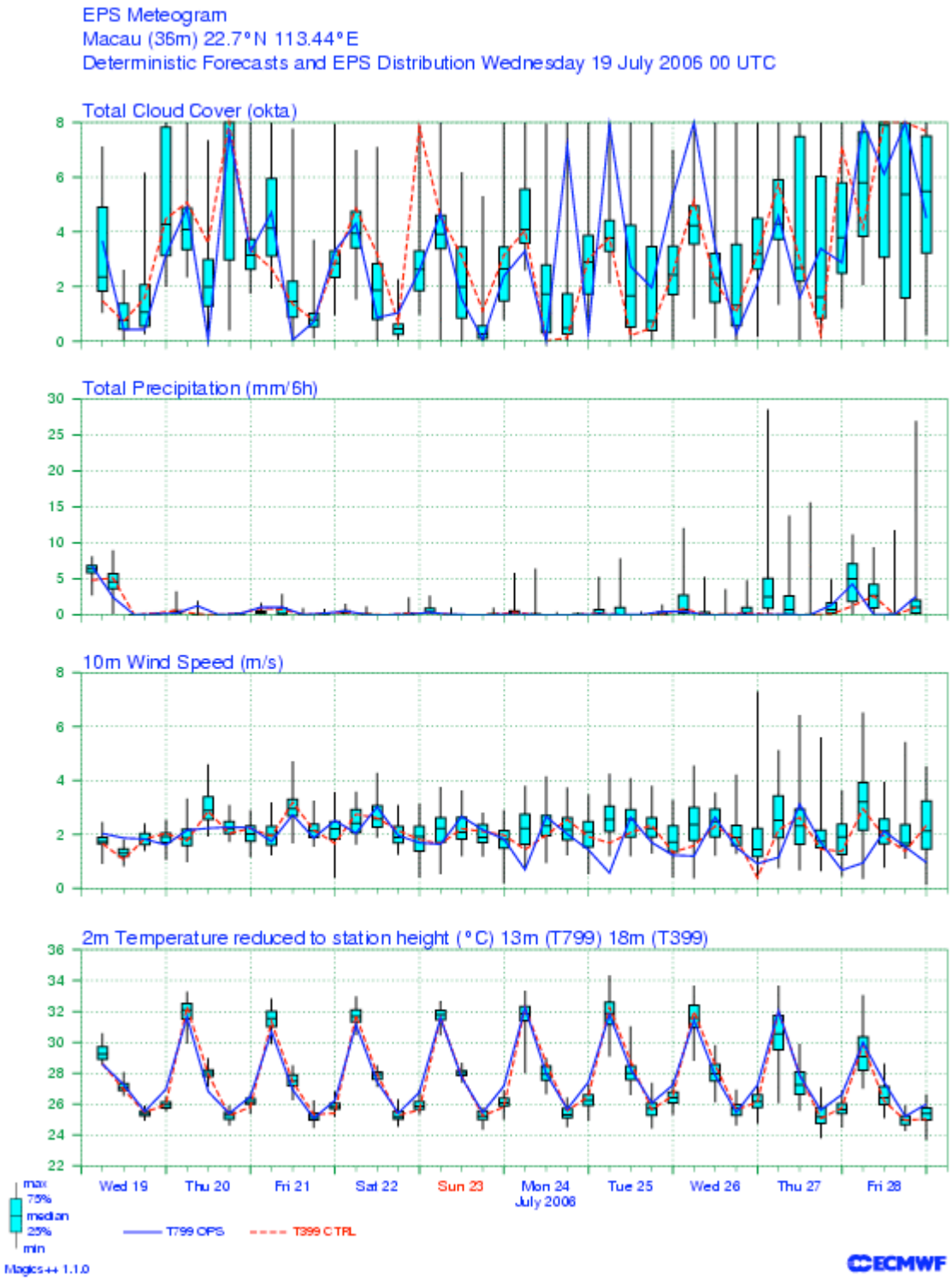

Figure 3: Sample of ECMWF EPS Meteogram for a city forecast (available from ECMWF's website : http://www.ecmwf.int)

2.8 ADVANCES IN PRODUCT DISSEMINATION AND DELIVERY

In recent years the advances in computing technology and the emergence of new and more efficient processes of communication, such as the use of the Internet, have increased the user demand and expectation for accessing more meteorological data and products by different means. NMHSs would benefit from using new technologies for production, communication and delivery of information.

Nowadays the products and information can be delivered through increasingly more sophisticated and efficient dissemination means. The most usual and common way of reaching the public is through the mass media. Radio represents a powerful weather broadcast medium, with the capability of reaching remote communities, especially in the developing countries. Other mass media to reach the public are television and press.

Due to the development of new technologies in communication, it is likely that mobile communications and the Internet will become increasingly important in PWS delivery. NMHSs are encouraged to explore the dissemination of weather warnings and information via mobile telephones.

The dissemination tools include the following.

- ***Fixed and mobile communications systems***: Fixed telephone lines/automatic telephone enquiry systems, mobile telephones (e.g. Wireless Application Protocol (WAP), SMS, Multimedia Messaging Service (MSM)), pagers, handheld devices (e.g. Personal Digital Assistant (PDA) and Pocket PCs), and fax on demand.
- ***Internet***: WWW (World Wide Web), FTP (File Transfer Protocol), E-mail (Electronic Mail) and RANET (RAdio InterNET)

There are many advantages of these dissemination tools.

- ***Quality***. NMHSs can issue their forecasts and warnings through a medium over which they have complete control.
- ***Visibility/Credibility***. NMHSs can effectively become their own broadcasters and be recognized as the official provider of high-quality weather information.
- ***Availability/Updates***. The latest information is always available and updates are provided as necessary.
- ***Visual***. The meteorological information can be in the form of images, including animated imagery.
- ***Capacity***. Vast amounts of detailed information can be made easily available.

It is worthwhile NMHSs putting effort into the development of their web sites to display dynamic information such as current weather, weather forecasts and warnings, and climatological information. Also it is important to include relatively stable materials for public education to promote public awareness and understanding of meteorological information.

The use of web sites as official sources of weather information from various NMHSs such as those for the Severe Weather Information Centre (SWIC) (http://severe.worldweather.int/) and the World Weather Information Service (WWIS) (http://www.worldweather.int/) have proved to be popular and successful. Both of these web sites, sponsored by WMO, were developed and hosted by Hong Kong, China. SWIC provides the basic and official warning information to the public and the media, while WWIS provides the official weather forecasts and climatological information for more than one thousand cities around the world.

2.9 PARTNERSIP BUILDING

The building of partnerships by NMHSs (e.g. with the public sector, media, non-governmental organisations (NGOs), academic sector, service providers and users) are essential for the continued improvement of PWS provided by NMHSs. Establishment of targeted strategic alliances between ministries and/or user groups is an effective mechanism to address the complexities associated with cross-cutting issues. It is important, to this end, for PWS staff to have the opportunity to participate in team- and partnership-building training and experiential learning activities using standard techniques. Some of these techniques are described in Table 4

Government Agencies

NMHSs need to establish close links with relevant government agencies to enhance weather information and warning services as well as to ensure an effective flow of information at all times, especially in case of severe weather. In particular, it is worth NMHSs engaging relevant government agencies as early as possible in the design phase of the arrangements for issuing warnings and advisories linked to the well being of people. The roles and responsibilities of different parties should be formalised in order to promote the sense of ownership and avoid confusion. Formation of intergovernmental working groups is useful for gathering expertise and gaining synergy to tackle issues with common interest such as the environment issues. Joint organization of exhibitions and talks covering various weather-related disciplines will be effective in increasing people's understanding of the nature of hazards, raising public awareness and preparedness of natural disasters, and promoting the intelligent use of weather and climate information.

Weather warning information has to be translated into risk-based assessments with an emphasis on the impacts to users in order to maximise the value of the information. Appropriate advisories accompanied with weather warnings are important for triggering effective response actions of users to combat the threats of hazardous weather. In the translation process of quantifying the weather risks, the expertise required and the responsibility may not be under the purview of NMHSs. As such, partnerships with other relevant agencies are required for the development and implementation of alerts and warning services, which directly link to the effect of severe weather. For example, quantitative studies of the relationship between flooding and rainfall intensity require knowledge of the surface runoff, capacity of the drainage system, and river flow. Consequently hydrologists in the flood monitoring agencies apply flood models to predict flooding using rainfall forecasts as the meteorological input. It is only cooperation

Table 4: Standard techniques used team- and partnership-building training and experiential learning activities.

Technique	Description
Belbin team roles	Belbin team roles describe a pattern of behaviour that characterises one person's behaviour in relationship to another in facilitating the progress of a team. The Belbin roles include implementer, shaper, completer/finisher, plant (generates new ideas), evaluator, specialist, coordinator, team worker and investigator. The value of Belbin team-role theory lies in enabling an individual team to benefit from self-knowledge and adjust according to demands being made by the external situation.
Myers-Briggs personality typing	The Myers-Briggs personality type indicator was developed based on studies on psychological types, temperament and behaviour. The four continuums of temperament, namely introverted-extroverted, intuition-sensation, thinking-feeling, judging-perceiving, which, when combined, give an indication of the underlying temperament of the individual.
Thinking hats	Each "Thinking Hat" is a different style of thinking, which is used to look at decisions from a number of important perspectives and to get a more rounded view of a situation. There are six thinking hats, namely White Hat (look at the facts and figures), Red Hat (listen to emotions and intuition), Black Hat (look at why this will fail), Yellow Hat (be hopeful and optimistic), and Green Hat (look from a higher and wider perspective to see whether the right issue is being addressed).

between meteorologists and hydrologists that makes flood forecasting possible.

Emergency Managers

NMHSs have to work closely with emergency managers to ensure that the severe weather warning systems function effectively and efficiently in the prevention and reduction of the impacts of natural disasters.

Collaboration between NMHSs and emergency managers need not only be at the end of the process when the emergency managers themselves need to take some actions depending on the severe weather warning issued by the NMHSs, but also before and during the development of a severe weather warning system. It is good practice for staff from NMHSs to work with emergency managers (a) in the design phase of a warning service and (b) before, during and after a severe weather event.

One of the most important aspects is that staff from both the NMHSs and emergency managers should work together as a team, since they are working for the same purpose – to reduce the impact of severe weather on society and to minimise casualties and losses due to severe weather.

There are several actions that can be taken to enhance team working.

- ***Contact points***. Assign people from the NMHSs and the emergency managers to be the regular contact points.
- ***Regular meetings***. Conduct regular meetings, not only between the focal points, but also the operational staff of both services to review the operational arrangements as well as to promote understanding.
- ***Direct contact***. Establish direct contact with the operational staff of the emergency managers by forecasters before and during the severe weather event.
- ***Education and training***. Provide education and training for operational staff from both services on topics relating to the general aspects of their operational work so as to increase the mutual understanding and recognition of what each services requires to be effective.

Before, during and after a severe weather event an NMHS could consider taking the following action.

- ***Before and during the severe weather event***. Alert and brief the emergency managers through the established focal points. Update data and information in real time. Use a variety of communication channels for reaching the public to explain the severe weather situation. Provide recommendations and advisories on precautionary measures, and draw attention to information provided by the emergency managers.
- ***After the severe weather event***. Review the severe weather event and warnings issued with the emergency managers. In association with the emergency managers issue a press release and/or conduct a press briefing on the severe weather event, the impacts to the region and the warnings issued.

The Media

The media fulfil a natural and traditional role as "partners" of the NMHSs in communicating weather information to the community, especially during severe weather situations. The public needs to be confident that when severe weather occurs the media will disseminate information from the NMHSs and the Civil Protection Authorities so that the public get to know what precautionary measures are to be taken.

It is important to have a good and efficient working relationship between NMHSs and the media. Most of the NMHSs have a long tradition of being a provider of meteorological information to newspapers, radio and TV. This provides a sound basis for developing good relationships with reporters and editorial staff. The result is

that all concerned will understand each others needs and the constraints under which they work.

Nowadays the public expects meteorological information not only for the region where they are living, but also the places to which they travel for holidays or business. So the national media need global weather information to meet the demands of users. An important and popular means of dissemination of global weather information is television, though newspapers also have a role.

The advent of international television networks now enables weather presentations with global coverage to reach wider audiences. Taking into account the demand of the public and consequently of the media for worldwide weather information and hazard warnings, this poses a challenge to all NMHSs for developing an appropriate system for the exchange of weather information and warnings.

In most countries, radio is widely accessed by the general public. As it is responsive to updated messages, it is usually considered as the preferred media for issuing hazard warning messages.

Some recommended actions to help create good relationships, improve the understanding of requirements and enhance credibility are described below.

- ***Focal point***. Designate a focal point for media liaison (preferably a senior authoritative spokesperson) in the NMHS who will give interviews, issue press releases and organise press conferences.
- ***Regular meetings***. Organise regular meetings with the media and visits to NMHSs.
- ***Products***. Introduce the available weather products to the media.
- ***Training***. Provide training to the NMHS personnel who conduct weather presentations on TV and radio, and generate text and graphical weather information for the media.
- ***Guidance material***. Create guidance material for improving the presentation of forecasts and warnings to ensure maximum clarity and understanding.
- ***New technologies***. Explore the use of new technologies in disseminating meteorological information via the media.
- ***Single source of information***. Demonstrate the importance of having a single source of information – the official source, especially in the case of severe weather warnings.
- ***Exchange of weather warnings***. Develop an information system for the exchange of weather warnings on an international basis so that warnings are issued in a timely and coordinated manner, contradictory warnings which cause public confusion are avoided and the "single voice" principle is upheld.

2.10 WORKING WITH ACADEMIA

NMHSs are facing difficult challenges arising from the rapid developments of technology and communications as well as the latest scientific advancements in numerical models. Many studies are carried out not only at the NMHSs but also at universities particularly in the area of NWP. Enhancing the cooperation with universities or academic institutions helps update NMHSs with the latest scientific developments in meteorology, such as the improvements in numerical models of the atmosphere and oceans.

Working together with academia can be established through various ways:

- ***Research cooperation***. Cooperation in research activities and validation of the results of research, and working together on projects involving data exchange.
- ***Involvement in operational meteorology***. Exploring the feasibility of operational implementation of a system and validating recent developments in numerical models with a view to improving weather forecasts and services.
- ***Supporting university students***. Complementing theory learnt by students at the universities with practical work at the NMHS and attaching final-year university students to the NMHS.
- ***Promoting a career in meteorology***. Organizing visits to the NMHS for the students, promoting the NMHS to the science students as a potential institution at which to work, and working together with universities to develop and produce educational packages to prepare students to work at the NMHS.
- ***Supporting school students***. Conducting talks and seminars at schools and interacting with the students and teachers, printing regular brochures for distribution in schools, and developing meteorology-related educational packages for inclusion in school curriculum for different levels.

2.11 PUBLIC COMMUNICATION

One of the most important purposes of the PWS is to provide comprehensive and useful weather services to the community. The NMHSs need to be aware of the public demands and the best way of communicating with the public in order to maximise the benefits to the community at large.

There are a number of ways to ensure that the public can make effective use of the information provided.

- ***Language***. Use appropriate, concise and user-oriented language.
- ***Products***. Develop user-friendly products based on the understanding of the needs of the public.
- ***Guidance***. Provide guidance to the public on how to use the meteorological information.
- ***Uncertainty***. Communicate uncertainties in weather forecasts to the extent possible.
- ***Verification***. Publish information about the verification of forecasts.
- ***Brochures***. Produce and distribute brochures on PWS of the NMHS.
- ***Two-way communication***. Implement two-way communication.
- ***Public education and awareness***. Promote public education and awareness by, developing educational products and services in cooperation with the media, organising seminars or talks for teachers and students, developing educational materials for different ages, including PWS in the school curriculum, and organising student visits to the NMHS.

It is worthwhile NMHSs taking action to identify public needs and the extent to which they are being satisfied. There are different ways to collect the required information.

- ***Meetings and seminars***. Conduct meetings with the targeted user sectors and organise seminars on PWS.
- ***Visits, open days and exhibitions***. Arrange visits to the NMHS, organise an "Open Day" at the NMHS (which can be scheduled with other special event, such as the World Meteorological Day) and hold public exhibitions.
- ***Questionnaires***. Develop questionnaires on how users evaluate the performance of the PWS of the NMHS, distribute it to the user groups and/or display it on the NMHS's web sites.
- ***Web site***. Provide an e-mail address on the NMHS's home pages to receive public comments and suggestions.
- ***TV and radio forums***. Participate in radio or TV forums with the invited public.
- ***Specialised staff***. Designate specialised staff in the NMHS for promoting and marketing PWS.

2.12 COMMUNITY OUTREACH

Community outreach tends to focus on the output of information rather than the actual acquisition of knowledge, yet to be effective, knowledge needs to be acquired. Community outreach goes beyond a selected group of learners and brings information to a much broader audience. It engages potential learners and encourages knowledge acquisition. Another important dimension of community outreach is that of bringing into the NMHSs the users needs, perspectives and expectations.

User Liaison

User liaison and consultation is an important component of outreach. There is a need to enhance close relationship between the service provider and the community. This can be done by addressing the following issues.

- ***User satisfaction***. Determine whether user needs are met, and gain an understanding of the users' capabilities and requirements so as to enhance their satisfaction.
- ***Community understanding***. Promote a better understanding by the community of how services can be and are provided, the infrastructure which is required to support their needs, and the determination to strive for a higher quality of service.
- ***Staff motivation***. Motivate the NMHS staff by sharing with them the importance of their job and demonstrating to them that their efforts are recognized by the public, through interactions and feedback received.
- ***Service improvement***. Stimulate the provision of a better quality of service and bridge the gap between the services provided and community expectations.

The broad objective of outreach is to enable NMHSs to take measures that will enhance user satisfaction.

There are at least two broad categories of outreach: the direct relationship between the NMHS staff and individuals from the user communities and the "remote" approach in which an outreach service is provided remotely and its effectiveness is measured by some remote means.

Community Outreach Implementation

Some points listed below are important to the implementation of community outreach:

- ***Liaison and consultation meetings***. Organizing liaison and consultation meetings with representatives of user groups in order to, discuss user needs and the service provided, consider potential future developments, review the quality of the service and update service specifications, and register complaints or compliments to be made known to staff with details of any action taken.
- ***Spokespersons***. Using spokespersons can be a most effective outreach tool and create recognition of a credible source.
- ***Surveillance methods***. Using surveillance methods to provide indicators of a gap or fault of the meteorological service.
- ***Outreach support***. Assessing whether the outreach support activity for a certain programme area or for a certain sector of the user community may be inadequate or absent.
- ***Measures of effectiveness***. Using more than one measure of the effectiveness of the outreach activity.
- ***Expertise***. Realizing that experts from other disciplines such as psychologists, sociologists, economists and marketing experts can contribute to a better understanding of the evaluation results.

Though time and resource consuming, using specialised channels of communication, especially interpersonal interactions, are the most way effective of shaping personal behaviours. Such specialised channels need to be chosen with the characteristics of the target audiences in mind. Reaching out to a homemaker and a teenager should naturally entail different direct, channels (Ho, 2005).

Community Outreach Evaluation

Each outreach activity or at least every activity area should include an evaluation component that is executed as part of the outreach activity. The NMHS will then know how well the outreach activities are working and the services are satisfying user needs. So it is essential to establish a basis for measuring performance.

Quantitative evaluations can measure changes in knowledge and attitudes, and qualitative evaluations can give a better measure in the case of behavioural changes.

For the purposes of evaluation of community outreach, the programme normally includes the following.

- ***Evaluation criteria***. A set of evaluation criteria based on what the community should be able to do and understand as a result of their learning.
- ***Baseline***. A baseline of pre-programme level of knowledge and understanding using a pre-testing method or other means.
- ***Evaluation processes***. The process which will be followed to evaluate the outreach programme, including how different phases of the programme will be evaluated.

After the final evaluation there needs to be an assessment of whether the programme was successful or needs improvements. The results of the evaluation can then be communicated and incorporated into any programme adjustments after review.

The methods of evaluation may include focus groups, debriefing meetings and follow-up interviews, surveys, pre- and post-testing, field observations and in-depth interviews, telephone interviews and on-line evaluation formats (for web-based outreach materials).

2.13 USER CONSULTATION

NMHSs need to gather feedback from the public on their service performance from a user perspective and incorporate the feedback into the improvement process of the services. When weather information can be accessed from multiple sources, including the private sector, it is essential to ensure that NMHSs are providing the necessary information for the safety, economic welfare and convenience of the public. Also there needs to be confidence that information is well understood by the public. To obtain and understand public needs and views, NMHSs can do the following.

- ***Questionnaires to the public***. Implement studies and issue questionnaires to the public to obtain users' views, suggestions, requirements and needs, and response to meteorological information. Public views on the following points can be obtained from questionnaires: capabilities and credibility of the NMHS, confidence in forecasts and warnings, language used in forecasts and warnings, and quality of TV and radio presentations.
- ***Questionnaires to organisations***. Distribute questionnaires on the performance of PWS to different organizations and display them on the NMHS's home pages.
- ***NMHS home page***. Provide an e-mail address on the home page of the NMHS to gather public views, suggestions and requirements.
- ***Radio or TV discussion forums***. Participate in radio or TV discussion forums with participation of the public.
- ***Open Days***. Organise an "Open Day" at the NMHS – normally, this can be scheduled with other special events, such as the World Meteorological Day.

2.14 PUBLIC AWARENESS AND UNDERSTANDING

Weather forecasts, which contribute to people's day-to-day convenience and well-being, need to be presented in plain and easy-to-understand language. In adverse weather situations it is particularly important that weather warnings are presented in such a way that the public understands what is happening, the consequences for them and what they can do to minimise the impact of severe weather. To avoid public confusion, any information issued by the NMHS and emergency managers should be consistent.

There are many means to reach the public but one important aspect is the content of the awareness message – it has to be comprehensive and fully understood by the public. It is good practice to include the following.

- Type of warning and issuing source/authority.
- Severity of the event, expected duration and regions to be affected.
- Conveyance of uncertainty by using such words as " if", "then", "may", "should", "could", etc. or by using probability of occurrence in different regions.
- Information for public safety and protection (also from the emergency managers).
- Bulletins in all the commonly spoken languages.

The desired characteristics of the dissemination of information via the media and more modern means of communication are given in Table 5.

As radio is more responsive to updated messages and it is also, in most of the countries, the preferred media for receiving severe weather warning messages, NMHSs should ensure that radio is as widely used as possible in dissemination of warnings.

Table 5: Desired characteristics for the dissemination of information by the media and more modern means of communication.

Dissemination medium	Desired Characteristics
Radio, TV and print	• Written in plain language. • Simple style. • Short and concise.
Internet, mobile communication system or electronic mail	• Clear, simple and easy-to-understand. • Bold colours (colour blindness constitutes a portion of the population). • Use well-known geographical landmarks. • Use symbols and different colours to identify the phenomenon and its intensity (explained in a key or legend). • Indicate the expected date and time that the phenomenon should reach a specific region, whenever possible. • Indicate probability of occurrence of the event in different regions. • Provide information on public safety and protection (also from the emergency managers).

It is essential to keep the public updated about the evolution of a severe weather event and to allow access to some of the real-time meteorological data. Nowadays, many NMHSs make available this information on their web sites.

The warning message will only be effective and useful if the public understands it. Therefore NMHSs need to develop actions to promote public awareness and preparedness for natural disasters and understanding of the warning message. One of the most important actions is public education. To this end it is worth creating a range of educational products and services in partnership with emergency authorities and academics on different themes.

Public education on the following is recommended.

- ***Role of NMHSs***. Enhancing the public's understanding of the NMHS's services, responsibilities, facilities and operations.
- ***Weather information***. Promoting the use of different types of weather information and communicating the use of wording in weather forecasts.
- ***Awareness of hazards***. Explaining the nature and the associated risks of different weather phenomena and increasing people's understanding and awareness of hazards.
- ***Response to hazards***. Raising awareness of recommended responses to warnings and defensive actions that are within the capacity of people.

Real-time education about severe weather can be accomplished by the provision of weather synopsis and precautionary measures through various dissemination channels during the warning period. This is particularly effective when people are in need of such information to understand the weather situation and take appropriate actions.

The role of the media in the education process is essential. They are the main disseminators of weather warnings to the public and therefore they play a vital role in the successful implementation of an NMHS's responsibilities for public awareness, educational activities and warning delivery. It is, therefore, important to maintain close contacts with the media and to organise educational programmes to support media activities.

Post-disaster studies have found that live interviews by a trusted local media commentator with emergency managers and hazard specialist before, during and after the severe weather event are extremely effective. Community residents are very receptive when it is known that the information has been derived and delivered from a local source. Live-to-air interview is an excellent means of both communicating hazard information and building community trust.

2.15 BUILDING PUBLIC CONFIDENCE

A major goal of an NMHS is to meet public expectations through the provision of comprehensive weather information with a particular emphasis on public safety and welfare. The public need to feel confident that they are safe against extreme weather events because there are public institutions, such as the NMHS, monitoring the evolution of the severe weather and issuing appropriate warnings.

NMHSs have to bring confidence and credibility to the public so that the public trusts the meteorological information and warnings. Increasingly more users are expecting high-quality information and comprehensive coverage of weather information from regional to global scales and from short- to long-range forecasts.

To build public confidence, NMHSs could take actions including the following.

- ***Interviews***. Organise interviews of well-trained meteorologists who can demonstrate their know-how and engender confidence in the expertise of the NMHS staff providing services. Live interviews during hazardous weather are an effective way of building trust especially when the information is from a local source.
- ***Quality of information***. Give clear, timely and accurate information to the public, especially in relation to hazards, and explain any uncertainties.
- ***Explanations of wrong forecasts***. Explain the reasons for wrong forecasts particularly in the case of severe weather warnings.
- ***Single source of information***. Emphasise that the NMHS is the authoritative source of weather information, especially for severe weather warnings, and uphold the "single voice" principle so as to avoid inconsistent forecasts which cause public confusion.
- ***Resources***. Demonstrate to the public that the NMHS keeps up-to-date with the new technologies not only in the retrieval of meteorological information but also in the presentation and communication systems, and that their personnel have the required expertise to formulate and deliver weather forecasts.
- ***Visits to NMHSs, brochures, exhibitions and talks***. Organise public visits to NMHSs,produce brochures on weather services regularly, and organise public exhibitions and talks to show the importance of meteorology with a focus on themes of interest to the public (e.g. meteorological observations and numerical weather prediction, range of weather services provided and the economic value of weather services, and climate variability and change).

2.16 MANAGING USER PERCEPTIONS

NMHSs often use objective verification schemes to calculate the accuracy of forecasts as a measure of service performance and quality. However, the measure of success from the user perspective is the extent to which user expectation is matched by the services delivered. Since the delivery of service requires resources, while it costs nothing to have high expectations, there is always a gap to be filled between the two (Lam, 2005). Once the level of service is raised, people ask for more. The better the forecast becomes, the more difficult it is to get even better, and the higher the user expectations for future performance.

As well as the expectation gap, there is also a gap in technical communication and influence. The availability of technically advanced products has had only a limited impact on users and even then it is only the most sophisticated users that see the benefits. The influence gap exists because users have few, if any, opportunities to influence the way products and services are developed. There is always a mismatch between user perception and user expectation. This gap can never be filled, but it needs to be managed in order to

narrow it to within the zone of tolerance of people through improved service and better communication as well as greater mutual influence between service provider and user (Figure 4). If this is done successfully there is no strong criticism of the services provided and people are generally satisfied with the weather services. At the same time this "toleration" gap can motivate NMHSs to continue striving for service improvement and enhancement.

Users may accept some variation in performance and any increase or decrease in performance within the zone of tolerance will only have a marginal effect on perceptions (Johnston and Clark, 2005). Critical factors which affect user perception of the service quality need to be identified. Satisfaction may be maintained if an incorrect forecast appears to be compensated by many incidents of reliable forecasts. However, people will hardly ever forget wrong forecasts when there is devastating weather. Weather forecasts and warnings in severe weather situations are most critical to changing user perception of service performance. A forecast failure for a significant event may reduce the range of tolerance and lower the threshold for dissatisfaction (i.e. people will more readily become dissatisfied).

Forecasts for long holidays, festive activities and large outdoor events carry more weight that those for usual days. The overall degree of satisfaction and performance perception is evaluated by summing up these satisfying and dissatisfying experiences.

To manage people's perception and to widen their zones of tolerance, alignment has to be made between user expectations and the nature of the service. In reality perfect forecasting is not attainable. Therefore, when there is a major failure in forecasting a severe weather event, special media briefings immediately afterwards to explain what happened and the forecasting limitations and difficulties will help manage people's expectations. This is especially effective if those involved in the briefing are open and frank. Outreach to the user sectors and engaging in public education programmes, which aim at informing the community about the nature of the hazardous phenomena, what NMHSs do to enable the users to handle the risks, and most importantly, the uncertainties inherent in the forecasts and warnings, are effective ways to manage user perception. Through these activities, there can be an enhancement of the capabilities of users in the use and interpretation of weather forecasts.

User reference groups are useful for identifying and monitoring the requirement for the perception of PWS services. Through managing the perception of user reference groups, these groups may serve as a role model to spread the message about the importance of the PWS.

NMHSs need to be aware that PWS products are pivotal to user perception of their performance. The user perception of the PWS may also impact on the publics' perception of the government's capability and commitment to the protection of life and property. All this puts an obligation on NMHSs to be aware of user perceptions and take action to improve perceptions.

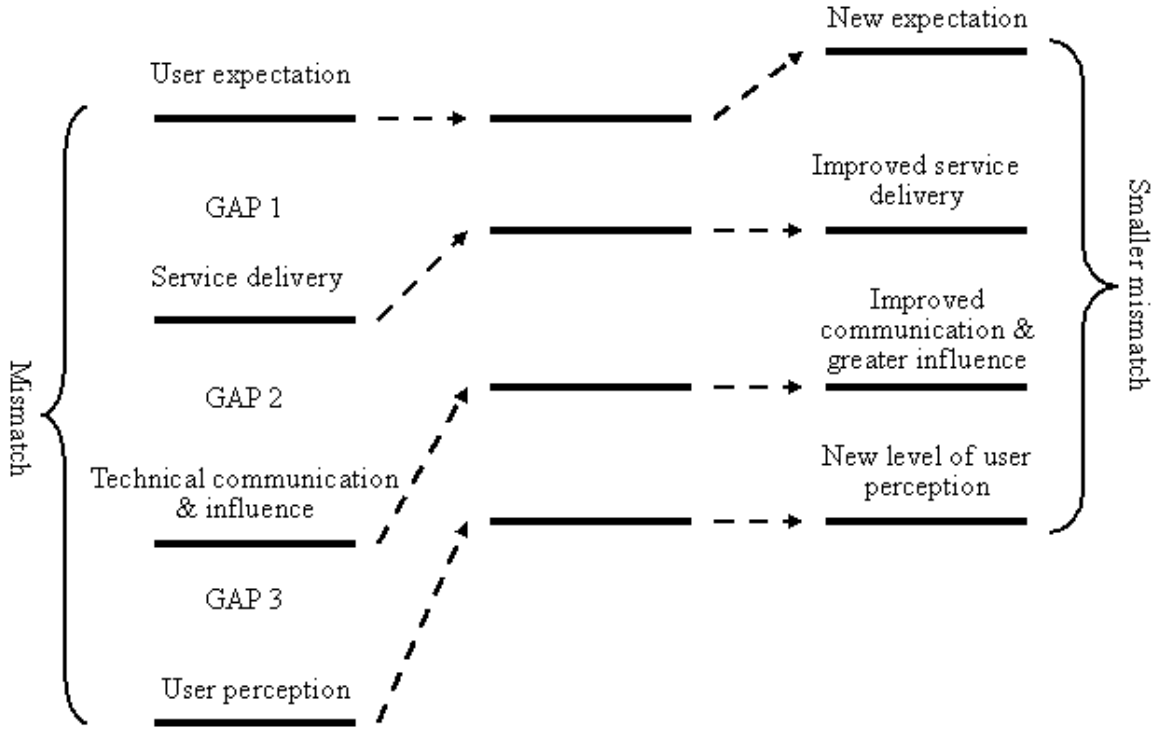

Figure 4: The mismatch between user expectation and user perception can be reduced with improved service and communication, as well as greater mutual influence between service provider and user.

2.17 INVOLVEMENT OF VOLUNTEERS

NMHSs have traditionally relied on thousands of volunteers to gather weather and climate data, including information on extreme weather phenomena, such as tropical cyclones or tornadoes, and hydrological information on river flows. Over many years volunteers have made a valuable contribution to the advancement of meteorology and hydrology.

Local weather observations made by volunteers are valuable to a wide range of users such as farmers, utility planners, business and local governments. Planners and decision makers also use these observations and others obtained from NMHSs to plan the socio-economic development of a place or region.

In some countries most of the voluntary observers are from the rural community (e.g. farmers, students from agricultural schools and people from rural settlements and cooperatives) as these people have a strong interest in knowing about the weather and climate due to the impacts they have on their livelihood. People living close to rivers are also motivated to contribute to timely flood warnings to protect the safety and interests of the community.

NMHSs also arrange for voluntary observations from aircraft and ships under the WMO Voluntary Observing Ships Programme. Ships' weather observations provide vital information needed to identify the prevailing weather systems and are especially important for the preparation of forecasts for the sea areas and the timely preparation of warnings of hazardous weather conditions.

It is worthwhile NMHSs stimulating the involvement of volunteers by targeting people from areas whose way of life might be particularly affected by the weather and climate (e.g. people from the agriculture and fishing sectors, and those living away from the cities). Schools are also important partners that have been collaborating with NMHSs on various projects, particularly those involving meteorological data measurements. These projects are important since they can make students enthusiastic about the weather and encourage them to consider a career in meteorology. While they are learning, they are also providing important information to the NMHSs.

People from different ages and professions might be recruited as volunteers, such as farmers and fishermen, students and schoolteachers, lighthouse keepers, civil servants, retirees (including military personnel), missionaries, park and forest rangers, and convenience store workers

To involve and motivate people to work as a volunteer, NMHSs could take a variety of actions.

- ***Direct contact, meetings and visits***. Contacting communities directly (e.g. schools and agricultural communities), organising meetings and arranging visits to the NMHS to describe the work of NMHSs, explain the benefits and the importance of their collaboration, and motivate potential candidates to join the volunteer groups of the meteorological community.
- ***Certificates and awards***. Giving certificates and awards to some of the outstanding volunteers (for example, on some specific dates such as the World Meteorological Day).
- ***Training and seminars***. Offering volunteers regular training and seminars as well as visits to NMHSs.
- ***Web pages of the NMHS***. Promoting collaboration with volunteers through the web pages of the NMHSs.

Volunteers, as contact points for the NMHSs with the community, have an important role in supporting the early warning system and raising awareness of rural communities to the risk of natural disasters.

2.18 QUALITY ASSURANCE

The public and specific users require assurance that the product or service provided by the NMHSs meets certain quality standards.

In recent years, the establishment of non-governmental providers of meteorological services has encouraged NMHSs to focus on user satisfaction, and consequently NMHSs have put increased emphasis on quality, specifically quality management.

The International Organization for Standardization (ISO) has developed the ISO 9001 series of international quality management standards for quality assurance of products and services. Based on this, different organizations, including NMHSs, can receive an external recognition of quality.

Quality assurance is a set of all planned and systematic activities implemented within the quality management system. Such a system consists of four basic steps: plan one's action, do the best one can, check the results of one's action relative to user satisfaction, and react to received information and improve future action.

NMHSs have to face different challenges but one of the most critical is the implementation of a quality management system. This might present difficulties in terms of costs (e.g. project team, training, performance measurements, audits), but the advantages are enormous, as described in Table 6.

It is worth all NMHSs putting into practice at least the basic components of quality management as listed below.

- ***Legal or statutory requirements***. Compliance with legal or statutory requirements.
- ***Mission statement***. Clearly articulated mission statement or mandate.
- ***Service statements***. Comprehensive level of service statements understandable to the user.
- ***User requirements***. Mechanisms for soliciting and validating user requirements.
- ***Scientific accuracy***. Mechanisms for ensuring scientific accuracy.
- ***Standards and operational procedures***. Comprehensive standards and operational procedures for the NMHS's key processes and product/service offerings.
- ***Performance monitoring***. Technical and scientific performance monitoring of indicators for key processes, services and products.
- ***Fault response***. Strategy and capacity for fault response and remedying under-performing processes.
- ***Programme renewal***. Mechanism or strategy for continuous programme renewal.
- ***User-based assessment***. Mechanism for user-based assessment of end products and services.

Table 6: Advantages of implementing a quality management system.

Area of activity	Advantages
User needs	• Gaining user confidence and goodwill. • Fostering relationship between the NMHS and the user. • Retaining users through the provision of quality products or services. • Ensuring the NMHS concentrate on a longer-term strategy in order to satisfy user needs instead of focusing only on short-term solutions.
Quality control	• Exercising control in ensuring that every step is carried out according to the documented procedures. • Ensuring greater quality awareness throughout the organization. • Providing assurance to responsible authorities and other government agencies that the NMHS has effective management systems. • Ensuring proper documentation is in place and is known by NMHSs staff in the auditing process. • Receiving external recognition of quality.
Development	• Contributing to sustainable development by the NMHS. • Providing a framework for continual improvement process.
Science and technology	• Increasing emphasis on technological changes. • Assisting the NMHS to be up-to-date with new technologies. • Assisting the NMHS with optimising science and technology opportunities in meeting the user needs.
Efficiency	• Increasing productivity and efficiency. • Contributing to elimination of unproductive work
Staffing	• Attracting more and better qualified candidates for recruitment. • Training staff to execute the documented procedures.

Most NMHSs have quality assurance measures for data collection, NWP models and forecast production processes. However it is not sufficient to just have these measures, it is also necessary to have performance management in the area of service delivery. Most important of all is to analyse whether the products and services meet the needs and expectation of the users. Therefore it is essential to get feedback from users.

To increase user support, information on the overall performance of PWS needs to be communicated to the public via the media, NMHS's website, and specific documents and posters. Of course the information has to be presented in a brief and easily understood fashion (e.g. verification of deterministic forecasts such as daily maximum or minimum temperature forecasts as compared to that observed).

Verification of the quality of PWS must be done on a routine basis. This information can be used internally for management, staff and programme development and externally for communication about the NMHS's activities. However, care must be taken in presenting this information as scientific verification may be difficult to understand for people outside the scientific community.

Performance reports can be included into the annual report of the NMHS and be put on the NMHS's website. Communicating these results to the general public can increase public awareness of the NMHS's activities and raise the credibility of the NMHS. It can even modify certain practices or accelerate the development of new services or products by the NMHS.

2.19 CULTIVATION OF A SERVICE ETHIC

In the past NMHSs have tended to put the emphasis on improving forecast accuracy with little consideration given to knowing how their products and services would be used by the community to whom they were directed. However, in recent years there has been a paradigm shift within the public sectors around the world – emphasis is now placed on the development of a user-focused service ethic. It is important, therefore, that all NMHSs take up this challenge in the development and delivery of products and services. This can be supported by ensuring that the initial training of new staff and refresher training for existing staff include elements designed to cultivate a user focus, a recognition that good quality services must be provided, and a commitment to service improvement at all levels of the NMHS.

Chapter 3
BUILDING THE REQUIRED CAPACITIES

This chapter deals with the principal mechanisms by which NMHSs and their staff can develop the capacities identified in Chapter 2. While many of these mechanisms are well established in the WMO Education and Training and Technical Cooperation Programmes, their specific application to capacity building for PWS is new. Also there are new mechanisms that are needed specifically for PWS capacity building that have not previously been used for WMO purposes. Figure 5 summarises the mechanisms of building the required capacities for delivering the PWS.

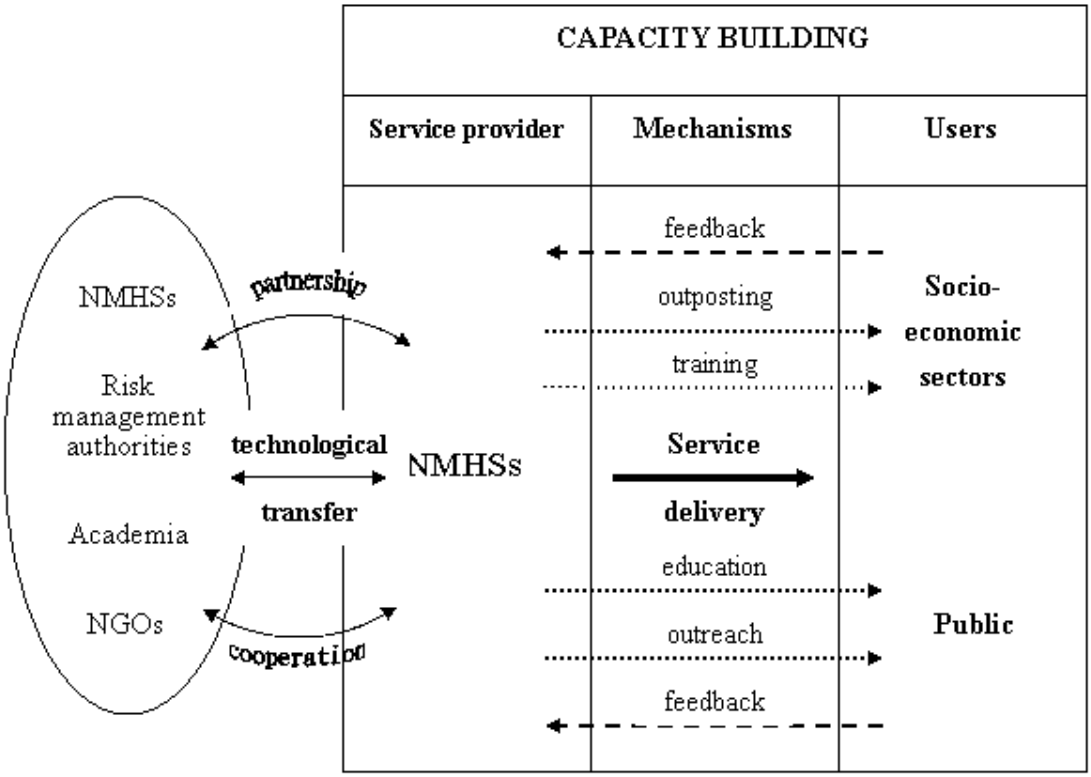

Figure 5: Mechanisms of building the required capacities for delivering the PWS.

3.1 COMPETENCY REQUIREMENTS

The job competency requirements, expressed in terms of knowledge and skills, for each of the main branches of meteorological and hydrological activities in typical NMHSs are detailed in the Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology (WMO-No 258, 2000). The guide provides an internationally recognised framework for training activities in basic and specialised fields of meteorology and operational hydrology, and is particularly relevant for NMHSs in developing countries. The framework emphasises the scientific and technical requirements, and the contribution they make to the improvements in weather monitoring techniques as well as the accuracy and reliability of weather forecasts. However, in order to reap the benefits of improved forecast accuracy and reliability, the improvement has to be translated into enhancement of weather services, and mechanisms need to be in place to ensure that people can benefit from the enhanced weather services. It is equally important, if not more important, to formalise the competency and skill requirements in the area of PWS for successful fulfilment of the role of NMHSs in supporting the safety, security and general well-being of society.

For NMHSs professional staff engaging in PWS the competency and skill requirements, as summarised in Figure 6, are given below.

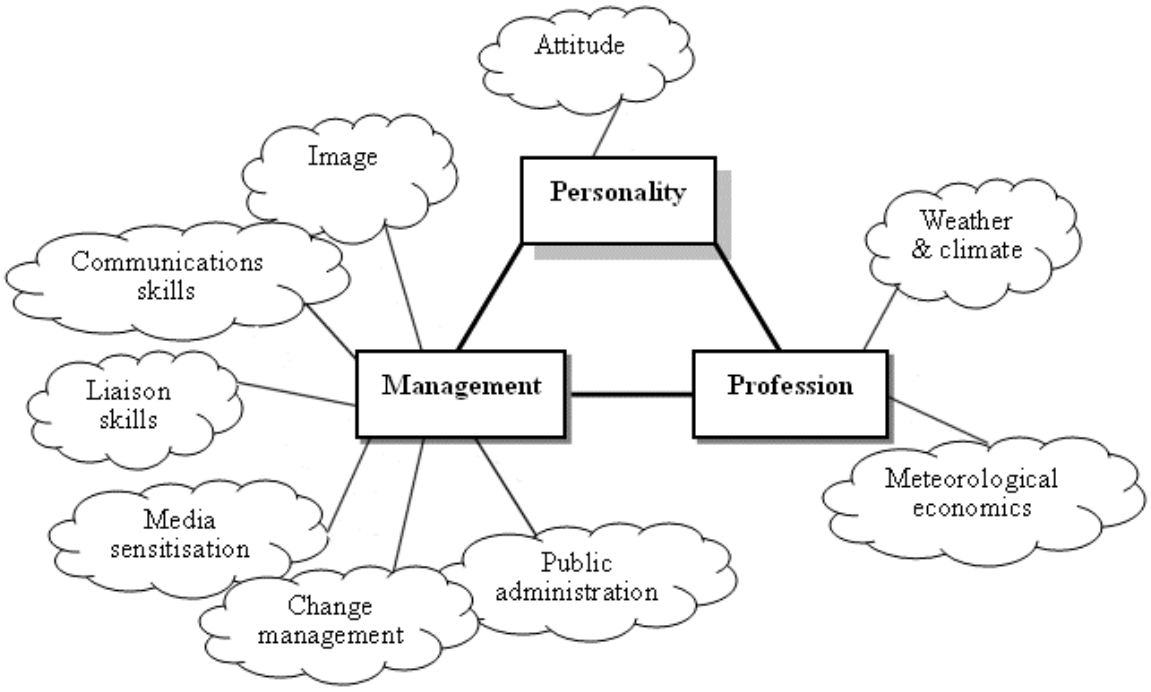

Figure 6: The competency and skill requirements for NMHSs professional staff engaging in PWS.

- ***Attitude***. Understand government policy and buy into the mission and values of the PWS of the NMHSs; possess clear vision and drive to achieve results; be people and results oriented; be enthusiastic, receptive, adaptive, motivated, and patient.
- ***Image management***. Be able to project the desired authoritative image; demonstrate self-confidence and professionalism; be a good listener.
- ***Communications skills***. Demonstrate skills in public and community relations; have skills in intercultural communication; be able to use simple and easy-to-understand language to communicate with and convey desired message to users; have good presentation skills to impress audiences; possess skills in marketing, interpersonal relations, handling complaints and crisis communication.
- ***Liaison skills***. Demonstrate negotiation and mediation skills to bridge the gap between user expectation and product generation or service outcome when liaising with external users and internal staff responsible for technical development of new products.
- ***Media sensitisation***. Be sensitive to hot topics and important weather or climate-related issues; learn from hindsight and be aware of opportunities and challenges affecting the PWS.
- ***Weather and climate***. Possess broad all-round knowledge and perspectives on various disciplines of meteorology, information technology, and communication and dissemination channels to gain the respect and trust of users.
- ***Public administration***. Possess basic knowledge of public administration which includes aspects of several disciplines such as sociology, political sciences, administrative law and public finance.
- ***Assessment of socio-economic costs***. Understand the economic framework for the provision of weather services; be able to evaluate the socio-economic costs and benefits of weather services; demonstrate to governments and users how weather, climate and environmental issues impact on sustainable development; possess basic knowledge of meteorological economics.
- ***Management skills (for managerial level)***. Be proficient in general management, management of diversity and change, policy formulation and implementation, financial management, leadership, priority setting and resource mobilization.

The competency and skills required for PWS need to be incorporated into the guidelines for training personnel in meteorology and operational hydrology in the future so as to maximise the values of weather and climate information to the users.

3.2 DEVELOPMENT OF COMPETENCIES

There are a variety of ways of developing the initial competencies required of NMHS staff that deliver the PWS. Attendance at training courses is probably the most common way of helping NMHS staff acquire the knowledge of meteorology and the associated skills required to deliver the PWS. These attributes are sometimes referred to as “hard skills” – the technical abilities and knowledge required to do a job. In addition seminars, workshops and conferences can also play a role.

Training Courses

Training courses are an integrated series of learning events which have a common aim. The learning events, which are mainly instructor led, could include lectures, exercises, case studies, experiments, simulations, self-study and projects using conventional learning techniques as well as e-learning (e.g. using internet, intranet, audio and video tapes, CD-ROMs or DVDs). Courses usually last several days or a few weeks, though some can last many months. Long courses may be split into modules covering different topics.

Courses are usually characterised in terms of either the content (i.e. the curriculum) or what it is expected to achieve (i.e. learning outcomes). In addition a statement of who the course is for (e.g. prerequisite knowledge, skills and experience) is required.

Training courses often require a big investment in time and resources. Therefore evaluation of the effectiveness of the training is particularly important, and it is appropriate for it to take place on three levels.

- ***Reaction***. Is the participant satisfied with the course?
- ***Learning***. Has the participant acquired the knowledge, skills and attitude specified by the learning outcomes?
- ***Job behaviour***. Has the participant changed work behaviour or job performance?

Distance and virtual web-based education can also make a significant contribution to developing competencies. Such materials can be used to replace a traditional training course or used to supplement more traditional training methodologies. The distant learning courses on various meteorological topics (especially weather forecasting) operated by the Cooperative Program for Operational Meteorology, Education and Training (COMET) Program (http://meted.ucar.edu/), which is in cooperation with WMO and some NMHSs, is a good example of high quality material that is focussed on the needs of forecasters and those involved in the delivery of the PWS.

Seminars, workshops and conferences

Seminars, workshops and conferences are methods that can be used to equip NMHS staff with the required expertise. Such events can aim to further improve service provision by providing information about the latest development in science and technology, cultivate a service culture within the organisation, or stimulate creative ideas and new initiatives to meet the emerging challenges and opportunities. A common feature of these events is that they are of short duration (a few hours up to a few weeks) but with specific objectives and scopes.

- ***Seminars***. These are meetings of specialists in a particular field or briefing sessions aimed at exchanging information and holding discussions. Often there is a single presentation covering some facet of knowledge or skill.
- ***Workshops***. These are meetings that offer opportunities for people with a common interest or problem to meet with specialists to receive first-hand knowledge and to undertake practical work. Such events are characterised by open discussion, a free exchange of ideas, and the active participation of everyone attending.
- ***Conferences***. These are events consisting of presentations and discussions where people with a common interest meet for several days or weeks to exchange views and share information on a specific topic. They usually involve a large number of speakers and other participants.

Transfer of knowledge, interactions and discussions among participants at these events can provide a catalyst for further development of products and services. In addition the establishment of personal contacts can pave the way for ongoing relationships which are of benefit to all concerned.

At the end of a workshop, seminar or conference there should be an evaluation of what has been learnt and how this can be applied to improve the PWS. Having a clear understanding of the follow-up actions and who will be responsible for carrying them out will enhance the value of attendance at any of these events.

Professional qualifications

In recent years there has been an increasing tendency to develop professional qualifications based on a clear definition of the competencies required in a particular area of employment. To gain the qualification someone has to demonstrate that they have all the required competencies. There are two main advantages in having professional qualifications.

- For foundation training the qualification sets a recognised standard that can be used by a variety of educational or training institutions.
- The qualification sets a framework for continuing education and training activities (e.g. an activity could be offered aimed at maintaining or enhancing a particular set of competencies).

The acquisition of professional qualifications is of value to NMHSs as there can be confidence that staff delivering services have the necessary expertise. At the same time individuals benefit by having formal recognition of their competence and this contributes to job satisfaction.

3.3 CONTINUING EDUCATION AND TRAINING

The general WMO approach to Continuing Education and Training (CET) is summarised in Chapter 5 of WMO No. 258 (2000). It is based on a philosophy of the need for informed anticipation of, and strategically planned adaptation to, continuous environmental and organisational changes.

In the case of the PWS, there is a special need for an outward looking approach to keep abreast of the changing requirements of all those in the broader community whose needs the PWS seeks to service. A well designed CET programme for PWS staff will thus involve, in addition to extensive interaction with user communities to establish and update users' needs and expectations, a range of CET activities that will help staff maintain and further develop their competencies. Such activities could include the following when tailored towards the PWS (WMO-No.1101, 2002).

- Coaching
- Computer aided learning

- Courses
- Guided reading
- Observation of colleagues
- Outpostings (including secondments and temporary placements)
- Self-study material
- Seminars, workshops and conferences
- Simulation
- Video-based learning

The method chosen to deliver CET will depend upon factors such as the desired outcome, strengths and weaknesses of the various training methods available, availability of training resources, preferred learning styles, and time available to complete the training.

As well as developing "hard skills" associated with scientific and technical competence it is also important that there are opportunities to develop "soft skills" which enhance effectiveness. Such skills include team working, analytical thinking, flexibility, problem solving, communicating ideas and information, planning and organising, and leadership. These skills tend to be associated with enhancing human relations and they are transferable between jobs. The development of these skills can use the same training approaches as for the development of hard skills. In addition there are some other powerful techniques available.

- ***Coaching*** – Involves a one-to-one process in which the coach supports the learner by giving guidance and feedback about the performance of tasks.
- ***Reflection*** – A learner thinks about how well a task that has been carried out, identifies how it could have been done better, and then takes action to develop the skills which will lead to the improvement in performance.
- ***Observation*** – A learner observes how a colleague carries out a task, asks questions, and thinks about what lessons can be learnt from the experience.

When developing CET programmers for people involved in delivering the PWS it is worth drawing upon recent experiences in various other countries to ensure that the most relevant new concepts are quickly recognised and exploited.

NMHS staff involved in PWS need to have a broad knowledge of a wide variety of fields including meteorology, hydrology, environmental science, political science, social science, public administration and business management. The knowledge they acquire from attending CET activities need not necessarily be of great depth, but a good balance of management, scientific and technical skills needs to be maintained. Therefore, the choice of which CET activities to pursue needs to be based on an awareness of the expertise required to deliver the PWS now and in the future, and any gaps in the necessary knowledge and skills.

3.4 OUTPOSTING TO USER SECTORS

One of the most effective mechanisms for building an understanding of, and sensitivity to, user needs amongst NMHS staff providing services to a particular sector is through outposting (including secondments or short-term placements) to organisations within that sector. Such outpostings might range from a few days for familiarisation purposes to a year or more when working on a major joint project. They enable people involved in the PWS to see the services from the user perspective. This allows them to better appreciate the use made of the information and how to present information in the most useful way. In addition this experience might lead to ideas for modifying existing products and services, or even identifying new ones.

There are important sectors making use of the PWS in ways that could be expected to benefit from enhanced appreciation of how the service information will be used: emergency services, fire authorities, farming cooperatives, fishing communities, water resource managers, media, power utilities and the retail sector.

The initiative for such outplacements can appropriately begin with the NMHS, either as a one-off approach or after holding a workshop between the NMHS and representatives of one or more of the user sectors. Such interaction can often lead to identification of mutually beneficial follow-up actions or joint projects. These might then be pursued through the outplacement of staff from the NMHS to some organisation within the user sector, or vice versa.

3.5 OUTREACH TO USER SECTORS

Outreach activities involve short-term contact with members of the public and other users of the PWS with the intention of providing information, raising awareness and exciting interest. Direct communication is one of the most effective ways to shape personal behaviour. Outreach activities are a mechanism for promoting communication between an NMHS and the user sectors. These activities may include talks, workshops, exhibitions, visits, meetings, promotion campaigns and "Open Days". Advice about establishing an outreach programme can be found in WMO/TD No.1354, 2006.

The effective implementation of various outreach activities leads to users of products and services developing trust and an increased sense of "loyalty". Through outreach activities users should be able to increase their competencies and capacities in the following.

- Understanding the nature of hazardous weather and associated warnings.
- Proper use and interpretation of forecast information and products.
- Awareness and preparedness for hazardous weather.
- Familiarisation with the appropriate response actions in severe weather.
- Understanding forecast limitations and accuracy.
- Fulfilling their roles as users.

Outreach activities open up possibilities for the development of new services to meet the needs and requirements of users.

The materials used in outreach activities needs to be tailor-made for target audiences based on their roles and competency levels. Although developing appropriate materials and organising outreach activities may require significant resources, there are long term benefits to the NMHS and the utility of the PWS to users.

Government briefings

Outreach to government officials can be generally divided into two target groups:

- People in key posts in government agencies who are the decision makers in their areas of responsibility in severe weather situations or who can influence issues that directly affect the activities of the NMHS.
- Operational staff who have contact with the NMHS or handle weather-related public enquiries.

If key decision makers are to make sound decisions during severe weather situations and on issues of public concern, such as environment and health, they must be familiar with the information and products provided by the NMHS and the way to make best use of them. The following points are worth bearing in mind when NMHS staff have to prepare briefings.

- ***"Contributions" rather than "features"***. Speaking the language of the decision makers, with emphasis on the socio-economic contributions of meteorological and hydrological services to society, will make them more receptive to the messages that are being delivered. Just providing information about the "features" of the NMHS and the PWS is unlikely to be convincing or of interest to them.
- ***Practical rather than hypothetical***. Presenting case studies about the value of meteorological and hydrological services will be worthwhile when trying to influence decision makers. The case studies could provide a firm foundation for claims about the benefits of these services by emphasising the practical rather than the hypothetical.
- ***Precise rather than general***. Delivering concise briefings with a well-defined aim will be more effective than a general discussion with no clear focus which the decision maker may consider a waste of valuable time.
- ***Supporting policy making***. Emphasising the role of NMHSs in support of policy-making in areas such as disaster mitigation and responding to climate change will help ensure that the expertise within the NMHS can be used at an early stage in making policy.

These types of meetings and briefings aim at facilitating the effective discharge of the responsibilities of government agencies in weather-related matters. They also offer opportunities for the development of new or improved services to the public.

Close coordination between the NMHS and key decision makers in relevant government agencies can help ensure effective flow of information about warnings of severe weather so as to trigger a fast response by the public and user sectors. A coherent approach is required to ensure that warnings and advice to the public from different sources are consistent so as to avoid misinterpretation.

The other group of government officials that need to be briefed are the operational staff who are the contact points for NMHS staff or on-the-bench staff who handle public enquiries. Briefings about weather warning services, use and interpretation of weather products, and service enhancements can be part of the induction process for newly recruited staff and act as a refresher for existing staff. The effectiveness of these briefings is enhanced if participants are encouraged to spread the message amongst their colleagues and downstream users. Through these briefings and other meetings the communication protocols for ensuring an effective flow of information in adverse weather situations can be established and developed.

Presentations for socio-economic sectors

Different socio-economic sectors have their own agenda and concerns about weather-related decisions. Any outreach activities such as presentations about products and services for various socio-economic sectors (e.g. education, agriculture, fishing, forestry, energy suppliers, transport, building and construction, and recreation) need to be focussed on the particular weather of interest to each sector and how to make the best use of the information available.

It is worth focussing outreach activities on key managers and operational staff from these socio-economic sectors so as to increase their ability to utilize weather information and warnings. Most of them may be service providers for whom relevant weather-related knowledge could improve their services and meet the demands of their own users. Once managers have become more knowledgeable about the PWS they can serve as trainers and role models to assist their staff in knowing how to use weather information, particularly in severe weather situations.

Another advantage of outreach activities is that the NMHS staff involved can receive direct feedback from users about the services they use. This information can then be used to improve the products and services provided to that particular sector. In addition, discussion with users could lead to the implementation of new tailor-made products and services.

As well as improving services, direct contact with users provides NMHS staff with the opportunity to create relationships which may be fruitful in the future. Also positive feedback from users can make the NMHS staff feel appreciated and add to job satisfaction.

Workshops for the Media

One particularly useful device already employed in a number of NMHSs is the regular (every few years) organisation of workshops for representatives of the major media outlets. Apart from their intrinsic value in establishing personal links and avenues for improved communication between NMHS and media staff, such workshops can serve as very useful forums for the development of guidance material (e.g. media codes of conduct in the provision of weather information and guidelines on the presentation of weather information).

Events aimed at the general public

Outreach activities aimed at helping the public make best use of the PWS, especially services associated with severe weather, fall into two broad categories: real-time education and public awareness initiatives.

- ***Real-time education***. When warning messages are issued they may contain information about the preventive actions that can be taken to reduce the impact of the event. Repetition of this kind of advice

helps to educate the public. This approach is particularly effective because the information is presented at a time when it is most needed. It is relevant to dealing with the current threat and provides a basis for responding to future events.

- ***Public awareness initiatives***. These initiatives are not linked to the occurrence of any specific weather event. They could include talks, exhibitions, visits, publicity events and distribution of brochures and leaflets. A programme to increase public awareness can be instigated at any time. However, when such programmes are associated with hazardous weather, the timing is very important. It would be appropriate to have a programme:
  - Just before and during the season in which the hazard occurs to help minimise the risk for individuals and communities.
  - Immediately after a hazardous event as this represents an opportunity to build upon personal experience.

  These initiatives can be delivered in a variety of formats using a range of dissemination mechanisms, but radio and television are especially effective in raising awareness.

3.6 MEDIA PRESENTATIONS

The media represent a multi-faceted challenge to meteorology. Sometimes it is seen as a user, while at other times it is considered to just be a channel to get information to end-users. However, use of the media is a highly effective way of getting a message across.

An NMHS is often in an advantageous position if it is responsible for weather presentations on the TV and radio. These can provide a unique opportunity to raise awareness about weather, climate and water issues.

Each of the media (TV, Radio, Web, Print) has different requirements (e.g. for imagery, quality of voice, quality of writing and design), and these have little to do with the quality of the underlying message. The challenge is to match the undoubted quality of the weather information with an equal quality of presentation. The value of weather information will be lowered if it is not well presented. Whichever type of media is used, the message needs to be clear and presented in such a way that it will resonate with the audience. In all cases the material should be designed to educate, inform, engage or motivate the audience.

The provision of presentation training to all NMHS staff who are required to interact with the media in the course of their work will help build the capacity in effective communication and increase the visibility and credibility of the NMHS. Also having well trained presenters will provide them with credibility when trying to establish good relationships with reporters and editorial staff.

When considering how to improve media presentations of PWS information it is often effective to compare and contrast a range of existing presentation styles and formats. A useful aid to this process is to compile examples illustrating a range of ways of presenting information, especially taken from TV and newspapers. These examples can be used in the development of new and improved styles and formats for conveying PWS information to the public via the media.

3.7 PARTNERSHIPS WITH NMHSs

As a device for PWS capacity building, the concept of partnerships between NMHSs can involve any of a number of possible configurations:

- ***Advanced NMHS and an NMHS from a developing country***. An advanced NMHS can agree to work with a particular developing country NMHS to systematically upgrade its PWS provision over an agreed period of time.
- ***NHMSs from developing countries***. Two or more developing country NMHSs in a region can agree to institute a project to jointly upgrade their PWS provision including through the sharing of costs of software development, joint workshops with the user communities, responsibilities in the region and so on.
- ***Advanced NMHSs***. A group of advanced NMHSs could agree to work together, pooling technical cooperation resources, to implement a systematic PWS upgrade programme for an individual country or a group of countries in a region.

As with all such arrangements, the key requirements for successful implementation of partnerships are a willingness to share expertise and technical knowledge, a strong commitment to the user perspective for PWS provision, and the identification of staff in both NMHSs who are capable of working together and have a commitment to improving the PWS.

Another valuable mechanism for the build-up of the capacities of NMHS staff in PWS provision is the attachment of staff for limited periods to another NMHS which takes a particular interest in the PWS. This could be particularly effective if it involves the attachment of PWS staff from developing countries in rotation with the PWS units or programmes of one or more of the advanced NMHSs. Such bilateral exchanges could be initiated from either side or result from a general discussion of capacity building in PWS in Regional Associations or other sessions.

3.8 TECHNICAL COOPERATION

One crucial aspect of the operation of the NMHSs is the international cooperation in monitoring the atmosphere and exchanging data and meteorological information in real-time – no individual NMHS can establish its own monitoring system for the entire world. The global interdependence of atmospheric processes makes the monitoring and prediction of weather and climate in an individual country heavily dependent on instant access to meteorological information from around the globe. This makes meteorology one of the most inherently international of all fields of science.

Some developing countries do not have sufficient capacity in terms of technical, infrastructural, and financial and related resources to develop and provide effective public weather products and services on their own.

The WMO is the United Nations specialised agency that coordinates, standardises and improves world meteorological activities and supports exchange of meteorological information between countries. For many

years, for example, WMO has assisted in the international coordination of exchange of tropical cyclone warnings.

In order to ensure continuous development of meteorological services in both developed and developing countries the following arrangements are desirable.

- ***Training events***. Holding training events specially directed at personnel from developing countries to ensure that all NMHSs have an adequate complement of trained scientific and technical personnel.
- ***Cooperation between NMHSs***. Developing close cooperation between NMHSs from developed and developing countries.
- ***Cooperation between NMHSs and academia***. Developing cooperation with academia to facilitate a two-way communication between the research and user communities. This enables an optimum application of research results to improve products and services, and encourages the design of research and development programmes that take into account users' needs and requirements.
- ***Regional groups***. Forming regional groups of NMHSs with similar economic, geographic and climatic features to develop and generate forecasts and products for a region. This eases the constraints imposed by insufficient resources and abilities of individual NMHS.
- ***WMO technical cooperation initiatives***. Using the WMO technical cooperation initiatives, assistance can be provided to ensure that NMHSs, especially those in developing countries, can provide adequate levels of meteorological services to protect public safety, support sustainable development and safeguard the environment.
- ***WMO Voluntary Cooperation Programme***. Using the WMO Voluntary Cooperation Programme (VCP), especially relevant to those NMHSs in developing countries, NMHSs can obtain support in the form of equipment and services (including training contributed on a voluntary basis by WMO Members) or by direct financing, through collaborative efforts of WMO Members.

The WMO Programme for the Least Developed Countries (LDCs) supports the LDCs to enhance their capabilities to participate and contribute actively in activities related to priority areas such as poverty alleviation and natural disaster preparedness and mitigation. Specific projects could be developed for individual countries and on a sub-regional basis for countries in Africa, Asia and the Pacific.

Technical cooperation is a vehicle to assist NMHSs in responding to trends and developments as well as to emerging issues and major challenges. The generation of new or enhanced products and services can sometimes be achieved through cooperation with other more advanced NMHSs through short-term attachments or expert visits. This avoids the need for extensive proposal development or identification of additional resources.

To optimize the effectiveness of technical cooperation, analysis of the national and regional needs, setting of goals, deliverables and priorities to the planned programmes, and development of a feasible implementation plan is essential before engaging in technical cooperation. Also the effectiveness of the programme needs to be monitored and managed during the implementation. After the implementation of the programme the deliverables should be evaluated as part of the capacity building process.

3.9 TRANSFER OF TECHNOLOGICAL AIDS

NMHSs need to keep abreast with developments in the field of science and technology and seek to maintain continuous improvement in their infrastructure. This will be achieved through mobilisation of resources to address present and emerging challenges. A close working relationship with other NMHSs, universities and research institutions at national and regional levels would facilitate transfer of technological aids in speeding up the development of prioritized products and services. Below are some examples of the technological aids that are transferable.

- Installation and use of observation platforms.
- Data monitoring tools, and data processing techniques and software.
- Data assimilation systems and regional models.
- Model post-processing techniques and software.
- Product and TV presentation software;

3.10 CONTRIBUTION OF WMO REGIONAL TRAINING CENTRES

There are more than twenty WMO designated Regional Training Centres (RTCs) around the world which provide training courses for various meteorological application areas including agriculture, aviation, climate, disaster prevention, environment, hydrometeorology, meteorology and etc. These Centres are located in Akure, Cairo, Lagos, Mulemba, Nairobi, Niamey, Oran, Tananarive (RA I); Beijing, Nanjing, New Delhi, Pune, Tashkent (RA II); Belem, Buenos Aires, Caracas (RA III); Barbados, San Jose (RA IV); Quezon City (RA V).

WMO Regional Training Centre (WMO-RTC) are institutions undertaking training in meteorology, hydrology and related sciences which are established to meet the expressed requirements of two or more WMO Members that cannot be met by existing facilities. The conditions which must be satisfied to be designated as a RTC include the following.

- The Centre should be open to students from all countries in the Region and, upon request, from interested countries in other Regions.
- The education level of the various courses of instruction carried out at the Centre should be consistent with the guidance material issued by WMO.
- The Centre should have processes in place to identify, with the support of the Regional Association Rapporteur on education and training, training needs and to evaluate the training provided;
- The Centre should have adequate buildings and training facilities, and have the necessary equipment and facilities for an efficient and effective use and exchange of training aids and modules based on modern technology;
- The Centre should have competent instructors in terms of both their technical ability and training skills;

- The Centre should have adequate arrangements for administration, governance, planning and self-assessment.

Satisfaction of these conditions should ensure the RTCs provide good quality education and training which takes account of regional needs in terms of the nature of the PWS and the weather phenomena experienced in that region.

The contribution that the RTCs can make to helping NMHSs provide their staff with competencies required to deliver the PWS depends upon the extent to which there is cooperation and interaction between RTCs and NMHSs. The aim is to have regioanl cooperation so that:

- Educational policies, practices and programmes at the RTCs which respond quickly to the new challenges faced by NMHSs.
- Training programmes offered by the RTCs which complement rather than duplicate the training available on a national basis.

The WMO Education and Training Programme (ETP) provides support to the functioning of the RTCs. They play a key role in the education and training of staff from NMHSs. WMO also organises or co-sponsors training courses, workshops and seminars in support of the training of personnel working in meteorology, hydrology, water resources and environmental fields.

3.11 REGIONAL AND SUB-REGIONAL COOPERATION

An important way of ensuring capacity building, resource mobilization and contribution to sustainable development at regional level is through enhanced cooperation between NMHSs and regional groupings such as the United Nations Economic Commissions and other regional arrangements that vary from region to region (Obasi, 2003).

Regional cooperation is important especially from the perspective of the need for the exchange of data, information, products and services. The sharing of observations, model output and warnings between NMHSs through communication means such as the Internet empowers individual NMHSs to improve their forecasts and warning services; in doing so they are contributing to the mitigation of weather related disasters at the global level. The synergetic effect is well demonstrated by the development of the multi-model ensemble method for weather forecasting, in particular for tropical cyclone forecasting, which has been adopted by a number of NMHSs.

Due to the advances in communication technology and increasing globalization of the media, the public can easily get access to information on severe weather events, including warnings, from neighbouring NMHSs. This information needs to be properly coordinated between neighbouring NMHSs so that the public take appropriate actions to minimise the impact of hazardous weather. Cross-border exchange of weather warning information makes a significant contribution to enhancing the effectiveness of weather warnings. Details of the implementation of cross-border warnings exchange can be found in the WMO Guidelines (WMO-No.1179, 2003).

Close regional and international cooperation can help bridge the gap between NMHSs of developed and developing countries in the provision of basic weather services to the community for the benefit of human well-being at the global level. The WMO Regional Programme (RP) interacts with the relevant activities of sub-regional economic groupings and regional organisations in the various WMO Regions. This enables NMHSs to play a role in the sustainable socio-economic development of their countries, thereby contributing to the solutions of regional and global issues of importance to society. It also assists in the development of NMHSs in the WMO Regions through the organisation of regional events (e.g. sessions of regional working groups, regional seminars and workshops, technical conferences and implementation coordination meetings). With the establishment of regional facilities such as Regional Training Centres (RTCs) and Regional Specialized Meteorological Centres (RSMCs), regional cooperation in capacity building and exchange of data and information can be further promoted.

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Annex A
SUPPORT FOR DELIVERING THE PWS

A1 ROLE OF OTHER GOVERNMENT AGENCIES

While, in most countries, the role of the NMHS as the sole government provider of the 'official' PWS is well established in some countries there are other government agencies which play a significant part in the delivery of the total PWS (broadly defined) to the national community.

The most important complementary agency for the NMHS, in its provision of the PWS, is usually the national broadcasting organization which is responsible for ensuring that the official forecasts and warnings are delivered in a timely, accurate and useful way. The working arrangements necessary to achieve this relationship may be negotiated between the NMHS and the organisation (as also with non-governmental media outlets) or may be determined by government policy or legislation.

A particularly important role in some countries is played by government emergency management agencies that tend to work in close collaboration with their NMHSs in conveying essential warnings and response information to threatened communities. This is especially relevant where there is a legally established responsibility of the NMHS for providing the single official warning service about the threat of natural hazards.

A2 ROLE OF PRIVATE METEOROLOGICAL SERVICE PROVIDERS AND ACADEMIC INSTITUTIONS

There are several countries where neither the NMHS, nor the NMHS and its partner agencies within government, carry the full responsibility for the provision of the PWS. In particular, there are some countries where the role of the NMHS is seen as largely restricted to the provision of the basic national meteorological infrastructure and essential warning services, with the formulation and delivery of the non-warning element of the PWS being entrusted to the private (commercial) sector. In these countries the provision of weather services through the mass media is largely 'regulated' through professional certification systems or other such arrangements.

A range of possibilities thus exists for the provision of the PWS.

- The NMHS carries full responsibility for delivery of the service to society, using either its own delivery mechanisms (e.g. web sites) or in established partnership arrangements with various sectors of the mass media.
- The NMHS works with a consortium of other government agencies (including emergency management agencies and environment protection authorities) to deliver a broadly coordinated suite of 'weather and related services' to the public.
- The NMHS collects the basic data, runs the models and produces the essential guidance products which are then used by the private sector (and, in some countries, academic institutions) to prepare and deliver services to the community.

A3 ROLE OF THE MEDIA

Irrespective of whether the NMHS is the sole provider of the PWS or not, the role of the mass media is critical to PWS provision in virtually every country.

In those countries where the NMHS is essentially the sole provider of the PWS, the establishment of an effective partnership between the NMHS and the media is essential for ensuring the services are effective in meeting community needs. The various branches of the media play different roles in the delivery of the service to the public.

- ***Conventional electronic media***. The conventional electronic media (radio and television) are of central importance for delivery of warnings and other time-critical information because of their wide reach and immediacy.
- ***Newer forms of electronic distribution***. The newer forms of electronic distribution (web-based services, Short Messaging Service (SMS) and the like) have some advantages. For example, in the case of Web information, there is the ability to provide access to large quantities of information that can be continually updated.
- ***Print media***. The print media, while less timely for perishable weather information, are still widely used by the public as a source of both graphical and numerical/textual information on current and predicted weather conditions, and for general information on weather and climate processes for public education.

In several countries, formal partnerships have been developed between the NMHS and individual or group representatives of the media to specifying the standards of delivery (e.g. accuracy and timeliness) of information to the community. Where the information content of the PWS is regarded as a public good and provided without charge to (and through) the media, it is somewhat easier for the NMHS to ensure the maintenance of essential standards for the information content of the service. However, where the NMHS charges for the service and/or competitive service providers operate, it is usually necessary to rely more heavily on professional certification standards to ensure the quality and reliability of the information available to the public.

A4 ROLE OF INFORMATION SCIENCE AND TECHNOLOGY

The rapid advances in technology have benefited the science of meteorology in almost all areas of operation; from weather observations, where remote sensing using radars and satellites has increased the range, quality and quantity of observed data, to communication of data using modern and faster data switching systems. Application of this modern technology has contributed greatly to the accuracy of Numerical Weather Prediction (NWP) by increasing the capability of NWP models to handle higher-resolution grids at ever reducing costs. New technology has also been applied in the fields of data archiving and meteorological research.

Advances in the area of Information Communication Technology (ICT) have heralded the new era of dissemination and presentation of weather information and forecasts. The delivery of weather information in different formats through mobile phones, handheld devices and the wireless network is expected to be a key development area of NMHSs in the provision of warning services to the public. The development of wireless broadband will facilitate users accessing the Internet anywhere at anytime. The same ease of access applies to warning information that is directly transmitted to mobile users. People can be kept well informed of changes in the status of warnings as well as on the latest assessment of the severe weather. Not only can simple warning text message be sent through SMS, displays of more complicated weather information in the form of graphics such as the location maps of tropical cyclones and forecast tracks or video clips capturing the effect of severe weather can be made possible on mobile phones. On the newly developed technology platforms such as 3G mobile networks, standards like Multimedia Messaging Service (MMS) allow mobile phone users to request and receive sound, images and video clips of weather information and warning messages.

The convergence of telecommunications, broadcasting and Internet services and the introduction of location-based service including Global Positioning Systems (GPS) and spatial and geographical information systems (S/GIS) provide an enabling environment for NMHSs to develop innovative applications and services.

Annex B
SOCIO-ECONOMIC SECTORS THAT BENEFIT FROM WEATHER, CLIMATE AND WATER SERVICES

Advances in weather observation technologies, data processing and communications, data assimilation and modelling, and the science of meteorology have significantly improved the scientific understanding of the dynamical and physical processes of the atmosphere and ocean and their interactions with other components of the Earth's system. As a result, unprecedented improvement has been achieved in the quality of weather forecasts and warnings. It is now possible to make useful deterministic weather forecasts seven to ten days in advance in extratropical regions and three to four days ahead in tropical regions. There have also been developments in seasonal predictions of phenomena such as El Niño and La Niña. Various weather-sensitive socio-economic sectors utilize weather and climate information to assist their decision-making. Also weather and climate information is essential to government planning for disaster risk management and economic development. It is of utmost importance for NMHSs to ensure that their staff involved in service delivery have a good understanding of the requirements of each sector. This can be achieved by including this requirement in their training programmes.

B1 DECISION MAKERS AND POLICY MAKERS WITHIN GOVERNMENTS

Decision makers within governments, as well as emergency response managers, require weather information to formulate contingency plans for natural disasters. Such plans stipulate the triggering mechanisms, policies, information flow, actions and responsibilities of various government agencies and emergency units in responding to natural disasters. For all severe weather conditions, which impose threats to society, warnings should be issued when required. Also different types of weather warnings and severe weather conditions need to be included in contingency plans. A comprehensive weather warning system designed and operated by an NMHS serves as an indispensable ingredient for its government's contingency plan to deal with severe weather events.

In adverse weather situations, NMHSs have the role of activating weather warning systems and keeping the key decision makers within government well informed of the latest weather assessments. The weather information can then be cascaded to other government departments according to the contingency plan. The cascading mechanism should ensure an efficient flow of information within government and emergency response units in order to trigger timely actions. The provision of a telephone consultation service by a NMHS to key government decision makers should help ensure effective delivery of information and facilitate their preparation for adverse weather.

The threat to sustainable development caused by climate change and natural hazards is significant and growing. In particular, climate change and weather extremes endanger investments in infrastructure, agriculture, human health, water resources, disaster management and the environment. Also they affect the vulnerability of people, especially those located in coastal zones, flood plains, arid areas and other high-risk environments. All this means that development activities and goals must take account of the risks associated with natural hazards and climate change. NMHSs need to support policy makers in making assessments of the risks to development. This means that as well as continuing to provide products and services that support day-to-day decision-making, it is likely that NMHSs will get increasingly involved in risk assessments and longer-term societal planning affecting national economic development activities.

B2 RISK AND DISASTER MANAGEMENT AUTHORITIES

Weather warning services for prevention of disasters when hazardous weather occurs are central to the role of the PWS. This is because most natural disasters are directly or indirectly weather related. No country can be spared the adverse impacts of natural disasters, but the less economically developed suffer most. In recent years, the number of people at risk has shown an increase of some 70 million a year (ADRC, 2003). According to the statistics of the International Federation of Red Cross and Red Crescent Societies (2004), the number of people affected by disasters climbed by 59% from an average of 163 million per year in 1984–1993 to 258 million per year in 1994–2004.

Weather-related hazards and threats span a wide range of temporal and spatial scales, from a few tens of seconds for a tornado to long-term global climate change, from a local scale of a few metres up to a planetary scale of thousands of kilometres. These hazards can be broadly categorized into the groups given in Table B1.

Some regions are especially prone to certain types of natural disasters due to their geographical and meteorological conditions. Natural disasters in some cases may not be entirely "natural"; most of the so-called "natural disasters" arise from the interaction between natural phenomena and human societies (Lam, 2005). For example, severe flooding may be exacerbated by deforestation. Also a massive concentration of people in hazard-prone areas or in cities and settlements where houses or infrastructures are not safely constructed or where land-use is poorly planned can lead to devastating consequences when natural disasters occur.

Poor and developing countries suffer the greatest damage in losses in social and economic terms because of their lack of resources, infrastructure and protective systems for disaster preparedness and prevention. The risk of natural disasters is increasing as a result of population growth, urbanization, deterioration of the natural environment,

substandard dwellings and public buildings, and inadequate infrastructure maintenance as well as increased poverty.

Risk and disaster management authorities need to quantify risks for the weather-related hazards before formulating a contingency plan for natural disasters. The way of quantifying risks depends on the purpose but most cases consideration needs to be given to some combinations of the following.

- Nature of the hazard, including its severity.
- Probability of occurrence.
- Exposure and vulnerability of human and natural systems.
- Number of people and the costs of the facilities at risk.

Table B1: Categorization of weather related hazards adapted from Zillman (2004) with modifications.

Category	Hazard
Severe weather phenomena	• Tropical cyclones (including hurricanes and typhoons) • Severe storms (including tornadoes, waterspout, extratropical cyclones, hail, wind and lightning) • Gales and blizzards • Turbulence
Extreme temperatures	• Heat waves • Cold snaps
Weather-produced and weather-related phenomena	• Floods (including river line and flash flooding) • Landslides • Avalanches • Ocean waves • Storm surges • Bushfires • Locusts infestation • Air pollution dust and sand storms • Wind-borne dissemination of disease and nuclear contamination • Freezing rain
Climatic hazards	• Drought • Long-term climate change
Geologically triggered weather and climatic hazards	• Tsunamis • Volcanic ash clouds • Earthquake-induced dam collapse, etc.

During the process of quantifying and mapping risk, an integrated approach is usually adopted with the use of physical, geographical and environmental information in conjunction with both social and economic data, and through integrated assessment models of various kinds (Granger, 1999). Risk management involves a systematic application of management polices, procedures and practices to the tasks of identifying, analyzing, assessing, treating and monitoring risks. The tasks include analyzing the risks, estimating their potential effects, and evaluating all the elements that are relevant to the understanding of existing or probable hazards and their effects on the community and the environment. As such, climate and real-time information from NMHSs is essential to the risk management work of emergency managers. Emergency managers seek to determine the appropriate vulnerability reduction, prevention and mitigation, preparedness and response strategies in terms of socio-economic impacts.

NMHSs contribute to disaster risk management in the following three ways:

- Providing timely warnings of weather, water and climate hazards for operational decisions.
- Supporting risk and impact assessments to determine who and what is the risk and why.
- Improving forecasts and analyses to help reduce or remove risks.

Community preparedness is crucial for the success of any disaster risk management strategy (Rogers, 2005). To ensure a smooth and effective flow of disaster-related information, the controlling authorities in the rescue, recovery and restoration phases need to have direct liaison and coordination with NMHSs and relevant working parties. In the event of a major incident involving widespread threats to life, property and security, and where extensive emergency response operations are required, the emergency managers should be in close contact with NMHSs. This allows them to obtain information on the developing weather situations and the latest assessment to facilitate their decision-making, strategy formulation, and staff and resource mobilization. Direct communication with the NMHS in critical times for decision-making increases the effectiveness of the operation of emergency managers. Also provision of information about the uncertainty of the forecasts, given in terms of a probability assessment of the

expected severity and the areas potentially at risk, would be of value. This information would be useful when they adopt an appropriate strategy to reduce the impact and socio-economic costs associated with severe weather.

B3 MARINE TRANSPORTATION AND OFFSHORE OPERATIONS

Provision of reliable marine weather information assists mariners to choose cost-effective sea routes and oil drill operators to optimize their operational schedules; in both cases there is a contribution to the total economy of water transport. In addition warnings to mariners relating to tropical cyclones, severe storms, high winds, squalls and thunderstorms, reduced visibility, sea conditions and storm surges, as well as information on tsunamis, are crucial to the safety of mariners and seafaring passengers. Information on tide and sea surface temperature is also useful to the fishing community.

In severe weather situations, the provision of timely weather information, particularly about wind and waves, is critical for water transport operators (e.g. ferry companies) so that they can make decisions about staff mobilization and service operations.

NMHSs supply weather information on request to rescue co-ordinating centres in support of maritime search and rescue operations. Also, when oil spills and other chemical leaks occur at sea, NMHSs provide weather and water current forecasts to the coordinating teams dealing with the problem.

Poor visibility may be the cause of shipwrecks. The safety of marine navigation is greatly hampered by reduced visibility. In addition, large waves and swell induced by high winds associated with intense monsoons, severe storms and tropical cyclones can also seriously affect safety at sea. Early weather warnings and advisories to mariners can help them take action being to reduce the adverse impact of these kinds of weather situation.

At the international level, the WMO/Intergovernmental Oceanographic Commission (IOC) Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), which is an intergovernmental body of experts, provides the intergovernmental coordination, regulation and management mechanism for an operational oceanographic and marine meteorological observing, data management and services system.

B4 AVIATION

Weather affects aviation in many ways. It impacts on the safety of aircraft, passengers and crews, and adverse weather conditions affect the costs of aviation operations and the efficiency of air traffic management.

Airlines have responsibility for ensuring safe flights for their passengers. Air traffic has seen strong growth over the last decades averaging 7% per year globally and exceeds 10% in some regions. Increased loads on the air traffic systems, in particular on busy hub airports and major air routes, has led to an increase in weather-related delays despite the technological improvements which allow aircraft to land in low visibility. Weather has also been found to be a contributing factor to many aircraft accidents and even more so to incidents where passengers are injured when aircraft experience strong turbulence. The aviation community is becoming more demanding about the accuracy and reliability of weather services, while expecting that these services (like all other ancillary services to aviation) are provided at lower costs and higher efficiency.

The aviation community (including operators, flight crewmembers, air traffic services units, search and rescue services units, airport managers and others concerned with the conduct or development of international air navigation) requires weather information and services for flight planning purposes and safety considerations. For example, actual and forecast meteorological conditions at aerodromes, specified areas around aerodrome and during the en-route phase of flights originating from the aerodrome are often required (WMO-No.732, 2003).

In the aviation community the various aviation users may have different requirements. General aviation or helicopter operations need substantially different meteorological information from that required by international airline operators. Therefore, liaison with users is essential if the maximum benefit is to be gained from meteorological information as both user requirements and the availability of meteorological information can change with time.

The majority of meteorological service providers for international civil aviation supply weather services and products based on an agreed cost recovery basis in support of their decision making following joint ICAO-WMO guidelines. They typically also provide specific weather forecasts for national and general aviation, including air sports, under national arrangements and regulations.

To summarise, with reliable aviation weather information and forecasts, the aviation community benefits in the following ways.

- ***High risk areas***. Warnings of severe weather and volcanic ash permit timely avoidance of high-risk areas and contribute to the safety of air transport.
- ***Optimized routes***. Long-haul routes are optimized according to upper level wind forecasts of very high accuracy.
- ***Ground handling***. Timely and accurate weather information can optimize ground handling, in particular the de-icing of aircraft.
- ***Airport management***. The efficiency of air traffic management and airport operations is increased through better planning of staffing requirements.
- ***Runway clearance***. Clearing of runways and manoeuvring surfaces is optimized using specialized snowfall and icing forecasts.
- ***Fuel costs***. Costs associated with carrying extra fuel and flight diversion are reduced using terminal area forecasts.

The International Civil Aviation Organization (ICAO) develops and promotes common rules and regulations for a safe, regular, efficient, and economic international system for air transportation. It accomplishes its mission through the application of Standards and Recommended Practices (SARPs). SARPs are rules and regulations that cover all technical and operational aspects of international aviation such as safety, personnel licensing, aircraft operations,

aerodromes, air traffic services, accident investigations and the environment. Where their regulations concern aeronautical meteorology, they are jointly developed, implemented and published by WMO and ICAO.

B5 LAND TRANSPORTATION

Adverse weather can have a serious impact on road transport. The rapid increase in the number of vehicles and the ensuing traffic load calls for an effective road management system in adverse weather. Use of reliable road weather information and forecasts assists road transport operators in taking prompt actions to ensure effective traffic management for the convenience of the travelling public, cost reduction in road maintenance and clearing, and risk reduction of weather-related road accidents.

Heavy rain reduces visibility and so poses dangers to drivers and passengers. It may also cause serious road flooding or landslides which brings land transportation to a halt. When a severe storm or tropical cyclone strikes, flying debris in high winds endangers the safety of road users and people in the street. Road users are highly exposed to severe weather and so they need timely warnings and advisories to help them decide whether to change their routes to avoid weather-affected areas and chaotic traffic. Also bridge and highway operators benefit from wind forecasts and warnings of high winds to facilitate their management of bridges, flyovers and highways.

Development of road weather condition models by NMHSs in close cooperation with highway authorities can contribute to safer driving conditions and effective road maintenance services. Weather elements such as cloud cover, wind speed, precipitation and surface temperature are essential ingredients in determining the heat balance at the road surface. The forecast of road surface minimum temperature and moisture is one of the most important constituents of road weather. Formation of dew, frost or ice at the road surface can be dangerous to drivers and other road users. Road transport operators need to obtain information on the weather conditions in order to determine the potential hazards to road users and to decide on their management strategies. In view of increasingly litigious road users, these forecasts and observations are a prerequisite for highway authorities to limit their liability when accidents occur.

Climate information on the diurnal temperature cycle and analysis of extreme wind and precipitation in vulnerable areas are useful to transport and infrastructure decision makers when designing transport facilities, such as railways and bridges, in a more cost-effective way. To this end, thermal mapping of the road surfaces in different weather conditions is becoming a standard method of determining a detailed road climatology. Real-time information and forecasts of road sensitive weather elements are required by transport managers to identify dangerous sections of the road, determine the road management strategies and select the most cost-effective solution (e.g. the anti-icing strategy). Weather information and site-specific forecasts provided to transport authorities and managers assists them in planning and managing transport facilities. This ensures a smooth running of essential road services for the public, reduces the chance of road accidents and minimise the adverse impacts of weather on road users. The information also enables transport managers to issue special announcements and precautionary advisories to road users to enhance public safety.

B6 AGRICULTURAL COMMUNITY

Food is vital for human life. In many developing countries agriculture is a dominant activity. NMHSs in highly agriculture-dependent countries often provide weather forecasts and services to the agricultural community as part of the PWS. In some countries which are prone to drought, the PWS also often include a drought monitoring programme. In some other countries, notably the developed ones, NMHSs provide specialized weather services to large and prosperous agriculture interests on a cost-recovery basis.

Weather, climate and water information provided by NMHSs can support the agricultural community in two key ways:

- Increasing the efficiency of agricultural production.
- Helping assess the risks associated with the vulnerability of agriculture to climate variability (e.g. potential spread of plant and animal diseases and probability of extreme weather).

At present the agricultural services provided by NMHSs tend to concentrate on increasing efficiency, but in future it is likely that more attention will need to be paid to risk assessment.

The growth of crops depends on temperatures, soil type and moisture content, amount of sunshine and rainfall. Consequently the proper application of weather and climate information and forecasts provided by NMHSs can improve agricultural production (e.g. improve land use, crop selection and production, locust and other pest control, and management practices). NMHSs can also provide vital information to assist the agricultural sector in scheduling the transport to market of vulnerable produce, thus reducing post-harvest losses and improving animal and crop production.

NMHSs can develop products and services for farmers and farm operators to assist them in the ways summarised in Table B2 (Sivakumar, 1998; WMO-No.834, 1999; WMO-No.1101, 2002).

NMHSs need to identify the factors which influence the planning and operation of the agricultural sector and determine the interaction between meteorological, hydrological and biological systems in the development of new products and services. They can also detect changes in soil moisture and assess the impact on agricultural production. Use of such information by the agricultural sector can allow timely remedial action and so help prevent food shortages.

NMHSs can provide early warning of impending outbreaks of crop pests and diseases and a risk assessment for the spread of plant diseases (e.g. citrus canker and wheat stem rust). Also they can help in the assessment of the potential impact of drought conditions on crops and support measures to reduce the vulnerability of agriculture to drought.

Table B2: Use of products/services for farmers and farm operators.

Product/Service	Use of Product/Service
Short-term forecasts	• Adopt appropriate strategies to minimise frost damage on winter horticultural crops. • Provide special weather warnings for agriculture (e.g. frost warning). • Decide the time for irrigation. • Prevent damage to plants from pests that utilize wind for their movement.
Seasonal to inter-annual climate forecasts to	• Decide the planting date for late planted crops, the cut off planting date for frost sensitive crops, the date of winter cereal planting, and plan spring plantings under irrigation after knowing the first and last dates of frost. • Plan intercropping, especially in dryland regions and the number of types of crops planted on the same piece of land. • Assist in operational decisions regarding the densities and row arrangement of the component crops in the intercropping system by knowing the seasonal forecasts of rainfall. • Plan irrigation schedules in the case of irrigated crops and supplementary irrigations for other crops when necessary. • Plan harvest operations and storage of produce. • Determine cropping strategies for the season, for example, the choice of crops and varieties, tillage systems, timing of field operations, investments in the level of inputs, and etc.
Advice to:	• Improve agricultural methods and operations. • Assess weather risks for agriculture. • Apply methods and techniques for pest control. • Apply agricultural decision-support tools. • Maximise the utilization of weather forecasts for agriculture (e.g. the use of real-time and forecast information for pest management on farms, irrigation scheduling and other farm operations). • Apply the results from operational modelling for short-term management and crop modelling. • Implement strategic applications to assist the development of sustainable agriculture and adaptations to climate change.

Collaboration between NMHSs and government departments responsible for the agricultural sector, and partnership with universities or institutions, can contribute to the effective development and implementation of useful agricultural services and products. An example of successful collaboration involves the Joint Agricultural Weather Facility run by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of Agriculture (USDA). They provide short-term tactical agricultural weather products and long-term strategic agricultural weather products (e.g. supply and demand estimates). Also they partner the University of Nebraska in the preparation of the U.S. Drought Monitor (Figure B1).

There is no doubt that NMHSs make a significant contribution to the overall efficiency and security of agricultural production.

B7 FISHERIES

The growth and survival of fish populations can be profoundly affected by fluctuations in ocean conditions caused by ocean processes such as the Pacific Decadal Oscillation (PDO) and the El Niño-Southern Oscillation (ENSO). These climatic phenomena result in shifts in sea surface temperature and plankton abundance in the long term. Ocean conditions then affect the local freshwater environment. As a result commercial fish populations may decrease through lack of food or migration away from adverse conditions.

Use of weather and climate information can help government agencies with their conservation management and policy making. It can also help them promote sustainable development of the fishing industry and to conserve aquatic ecosystems.

High flows in streams and rivers cause a disruption of upstream migration and interfere with spawning activities. Also severe flooding can cause high mortalities and losses of newly hatched fish. Flooding in streams and rivers may also introduce substantial amounts of silt into spawning streams, which affects fish survival. Therefore, forecasts of severe river flooding are useful for fisheries resources management.

Warnings on severe storms and tropical cyclones, in particular the track and intensity forecasts, are critical for protecting the safety of fishermen at sea.

B8 EDUCATION SECTOR

The future is in the hands of the young people who are now in schools. The better they understand the interaction between humans and climate, the more secure and sustainable the future developments will be. Consequently it is important that NMHSs invest in outreach activities for the education sector.

School teachers and students benefit from educational packages for different levels prepared by NMHSs. With these resources teachers can organise classroom activities such as weather diaries and weather observations, and initiate student projects related to weather and climate. These activities, coupled with the outreach programme of NMHSs, can stimulate interest of students in meteorology and hydrology and promote their awareness of hazardous weather. In addition there are many challenging issues in the meteorological field, which relate to human safety and security as well as the sustainable development of the Earth's systems, where education can play a key role.

Outreach activities can help teachers, parents and school transport managers understand the nature of hazardous weather, the meanings of various severe weather warnings, and the appropriate precautionary measures and response actions. Schools may need to suspend classes if severe weather is expected. Preparation of response plans for severe weather and a better understanding of the nature of severe weather can facilitate orderly responses from the education sector to ensure the safety of students in the event of hazardous weather.

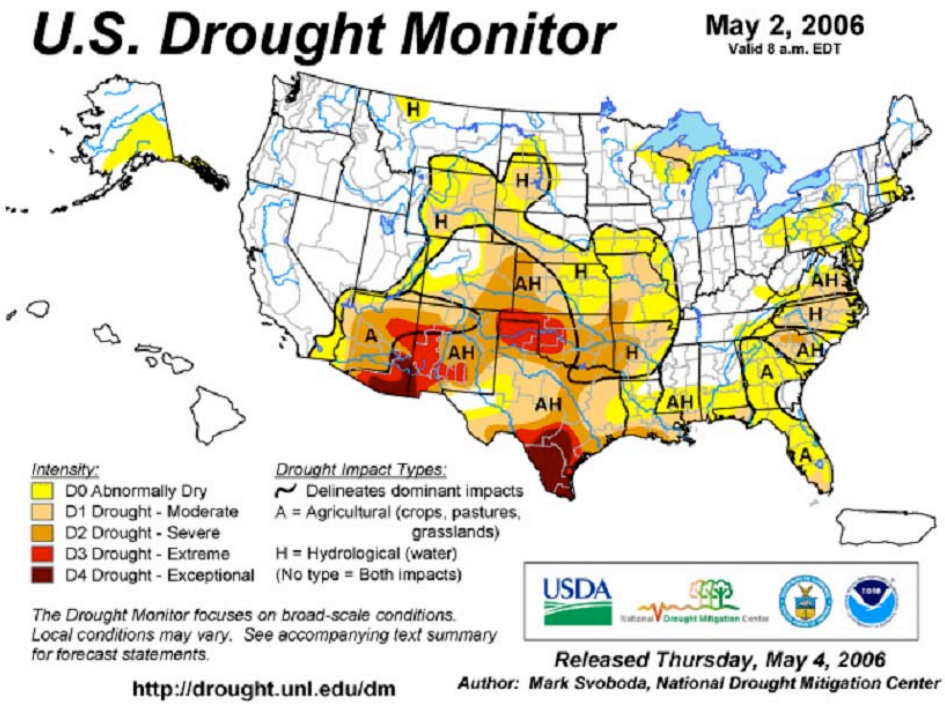

Figure B1: Sample of the drought monitor product developed as a result of the collaboration between NOAA, USDA and the University of Nebraska in the USA.

B9 ENERGY

The public is dependent on energy supplied by public utilities and other components of the energy sector for most day to day activities. The energy efficiency of a country has an important impact on its economic and social development. The energy sector includes both renewable and non-renewable resources, and covers a wide range of activities from energy resources exploration, extraction and production, to electricity production, transport and distribution. It is composed of utility companies for electricity, natural gas and oil.

The output of the energy sector is highly dependent on weather and climate conditions, regardless of the field of activity, production means and timescale. Many energy utilities contract with NMHSs for specialized forecasts and climatological services to assist them in operational planning to meet expected demands for electrical power, heating fuel and gasoline.

Weather forecasts and observations are used to estimate consumption, determine fuel needs, optimize operation and maintenance practices, and to aid generation scheduling and emissions minimisation. Climate and weather forecasts, model output and monitoring information have been comprehensive inputs to the management and operation of the electric and natural gas industry for many years (Nye, 2001). In addition the implementation of plans to increase the use of renewable energy sources requires information about weather and climate.

Consumption of energy varies directly with changes in weather. Electricity facilities are subject to damage and service interruptions by various adverse weather conditions. Extreme events such as heat waves or cold waves, windstorms or floods can have dramatic consequences on electricity production or the electrical grid of a country. Also drought severely affects the generation of hydroelectric power.

Overloading the electric power supply by unexpectedly high consumption of electricity by air-conditioning systems in hot weather or the disruption of electricity supplies by lightning strike may cause the blackout of a city. Weather forecasts and warnings issued by NMHSs assist the energy sector to minimize disruptions to the power supply in severe weather. They can also assist energy companies to deploy repair crews and other essential staff efficiently so as to minimise risk and inconvenience to the public. Also variations in weather on normal days have an impact on the load level, energy production, transport and distribution management, as well as energy prices.

Climatological data and projections of climate scenarios are necessary for the long-term planning of energy supply and the design, siting and capacity of power stations. Information about future climatic conditions and market dynamics is crucial to reduce the uncertainty in the forecasts of supply and demand. Reliable forecasts facilitate the management of energy-related risks at all timescales from a few minutes to a century.

The utilities also use weather and climate information for energy trading. Area specific forecast products with added-value information (e.g. heat index forecast, heating and cooling degree-days), and energy-demand temperature indices are useful tools for the energy sector. Transforming a "weather or climate forecast" to an "energy forecast" is beneficial to the national economy.

Energy policy and supply constraints have created a number of challenges for the energy industry in terms of addressing supply and demand issues while satisfying environmental concerns. The energy industry is now facing a host of new drivers – such as deregulation, environmental policies and globalization – that increase the need for climate and weather services and other environmental information. In addition, because of these new drivers, a host of new entities are emerging in the deregulated electricity industry, each of which needs weather and climate information to optimize operations (Hayes, 2001).

NMHSs assist government energy agencies to plan the development of new energy technologies and strategies to ensure a reliable and diverse energy supply, clean and affordable power, and efficient energy use.

Due to the complexities of energy systems it is important that NMHSs collaborate with companies in the energy sector. These companies are sophisticated users of weather and climate information. The NMHSs can help the companies make the best use of the products and services available. In addition dialogue with these companies can lead to the identification of potential new services which would support the development of the sector (e.g. incorporating probabilistic weather forecasts into the users' decision-making support tools).

B10 WATER RESOURCES MANAGEMENT

One of the essential elements of life on this planet is fresh water. To establish a sustainable way of life that will not threaten future generations there is a need for sustainable management of the world's limited resources of fresh water. Water resources cannot be managed unless information is available on the location, quantity and quality of water sources, and their likely variability in the foreseeable future. Weather information provided by NMHSs, especially about precipitation data and forecasts, is crucial to water management for:

- Securing the availability of drinking water.
- Preventing and controlling floods so as to reduce loss of life and property due to flooding.
- Conserving ecosystems.

The pressure of population growth is having an increasing impact on hydrological processes, particularly through changes in land use such as urbanization and deforestation. Conversely, the public at large is increasingly suffering from the impact of hydrological extremes in the form of floods and droughts. During the 25 years from 1966, the number of people affected by floods exceeded that associated with all other major disasters combined (Fattorelli et al., 1999).

Water resources are essential to the supply of drinking water, irrigation for agricultural production, inland water transport and cooling of power stations. Projects such as the construction of dams, aqueducts, wells, pumps, water and sewage treatment plants, and drainage works are all designed on the basis of knowledge of a region's climate. Once built, the efficiency of operation relies on up-to-date information and forecasts of temperature, precipitation, humidity and wind. Predictions of dry weather require conservation of existing water supplies and planning of water storage. Predictions of excess water, which may lead to flooding and pose threats to life and property especially in low-lying and poorly drained areas, demand a prompt response from the relevant agencies (e.g. opening of dam gates or diversion of water for discharging to the open seas). This vital flow of information depends on close links between NMHSs and the agencies which operate national water resource projects and provide flood control services.

For effective long-term management of water resources, information on climate change, population growth and change in human behaviour is required. Development of water use models with meteorological inputs (e.g. daily rainfall amount and maximum daily temperature) and monthly average daily water use may improve demand reduction strategies. In this way they enable the optimum use of rainwater, storm water and wastewater to augment urban water supplies.

Flood forecasting and warning systems play a key role in reducing flood damage and enhancing safety of life. Improvement in flood forecasting has been made possible by using hydrological forecast models with meteorological inputs (e.g. observed rainfall and quantitative rainfall forecasts) as well as other hydrological inputs. These developments have contributed to the flood warnings becoming more timely and accurate.

Water management benefits from the ability of NMHSs to provide improved forecast quality, improved regionalization of forecasts and wider accessibility of forecast products. NMHSs need to be equipped with up-to-date knowledge on weather forecasting and climate change to provide seasonal and long-term forecasts in support of water resources management.

At the international level, the WMO Commission for Hydrology addresses issues related to the basic hydrological observation network, water resources assessment, flood forecasting and management, and adaptability to climate

variability and change. Also it promotes exchange of technology and capacity building among Members.

B11 HEALTH

Good human health is a basic requirement for sustainable development. The inclusion of biometeorological information in publicly issued weather bulletins can be useful to the public and decision makers by letting them recognize and avert health risks at an early stage. This information can be used in various ways to contribute to the health and well-being of society, especially in the framework of preventive planning.

Extremely cold and hot weather affects the health of people, especially the elderly, young children and anyone with respiratory diseases. The temperature a person feels (warm or cold) depends upon the ambient temperature and the wind and humidity conditions. Due to differences in geographical location, behavioural patterns and people's adaptability, the definition of extreme temperatures varies across the world. Methods of evaluating stress and formulating indices or warnings of extreme temperatures are geographically dependent. Consequently NMHSs need to have their services tailor-made for their own countries.

Timely air quality information can assist the public in coping with problems caused by ground-level ozone and other pollutants. Air quality advisories issued when predetermined pollutant thresholds are exceeded can result in actions to reduce pollution levels and encourage people to avoid polluted areas thereby alleviating adverse effects on health.

People who are allergic to pollen would benefit most from information on the exact time of ripening and release of pollen, so that they can take actions to minimise the adverse effects on their health. The presence of pollen, its density and trajectory, as well as the possibility of it being washed out from the atmosphere by precipitation, all depend on the weather.

Increased UV radiation has been shown to increase the incidence of skin cancers and cataracts in humans, and may also affect plants, aquatic organisms and other natural systems. The monitoring of UV values and incorporation of the measurements into a simplified UV-index can alert people to protect themselves during critical periods of elevated UV intensity. They can respond by avoiding outdoor activities, wearing protective clothing and applying sunblock to the skin.

A range of infectious (particularly vector-borne) diseases is geographically and temporally limited by variations in environmental variables such as temperature, humidity, rainfall, vegetation and land-use patterns. The direct impact of climate on infectious diseases can occur by three principal pathways: affects on human behaviour, affects on the disease pathogen, and affects on the disease vector (WHO, 2005). An early identification of an epidemic of infectious disease is important for controlling the disease and reducing the resulting mortality and morbidity in human populations. With the incorporation of both climatic and non-climatic factors, climate-based early warning systems can be developed for infectious diseases in the health sector.

A number of climate sensitive diseases have been identified by WHO as candidate disease for climate-driven early warning systems (WHO, 2005). Climate information can be used in disease monitoring and surveillance. In places with poor epidemiological data, such as in sub-Saharan Africa, climate information can be used to model the distribution of climate sensitive disease. Climate data is also useful in formulating health policy and improving epidemic preparedness and response.

Weather changes can affect non-communicable diseases and the well-being of individuals. It may result in deterioration in cardio-vascular and respiratory diseases, occurrence of blood clotting, aggravation of inflammation and the increased risk of occupational and traffic accidents. Other adverse effects may include sleep disturbances, lack of concentration, headaches and fatigue. Regular coordination between NMHSs and user sectors (including policy makers, enforcement agencies, health authorities and emergency response agencies) can ensure the usefulness of the biometeorological information that is made available.

Hospitals play a critical role in providing treatment and support to patients with severe infectious diseases and those suffering from weather stresses, as well as victims in the aftermath of a natural disaster. Hospital administrators require a good understanding of the types of natural phenomena that can affect their facilities. With climate and current weather information from NMHSs, together with other relevant information, hospital administrators can determine the optimal amount of resources to invest in order to reduce the risks posed by natural hazards and ensure that they are able to fulfil their essential role as the provider of critical care to victims and patients. Close cooperation between NMHSs and the health sector, for example in providing data on patients for use in models to forecasts the impact of weather on vulnerable patients (e.g. cardiac patients), can benefit the community. Also this helps hospital administrations to plan staffing levels when the likelihood of a particular illness increases.

The *"WMO Guidelines on Biometeorology and Air Quality Forecasts"* (WMO-No.1184, 2004) and its supplement issued in 2007 provide useful guidance to NMHSs on methods of incorporating biometeorological information into the suite of products and services offered to the public. Alerts in the form of indices, warnings and advisories can increase people's awareness in biometeorology-related threats, and enable people to take actions to minimise adverse atmospheric environmental effects.

B12 NATURAL RESOURCES MANAGEMENT

Management of natural resources is the key to ensuring a sustainable and equitable development of global social and economic systems. Natural resources are the basis for life on Earth, and their exploitation constitutes the primary source of livelihoods for most of the world's population. A shortage of resources such as fisheries, forestry and mining may lead to human conflicts. Also loss of livelihoods may cause social tension, migration and settlement of people in vulnerable areas. Promotion of environmental conservation and equitable use of natural resources can assist in mitigating the risk of natural disasters, reduce social tensions and avoids human conflicts. Climate and weather

information facilitates the development of natural resource management tools and conservation planning by environmental protection agencies. This helps protect the security of communities and contributes to ensuring sustainable development. The challenge is to strike a balance between conservation on one hand and the use of natural resources to meet socio-economic aspirations on the other.

Forests play a key role in the hydrological cycle and in carbon storage, and they are important in terms of biodiversity. Also they are sources of wood fuel, building materials, food and timber for paper amongst other things. To protect lives (human, animal and plant) in forests and countryside from the danger of fires, NMHSs generate forecasts of temperature, humidity and wind required for evaluating the risk of fires in dry seasons. They also monitor the dryness of the vegetation before issuing warnings and advisories to the public about fire risk. Environmental protection agencies and environmental conservation authorities can formulate their fire plans with the use of climate data, weather forecasts, wildfire warnings and advisories. NMHSs can also facilitate aerial spraying of insect pests by providing forecasts of wind conditions to the relevant government agency or forestry administration.

Continued exploitation of a fragile environment can give rise to desertification of large areas. Meteorological information can be made available to define and help manage new farming systems that permit a new equilibrium between increased population and existing natural resources, including climate with its inherent variability.

Wetlands are among the world's most productive environments and diverse ecosystems. They are vulnerable to the impacts of climate variability and change. Environmental protection agencies and agricultural agencies can benefit from the use of weather information and forecasts of climate variability and climate change in their wetland conservation activities.

Minerals and petroleum are vital to livelihoods and to the economic and social development of a country. Mining contributes a significant amount to the Gross Domestic Product (GDP) and foreign exchange earnings of some countries. Use of explosives in mining is restricted in thunderstorms or high winds. Therefore managers in the mining industry require forecasts and warnings of thunderstorms, high winds and heavy rain to decide when to suspend and resume operations and so ensure the safety of miners.

Extraction of petroleum generates greenhouse gases which affect climate. Updated information about climate change and advisories issued by NMHSs can raise the awareness of oil companies and government officials about the importance of reducing greenhouse gas emissions by formulating strategies and adopting appropriate measures.

B13 TOURISM, LEISURE AND SPORT

Tourism makes a major contribution to the economies of both developing and developed countries. The NMHSs products and services support tourism, recreational parks and big outdoor events or leisure activities in many ways. Most importantly, NMHSs provide weather warnings to ensure the safety of people engaged in outdoor activities. To increase their visibility to tourists and visitors, NMHSs can provide weather observations at tourist locations by installing automatic weather stations and even network cameras that capture real-time weather images for displaying on the websites of NMHSs.

The provision of short-range and medium-range forecasts can assist members of the public make choices about the location and type of outdoor recreational activities. NMHSs can produce public weather products that are tailored to the needs of the tourism and leisure sector (e.g. boating, sailing, windsurfing, skiing and ballooning). In addition NMHSs can support special outdoor events, such as festive and cultural events that involve a large number of people, by providing short-term forecasts for specific locations and times.

Weather information is also important for organizing sports events. Big sports events are often of world-wide interest (e.g. Olympic Games, Grand Prix motor racing and World Cup events) and they require very specific weather information and short-term forecasts from NMHSs to support the running of different types of outdoor sporting events (e.g. skiing, windsurfing, cricket, softball, baseball and tennis). If severe weather occurs NMHSs can provide weather services to event organisers to help them make decisions about programme management with a view to ensuring the safety of athletes and spectators. An orderly and effective response of a large number of spectators to severe weather threats is required to avoid chaos.

As for the athletes, those engaging in outdoor sports such as windsurfing need to adopt different strategies in different wind conditions. Some NMHSs may send their weather experts to the site of the event to provide tailor-made weather forecasts for their national athletes. Some NMHSs also participate in forecast demonstration projects during the Olympic Games which serve as a test bed for their nowcasting and numerical model forecasting tools, and a forum for scientific exchange among NMHSs and academia. This was done successfully during the Sydney Olympic Games in 2000 and is planned for the Beijing Olympics in 2008.

B14 FINANCIAL SECTOR

Major impacts of weather on financial services are caused by severe weather and extreme events. Some countries are more vulnerable than others because of their geographical location, population distribution, or national wealth. In developing countries, there may be high mortality in extreme weather, but relatively small costs to the financial sector because of relatively low levels of insurance. However, in developed nations the loss of life may be less but there may be much higher costs to the insurance industry. The impact of severe weather on the financial sector is larger in terms of higher economic cost when the stock and futures exchanges markets suspend their operation due to severe weather.

Insurance cover is being increasingly used to protect against the vagaries of adverse weather. Statistics compiled by the Munich Insurance Group (Berz, 1999) show that during the period 1950–1999 the great natural catastrophes, which were mainly weather- and climate-related, caused economic losses of US$ 960 billion and insurance losses of

US$ 141 billion. The insured losses in the 1990s are about 15 times those in the 1960s. The overall economic losses and insured losses arising from natural catastrophes have increased in the past decades as shown in Figure B2 (Munich Re, 2006). There is also growing concern among the insurance industry that, in addition to the increasing number of natural and human-induced disasters, the impact of climate change will result in greater economic losses.

In view of the uncertainties in weather and climate forecasts, a weather derivatives market has developed in some countries to help large energy trading companies manage weather risks. This derivatives market was originally developed in response to the deregulation of the power industry. The market then expanded to include end-user weather-sensitive industries such as agriculture, renewable energy, coal and natural gas. Though severe weather imposes negative impacts on the financial sector, such as increasing inventory costs and socio-economic costs, weather creates new opportunities in the financial sector as in the case of the development of insurance and derivatives markets.

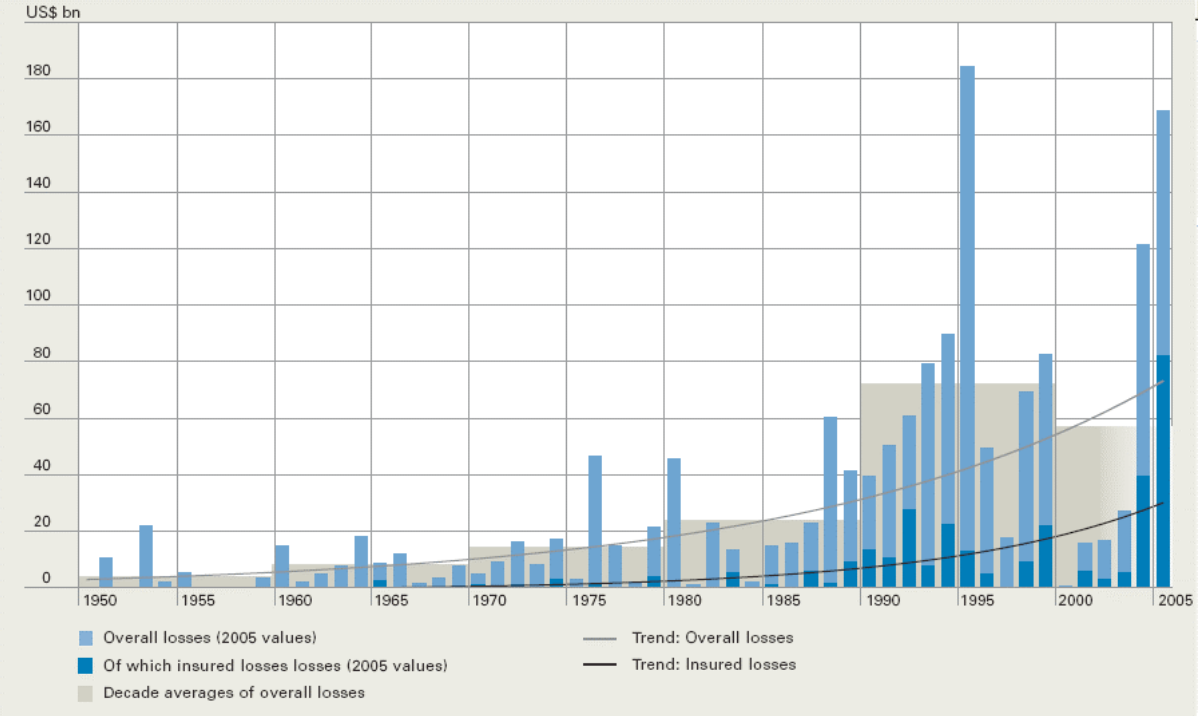

Figure B2: The overall economic and insured losses arising from natural catastrophes during 1950–2005 (adapted from Munich Re, 2006).

B15 CONSTRUCTION INDUSTRY

The design and construction of structures (including buildings, bridges, highways, dams, drainage systems and water resources management systems) requires climate data for extreme value analysis and selection of an appropriate set of design criteria based on the probabilistic occurrence of extreme events during the service life of the structure. The design of hydraulic structures and drainage systems are based on the analysis of a long period of historical rainfall and runoff data for a specific area.

Wind loads can be analysed in the design of buildings. As safe refuges, buildings should be able to withstand high winds and gusts which may occur during the expected lifetime of the building. The magnitude of the design wind loads for a specific structure at a certain location depends on the maximum wind speed expected for a given return period in that region, taking into account the shape, size and type of the structure.

Climatic temperature data is often used to assess the thermal stress on the structure and heat stress on people living in the building. Temperature usually has an effect on the long-term durability of a structure. For reinforced-concrete slabs, building codes usually specify a minimum level of reinforcement to resist stresses that develop as a result of temperature effects. Also relative humidity affects cement hydration, strength development, shrinkage and creep in concrete. Many other climatic factors also affect the behaviour and durability of structures (Phillips, 2003).

In addition to the direct cost of damage to existing structures, adverse weather also affects construction activity and consequently construction costs. High winds, rain and temperature are factors that influence productivity on site. Temperatures also affect the process of concreting. For example, hot weather, especially on windy days, can cause early shrinkage in concrete slabs. Short-range forecasts of rainfall and temperatures as well as warnings of severe weather are required by the construction industry during the construction phase of structures.

Snow on roofs that are built without due consideration to the weight of snow can lead to the collapse of buildings resulting in deaths and injuries. Proper weather data and warnings from NMHSs are required by the construction industry when buildings are constructed in heavy snow-prone places.

B16 MANAGEMENT OF THE URBAN ENVIRONMENT

The principal weather-related concerns in urban areas include severe weather, urban runoff, air quality, water quality and climate issues. Severe weather in urban areas (e.g. severe storms, tropical cyclones, flash flooding and extreme temperatures) pose significant threats to human life and property as well as stress on public transport systems for commuters. NMHSs provide real-time weather information and timely warnings and advisories so that the public can take appropriate actions to minimise the weather impacts. They also support other government agencies in formulating policies and strategies in relation to urban weather for the enhancement of the environment. Indeed multi-agency preparedness is a key component in supporting disaster risk management for urban areas.

Urban weather issues are becoming increasingly critical as global population continues to grow and more rural areas turn into cities. The interaction between pollutants generated in cities with fast growing industries and naturally occurring airborne substances affects air quality. Motor vehicle emissions coupled with local, fine-scale effects of the urban environment on air movement risk exacerbating the impact of air pollutants on human health. Public health and safety also risks being affected by the dispersion of hazardous materials from chemical, biological, radiological or nuclear releases by airborne and/or waterborne transport. Urban topography comprising high-rise buildings affects local wind fields; this complicates the prediction of the spread of plumes of pollution and thus the concentration of the hazardous substances in the urban areas. Dispersion of air pollutants and transport of contaminated water to wider regions downstream creates a risk to the natural ecosystem as a whole. Air quality information and advisories are necessary to enable the public to avoid polluted areas. They are also useful in assisting other government agencies and the private sector to adopt measures for reducing air pollution levels.

In many countries, the measurements of air quality are taken by environmental protection agencies. Some of them may cooperate with NMHSs to provide air quality advisories or Air Pollution Index (API) to the public. NMHSs play the important role of providing weather observations and forecasts in support of air quality forecasting. Weather model outputs (including forecasts of wind fields, precipitation and atmospheric stability) are essential inputs to dispersion and air quality models for the prediction of air quality. Research and development in the field of urban weather undertaken by NMHSs and the provision of weather services can provide benefits to urban commerce and sustainable development. NMHSs can also assist government agencies in weather related legislation and urban planning.

Not only are urban areas affected by weather and climate, but they also exert their own unique influence on local-scale weather and climate. The climate in and around urban areas is altered in part by human modifications during urbanization. Natural vegetation is replaced by buildings and paved streets that seal the Earth's surface and add a greater vertical dimension to the environment. These changes affect the absorption of solar radiation and heat storage capabilities, evaporation rates and surface temperature (heat island effect), as well as local turbulence and wind patterns. This, in turn, can drastically alter near-surface atmospheric conditions. Human activities in urban areas also generate water vapour, heat and pollutant emissions that directly impact on the temperature, humidity, air quality and visibility in urban areas. On slightly larger scales, urbanization can also lead to changes in precipitation over and downwind of developed areas. In addition urban life is also responsible for much of the greenhouse gas emissions that are thought to be altering climate on regional to global scales (NOAA, 2005).

There has been a rapid development of large coastal cities, but such cities are increasingly vulnerable to the impact of climate. NMHSs need to respond to these challenges by providing early warning about weather hazards to help mitigate the impact of these events and support the emergency authorities in taking appropriate action.

B17 LAND AND URBAN PLANNING

Climate information supports aspects of land and urban planning which concern safety, human comfort and energy conservation. Frequency analysis and extreme value statistics of climatological data can help identify areas vulnerable to severe weather. Taking into consideration other environmental information such as soil type with climatic analysis information, land use can be assigned more properly and so minimise human impact on the environment. Proper land use and building codes make homes a safe refuge for people during hazardous weather.

Urban design deals with planning the structure of settlements. Appropriate urban planning and building design takes into account climatic effects so as to provide measures that help reduce the impact of low temperatures, reduce heat stress for people living in cities and minimises the urban heat island effect. For example, good ventilation in buildings and settlements prevents excessive accumulation of heat in cities. Also the need for air-conditioning inside buildings becomes less thereby reducing the use of electricity and hence saving energy. To maximise thermal comfort in urban areas, climatic aspects need to be considered on all scales, from the design of individual building to regional planning (WHO, 2004).

Urban design affects the urban climate. The surrounding human-made and natural features can potentially create a multitude of microclimates through pockets of sun and shade, with varying degrees of protection or exposure to wind (Forwood et al., 2000). The land and urban design should also take these factors into considerations

Local and regional variations in seasonal conditions and weather patterns are critical for long-term urban planning and management (NOAA, 2005). Climate information and forecasts can assist government agencies in formulating strategies and taking actions to reduce the anthropogenic influence on the environment and climate. In order to tackle the emerging weather and climate related problems effectively in highly populated urban areas, an interdisciplinary approach to strategy formulation and cooperative effort from NMHSs, emergency managers, scientists and members of the private sector is required.

B18 GENERAL PUBLIC

Weather is important to the general public from the perspective of improving decision making and planning in the face of day-to-day weather changes, as well as from the standpoint of responding to severe weather events. Day-to-day weather associated with temperature, winds, precipitation or other meteorological elements can disrupt decision making and affect the "cost of doing business" in terms of economic efficiency and competitiveness. Reliable and useful weather information is able to influence the behaviour of members of the public and contribute to the well being of a community.

In severe weather situations, a fast and orderly response by members of the public can be achieved by operating an effective weather warning system. Towards this end, public education and outreach activities are indispensable methods for promoting understanding of the warning system and the nature of hazardous weather. The display of concise weather forecast and warning information, weather cartoons or warning logos on the electronic boards outside buildings and in public transport premises can help people to make weather-related decisions and adjust their plans. It can also increase the effectiveness of weather warnings.

In rural areas, a mechanism for alerting people about weather hazards can be designed and implemented, for example by using sirens or broadcasts over local radio channels.

In modern cities, NMHSs can develop innovative applications, contents and services that make individual alerts possible by taking advantage of the convergence of telecommunications, broadcasting and Internet services as well as location-based service such as GPS and GIS. Interactive real-time display of weather information such as wind and rainfall on top of GIS over the regions at users' choice is useful for making timely decisions and taking appropriate response actions. Also GPS embedded in mobile phones can identify the locations of people with mobile phones within minutes. Use of the latest technology in disseminating weather information can help the travelling public make timely decisions in severe weather, and thus reduce the disruptive impact of hazardous weather phenomena.