World Meteorological Organization

NATIONAL METEOROLOGICAL AND HYDROLOGICAL SERVICES, THEIR PARTNERS AND USER COMMUNITIES

Follow-up to the Madrid Action Plan - for Improved Social and Economic Benefits of Weather, Climate and Water Services

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NOTE

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National Meteorological and Hydrological Services, Their Partners and User Communities:

A follow-up to the Madrid Action Plan - for Improved Social and Economic Benefits of Weather, Climate and Water Services

EXECUTIVE SUMMARY

This report has been prepared to build upon the Madrid Action Plan (MAP) that resulted from the WMO International Conference on Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services, Madrid, Spain, 19-22 March 2007, which is also known as the Madrid Conference. The report is presented in three parts and four appendices. The first section, Part I of the report relates to the Madrid Conference and the MAP. The MAP actions are analysed and proposals are made regarding the ways that both National Meteorological and Hydrological Services (NMHSs) and the WMO Secretariat can move ahead on these actions. Part II of the report is focussed on users and capacity-building. It builds on the proposals that appear in Part I. Part III discusses the quantification of benefits that the NMHSs and their services provide.

Appendix I is comprised of six projects with topics that directly focus on the items in Parts I-III. These are presented as somewhat independent projects that could be carried out as part of developmental and capacity-building projects that would enable NMHSs to enhance their capacity to provide improved services and hence their value to society. The Projects are: 1. Review of Institutional Framework - Know your NMHS and solidify the base; 2. Dialogue and Collaboration with Partners, Decision-Makers and Users; 3. Education and Training – Decision-Makers and Users; 4. Developing Capacity - Integrated Environmental Prediction - including health-related services; 5. Developing Capacity - Natural Hazards and Emergency Services; and, 6. Developing Capacity - Climate Services.

The report also includes three further appendices that provide information related to climate change and disaster risk reduction in the international context. These appendices are: II - Bali Action Plan and Copenhagen Accord; III - The International Framework for Natural Hazards Actions and Research; and, IV - The World Climate Conference 3 and the Global Framework for Climate Services.

1. Introduction

Governments exist, in principle, to provide public goods[1], protect their citizens from harm and enhance overall benefits to their national society.[2] They work to achieve these objectives through combinations of provision of services and information, regulations, payments and inducements. These efforts are dependent on generated taxes and designed to achieve monetary, as well as societal benefits. This report will focus in particular, on National Meteorological and Hydrological Services (NMHSs) of 189 WMO Members around the world.

An important aspect of the protective responsibilities of a government includes the provision of information and, when appropriate, warnings regarding weather and weather-related events. The number of disasters, where communities are impacted beyond their capacity to cope with local resources, has risen dramatically (by about a factor of six over the past four (4) decades)[3]. *"Over the last two decades (1988-2007), 76% of all disaster events were hydrological, meteorological or climatological in nature; these accounted for 45% of the deaths and 79% of the economic losses caused by natural hazards.*"[4] In light of this emerging trend, a strong emphasis must be put on the provision of these services by the government. This quote went on to say: "*The real tragedy is that many of these deaths can be avoided*." Although emergency management organizations have a primarily role in reducing deaths, they rely on information and warnings. Governments need to respond to this challenge, and in most cases, the role of provision of information and warnings is and should be entrusted to NMHSs in partnership with emergency management organizations. From the NMHSs' perspective, the primary user community for these services are citizens, especially those most vulnerable to weather and weather-related stresses. The media consume this information in their role as partners in delivery of these services and their benefits.

Governments also act to enhance the national economy and generate benefits that occur on both an individual level, such as subsidies, allowances, etc., and an economy-wide level.[5] It is at this second level where the NMHSs play a role. Meteorological services and information provided to society can be utilized to make society more efficient, less impacted and otherwise enhanced. In this case, the user communities of NMHS s are a wide variety of weather-sensitive sectors of society and the economy.

This document specifically addresses the relationship between NMHSs and their user communities. It seeks to evaluate the present situation, focusing on ways in which the two can work together more efficiently to generate benefits. In turn, these partnerships will enhance the actual and perceived values of NMHSs.

The first section, **Part I**, of the report relates to the Madrid Conference and the MAP. The MAP actions are analysed and proposals are made regarding the ways that both NMHSs and WMO can move ahead on these actions.

Part II of the document is focussed on users and capacity-building. It will build on the proposals that appear in Part 1.

Part III discusses the quantification of benefits that NMHSs and their services provide.

[1] Public goods refer to those benefits and services that are generally provided by the government to society. They are characterized by non-excludability and non-rivalry aspects. Examples could be law enforcement or garbage collection. Gunasekera, Don. "Public, Private and Mixed Goods" Measuring the Economic Value of Meteorological Information. (WMO, 2002) Pg 366.

[2] Mills, Edwin. *The Burden of Government*. (Stanford, Hoover Press, 1986) Pgs 3, 15, 27, 29.

[3] The United Nations International Strategy for Disaster Reduction. http://www.unisdr.org/disaster-statistics/occurrence-trends-century.htm,

[4] Wahlström M., (Assistant Secretary-General for Disaster Risk Reduction and Special Representative of the U.N. Secretary-General for the implementation of the Hyogo Framework for Action) – quoted in: Birkmann, J, Tetzlaff, G, Zentel, KO, ed. *Addressing the Challenge: Recommendations and Quality Criteria for Linking Disaster Risk Reduction and Adaptation to Climate Change*. DKKV Publication Series 2009, 38:5

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[5] Mills**,** Edwin, Pg 27.

Part I – The Madrid Action Plan

I.1. The WMO International Conference on Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services and the Resulting Madrid Action Plan (MAP)

The WMO International Conference on Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services (Madrid, Spain, 19-22 March 2007) had as its objective, the assessment of the current value of weather, climate and water information and services, as well as how these benefits could be greatly increased[6]. Decision-makers from many and diverse user sectors participated in the Conference. In the end, it was concluded that although information and services are extremely valuable, there is enormous potential for increased benefits[7]. The Conference and the resulting Madrid Action Plan (MAP) identified and focussed on the challenges facing NMHSs as service providers, and their communications with their user communities.

To enhance the social, economic and environmental benefits in both developed and developing countries, there is need to build stronger partnerships between provider and user communities at every level of society[8]. Central to the response to these challenges is an increase in the awareness among decision-makers of the impacts of weather, climate and water, as well as the benefits of improved use of meteorological and hydrological services. In this regard, it is important that NMHSs endeavour to better understand and participate, in a positive way, in the political processes of governments.

This necessitates making better connections with the political policymakers where this is possible. A solidified connection and better understanding of the valued role of NMHSs in reducing loss of life and economic damages should lead to further support (both in terms of mandate and budgetary resources) from decision-makers in order to effectuate these societal benefits.

The overall objective of the MAP is: "*to achieve, within five years, a major enhancement of the value to society of weather, climate and water information and services* …"[9]The MAP identified 15 actions aimed at meeting the overall objective. Many sectoral foci are stated or implied. In order to achieve the overall objective, each of NMHSs needs to realize that they have their own national identities and that their role *vis-à-vis* these actions will be varied. It is important for each of NMHSs to examine their role relative to other organizations on their national scene to put these actions into national perspective. Part of this process includes learning from the best practices of others who provide similar services. These 15 actions may be usefully grouped to enable addressing them in a coordinated, coherent, and strategic way. Although there are several possible groupings, the following is suggested as a way forward. The two key issues are: the relationships with the user communities of NMHSs; and the capacity of NMHSs to identify, assess and build on those relationships. These will be called partnerships (between users and providers) and developing capacity:

- Partnerships: to develop relationships between NMHSs as providers; and users weather, climate and water information; and,
- Developing capacity: to develop additional capacities beyond what is presently available in many NMHSs.

I.1.1. Madrid Action Plan - Partnerships Between Users and Providers

The first category of actions, Partnerships, would include MAP Actions 1, 3, 7 and 9.

Action 1. Review the **institutional framework** governing meteorological and hydrological service provision in order to strengthen partnerships with different sectors of the economy.

Action 3. Embark on capacity-building endeavours through the creation of **education and training** opportunities for both *users and providers* of weather, climate and water information, in order to increase awareness of users to the opportunities afforded by weather, climate and water services and to assist the providers of these services to understand more fully user requirements.

Action 7. Facilitate and strengthen **dialogue** and **collaboration** between providers and users of weather, climate and water information and services through international, regional and national platforms and programmes, and through the development of appropriate tools and methods.

Action 9. Strengthen existing, and establish new, operating **partnerships** between users and providers of weather, climate and water services to share responsibility

[6] World Meteorological Organization. "Madrid Conference Statement and Action Plan". *Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services.* (Madrid, World Meteorological Organization, 2007). Pg 1.

[7] World Meteorological Organization. "Madrid Conference Statement and Action Plan", Pg 8.

[8] World Meteorological Organization. "Madrid Conference Statement and Action Plan", Pg 2.

[9] World Meteorological Organization. "Madrid Action Plan". *Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services.* Madrid, March 19-22, 2007. Pg 1.

for effective delivery of services, and evaluate their performance.[10]

There is logic to thinking about them in a sequence. In working with partners, providing education and training opportunities and building new partnerships, it will be appropriate, on the basis of this enhanced knowledge and experience, to review the institutional framework and to strengthen partnerships, - that is **Action 1**. **Action 7** - to facilitate and strengthen dialogue and collaboration between providers and users, which includes developing appropriate tools and methods, would build on this institutional understanding. Then consider **Action 3** - to provide education and training opportunities for both users and providers as a ways of building understanding and relationships. **Action 9** focuses on building partnerships between users and providers of services to build more effective delivery of services. Additionally, this Action discusses the possibility of evaluating the performance of these partners. While necessary, it should be recognized that evaluation may be a sensitive issue with potential partners and needs to be addressed in a positive, partnership approach. Figure 1, below, shows Actions grouped for NMHSs or more broadly a national weather-climate-water-environmental agency.

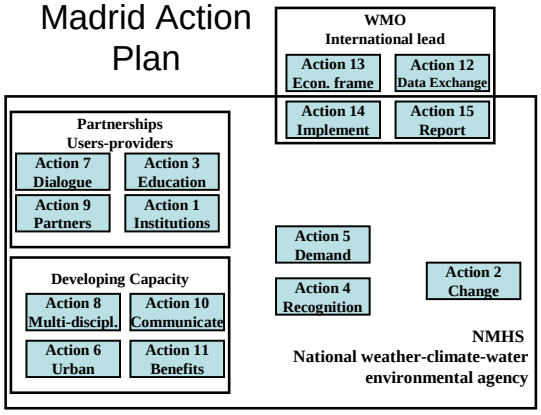

Figure 1 – The Madrid Action Plan – schematic grouping of action items

I.1.2. Madrid Action Plan – Developing Capacity

A second group of actions is labelled 'developing capacity'. The areas of capacity-building identified in the MAP were: multi-disciplinary programmes; communications; urban environment; and quantifying economic benefits. It seems clear that these are broad examples and developing capacity will need to be tailored to the particular circumstance of NMHSs in their national context. The MAP Actions related to developing capacity of NMHSs are:

Action 8. Strengthen existing, and develop and implement new, **multi-disciplinary programmes** that will define and improve ways and means to generate and deliver those weather, climate and water services, which address the developmental, societal, economic, environmental and health concerns of the countries.

Action 10. Facilitate and strengthen the ability of NMHSs to effectively **communicate** weather services and products, through all forms of media, in such a manner as to maximize the benefits provided to society by the meteorological and hydrological community.

Action 6. Develop analysis of the **urban environment** as a critical ecosystem requiring targeted observation, research, and meteorological and hydrological services.

Action 11. Encourage NMHSs and the social science research community to develop knowledge and methodologies for **quantifying the benefits** of the services provided by NMHSs within the various socio-economic sectors, in particular:

- Develop new economic assessment techniques including especially techniques of economic assessments for developing and least developed countries;
- Develop WMO guidelines on operational use of economic assessment techniques;
- Train national staff on the use and practical application of economic assessment of the benefits of services provided by NMHSs; and,
- Present results of economic assessments to governments and donors or international financial institutions with the goal of modernizing the infrastructure of NMHSs and strengthening their service delivery capacity.[11]

Actions 6 and **8** focus on the development of capacity in urban environment and multi-disciplinary programmes. The importance of developing capacity in climate, air-quality and water services should be emphasized under **Action 8**. Additionally, **Action 10** addresses capacity-building in communications, utilizing all forms of media. The fourth capacity-building area focuses on the development of knowledge and methodologies for quantifying the benefits of the provided services.

I.1.3. Madrid Action Plan – Role of WMO

Whereas NMHSs would be the primary actors for the Actions listed in the preceding sections, there are four actions where WMO (NMHSs, the Secretariat, Constituent

[10] All of the actions listed can be found in: World Meteorological Organization, Madrid Action Plan, Pgs 1-2.

[11] The actions listed above can be found in: World Meteorological Organization. Madrid Action Plan Pgs 1-2.

Bodies which form an international organization) should take the lead in partnerships with NMHSs. These are:

Action 12. Encourage the free and unrestricted exchange of meteorological, hydrological and related data to support research and improve operational services.

Action 13. Build on the earlier WMO work on the development of a comprehensive economic framework for meteorological service provision.

Action 14. Develop, as a matter of urgency, the implementation plan to give effect to the actions set out above.

Action 15. Monitor and report every year to key partners on progress with the implementation plan, and organize a further, more broadly based, conference in five years to take stock of achievements under this Action Plan.[12]

WMO must take the lead for **Action 12** (related to the free and unrestricted exchange of data, which has recently become an issue again in a somewhat different context[13]) and **Action 13** (on developing a comprehensive economic framework for meteorological service provision) due to their internationally cooperative nature. Ideally, WMO work on the economic framework would inform the work of NMHSs on developing capacity to quantify benefits; i.e., **Action 13** feeds into **Action 11**, as shown in Figure 2. Similarly, **Action 14** (the MAP implementation plan) and **Action 15** (the monitoring and analysis of progress) require cooperation between the WMO and NMHSs. Due to their international nature, it is presumed that that WMO would take a leadership role. This process is explained by the overlapping rectangles in Figure 1.

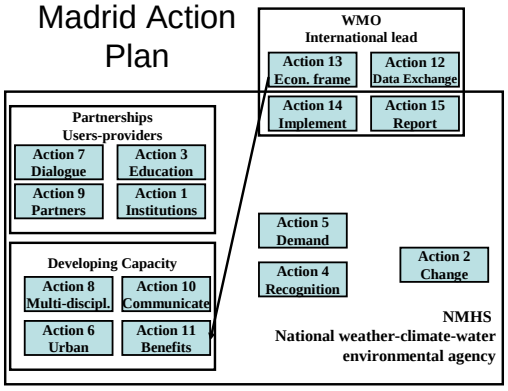

Figure 2 – Madrid Action Plan – schematic roles of WMO-led activities in benefiting NMHSs

As part of an umbrella project, WMO should take the lead through workshops and the creation of regional groupings of NMHSs so that they can more easily undertake joint projects and learn from best practices of other similar NMHSs. Additionally, WMO could promote its own initiatives on the Plan through these workshops. It is important that the WMO projects recognize the assignments proposed below for NMHSs. Using their limited resources, but considerable expertise, and connections to all NMHSs, it will be much easier for WMO to understand the larger picture and thus, to develop initiatives that would benefit all NMHSs.

I.1.4. Madrid Action Plan – Logical Sequence of Actions

As noted above, there is a logical sequence between the Partnerships and Developing Capacity actions and those that result from them. The remaining three Actions under the MAP are as follows:

Action 2. Lead a quantum **change** in the way that weather, climate and water information and services are produced, used and communicated by identifying, confirming and responding to the rapidly increasing and evolving needs of multidisciplinary stakeholders for appropriately timed and scaled weather, climate and water information and services.

Action 4. Foster increased **recognition** by governments and other stakeholders of the contribution that NMHSs and their partners are making to secure and sustainable living.

Action 5. Adopt the following steps to meet the growing **demand** for weather, climate, water and related information and services:

- Strengthening of observational programmes, and the associated research and development;
- Development of the next generation of climate and Earth system models with resolutions of 10 km or finer, and the corresponding data assimilation systems;
- Significantly strengthening multi-disciplinary research programmes required to develop the understanding underpinning the development of these models;
- Improving delivery and distribution systems, including early warning systems, to allow NMHSs to meet the needs of institutions, agencies and the general public; consolidating existing and, when appropriate, creating new regional operational centres to mutualise competencies and resources.[14]

Success in building partnerships with users, providers and others, as well as the development of enhanced capacity

[12] World Meteorological Organization. Madrid Action Plan. Pg 2.

[13] Hefferman, O., 2009: World climate services framework agreed. Nature, 461, 159. Gunasekera, D., 2009: Sharing: project will make climate data freely available to all. Nature, 461, 1053.

[14] World Meteorological Organization. Madrid Action Plan. Pg. 1

within NMHSs will lead to increased **recognition** (Action 4 increased *recognition* by governments and other stakeholders - to secure and sustainable living) and help to meet the increasing **demand** for additional information and services (Action 5) (see Figure 3).

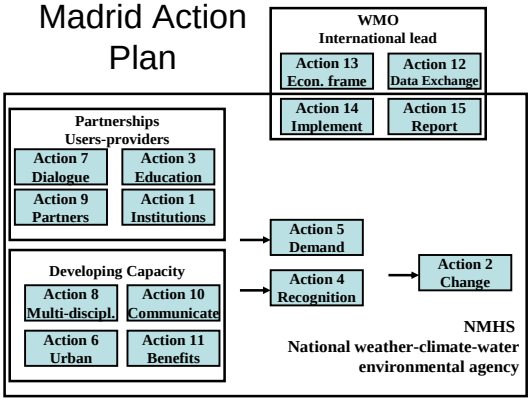

Figure 3 – Madrid Action Plan – Successful implementation of actions will lead to increased recognition and help to meet the increasing demand for services – resulting in change

Growing demand and recognition will prompt the need and capacity for **change** (Action 2). This in turn, will lead to a quantum transformation in the way that information and services are produced, used and communicated. This change will entail identifying, confirming and responding to the rapidly increasing and evolving needs of multi-disciplinary stakeholders for appropriately timed and scaled weather, climate and water information and services. Further, there is the need to develop specific and detailed action plans for these changes, as well as quantify the question of how much is a quantum change.

I.1.5. Additional Areas for the Madrid Action Plan

The MAP identified building capacity in the areas of multi-disciplinary, urban, communications and quantification of benefits. It is suggested that, having done an analysis of their institutional framework and engaged in dialogue with partners and users, each of NMHSs identify specific areas for capacity-building. It is additionally recommended that the WMO undertakes a survey in order to optimise the transfer of ideas, approaches, technology and "best practices" among NMHSs with common interests.

In the science-policy field of research, examinations have been made of the types of information that have had the most impact on decision-makers. Generally, the conclusion has been that information regarding "consequences" is what holds the most significance[15]. In this context, it is important to examine the ways in which weather, climate and water information is presented. Simply stating that the weather will change is no longer adequate and must now be accompanied by a presentation of information on the consequences of those changes. The demand calls for us to go beyond the question of 'what is changing' to providing an understanding of why it matters and what can be done about it.

Some additional issues that need to be added into the action plan include more specific identification of roles in:

- emergency management;
- health services;
- climate services; and,
- sustainable development.

As previously stated, the protection of their citizens is the fundamental role of a government. Part of that role is the provision of information and, when appropriate, warnings of weather and weather-related events to citizens. In order to achieve this, NMHSs need to examine and build on their partnership with the emergency management organizations, moving from a distant, to a direct and mutually beneficial relationship. There has, as a result of tragedies around the world, been a great increase in governmental interest in disaster management lately, yet the role of NMHSs has only been identified in a handful of cases. It is suggested that building capacity in the area of emergency management, including how to better portray the value of the services in prevention and preparedness, is important. The connection between natural hazards and pubic safety issues does not yet seem to be sufficiently developed.

There is growing awareness of the linkages between human health and weather and climate. These include: the impacts of heat and cold, UV radiation, pollen and dust, high Ozone concentration; and the spread of communicable diseases. Air pollution results from natural and especially, human-generated emissions pumped into the atmosphere[16], as well as the processes by which the atmosphere redistributes or removes the pollutants. As the climate changes there will be an increase cardio-respiratory morbidity and mortality associated with ground-level ozone[17] and focussed weather-air quality forecasts can

[15] Dimitrov, Radoslav. "Knowledge, Power and Interests in Environmental Regime Formation." *International Studies Quarterly. 47 no. 1 (2003), Pg 143.*

[16] United Nations Environment Programme. "Greenhouse Gases and Aerosols". *Information Unit for Conventions.*http://unfccc.int/cop3/fccc/climate/fact03.htm.

[17] Confalonieri, U., B. Menne, R. Akhtar, K.L. Ebi, M. Hauengue, R.S. Kovats, B. Revich and A. Woodward, 2007: Human health. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel*

reduce this impact. It is thus important that air quality-health should be an issue for NMHSs, as air quality itself depends on the meteorological conditions as well as the emissions.

Climate services are another area that requires greater attention within the action plan. With the agreement on the Bali Declaration there has been added emphasis on the needs for climate change adaptation[18]. In September 2009, the World Climate Conference 3 decided to "*establish a Global Framework for Climate Services to strengthen the production, availability, delivery and application of science-based climate prediction and services*."[19] The Conference responded to the challenge of the United Nations Secretary General, Ban Ki-moon, "*Now is the time to invest in science, and to commit to rigorous and sustained climate observation, research, assessments and the provision of information. The establishment of the Global Framework for Climate Services will be an important step toward strengthening the application of climate knowledge in local, regional, national and international decision-making*"[20]. It is essential that NMHSs aggressively position themselves as providers of that information on an ongoing basis, as it is a logical extension of weather forecasts.

Finally, sustainable development is an area which requires greater attention. Here, the focus will be on predictions for the future state of the environment, a logical extension for many NMHSs. This issue area will be discussed in greater detail in section II.4.3.

I.2. Project Proposals Related to the Madrid Action Plan

A series of projects is presented that can be undertaken by the WMO and the individual NMHS, some in regional or other groupings with the participation of the WMO. These are:

1. Review of Institutional Framework - Know your NMHS and solidify the base;
2. Dialogue and Collaboration with Partners, Decision-Makers and Users;
3. Education and Training – Decision-Makers and Users;
4. Developing Capacity - Integrated Environmental Prediction - including health related services;
5. Developing Capacity - Natural Hazards and Emergency Services; and,
6. Developing Capacity - Climate Services.

These projects are grouped into two clusters: those related to Partnerships (Projects 1-3) and those related to capacity-building (Projects 4-6). The WMO umbrella project described briefly above, contributes in two ways. First, through working with experts in data exchange and economics, WMO can provide policy leadership to benefit NMHSs.

An important additional role will be the facilitation of the exchange of information and expertise between NMHSs. The projects are described in more detail, in Appendix I and will be referred to in the following sections, where appropriate.

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on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 391-431.

[18] United Nations International Strategy for Disaster Reduction. "ISDR Strategy to Support the Bali Action Processs." Feb, 2008. Pg 1.

[19] Conference Declaration, World Climate Conference – 3 Geneva, 31 August – 4 September 2009 http://www.wmo.int

[20] ibid

Part II – Capacity-Building - Partners and Users

II.1. Introduction

In order to build stronger partnerships with user communities at every level of society, it is important to identify them and analyse their needs and activities, focussing on how they do or could effectively use information from NMHSs. The Madrid Conference and associate regional conferences identified six user sectors:

- Agriculture, water resources and the natural environment;
- Human health;
- Tourism and human welfare;
- Energy, transport and communications;
- Urban settlement and sustainable development; and,
- Economics and financial services.[21]

Within the particular context of NMHSs, it will be appropriate to consider different groupings and to put more emphasis on some user communities than others. It can be noted that for some, national defence will be an important user, yet it is not featured on the list. Further, for example, while agriculture and water resources have natural linkages, the relationships between an agro-industry and its use of water may be in conflict with environmental issues. In cases of conflict, the central role of NMHSs as providers of public-good information without bias should be used as a basis for products.

The 189 NMHSs around the world exist in a wide range of circumstances. Their positions within their national governments vary considerably, with most being encapsulated in government departments whose key objectives differ from, or are well beyond, those of the NMHS. For example, many NMHSs are located in, or hosted by, environment ministries, where the emphasis is commonly on reduction of human impacts on the environment (environmental regulation) and the preservation of natural ecosystems. Others lie within the jurisdiction of agricultural departments which have an appropriate emphasis on food production and the agricultural economy. Still, others are located in transportation ministries whose focus is the safe and efficient operation of air, marine and land-surface transportation. Finally, some NMHSs are linked to departments of commerce or defence. It is important to note that while weather is important for military operations, there are only a few NMHSs located within defence departments, since in some cases the military operate their own weather services, with varying degrees of independence from the civilian or non-defence weather service[22].

Although NMHSs have widely ranging involvement in commercial activities, in some, these activities are contrary to their public service mandates. For example, in Europe, the budgets of many NMHSs have been cut to the point that commercial activity is needed to sustain the service.[23] Hence, any strategy for increasing the interactions between the NMHSs and their user communities must recognize the reality of the positioning of NMHSs and their varying user communities within the larger framework of society.

All NMHSs have users that they have served, usually well, for many years. Additionally, since these users may be beyond the host department and its mandate, it is important to solidify these relationships for the users' security as well as that of NMHSs. Having regular meetings to discuss products and services with the users will help to develop trust and a more solid foundation in the relationship. Similarly, demonstrating responsiveness by ensuring that the products and services are tailored to meet the individual needs of NMHSs' partners and users are an important aspect of strengthening this connection. Additionally, it will most likely be valuable to develop benchmarks and criteria for the products and services. The objective of these analyses of decision-makers, partners and users is to identify those who will make a significant contribution towards the:

- recognition of the present value to society of weather, climate and water information and services; and,
- achievement of major enhancement of those values to society.

It is important to note that these results may not be the same. NMHSs, through their analyses, should better understand those partners and users that fit into the two categories. Based on this study, an appropriate action plan can be developed that will, through interaction and partnerships, move towards achieving the MAP and the NMHSs' objectives.

Any list of users will be dependent on national and regional circumstances. Additionally, there will be seasonal emphases. The following list extends from the list above and groups user communities somewhat arbitrarily into largely public-good activities (1-4), special clients (5-6) and economic activities (7-16):

[21] World Meteorological Organization. Madrid Conference Statement. Pg 2.

[22] This can be seen in the United States. Department of Defense Websites. http://www.defenselink.mil/sites/

[23] World Meteorological Organization. *Summary of the Findings from the Questionnaire on Role and Operation of National Meteorological Services.* 2002.

Public good activities:
1. Human health and welfare;
2. Emergency management;
3. Sustainable development;
4. Natural environment;

Special clients:
5. Urban settlement;
6. National defence;

Economic activities:
7. Transport - air, marine and land-surface;
8. Agriculture;
9. Forestry;
10. Energy;
11. Tourism and recreation;
12. Construction;
13. Communications;
14. Retail marketing;
15. Insurance; and,
16. Economics and financial services.

This typical inventory of users will need to be adapted to NMHSs' services. At this point, it is not possible for these discussions to be more than preliminary and it will thus be important for NMHSs to undertake independent analyses, based on the projects described in Part I. For each of these, there is a range of possible services including weather, hydrological (water) and climate and derived services such as air quality, sea state and ice state.

II.2. The NMHSs Perspective

The overall objective of the MAP is: "*to achieve, within five years, a major enhancement of the value to society of weather, climate and water information and services …*"[24] It is thus important that NMHSs have an excellent understanding of their most valuable stakeholders, since not all are of equal importance. Unfortunately, the present value of these services is not adequately recognized. In order to achieve the MAP objective then, gaining recognition of present value must be an initial goal, as this must be achieved before it is possible to enhance value of such programs. Since the media and political processes seem to recognize and reward 'visible' changes most frequently, it will be important to strategically focus on the changes that will gain recognition.

While the MAP calls for stronger partnerships between provider and user communities at every level of society, it also advocates increasing awareness among decision-makers[25]. It is important to note that these are not equivalent actions. Specifically, it is important to target those that have influence over NMHSs budgets and mandates as real change can only be made with their participation.

Although most NMHSs are within government departments, NMHSs can and should function more like a business than most government agencies currently do. NMHSs are mandated to deliver a set of services and products and thus, operate like a business with operational considerations, delivery schedules and clients, who may be paying directly or indirectly (through their taxes) for the services. As government business-like organizations, NMHSs can learn much from good business practices. These include knowing what is needed and desired in the market, meeting delivery and quality of services criteria and knowing the clients and what will satisfy them. NMHSs need to identify key clients. Additionally, while NMHSs may not have the same annual profit-loss statements as a private sector corporation, they do function with a "bottom line" concerning client satisfaction. This relationship is equally as important since continued, or enhanced, funding relies on satisfactory provision of services. Further, while the main client may be the general public, other users may have financial and political influence which is important to the continuing funding of NMHSs. It is possible to gauge the satisfaction level of clients through established performance benchmarks and standards that have been developed in consultation with clients and through surveys, polls and other means of assessing client satisfaction. For the public, satisfaction can be ascertained through monitoring of complaints, letters to the government, media coverage and other social science means of gauging opinions.

Given the wide range of institutional positions and capacities among the 189 NMHSs, the first strategy for NMHSs moving ahead on the MAP is to recognize this reality and undertake an analysis of their own positioning and capacity. It is important to solidify the base position of NMHSs by understanding the users within the mandate of the host departments (see Project 1). Careful analysis of host departmental structure, mandate and funding criteria can lead to mutually-supportive partnerships within the host department. Although the overall objective is to enhance the recognition and capacity of the Service, it must be built on a solid base of the present arrangements and situation. Through this process of identifying, and then connecting with the users of the host departments, NMHSs analysts will gain experience regarding approaches and methodologies used to reach out to other users. Products and services, both for internal and external users, should be tailored to meet their needs and NMHSs should be seen to be responsive with benchmarks and criteria for the products and services. Obtaining the recognition and support of key clients and users of the host departments is also important since they can influence the departments in positive ways. WMO can again play a role here.

[24] World Meteorological Organization. Madrid Action Plan, Pg 1.
[25] World Meteorological Organization. Madrid Conference Statement. Pg 1.

II.3. Dialogue and Collaboration with Partners, Decision-Makers and Users

The Conference's assessment was that increased awareness and the resulting support for NMHSs would come through the development of improved methodologies for evaluation and demonstration of societal benefits of weather, climate and water services.[26] Further, this development would result from involvement of NMHSs in formulation of national social and economic development strategies. Here, it is important that the focus on societal benefits address both the social benefits, though they may not be easily quantifiable, as well as the economic benefits. Further, it is essential that these benefits be viewed through a political lens, since it cannot be demonstrated that government decision-makers are solely, or even in a major way, driven in their funding decisions by economic, as opposed to political, considerations. Most governments are motivated in the end, by the desire to remain in power - either through re-election or through maintaining authority. It is therefore necessary for NMHSs to undertake an analysis of the motivators of decision-makers, focusing on those decision-makers that will make, or influence the decisions that directly impact upon NMHSs mandates, budgets or resource allocations, and rules of engagement.

Hence, the analysis should include the social sciences of politics and sociology, which will be useful in the analysis of political and social pressures as well as opportunities. It is in this context that the dialogue and collaboration with partners, decision-makers and users should be undertaken (see Project 2).

It is important to understand the distinction between partners, decision-makers and users, especially distinguishing those that have significant power. Decision-makers can be those who decide on the use of NMHSs information or the decision-makers of the users. In this case however, the focus will be on the decision-makers whose decisions directly and indirectly influence the mandate, funding and recognition of NMHSs. In this context, this term may refer to a wide range of people that will vary from service to service. To illustrate further, those that influence funding may be very different than those that influence recognition. Hence, the key decision-makers within government should be identified. Other groups that influence decision-making are the media and general public. For the media, it will be useful to develop contacts with key personnel who have a natural interest in or knowledge of weather and weather services. Providing these contacts with information (i.e., "stories") may help to generate a positive attitude and favourable press. This can contribute to positive influence over governmental decision-makers. Finally, users can greatly influence decision-makers but it is important to realize that there are many groups within this category (although there are likely overlaps between the communities). Although the user communities do not usually hold direct decision-making powers with regard to NMHSs mandates and budgets, key users may still be important decision-makers. Recall the list of 17 user groups identified in the Introduction and grouped as: public good; special clients; and, economic activities. Some are particularly human-related (human health, human welfare, emergency management, urban settlement) and these users often exert great influence over decision-makers and it is thus important to create a useful discourse between them and policy-makers.

In the case of economic activities, many nations wrestle with issues of efficient information provision. They must choose whether services to the user should be offered by NMHSs as a public good (without or for nominal charge), by NMHSs as a commercial activity, by the private sector, or some combination of these. One approach towards better interfacing between the decision-makers and users is to involve them in a decision-making - priority setting exercise (see Project 2). An advisory group or leaders council (this name has a positive sense to it) of selected, non-competing organizations from industry, government and Non-Governmental Organizations (NGOs) can meet annually to identify the knowledge gaps that will help unlock some of their business sustainability challenges. In the case of NMHSs, the members would be challenged as to how they could more effectively use weather, climate, and water information in carrying out their mandates or commercial functions.

A general approach towards working more productively with users is to focus on a better understanding of their needs and using this information to find ways of better meeting those needs. It is important that NMHSs go beyond issuing a forecast and assuming that users find it useful. There is a need for focussed examination, including lengthy discussions with important users, to clarify the extent and shape of their needs as well as how a modified service could better address them. One issue is the communication of information regarding the uncertainty in the forecasts[27]. To be most effective, starting this process with long-established users could provide a base of knowledge and experience which would be useful in addressing potential new users. It is important to note that answering the key question of how to work better with user groups will necessitate selecting which users one can best serve using available capacity. Analysis through meetings and questionnaires should be undertaken to determine which interfaces work well and which ones are performing poorly. In both cases, getting to know the users is a positive step, towards solidifying good interfaces or helping to improve those that are not working.

[26] World Meteorological Organization. Madrid Conference Statement. Pg 3.

[27] Roulston, M.S., Bolton, G.E., Kleit, A.N., Sear-Collins, A.L., 2006: A Laboratory Study of the Benefits of Including Uncertainty Information in Weather Forecasts. Weather and Forecasting. 21-1, 116-123.

A number of these changes will require NMHSs to go beyond their traditional disciplinary mix and bring in the expertise of good economists, sociologists, media analysts and political scientists. This could be accomplished through research alliances with universities and colleges, or alternatively, by hiring individuals with different skill sets. For example, one relatively successful approach has been to assign good meteorologists, climatologists or geographers to work in university research institutes that are broadly based. Through their interactions with and challenging stimulation of faculty, top-level expertise has been brought to bear on some social science issues that could not or were not being addressed within the research cadre of Meteorological Services nor with the traditional atmospheric science or meteorology programs at typical universities. A particularly challenging area has been the use of socio-economic science approaches to assess benefits of NMHSs services. The economics approach asserts that the value of meteorological information, knowledge or services rest on the principles of the Bayesian decision theory which implies the maximisation of expected utility. Thus, economic analysis is important in that cost-benefit or valuation analysis can lead to clarification in monetary and quantitative terms.[28]

Equally important is the understanding of how to better present and communicate weather information so that it meets the needs of users. As Descurieux explains,

> *relevance and value mean the social utility or good, societal "value added", the "goodness" of outcome and community benefits (or lack thereof) derived from the available meteorological information, weather preparedness and warning services. This definition reflects the position of a growing number of ethicists, social scientists, marketing and management specialists who think that the economic value and quantitative approaches fail to reflect the complex, multi-dimensional and non monetary value of services.*[29]

In other words, while it is important to understand and utilize economic reasoning in analyzing the effectiveness, efficiency and daily operation of NMHSs, this approach alone cannot provide an accurate reflection of their value. Where there is a commercial provider between NMHSs and users, it may be appropriate, with care to commercial sensitivities, to directly contact the user and ascertain their satisfaction with the present arrangements as well as how a better arrangement might work.

Additionally, NMHSs and WMO need to work together to establish better contacts with appropriate international associations and organizations that represent large numbers of commercial activities across the economic sectors of: transport; agriculture; forestry; energy; tourism and recreation; construction; communications; retail marketing; insurance; and, economics and financial services. In some cases, a UN agency is already dedicated to this issue, but it would be better to make direct contact with the user organizations. The UN agency could be asked to identify and make the connections in order to establish such meetings. Additionally, a survey should be done of NMHSs in order to get their input on appropriate international organizations.

II.4. Consideration of User Communities

II.4.1. Human Health and Welfare

As has been previously discussed, weather, climate and water can have both direct and indirect impacts for the health of citizens. The direct impacts of storms and floods will be discussed in the next section. In this section, the focus will be on the health impacts related to weather and climate.

Good health is one of the primary aspirations of human social development30. Health is influenced by environmental, seasonal and climatic conditions. Climate influences health through a number of mechanisms. This impact may be direct, through cold or heat stress, or indirect via impacts on natural systems. The World Health Organization (WHO) recently identified 14 major climate sensitive communicable diseases, including Malaria, Meningitis, cholera and dengue. WHO also acknowledges that many non-communicable coronary and respiratory diseases are climate sensitive.

Clean air is one of the major priorities of most governments because research indicates that poor air quality has the potential to seriously affect the health, environment and economy of the nation[31].

NMHSs can play several roles in a national clean air or air pollution strategy. As scientific advisers on the environment, NMHSs can help to explain the difference between emissions from anthropogenic and natural sources, as well as how atmospheric conditions can modify, transport, dilute or concentrate pollutants. Additionally,

[28] Gunasekera, Don."Measuring the Economic Value of Meteorological Information." *World Meteorological Organization Bulletin*. 52 no. 4 (2003): Pg 367.

[29] Descurieux, J., 2010: Post Hoc Evaluation of Hazardous Weather: Snowstorms in the Montréal, Québec, Area in March 2008. Weather, Climate, and Society. 2: 36-43

[30] D.: Rogers et Al "Health and Climate Opportunities" Procedia; Earth and Planetary Science (2010)

[31] Environment Canada. "Health, Environment and the Economy". *Clean Air Online. (2009)* http://www.ec.gc.ca/ cleanair-airpur/ Health,_Environment_ and_the_Economy-WSD8331ABC-1_En.htm

NMHSs can undertake the program that monitors the current values of pollutants. These roles have natural synergies with their present scientific and monitoring functions.

Furthermore, NMHSs should play a role in the production and dissemination of air quality forecasts. The difference between a smog day and a non-smog day is not usually the emissions but the meteorology - those conditions that favor chemical reactions and concentration as opposed to dilution of the pollutants. Specifically, they should work on being able to provide up-to-date information regarding air quality (including advisories and maps) in such a way that citizens are able to make informed decisions to protect their health, the health of their family, and the environment. An air quality health index for example, can provide general information on the level of air pollution ozone, nitrogen dioxide, total reduced sulphur compounds, carbon monoxide and fine and coarse particulate matter. These indices and health messages associated with the advisories should be linked to weather forecasts and presented in a similar manner to improve ease of understanding. In addition to allowing individuals to decide how to reduce the risk to their health, the provision of this information could help individuals decide how to reduce their own personal contribution to air pollution as well.

There are two benefits of linking the weather and air-quality-health information. First, it benefits the user in providing a consistent and integrated message. Secondly, it benefits NMHSs in connecting in the minds of the users (and government officials) the importance of weather to air quality and to health.

Partnership between WMO and the World Health Organization (WHO) is essential to providing an international basis for these activities. There are barriers to this work, including the scientific basis for high-quality forecasts, but the major obstacles are likely to be administrative or jurisdictional. Health agencies may not be aware of the positive attributes of such initiatives and NMHSs, with the support of WMO and WHO, need to make the case. Protocols that outline the best ways to reach these groups, as well as policies aimed at overcoming the lack of awareness, are needed. One approach could be for countries that have been successful in the field of weather and health to assist others with approaches and methodologies - best practices and success stories.

II.4.2. Emergency Management

A part of the governmental role of protection involves the provision of information and, when appropriate, warnings of weather and weather-related events to citizens. Events over the past decade have demonstrated that there is an increasingly strong need for these services,[32] which are usually entrusted to NMHSs in partnership with emergency management organizations. Major political and national leadership attention has been given to natural hazards (the international framework for natural hazards action has been summarized in Appendix II for further information). Hyogo Framework for Action (2005b) identifies the importance of enhancing early warnings which is, in most cases, the responsibility of NMHSs.

NMHSs are naturally positioned to play a major, and often, leading role in natural hazard mitigation and preparedness, yet they are often not visible on this issue. The connections between NMHSs, natural hazards and public safety issues do not seem to be sufficiently developed. Here again, it would be beneficial to utilize WMO by having NMHSs work with the UN International Strategy for Disaster Reduction, to provide internationally-recognized agreements as the basis for NMHSs-emergency management cooperation on these activities. Again, the barriers to this cooperation are mostly administrative or jurisdictional. Emergency or disaster risk management is usually defined as a range of policies and practices developed to prevent, manage and reduce the impacts of disasters.[33] It includes the elements: Mitigation - the lessening or limitation of the adverse impacts of hazards and related disasters; Prevention - the outright avoidance of adverse impacts of hazards and related disasters; Preparedness - the knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions; Response - the provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected; and, Recovery - the restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors.[34] Currently, emergency management organizations focus much of their funding and attention on the response-recovery phases despite empirical studies which have shown that investments in prevention and preparedness can result in economic benefits[35]. Although NMHSs could have a role in making response and recovery more effective, their biggest contributions are made through the provision of information and warnings. Forecasts, which inform and warn are an essential part of the prevention and preparedness stages of disaster management as they help to ensure that hazards do not become disasters, or, at the very least, they limit the amount of devastation than would have

[32] Events such as hurricane Katrina (2005), the ice storm in Montreal (1998), in addition to the increasing numbers and impacts of severe weather events.

[33] The United Nations International Strategy for Disaster reduction. www.unisdr.org

[34] The United Nations International Strategy for Disaster reduction. www.unisdr.org .

[35] Mileti, Dennis. Disasters by Design: A Reassessment of Natural Hazards in the United States. (Washington, Joseph Henry Press, 1999). Pgs 219, 239.

occurred without the information and its effective implementation. Thus, for NMHSs focus is on activities leading to the reduction and control of disaster risk factors and the impacts of natural and human-induced environmental hazards. Public perception-decision-making in the context of natural hazards, risks and uncertainty is an important area for further examination, as well as the study of human behaviour and cultural contexts for vulnerability analysis. For example, understanding how people respond to warnings is important[36]. NMHSs could play a role here, assuming that they have the capacity to go beyond the traditional fields of meteorology.

II.4.3. Sustainable Development, Natural Environment and Urban Settlement

The areas of users in sustainable development, natural environment and urban settlements are considered together because there are many commonalities between them. Many governments and institutions, including urban settlements, consider sustainable development to be a guiding principal or approach for issues related to environmental governance. The concept of sustainable development that "humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs"[37] brings together social, environmental and economic considerations. In practice, it means that societies need to look to the future and make investments now that will allow future generations to meet their needs, consistent with those of present generations. Meeting the needs of future generations implies prediction - being able to foretell what will or might happen and how actions and decisions taken now result in differences in the future[38]. In the broad scope of public policy discussions, two issues, sustainable development and climate change, are intrinsically linked, as noted by Runnalls, President of the International Institute for Sustainable Development, *"…climate change, (is) the greatest problem facing sustainable development today."*[39] This connection was also recognized in the United Nations Framework Convention on Climate Change (UNFCCC) with its objective of "… stabilization of greenhouse gas concentrations … to enable *economic development to proceed in a sustainable manner…"* [40]

There is a logical role for NMHSs as the delivery agent for information to the government and the larger user community. As some of this information will come from regional-global institutions, there is a role for WMO in coordinating and helping to package the information. Although many users wish to know the present or past state of the physical environment, there is a growing demand for information on the present and future states of the environment as a basis for decision-making. Environmental prediction (see Project 4) is built on the assumption that predictions of future states of the environment are or will be possible. Importantly, the predictions needed by policymakers require the strong connection between science, policy and service which are unique to most NMHSs. Additionally, if progress is to be made, society must be informed about inevitable environmental change and variability in order to take action.

NMHSs can become the voice for predictions that can be used to provide a new relationship with the future. To accomplish this, NMHSs will need to extend the forecast system beyond the typical domain of weather, a move which requires the use of skills and information on the total environment. Composite forecasts bring together readings on weather, air pollution, UV indices, etc., in a way that individuals can not only respond to but can, in some cases, influence the outcome. In particular, these services would be most useful for clients in urban settlements, human health and environment agencies.

NMHSs should not hesitate to extend themselves in this way. Not only is there a scientific basis to this type of forecast, but there is a strong operational, prediction service approach as well, which does not generally exist in other organizations related to environmental issues. Looking ahead a decade or two, more fully integrated observing-prediction-dissemination systems supported by research and development are possible, even likely, and NMHSs should position themselves as leaders of this movement, rather than a reactionary. These integrated environmental prediction systems will provide the basis for sustainable development.

Based on this philosophy, NMHSs should meet with their counterparts in environment ministries, cities and urban governments to open the dialogue about how NMHSs can

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[36] Lazo, J.K., Waldman, D.M., Morrow, B.H., Thacher, J.A., 2010: Household Evacuation Decision Making and the Benefits of Improved Hurricane Forecasting: Developing a Framework for Assessment. Weather and Forecasting. 25-1 207-219

[37] World Commission on Environment and Development. 1987. "Chapter 2: Towards Sustainable Development." *Our Common Future*. Pg 1. www.un-documents.net/ocf-02.htm#1

[38] McBean, Gordon. "Role of Prediction in Sustainable Development and Disaster Management." *Globalization and Environmental Challenges: Reconceptualizing Security in the 21st Century. (*New York, Springer Berlin Heidelberg, 2008): Pg 929.

[39] Runnalls, D. "Sustainable Development and Nuclear Waste", in: *NWMO Background papers* (Toronto, Nuclear Waste Management Organization, 2003) Pg 7. see at: <www.nwmo.ca>.

[40] United Nations. Sustainable Development Policies and Measures: A Strategic Approach for Enhancing the Climate Regime Post 2012. *United Nations Framework Convention on Climate Change*. 2006. Pg 5. See www.unfccc.int/

assist them with their informational needs regarding the state of the environment and sustainable development.

II.4.4. National Defense

National defence is a special user or client of meteorological information. In some countries, NMHSs are also the meteorological service for the defence agency (being within it such as the United Kingdom [41] or contracting to it such as Canada[42]). In some governments, there are separate military weather services (such as the United States of America)[43]. Hence, the approach and dialogue with defence users will be quite dependent on national structures. In interacting with defence agencies, it is most important to understand their operational needs with respect perhaps to varying locations and some level of secrecy of operations. Again, WMO could foster a transfer of ideas and approaches between those NMHSs who have defence agencies as users as well as those who do not but wish to.

II.4.5. Transport- Air, Marine and Land-Surface

Transportation (including air, marine and land-surface) needs and capabilities contributed to the formation of many weather services, despite the fact that there are important differences between each sector within transportation. In many countries today, there are strong commercial aspects to aviation weather in particular. Focusing initially on aviation, the role of NMHSs may be dictated by broader public policies such as relative roles of public and private sector. To work more productively with them, Meteorological Services will need to be able to deliver products and services competitively in a commercial environment.[44] WMO is working closely with relevant International Civil Aviation Organization (ICAO) operations and study groups, where International Air Transportation Association (IATA) and other user groups are represented. Quality Management Systems (QMS) are addressing the issue of customer satisfaction and the Aeronautical Meteorology Programme of WMO has a dedicated expert team on customer focus. It should be noted that there may be some instances in which the non-national private sector has directly interfaced with the aviation sector, excluding Meteorological Service[45]. This is the case of many countries where meteorological services to aviation are provided by "agencies", typically part of or associated with the Air Navigation Service Provider (ANSP). Thus, there is a need for discussion with government policy organizations, such as the ministry of transport (or the governing body of civil aviation), as to whether the relationships should be altered or maintained. In this situation, it should prove beneficial to have completed an institutional analysis which can then be provided to the governing party. Barriers to better relationships need to be identified. These barriers are typically two-fold: (a) the Meteorological Service is not capable of delivering an adequate service due to, for example, insufficient funding; (b) the Service is unaware of aviation requirements, has a lack of appreciation of the gap between their view of the appropriateness, quality and usability of their products and services and the customer perspective, charges too much, or has insufficient consultation mechanisms. Optimization of the value of forecasts for aviation needs to be examined[46]. The long-term dependable delivery capacity of NMHSs compared to perhaps some private sector or non-national competitors may be an issue. Much of the analysis as applied to aviation will be helpful, but not predetermining, for the other transportation sectors.

In the met-ocean services area, marine forecast and warning services are mostly provided by NMHSs, while ship routeing services and services for the ocean transport of goods are provided to shipping companies by both NMHSs (often against compensation) and commercial services. WMO has been working closely with the International Maritime Organization (IMO) and the associations of ship operators in defining the minimum requirements for the routeing advice and in implementing the Global Maritime Distress and Safety System (GMDSS) for international navigation. A list of focal points for ship routeing services is published in WMO Publication No. 9, Volume D - Information for Shipping. The off-shore industry requires a broad range of marine meteorological and oceanographic services for site exploration, production and transport, which are often provided by commercial service providers. The industry sector is represented by the International Association of Oil and Gas Producers (OGP), which established collaborating arrangements with WMO through JCOMM in October 2007[47].

For land-surface transportation, "road weather" has become an important issue and possesses both commercial and public good aspects. Understanding the role of weather

[41] United Kingdom Met Office. http://www.metoffice.gov.uk/defence/

[42] Meteorological Service of Canada. http://www.msc-smc.ec.gc.ca/msc/contents_e.html

[43] Department of Defence Websites. http://www.defenselink.mil/sites/

[44] For instance, services broadened to include thunderstorm decay and high winds could save New York City airports $1.5 million dollars as it would cut down on delays. Allan, S; Gaddy, S; and Evans, J. 2001. *Delay Causality and Reduction at the New York City Airports Using Terminal Weather Information Systems.* (Lexington, Lincoln Laboratories Massachusetts Institute of Technology) Pg iii.

[45] In this case, the New York City airports were using integrated terminal weather systems. Ibid.

[46] Keith, R., 2003: Optimization of value of aerodrome forecasts. Weather and Forecasting. 18-5, 808.

[47] WMO Bulletin, Vol. 58 (2), April 2009: Meteorological Services for Transport

on the capacity of roads is important[48]. Here, NMHSs could potentially become the supplier of choice by combining road weather and other services, such as those relating to air quality, in order to make a more versatile and useful package[49]. This improvement would be linked to the role with urban settlements as previously discussed. It will be appropriate for NMHSs to explore new options to expand their services consistent with their mandate and capacity, in order to gain the recognition and benefits associated with being the provider of choice[50].

II.4.6. Agriculture and Forestry

Agriculture and forestry are two economic areas where there have been traditional NMHSs partnerships spanning a broad range of users. NMHSs should consider providing a broader but focussed set of products to meet the specific needs of these groups. For example, tailored spring and fall freezing event warnings and fire hazards indices and warnings, would be of special interest to all in this sector[51]. Here again, the formation of partnerships with the national agriculture and forestry agencies, would be the best way to consult and serve these groups. The ability to quantify the benefits of the proposed service provision as well as the possession of documentation regarding skills of forecasts would be very useful in these discussions.

II.4.7. Energy

Energy services are an example of a new and largely untapped opportunity for NMHSs. These could include: daily or seasonal forecasts for solar, hydro[52] and wind power; seasonal forecasts for companies to optimize their distribution and, in some countries, to meet regulatory requirements for natural gas. NMHSs could also serve as consultants on the optimum positioning of wind and solar generators[53]. An integrated environmental prediction system for an integrated energy production system could include estimates of usage (dependent on heating, air conditioning and other needs) as well as how to optimise the daily mix of fossil fuel-based power (factoring in air pollution) with wind, solar and hydro power. Further, by providing information for the days ahead, companies will be able to decide on their use of energy reservoirs, such as water reservoirs, or surplus wind power to be available later as hydro power on a low wind/solar day.

NMHSs can use the national energy agency as a vehicle for implementing such a system. Further, WMO could assist both by proposing studies of such systems and their effectiveness in countries that possess them, as well as through the International Energy Agency.

II.4.8. Tourism and Recreation, Construction, Communications, Retail Marketing

This potential class of user groups share the need for focussed information on a daily basis to enable them to conduct short-term planning (including optimization of services to their clients[54], and planning of staff functions) as well as longer-term information to plan for seasonal strategies[55]. Again, there are examples of NMHSs that currently offer these services and they should be used as examples for NMHSs who wish to expand their services. Further, there are national and international organizations in each of these areas which could prove helpful. A Meteorological Service could ask itself - when was the last time it was present at a tourism convention?

II.4.9. Insurance, Economic and Financial Services

In contrast to organizations in section II.4.8, services in these areas require longer-term forecasts tailored to different sectors of the economy. These activities, except for emergency management as per previous discussion, are often carried out by private consulting companies due to the

[48] Cools, M., Moons, E., Wets, G., 2010: Assessing the impact of weather on traffic intensity. Weather, Climate, and Society. 2: 60-68.

[49] Committee for Environmental Services, "Operations and Research Needs". *Weather Information for Surface Transportation (WIST) Initiative Document: First Steps to Improve The Nation's WIST Capabilities and Services.* (Maryland, Office of the Federal Coordinator for Meteorological Services and Supporting Research, 2005). Pg 1.

[50] WMO Bulletin, Vol. 58 (2), April 2009: Meteorological Services for Transport

[51] Seasonal climate forecasts are also helpful in identifying the onset and length of rainy seasons etc. In Huda, A; Packham, R; Clewett, J and George. D. "Introduction and Overview", *Using Seasonal Climate Forecasting in Agriculture: A Participatory Decision-Making Approach.* (Canberra, Australian Centre for International Agricultural Research, 2004). Pg 9.

[52] Stull, R., and McCollor, D., 2008: Hydrometeorological Short-Range Ensemble Forecasts in Complex Terrain. Part II: Economic Evaluation. Weather and Forecasting. 23-4, 557-575.

[53] Roulston, M; Kaplan, D; Hardenberg, J; Smith, L. "Using Medium Range Weather Forecasts to Improve the Value of Wind Energy Production". *Renewable Energy 28 (2003). Pg 590.*

[54] In the construction industry for example, accurate information on the amount of precipitation, wind and temperature are needed in order to ensure stable and long-lasting structures. Phillips, J. *Weather Information in the Construction Industry*. 2003. www.wmo.ch/pages/about/pdf/Construction1.pdf pg 1.

[55] World Meteorological Organization. "Climate and Tourism". *World Climate News.* 27 (2005): Pg 4

interests of commercial advantage. Some major events like hurricanes can affect insurance stock prices[56].

II.5. General Comments on Interactions with User Communities

The general objective of all NMHSs is to be able to work more productively with their existing user communities and to expand this base into new sectors. In many cases, this process will require examining how to work more effectively. Most NMHSs do not have the extensive capacities necessary to meet all user needs and it is therefore necessary to be selective. Recall the overall objective of the MAP is: "*to achieve, within five years, a major enhancement of the value to society of weather, climate and water information and services …*"[57] It is necessary then, to decide which of the possible user communities will provide the opportunities and return on investment needed to best meet that objective. Working with cities, through integrated environmental prediction, could prove to be a lucrative possibility. It must be noted however, that while increased funding is a goal of most NMHSs, a significant portion of the benefits will come in the form of increased recognition which in turn will lead to the greater possibility of gaining new resources.

As a first step towards approaching users, it is important to understand why current interfacing techniques have been unsuccessful. From there, the next step is to get to know the users, through a succession of meeting opportunities which focus on the development of better interactions.

Another aspect which must be addressed when working with user communities is the existence of perceived barriers. To commence this process, these obstacles must be identified and ascertained. If it is decided that they present a real threat, the fault must be located, which can require objective analysis. Some barriers are due to existence of inappropriate protocols; others are due to lack of awareness and can be overcome through better communications. In approaching any user, it is most important to have knowledge of their needs, based on careful analysis of the user community. This knowledge will help to overcome barriers as it can offer new approaches, products and communications methods which may be helpful.

When interacting with government agencies and other countries, the contacts will likely be best made at the senior, heads of NMHSs level. However, there are many user communities with whom the best contacts will not be through the head of Service or Permanent Representative.

Training courses on how to best interact with the user community will be important and are best done through practical examples. The search for "best practices" can be done across NMHSs of the world. Once the contacts are made, it is effective to further engage them in educational and training activities as is discussed next.

II.5.1. Education and Training – Decision-Makers and Users

Building on the analysis of decision-makers and users and their needs, it is appropriate to consider actions to provide education and training opportunities for both users and providers (see Project 3). The Madrid Conference and associate regional conferences provided important information on identifying user needs and expectations, and this information could be used as part of the basis for developing education and training approaches. Some best practices in one region may be applied with modification in another region or for a different user community. These training sessions can have the dual benefit of providing capacity-building for users and providers while building recognition of the value of NMHSs services, and also providing an opportunity to gain feedback and thus, better understand the users.

The objective of education and training opportunities for the users would be to:

- Allow them to be more effective in their use of NMHSs to carry out their functions - with benefits to society and also, as a feedback, benefits to NMHSs in that their services have more value;
- Provide an opportunity for NMHSs to better know their users through this positive and direct interaction;
- Contribute to the achievement of major enhancement of those values; and,
- Enhance the recognition of NMHSs and the demand for services from NMHSs.

The educational and training capacity development should be a joint partnership of WMO, NMHSs and local educational institutions, such as colleges and universities. This would provide, as discussed further in Project 3, opportunities for leverage and reaching a broader community. Priority should clearly be given to education and training opportunities for users of weather, climate and water information, in order to increase awareness among users of the afforded opportunities. These are clearly within the mandate of NMHSs. By focusing on some new initiatives, a greater response could be generated from the user communities who are unaware of the potential for new developments.

[56] Ewing, B.T., Hein, S.E., Kruse, J.B., 2006: Insurer Stock Price Responses to Hurricane Floyd: An Event Study Analysis Using Storm Characteristics. Weather and Forecasting. 21-3, 395-408.

[57] World Meteorological Organization. Madrid Action Plan. Pg 1.

II.6. Serving Partners and Users Better through Enhanced Capacity

II.6.1. Integrated Environment Prediction

Environmental prediction (see Project 4) combines the scientific forecast of future states of the environment with the creation of policy. Following Environment Canada, it can be defined as: "Developing and using knowledge of environmental and socioeconomic sciences to project likely or conditional states of the natural world in order to assess future risks and opportunities that support decision-making regarding human health and safety, the environment, and socio-economic well-being"[58]. It is possible for NMHSs to utilize predictions to inform people about implications regarding the environmental impact on society as well as the societal impact on the environment. In particular, predictions increase awareness of the impacts that societal collective activities have on the future and can frame these results nationally or internationally.

The value and use of this information depends on the time scale of the prediction. For example, the smog forecast for today allows individuals to modify their outside activities, adapting to reduce their exposure. In contrast, a forecast of smog for later in the week could allow individuals, as well as industry, to adapt their activities in order to better reduce emissions and, hence, reduce the smog level. In the future, in order to respond to, and better serve user needs, there could be composite forecasts that bring together forecasts of weather, air pollution, Ultra-Violet (UV) indices, etc., with other variables as full environmental predictions for citizens. In this way, individuals can not only respond to, but in some cases, can influence the result. Particular clients in these areas would be urban settlements and human health and environment agencies.

NMHSs role could become that of a clear, science-based information source, providing information on the past, present and future states of the environment, in as broad a sense as is scientifically credible while remaining within their mandate. As such, NMHSs could provide both government and citizens with information for decision-making and adaptive response. Hence, NMHSs's predictive role could lead to effective government action to warn and inform citizens and governments so that corrective and adaptive actions can reduce the negative (and enhance the positive) aspects of atmospheric environmental change.

II.6.2. Climate Services

The word **climate** appears in many of the MAP Actions, yet there is no focus on climate services. This represents a missed opportunity. Climate change is an issue of major national and international interest, with heads of state often speaking on the issue as well as attending major climate change meetings. Over the last few years, climate change has been at the forefront of the international political agenda. The **Bali Action Plan** and the **Copenhagen Accord** (see Appendix II for more information) both put major emphasis on the needs for climate change adaptation. The Copenhagen Accord[59] stressed the "need to establish a comprehensive adaptation programme including international support." It called upon developed countries to provide "adequate, predictable and sustainable financial resources, technology and capacity-building to support the implementation of adaptation action in developing countries." The Copenhagen Accord also declared that the increase in global temperature should be kept below 2^{o}C warming and called for an assessment to be completed by 2015, including the scientific question as to whether the target should be 1.5^{o}C.

NMHSs should aggressively position themselves as the providers of information relating to adaptation techniques, as a logical extension of weather forecasts and based on seasonal and longer term forecasts. The concept of integrated environmental prediction, discussed earlier with its integration of time scales from minutes to decades, provides a basis for climate services to be seen as an extension of weather services. MAP Action 11 on quantifying the benefits should include the benefits of climate services which have been demonstrated in some recent studies[60]. NMHSs also play the key role in measurement of global temperature change and should play a more active role in ascertaining the level of "dangerous anthropogenic interference" and changes to climate.

Most recently, the Conference Declaration of the **World Climate Conference 3** (see Appendix IV) stated that participants agreed to "establish a Global Framework for Climate Services (hereafter referred to as "the Framework") to strengthen the production, availability, delivery and application of science-based climate prediction and services." NMHSs need to be leading on this initiative, both nationally and, through WMO, internationally.

[58] Environment Canada. www.ec.gc.ca

[59] See Copenhagen Accord in Documents of UN FCCC CoP15. http://www.unfccc.int

[60] Sultan, B., Barbier, B., Fortilus, J., Mbaye, S.M., Leclerc, G., 2010: [e] Estimating the Potential Economic Value of Seasonal Forecasts in West Africa: A Long-Term Ex-Ante Assessment in Senegal. Weather, Climate, and Society. 2: 69-87. Vogel., C., Koch, I., Van Zyl, K., 2010: A Persistent Truth"—Reflections on Drought Risk Management in Southern Africa Weather, Climate, and Society. 2: 9-22

Part III - Quantification of Benefits of NMHSs Services

III.1. Introduction

The Madrid Conference's assessment was that increased awareness and the resulting support for NMHSs would come through the development of improved methodologies for evaluation and demonstration of societal benefits of weather, climate and water services[61]. This would result from NMHSs involvement in the formulation of national social and economic development strategies. Since it is not demonstrated that government decision-makers are solely, or even in a major way, driven in their funding decisions by economic, as opposed to political considerations, it is important that socio-economic analysis always be framed in the political context of the country. Thus, social and political factors must be analyzed in addition to economic aspects in order to understand decisions that are seemingly contrary to economic logic. It is therefore necessary that NMHSs undertake analysis of the motivators of decision-makers, focusing on those decision-makers that will make or influence the decisions that directly impact upon NMHSs mandate, budget or resource allocations, and rules of engagement.

III.2. Economic Benefits – A Theoretical Framework

In order to understand the theoretical economic framework, it is appropriate to start with the paper by Freebairn and Zillman (2002) [62]. Responding to the need for more rigorous and broadly based determination of the economic value of meteorological services, their work provides much needed background on approaches. It is suggested by Freebairn and Zillman, that these approaches could be used as an aid to decision-making, to be committed to their provision at the national level. First, they note, in economic terms, that meteorological infrastructure and weather, climate and air quality forecasts and warnings have non-rival consumption or use properties.[63] This means that the economic benefits from meteorological services are evaluated by the sum of the benefits reaped by the very many and diverse users of the services, both now and in the future. To clarify, non-rival economic sense means that once the information is available, its use, by one set of users does not reduce the information available for use by other users. This is often referred to as public good services. In this case, the total benefits and marginal benefit functions of meteorological services with non-rival consumption properties should be the sum of benefits for all users. The very many and diverse users makes it inherently difficult to evaluate all their benefits. They provide analysis as to how to determine these benefits functions, at least in theory. Within these approaches there are four main methodologies that are appropriate for use in valuation studies: market prices, normative or prescriptive decision-making models, descriptive behavioural response studies and contingent valuation studies.

The market prices technique has applicability for those services which have private good characteristics of rival consumption and ease of exclusion. Where there are mixed public and private goods, some measure of benefits gained, may be ascertained from market prices. For the areas where public good services dominate, there is very limited applicability of market prices for valuing meteorological services.

Prescriptive or normative models are the most common set of techniques used to estimate the benefits of meteorological services. Simplified optimizing decision models, under conditions of imperfect knowledge about weather or climate conditions, are solved for different levels of meteorological services provided. The gain in expected payoffs, including more profits, lower costs and higher utility, are a measure of the marginal benefits of the increased services. Changes in decisions following the use of extra or better meteorological information are assumed not to alter the decisions of others, nor to change the prices of outputs or the costs of inputs.[64]

As Freebairn and Zillman explain, "descriptive behavioural studies can be used to make estimates of the value of meteorological services by inferring values from the observed behaviour of individuals, businesses and governments as determined by user surveys of decision-making"[65]. Descriptive studies are considered more realistic, in comparison to prescriptive models in that they are based on, and recording, actual behaviour[66]. However, in attributing changes in decisions and extra benefits to meteorological services, and to increases in the volume of meteorological services, a common difficulty, is that other parts of the decision environment are also changing. The value of improved forecasts, such as tornado warnings[67]

[61] World Meteorological Organization. Madrid Conference Statement. Pgs 1, 3.
[62] Freebairn, J. and Zillman J, *Economic benefits of meteorological services.* Meteorol. Appl. 9 (2002): Pg 3.
52 Ibid Pg 35.
[63] Ibid Pg 35.

[64] Excellent descriptions of the procedures and examples are given in Katz, R & Murphy, A. "Economic Value of Weather and Climate Forecasts*." Climate Change.* 45 no. 3 (1997).
[65] Freebairn and Zillman, Pg 39.
[66] Ibid.
[67] Simmons, K.M., Sutter, D., 2008: Tornado Warnings, Lead Times, and Tornado Casualties: An Empirical

and the implications of false alarms and missed forecasts[68] need to be carefully examined. Asking questions about decision responses to increases in the volume of meteorological services involves hypothetical situations which make them vulnerable to the same criticisms as those raised against prescriptive studies.

Contingent valuation methods are sometimes used to estimate the benefits of public goods by asking users to "nominate the sum they would be willing to pay for a particular level of public good. Although the procedure is somewhat controversial, the contingent valuation method has been used to obtain estimates of the value of meteorological services."[69] Samples of users, which may be individuals or businesses, are asked to provide information; it is best if these users are a random sample. The direct interviewing method, which is costly, is considered necessary to "ensure respondents fully understand the context of the 'willingness to pay' questions and to allow for crosschecking of answers"[70]. For example, Freebairn and Zillman explain, "users may be asked what would they be willing to pay to have access to currently available general forecasts relative to no forecasts; or, if the accuracy of rainfall forecasts for the next season were to be increased by 50%, what would they be willing to pay for this extra accuracy?"[71]

Freebairn and Zillman conclude that the outcomes of an enormous number of decisions by individuals, businesses and governments are weather and climate sensitive[72]. Further, the decisions and outcomes can potentially be improved by using currently available services. Normative and prescriptive models clearly indicate the wide range of sources of potential economic benefits and improved use of meteorological services. Descriptive and contingent valuation studies confirm that many change decisions with the use of meteorological services and that the information is valued. These studies also highlight the variety of decision-making methods, the dangers of oversimplification with predictive models, and the fact that not all decision-makers use meteorological services[73]. Since most meteorological services have public good properties, they conclude that it will remain difficult to obtain comprehensive estimates of either the total benefits or the marginal benefits of the basic infrastructure, the climatological record or the public forecasts and warnings provided to the community at large[74]. Further work on market prices, prescriptive models, descriptive models and contingent valuation methods is needed to estimate the economic value of the full range of economic benefits of meteorological services meteorological services. The different approaches have different advantages and disadvantages. Additionally, the different benefit measurement procedures complement each other.

Gunasekera further analyzes these approaches and adds two others. Conjoint analysis is similar to contingent valuation in that, "it also uses a hypothetical context in a survey format involving the users of meteorological information"[75]. It requires survey respondents to rank or rate multiple alternatives where each alternative is characterised by multiple attributes. This enables the estimation of the value consumers derive from the various attributes of such information (see, for example, Lazo and Chestnut 2002; and Brown 2002). Doswell and Brooks (1998) have earlier analyzed the value of weather services in the context of budget cutting by governments[76].

Since the weather-economy intersections are multi-factor and multi-sector, the same meteorological event could generate benefits in some areas while incurring losses in others. An economy-wide approach to analysing the value of information is required under such circumstances, to estimate the overall value of such information[77]. A useful tool for this method is a general equilibrium model. Such models have been used to analyse various issues relating to trade, health, education and the environment.

III.3. A Template for Socio-Economic Assessments

In order to quantify the benefits and ascertain the true value of forecasts[78], there is need for the development of an appropriate template, as well as assessments and quantification of socio-economic benefits of services delivered by NMHSs. Once established, an additional need for advice on how the template could be applied for NMHSs to gather this information emerges. As discussed below, economic approaches already exist for these methodologies, with some originating in academic studies and others being

Investigation. 23-2, 246-259. Simmons, K.M., Sutter, D., 2008: WSR-88D Radar, Tornado Warnings, and Tornado Casualties. Weather and Forecasting. 20-3, 301-311.

[68] Simmons, K.M., Sutter, D., 2009: False alarms, tornado warnings and tornado causalities. Weather, Climate, and Society. 1: 38-53. Brotzge, J., Ericksen, S., 2010: Weather and Forecasting. 25: 159-172

[69] Freebairn, J. and Zillman J, *Economic benefits of meteorological services.* Meteorol. Appl. 9 (2002): pgs 39-40.

[70] Ibid. Pg 40.

[71] Ibid.

[72] Freebairn and Zillman, Pg 35.

[73] Ibid. Pg 43.

[74] Ibid Pg 41.

[75] Gunasekera, Don. *Economic issues relating to meteorological services provision.* BMRC RESEARCH REPORT NO. 102 (Canberra, Bureau of Meteorology Research Centre, 2004, Pg 53.

[76] Doswell III, C.A., Brooks, H.E., 1998: Budget cutting and the value of weather services**.** Weather and Forecasting. 13-1, 206-213.

[77] Gunasekera, Don (2004) Ibid, Pg 25.

[78] Millner, A., 2009: What is the true value of forecasts? Weather, Climate, and Society. 1: 22-37.

specific to Meteorological Services, such as that of the National Oceanic and Atmospheric Administration (NOAA).

One approach is that presented by Jeffrey Lazo in his paper on "Economics of Weather Impacts and Weather Forecasts". As Lazo has demonstrated in his examination of the economics of weather impacts and forecasts, it is essential for NMHSs to gain a better understanding of, "(1) the distinction between impacts and forecasts; (2) how to value each; and, (3) how economic information is important for decision-making that supports National Meteorological and Hydrological Services (NMHSs)"[79]. Different weather conditions will result in changes to and/or affect economic activity and decision-making. Not only does weather impact the economy, but we must further consider how decision-makers respond to weather forecasts - which are the economics of weather *forecasts*, and these are not the same. In fact, there may not necessarily be direct or clear relationships between the economic impacts of weather and the economic value of weather forecasts. It is clear that the value of a forecast can be achieved only if the forecast is received, understood and presented in a way that the decision-maker can make decisions such that they expected impact of the weather is changed, in a positive way.

As discussed in the previous sections, it is essential to understand the users of information products because it is only through their use of the information and the analysis of how it is used, that the economic and social value of the information is actually accrued. The weather forecast and impact "value chain," shown below, must also be analysed before the economic value can be ascertained.

[79] Lazo, Jeffrey. Some Perspectives on Social and Economic Benefits of Weather, Climate and Water Related Information. WMO/TD-No. 1365 (2007)

[80]

The value of the forecast: (1) depends on who is receiving and using the information; (2) the temporal and spatial scales of the valuation study; and, (3) the type of information being valued (e.g., all weather information or just temperature information) and thus there can be no simple answer to the question "What is the value of a forecast?"

Although the traditional focus of NMHSs has been on processes 1 and 2 and occasionally 3 in the above figure, the value of the forecast may be lost in its communication or its use by users and/or decision makers. Ultimately, value accrues from the behaviour of users and the impacts of their decisions[81].

In order to increase the economic value of the forecast, investments of resources need to be made in all of these processes and the relative amount of investment may be quite different from the traditional view and approach of NMHSs.

When undertaking analysis to determine economic value of their services, NMHSs should ascertain in advance the reasons in their own national context for such analyses. Following Lazo, there are five possible reasons for such analyses:

1. *Justify programmes:* Showing net positive economic benefits of NMHSs is becoming more critical as these services do battle to justify their budgets. Data on the economic value of such services can carry significant weight for policy decision-making and budget-setting - even recognizing that many political decisions are made irrespective of economic trade-offs.
2. *Evaluate programmes:* When determining whether to invest in a specific programme, many local, national, and international funding agencies require an economic assessment of the net benefit of such a program - a benefit-cost analysis. Although quantifying costs can be relatively straightforward, estimating benefits from NMHS can be more difficult because those receiving the benefits are usually not NMHSs but rather a wide variety of economic and societal sectors.
3. *Guide research investment:* Similar to benefit-cost analysis, assessments should be made when agencies decide what research to undertake to improve (or perhaps even maintain) weather services. Identifying likely outcomes of alternative investments and quantifying benefits and costs helps to guide choices between research investments. Even if rigorous analysis is not possible because of uncertainties or lack of economic information, framing the problem in terms of benefits and costs can help decision-makers identify projects to undertake and those to put aside.
4. *Inform users about benefits:* Understanding the use and benefits of forecasts is also important for informing potential users about how and why they could use weather information. Demonstrating value to users goes a long way towards gaining their involvement and support.
5. *Develop end-to-end-to-end systems:* Ultimately, the best use of economic information will combine all these approaches into integrated end-to-end-to-end forecast and warning systems. In such systems, the preferences, needs and values of users will guide decision-making throughout the system in terms of what types of information to provide and how to disseminate it, along with what research to undertake and what programmes to support.[82]

Once the reasons for the analyses have been established, and the audience for which the results are to be presented identified, the tools and approaches to valuing the benefits and costs of goods and services provided by NMHSs are standard economic methods. NMHSs should resist the temptation to develop new techniques, for several reasons, including that analyses from standard recognized approaches are more likely to be accepted by the decision-makers and will likely be more cost effective in terms of operational expenses. The meteorological community should work with economists to bring the appropriate theories, methods and tools to economic analysis of weather impacts and forecasts. Accepted theories and methods pertinent to issues in valuing weather information services include:

1. estimating benefits of services that are not actually bought and sold in competitive economic markets (such as most weather forecasts);

[80] Lazo, Jeffrey. *Economics of Weather Impacts and Weather Forecasts. (Madrid, World Meteorological Organization, 2007) Pg 2*

[81] Roulston, M.S., Smith, L.A., 2004: The Boy Who Cried Wolf Revisited: The Impact of False Alarm Intolerance on Cost-Loss Scenarios**.** Weather and Forecasting. 19-2, 391_398.

[82] Lazo, Pgs 2-3.

2. valuing benefits and costs that occur over a range of time periods;
3. valuing the impacts of weather and forecasts on lives saved or lost; and,
4. valuing information about uncertain future events (which is the fundamental value of weather forecasts).[83]

In estimating the value of forecasts, comparison can be made with different types of information - ranging from no information to perfect information (see below).[84]

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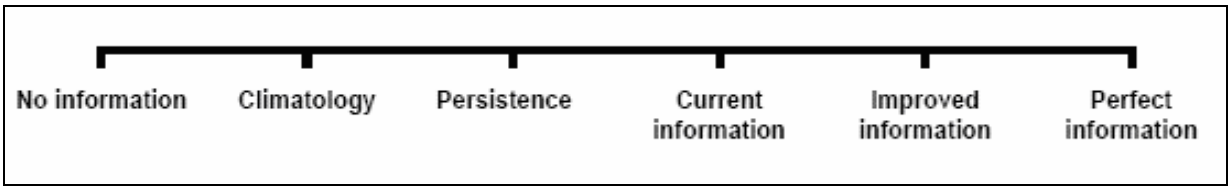
[83] Ibid. Pg 2
[84] Ibid. Pg 1.



In the figure above, it is assumed that the value of climatology is lower than persistence but that may not always be the case. Because of the wide variety of approaches (as outlined in the previous section) and their applications, NMHSs will be well advised to follow the strategy of: identifying the prime reason or motivation for their economic analyses; selecting the products or services of most interest, and; selecting the main user sectors from their own analysis of the likely benefits for the Service. It is then possible to undertake an examination of the many case studies that have been done, and select those which best met their needs, as models. Gunasekera has presented analysis of five case studies using the following template:

Template for examining the case studies

Background

- Remarks to place the specific meteorological information examined in the case study in context.

Objectives

- How the case study has specified its objectives including any links to the public policy-making aspects, which are underlying the broader meteorological services provision issues.

Methodological Framework

- Summarize the key features of the conceptual or methodological framework used in the case study and the board approach employed in pursuit of the study's objectives.

Data and information requirements

- The data and other information that have been used in the case study and focus on the issues such as availability of relevant data, data collection and possible multidisciplinary nature of issues concerned.

Involvement of other parties

- The need for and the usefulness of the involvement of parties other than meteorologists in undertaking the analysis underlying the case studies. In particular, the usefulness of initiating strategic alliances and cooperation with relevant institutions and personnel will be canvassed, in the context of fostering an interdisciplinary approach to the estimation of the economic value of meteorological information.

Key findings and policy implications

- The key findings of the case study and highlighting the possible policy implications with respect to the role and responsibilities of NMHS.[85]

The examination of case studies against this template and their own priorities will allow NMHSs to ascertain the most appropriate socio-economic benefit analysis for their purposes.

[85]The template can be found in: Gunasekera, D. *Economic issues relating to meteorological services provision.* Pgs 56-57

Appendix I – Projects

Project I – Review of Institutional Framework – Know your NMHS and Solidify the Base

There is a wide range of institutional and societal positions and capacities among the 189 NMHSs. The first strategy for any Service moving ahead on the MAP is to recognize this reality and undertake an analysis of their own positioning and capacity. A major part of this is the MAP: **Action 1**. Review the **institutional framework** governing meteorological and hydrological service provision in order to strengthen partnerships with different sectors of the economy.

Recognizing that NMHSs are usually within a host government departments, ministries or agencies where the key objectives of the host differs from that of the Service, it is important that the Service first does what may be called "solidifying the base" - that is, understanding the decision-makers and users within their own ministry. Since the core budgets or financial resources for most NMHSs come from their single host department, it is important that this relationship is secure and hence, the first and initially most important user community that the Service must concern itself with is the host department. Establishing the values of and role within the host ministry is an important first step.

In some cases, this process will be relatively straightforward since a relationship has already been established. In others, however, it will be complex. By way of example, consider a Meteorological Service embedded in, or hosted by, a ministry of environment. The environment ministry will likely be first and foremost focused on environmental protection and conservation of species. The operational-orientation of the Service will be foreign to a policy and regulatory-oriented environment ministry. While weather forecasts are an important service, they are often assumed by political leaders and senior bureaucrats to occur spontaneously, and thus, are only an issue when there is a failure.

It is often thought that if one can just show that the benefits (relative to costs) are strongly positive, then the Service will be supported. While this may usually occur in the private sector, the public sector in which NMHSs reside is not bound to this principle. It is important to understand the roles and responsibilities of the host department. Departments and ministries usually have specific responsibilities for certain sectors within the government or for economic or social sectors in the country. Benefits that accrue to the national economy, but are beyond the mandate of the host department, will be considered useful but not directly relevant to the budgetary considerations of the department. Additionally, in many departments, the use of available fiscal resources does not depend largely on cost-benefit analyses, but on fulfilling mandates instead. Recognizing that the motivations for governments and ministers, focusing mainly on re-election bids, are often more political than economic, NMHSs must search for ways in which their services directly contribute to the host department's mandate. For example, if species conservation is a prime objective, how can the Service ensure that their delivered services or science-capacity are most relevant, thus drawing the necessary support.

Another aspect is that NMHSs usually function differently than many government agencies and most likely differently than other sectors of the host department as well. Although most NMHSs are within government departments, they can and should function more like a business than most government agencies. The Service is mandated to deliver a set of services and products; it operates like a business with operational considerations, delivery schedules and clients, who may be paying directly or indirectly through their taxes for the services. It is important that NMHSs recognize that they are not like many government agencies and take heed of good business practices that could assist them. These include knowing what is needed and desired on the market, meeting delivery and quality of services criteria and knowing the clients requirements.

In the end, the Service needs to undertake a careful and realistic analysis of the roles that it plays in the host department, ascertaining where it plays significant roles towards the department's mandate and meeting its core objectives. Part of this analysis should include, with due care and attention, consideration of whether the Service would be better positioned elsewhere within government and, if so, what are the processes and the probability of success of arranging such a re-location. Given that the NMHS is to remain within the present host department, it will be necessary to identify the users most important to the department's mandate. For example, in an agricultural department, the users of most import are the farm groups and agricultural producers. In a transportation department, clearly the aviation and marine shipping are the key users. For an environment department, the key users may be the water control agency and/or the air quality agency.

Through this process of identifying, and then connecting with the users of the host department, the Service analysts will gain experience regarding approaches and methodologies to more effectively reach out to users. Because it is important to be seen to be responsive, products and services should be tailored to meet clients' needs. Additionally, it is valuable, to develop benchmarks and criteria for the products and services. For example, if the agricultural sector is particularly sensitive to certain temperatures or timing of precipitation, it would be appropriate for NMHSs representatives to work with the user community and the host department (if it is an agricultural department) to develop some indices and

measures of skill or accuracy in delivering products against those benchmarks. In these circumstances, WMO could play a role in helping to establish realistic, valued and achievable benchmarks.

In the end, the process of knowing NMHSs and solidifying the base must come from a careful analysis of the host departments' structure, mandate and funding criteria. Where possible, mutually-supportive partnerships within the host department should be made and maintained. Further, it is important to obtain the recognition and support of key clients and users of the department, since they can influence the department in positive ways.

Project 2 - Dialogue and Collaboration with Partners, Decision-Makers and Users

In Project 1, it was recommended that NMHSs first completely understand their own position within their host departments and work to solidify a base. Related to this, is obtaining a better understanding of the Decision-Makers and Users that matter. The overall objective of the MAP is: "*to achieve, within five years, a major enhancement of the value to society of weather, climate and water information and services …*"[86] As a first point, it is probably realistic to state that generally, the value of these services is not recognized in many countries. Hence, part of moving ahead on MAP must be to first gain that recognition of present value. Once that has been achieved, it will be possible to generate ways to enhance value. Approaches taken to enhance the value then should have the parallel objective of enhancing recognition of present and enhanced value. Since the media and political processes seem most often to recognize and reward "visible' changes, it will be important to strategically focus on those changes that will gain recognition.

These actions relate to the MAP:

Action 7. Facilitate and strengthen **dialogue** and **collaboration** between providers and users of weather, climate and water information and services through international, regional and national platforms and programmes, and through the development of appropriate tools and methods.

Action 9. Strengthen existing, and establish new, operating **partnerships** between users and providers of weather, climate and water services to share responsibility for effective delivery of services, and evaluate their performance.

NMHSs can and should play a role in the formulation of national social and economic development strategies and any assessment of benefits should be in both the societal and economic areas. There is also the necessity of addressing the political aspects of programs. The MAP **Action 11** should, in this context, be broadened to include the social sciences of politics and sociology, which will be useful in the analysis of political and social pressures and opportunities.

Thus, social and political factors must be examined, in addition to economic aspects, in order to understand decisions that are seemingly contrary to economic logic. Additionally, it is therefore necessary that NMHSs undertake analysis of the motivators of decision-makers, focusing on those decision-makers that will make or influence the decisions that directly impact upon NMHSs mandate, budget or resource allocations, and rules of engagement.

A MAP theme is to increase awareness among decision-makers[87]. The decision-makers can be those who decide when and how to use NMHSs information, but in this paper the focus will be on the decision-makers with respect to the mandate and budgetary resources of the NMHSs. While users may influence these decision-makers, they are not the same group (although there are likely overlaps between the communities). Note that the MAP also calls for stronger partnerships between provider and user communities at every level of society. The user communities are not usually the direct decision-makers with regard to NMHSs mandate and budget, but key users may still be important decision-makers, as defined below.

Decision-makers are those people whose decisions directly and indirectly influence the mandate, funding and recognition of NMHSs. Hence, they may be a wide range of people that will vary from service to service. Those that influence the funding may be very different than those that influence the recognition. Through the analysis suggested in the section on "Know your NMHS and solidify the base" above, the key decision-makers within government, the media and general public should be identified. In building stronger partnerships with the user communities at every level of society, it is key to identify them and analyse their needs and activities with the focus on how they use or could use NMHSs information effectively. The Madrid Conference and associate regional conferences identified six user communities:

- Agriculture, water resources and the natural environment;
- Human health;
- Tourism and human welfare;
- Energy, transport and communications;
- Urban settlement and sustainable development; and,
- Economics and financial services.[88]

Within the particular context of NMHSs, it will be appropriate to consider different groupings, putting more emphasis on some user communities than others. It can be noted that for some, national defence will be an important user and it is not on the list. Further, for example, agriculture and water resources have natural linkages but the relationships between an agro-industry and its use of water may be in conflict with environmental issues. The Service will have to decide, based on its circumstance and mandate

[86] World Meteorological Organization. Madrid Action Plan, Pg 1.

[87] World Meteorological Organization. Madrid Conference Statement. Pgs 1, 2.

[88] World Meteorological Organization. Madrid Conference Statement. Pg 2.

what are its relative responsibilities with respect to competing uses among the users of its information.

The objective of these analyses of decision-makers and users is to identify those who will make a difference towards the:

- recognition of the present value to society of weather, climate and water information and services; and,
- achievement of major enhancement of those values to society.

These will not necessarily be the same. Through their analysis, NMHSs should, carefully understand those decision-makers and users that fit in the two categories and develop an action plan that will move towards achieving the MAP and NMHSs objectives.

One approach towards better interfacing with the decision-makers and users is to involve them in a decision-making - priority setting exercise. Once established as an advisory group or leaders council (this name has a positive sense to it), then the method below, used by the Canadian Leadership Council of the Research Network for Business Sustainability, may be useful, with appropriate modification to fit specific purposes.

1. **Assemble the right people:** A range of members from host department, other government departments, NGOs and a variety of user corporations or clients. The corporations or clients should be chosen to be non-competitors to ensure that the dialogue is open. The representation from all sectors is important. Including sectors like insurance, health, agriculture, transport would be useful.

2. **Roughly survey their initial views:** Before the meeting, each member is requested to send in a list of their top three (3) issues with a brief description. This serves to get them thinking about the issue and encourages them to solicit input from their colleagues and also serves as a starting point for the meeting.

3. **Start broad, then narrow and prioritize:** At the meeting, a 'nominal decision-making process' is used to arrive at the priority issues, which in the NMHSs case could be different types of information or different and more effective delivery of some services or information types. After introductions, all members are requested to write their priority issues on sticky notes and stick them onto large sheets of paper that are posted around the room. Each sheet of paper represents a general category of issues (e.g., accounting, finance, human resources, etc.). Then during a break, all the sticky notes are sorted and the topics prioritized and least important ones eliminated. Opinions from around the room are solicited with explanations given. With this sense of the general order of priority, a discussion is undertaken on the ways in which those priorities could be achieved. This may also result in synergies between the priorities in that doing one may also contribute or partially meet another. Arriving at a consensus among all council members will be important in terms of positive rapport with the users and increase the likelihood that resources become available to meet the needs. Involving a government representative from the financial ministry may be helpful.[89]

For background information, this Leadership Council is comprised of 15 non-competing organizations from industry, government and NGOs. Each corporate member represents a different industry, with most Canadian industries represented. They meet annually to identify the knowledge gaps that will help unlock some of their business sustainability challenges.
In the NMHSs case, the members would be challenged as to how they could make more effective use of weather, climate water information in carrying out their mandates or their commercial functions.

[89] Personal communication with Professor T Bansal. Richard Ivey Business School, University of Western Ontario. For a similar model, please see: Marketing Science Institute. (http://www.msi.org/research/index.cfm?id=43).

Project 3 - Education and Training – Decision-Makers and Users

Within the overall objective of the MAP: "*to achieve, within five years, a major enhancement of the value to society of weather, climate and water information and services …*" there was:[90]

Action 3. Embark on capacity-building endeavours through the creation of ***education and training*** **opportunities for both *users and providers*** of weather, climate and water information in order to increase awareness of users to the opportunities afforded by weather, climate and water services and to assist the providers of these services to understand more fully user requirements.[91]

It is appropriate to consider actions to provide education and training opportunities for both users and providers. It will need to be carefully decided, whether the capacity-building endeavours should be aimed at the users and providers and/or for the NMHSs. Both are needed but in very different capacities.

The Madrid Conference and associate regional conferences identified six (6) user communities and provided important information on identifying their needs and expectations. It will be useful to examine these regional reports to see how the best practices and similar issues in one region may be applied with modification in another region or for a different user community.

The objective of education and training opportunities for the users would be to:

- Make them more effective in their use of NMHSs services and promote feedback. This would benefit NMHSs in that their services would have more value;
- Provide an opportunity for NMHSs to better know their users through this positive and direct interaction;
- Contribute to the achievement of major enhancement of those values to society; and,
- Enhance the recognition of NMHSs and the demand for their services.

In this way, these actions on education and training will contribute to the MAP:

Action 4. Foster increased **recognition** by governments and other stakeholders of the contribution that NMHSs and their partners are making toward secure and sustainable living.[92]

They will also lead to increased demand for services such that MAP Action 5 becomes necessary.

Action 5. Adopt the following steps to meet the growing **demand** for weather, climate, water and related information and services.

In developing the education and training opportunities, NMHSs should keep the above objectives in focus.

Action 3 noted that capacity-building endeavours were needed. These should be three fold: capacity-building within NMHSs, to be able to provide these education and training opportunities; and capacity-building in both the direct user community and within the other providers of information. In the latter case, it is appropriate to analyse how or why this should be done by NMHSs. Is it part of the mandate and will it lead to enhanced recognition and resources to deliver services by NMHSs?

The Leaders Council, discussed earlier, would serve a useful purpose in the identification of the priority areas for education and training. Members of the Council could also possibly serve both as participants and as "test" cases.

The educational and training capacity development could be offered in cooperation with an existing education and training institute, such as a college. In that case, the Service and the college could jointly develop the content and curriculum with a possibility for joint presentation as well. In this way, NMHSs resources are leveraged and there is the potential for reaching a larger user community which further enhances recognition of the value of NMHSs services. There is also a role for partnerships among NMHSs and WMO in the development of training courses that could be offered in a number of countries with appropriate tailoring of the curriculum.

The education and training opportunities for users of NMHSs services, in order to increase awareness of users to the afforded opportunities, should be the priority. These are clearly within the mandate of NMHSs. These training opportunities should be linked with the MAP:

Action 6. Develop analysis of the **urban environment** as a critical ecosystem requiring targeted observation, research, and meteorological and hydrological services.[93]

Action 8. Strengthen existing, and develop and implement new, **multi-disciplinary programmes** that will define and improve ways and means to generate and deliver those weather, climate and water services, which address the developmental, societal, economic, environmental and health concerns of the countries.[94]

By focusing on some new initiatives, a greater response from the user community could be generated. The urban environment could be served by a focus on

[90] World Meteorological Organization. Madrid Action Plan, Pg 1.
[91] Ibid.
[92] Ibid.
[93] World Meteorological Organization. Madrid Action Plan, Pg 1.
[94] Ibid.

municipal officials who have responsibilities for planning, emergencies, and air pollution.

An additional issue as a possible focus for education and training is the area of climate services.

Project 4 - Developing Capacity - Integrated Environmental Prediction

If a Meteorological Service warns of a tornado in the next ten minutes, the expected response of citizens is to run for cover. If, on the other hand, information is provided that there is an increased probability of tornadoes over the next season, the response should be coordinated actions by governments at all levels to prepare for these events. Specifically, preparations should include the re-designing of structures, building codes, etc., and better education and planning of response actions. Further, forecasts of the hydrological cycles, leading to better predictions of floods and droughts, provide the possibility of a range of responses. Hence, the response to the information depends on the time scale of the prediction.

Another example can be observed in regard to smog forecasts. When the smog forecast is delivered on a daily basis, the individual response may be to modify outside activities, adapting to reduce exposure. In comparison, if a weekly forecast can be delivered, individuals as well as industry, can adapt their activities to better reduce emissions and, consequently the smog level. In smog forecasts, it has been traditional to only issue "alerts" or warnings, when the atmospheric concentration of ground-level ozone or other pollutants are expected to exceed some pre-specified threshold. Studies of the effects of atmospheric pollutants on human health show that some parts of the population are affected by much lower values invalidating the concept of a threshold below which there is no impact. When forecasts can be combined with a public education program, people can learn, through personal experience, how different levels of pollutants affect them and can adjust their activities accordingly. For this reason, some governments are now issuing smog forecasts as an index, and coupling this effort with educational materials. Many NMHSs are now involved in predictions of incidence of Ultra-Violet (UV) radiation. These need to be coupled with public education information on the relationships between an index of UV radiation and human health (skin sensitivity). Daily UV forecasts depend on cloudiness and other factors, but over the longer-term depend on stratospheric ozone layer depletion. As we look to the future, we should see composite forecasts that can bring together forecasts of weather, air pollution, UV indices, etc., along with other variables. By producing full environmental predictions in this manner, it is hoped that citizens, would be able to respond to and, in some cases, influence the result.

On a much longer time scale, we can think of and compare response strategies to seasonal forecasts of warmer summers, climate variability, and a decadal to century forecast of warmer decades, i.e., climate change due to human-caused increases in the concentrations of greenhouse gases.

The aforementioned are examples of integrated environmental prediction in that they extend the forecast system beyond the typical domain of weather and involve the use of skills and information on the chemistry and physics of the atmosphere. This concept has also been extended into the realm of the natural environment, specifically focusing on oceans, waves, ice and hydrology. Currently, work is being done to alleviate the limits on the skill and accuracy of deterministic forecasts by introducing predictions of statistical quantities, probabilities, vulnerability and/or risk. These efforts add significant value to the prediction system.

The concept of integrated environmental prediction with a continuing, broad ranging scale of information and warnings, for example, extends from:

1. **Minutes for tornadoes; to**
2. **Days for winter storms and air pollution episodes; to**
3. **Weeks for floods and droughts; to**
4. **Seasons for probabilities of events; to**
5. **Decades for climate variations.**

The atmosphere, which has been the focus of NMHSs from the beginning, is but one component of the environmental system. Because of its varying nature and role in driving change, it is natural to extend weather forecasting into physical environmental prediction, encompassing the atmosphere, components of the land-surface, the hydrological cycle, the Cryosphere and the oceans, with limited bio-ecosystem elements. Further, there is the possibility, and desirability, to evolve towards full environmental prediction, with full and interacting bio-ecosystems.

NMHSs role could become that of clear, science-based information sources, specifically focusing on the past, present and future states of the environment, in as broad a sense as is scientifically credible and within the mandate. The role is to provide both government and citizens with information for decision-making and adaptive responses. The result is that part of the negative impact will be mitigated, though there may still be some negative effects due to the fact that intervention is usually not fully offsetting. In essence, this role could lead to more proactive government actions that warn and inform citizens and governmental offices such that corrective and adaptive changes can be made, which reduce the negative aspects of atmospheric environmental change.

The concept of *seamless* prediction defined as being "i.) *Spatially and temporally continuous, spanning highly-localized cloud systems to global circulations transcending minutes, years, decades, centuries and millennia; transcending mesoscale weather lifecycles to long-term climate variability and change; ii.) integrated across the disciplines of physics, mathematics, chemistry, socio-economics and its earth-system elements eg. weather,*

climate, atmospheric composition, land surfaces and ecosystems, ice and ocean"[95] is advocated.

It is clear that a capacity for providing information and warning services related to each of the main user communities is needed.

NMHSs should not hesitate to extend themselves in this way since they utilize a scientifically based prediction service approach that does not generally exist in other organizations related to environmental issues. Looking ahead a decade or two, more fully integrated observing-prediction-dissemination systems supported by research and development are possible, even likely, and NMHSs should position themselves as leaders of this movement and not merely reactionaries. These integrated environmental prediction systems will provide the basis for sustainable development.

[95] Shapiro, M et al. 2009. "An Earth-System Prediction Initiative for the 21st Century. Submitted to the Bulletin of the American Meteorological Society. Pgs 4, 5.

Project 5 - Developing Capacity - Natural Hazards and Emergency Services

In principle, governments exist to provide collective means to their societies, protect citizens and to enhance overall societal benefits to the community. Part of that protective role is the provision of information and, when appropriate, warnings of weather and weather-related events to citizens. The number of disasters where communities are impacted beyond their capacity to cope with local resources has risen dramatically (by about a factor of six over the past four (4) decades) and more than 75% of the trigger events are hydrometeorological (storms, floods, droughts and related events).[96]In light of this increase in disasters, there is a strong need for services. In most cases, this role is entrusted to NMHSs in partnership with emergency management organizations. The primary user communities for these services include citizens, emergency management organizations and often the media as a partner in delivery of these services.

There is major political and national leadership attention to natural hazards. The international framework for natural hazards action is summarized in Appendix I.

The 2002 World Summit on Sustainable Development and the related Millennium Development Goals (MDGs) led to a Johannesburg Plan of Implementation (UN Department of Economic and Social Affairs, 2002) which includes commitments by governments to: "Protecting and managing the natural resource base of economic and social development."

"An **integrated, multi-hazard, inclusive approach** to address vulnerability, risk assessment and disaster management, including prevention, mitigation, preparedness, response and recovery, is an essential element of a safer world in the twenty-first century. Actions are required at all levels to:

Develop and **strengthen early warning systems and information networks** in disaster management, consistent with the International Strategy for Disaster Reduction;"[97]

In 2005, governments attending the World Conference on Disaster Reduction (Kobe, Hyogo, Japan) agreed that:

"We can and must further build the resilience of nations and communities to disasters through **people-centred early warning systems**, risks assessments, education and other proactive, integrated, multi-hazard, and multi-sectoral approaches.[98]"

From the World Conference on Disaster Reduction and especially the agreed expected outcome and strategic goals, five priorities for action are stated as part of the Hyogo Framework for Action ISDR (2005b), together with some illustrative and research-specific sub-items:

(i) Identify, assess and monitor disaster risks and enhance early warning.

The starting point lies in the knowledge of the hazards and the physical, social, economic and environmental vulnerabilities to disasters that most societies face, and of the ways in which hazards and vulnerabilities are changing in the short and long-term

(ii) Use knowledge, innovation and education to build a culture of safety and resilience at all levels.

(iii) Research: Strengthen the technical and scientific capacity to develop and apply methodologies, studies and models to assess vulnerabilities to and the impact of geological, weather, water and climate-related hazards, including the improvement of regional monitoring capacities and assessments.

(iv) Strengthen disaster preparedness for effective response at all levels[99]

The MAP also included:

Action 11. Encourage NMHSs and the social science research community to develop knowledge and methodologies for quantifying the benefits of the services provided by NMHSs within the various socio-economic sectors. [100]

NMHSs should identify the natural hazards services of particular relevance to each of the user communities.

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[96] The United Nations International Strategy for Disaster Reduction.http://www.unisdr.org/disaster-statistics/occurrence-trends-century.htm,

[97] World Summit on Sustainable Development. *Plan of Implementation of the World Summit on Sustainable Development.* 2002. Pgs 20, 21.

[98] United Nations International Strategy for Disaster Reduction. "Hypgo Declaration". World Conference on Disaster Reduction.(2005): Pg 2.

[99] United Nations International Strategy for Disaster Reduction. "Hypgo Framework for Action". World Conference on Disaster Reduction. (2005): Pgs. 14-20.

[100] World Meteorological Organization. Madrid Action Plan, Pg 2.

Project 6 - Developing Capacity - Climate Services

In many of the MAP actions, namely:

Action 7. Facilitate and strengthen dialogue and collaboration between providers and users of weather, **climate** and water information and services through international, regional and national platforms and programmes, and through the development of appropriate tools and methods.

Action 3. Embark on capacity-building endeavours through the creation of *education and training* opportunities for both *users and providers* of weather, **climate** and water information in order to increase awareness of users to the opportunities afforded by weather, climate and water services and to assist the providers of these services to understand more fully user requirements.

Action 9. Strengthen existing, and establish new, operating partnerships between users and providers of weather, **climate** and water services to share responsibility for effective delivery of services, and evaluate their performance.

Action 8. Strengthen existing, and develop and implement new, multi-disciplinary programmes that will define and improve ways and means to generate and deliver those weather, **climate** and water services, which address the developmental, societal, economic, environmental and health concerns of the countries.[101]

The word **climate** appears, usually as climate information or climate services. Despite this connection, there is no focus on climate services.

Climate change is an issue of major international and national interest, with heads of state often speaking on it and attending major climate change meetings. One such meeting was the Conference of the Parties 13 under the UN Framework Convention on Climate Change. The resulting **Bali Action Plan**, agreed to by all states, (see Appendix II for more information) addressed:

(i) **Enhanced action on adaptation**;

(ii) **International cooperation to support urgent implementation of adaptation actions**;

(iii) Enhanced action on **technology development** and **transfer** to support action on mitigation and **adaptation**;

(iv) Enhanced action on the provision of **financial resources** and **investment** to support action on mitigation and **adaptation** and technology cooperation;

(v) Means to incentivize the **implementation of adaptation actions** on the basis of sustainable development policies;

(vi) Financial and technical support for **capacity-building** in the assessment of the costs of **adaptation** in developing countries, in particular the most vulnerable ones, to aid in determining their financial needs.[102]

With this added emphasis on the needs for climate change adaptation, it is essential that NMHSs aggressively position themselves as the providers of that information as it is a logical extension of weather forecasts. Specifically, this trend is noted in emerging prediction systems which require integration of multiple issue areas (weather, climate, air quality and water) and time scales (minutes to decades). The connection between climate change adaptation, natural hazards and public safety issues does not seem to be sufficiently developed thus far. The MAP also included:

Action 11. Encourage NMHSs and the social science research community to develop knowledge and methodologies for quantifying the benefits of the services provided by NMHSs within the various socio-economic sectors.[103]

This effort should include the benefits of climate services since all six user communities identified in the MAP will have certain climate issues and services that are of special relevance to them. As part of the development of their climate services portfolio, NMHSs should take advantage of the World Climate Programme and particularly the World Climate Research Programme (WCRP), which is sponsored in large part by the WMO. This will ensure access to scientific advances in regional seasonal to decadal climate predictions and projections. The Global Change START Programme, which accommodates regional research networks and capacity-building programs of the World Climate Research Program (and other sponsors), provides an opportunity for working together on projects that can develop those services. Additionally, NMHSs need to ensure an active role in their country participation in the UNFCCC process.

[101] World Meteorological Organization. Madrid Action Plan, Pg 1

[102] United Nations Framework Convention on Climate Change. Bali Action Plan. 2007. Pgs 2, 3.

[103] World Meteorological Organization. Madrid Action Plan, Pg 2.

Appendix II - Bali Action Plan and Copenhagen Accord - Relevant Sections

Bali Action Plan

The Bali Action Plan[104] was approved by the United Nations Framework Convention on Climate Change Conference of the Parties 13, held in Bali, December 2007. It is specifically relevant in the context of this report since it lays out a framework for action on climate change adaptation. NMHSs can and should play a lead role in the national climate change action plans as the provider of climate information, including predictions.

What follows are the relevant sections of the Bali Action Plan. Underlining has been added for most important sections.

1. Decides to launch a comprehensive process to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012, in order to reach an agreed outcome and adopt a decision at its fifteenth session, by addressing, inter alia:

(c) Enhanced action on adaptation[105], including, inter alia, consideration of:

(i) International cooperation to support urgent implementation of adaptation actions, including through vulnerability assessments, prioritization of actions, financial needs assessments, capacity-building and response strategies, integration of adaptation actions into sectoral and national planning, specific projects and programmes, means to incentivize the implementation of adaptation actions, and other ways to enable climate-resilient development and reduce vulnerability of all Parties, taking into account the urgent and immediate needs of developing countries that are particularly vulnerable to the adverse effects of climate change, especially the least developed countries and small island developing States, and further taking into account the needs of countries in Africa affected by drought, desertification and floods;

(ii) Risk management and risk reduction strategies, including risk sharing and transfer mechanisms such as insurance;

(iii) Disaster reduction strategies and means to address loss and damage associated with climate change impacts in developing countries that are particularly vulnerable to the adverse effects of climate change;

(iv) Economic diversification to build resilience;

(v) Ways to strengthen the catalytic role of the Convention in encouraging multilateral bodies, the public and private sectors and civil society, building on synergies among activities and processes, as a means to support adaptation in a coherent and integrated manner;

(d) Enhanced action on technology development and transfer to support action on mitigation and adaptation, including, inter alia, consideration of:

(i) Effective mechanisms and enhanced means for the removal of obstacles to, and provision of financial and other incentives for, scaling up of the development and transfer of technology to developing country Parties in order to promote access to affordable environmentally sound technologies;

(ii) Ways to accelerate deployment, diffusion and transfer of affordable environmentally sound technologies;

(e) Enhanced action on the provision of financial resources and investment to support action on mitigation and adaptation and technology cooperation, including, inter alia, consideration of:

(i) Improved access to adequate, predictable and sustainable financial resources and financial and technical support, and the provision of new and additional resources, including official and concessional funding for developing country Parties;

(ii) Innovative means of funding to assist developing country Parties that are particularly vulnerable to the adverse impacts of climate change in meeting the cost of adaptation;

(iii) Means to incentivize the implementation of adaptation actions on the basis of sustainable development policies;

(iv) Financial and technical support for capacity-building in the assessment of the costs of adaptation in developing countries, in particular the most vulnerable ones, to aid in determining their financial needs.

Copenhagen Accord

The Copenhagen Accord[106] as negotiated by delegations present at the United Nations Climate Change Conference 2009 in Copenhagen and noted by the UNFCCC CoP15. The relevant sections are given below with underling added to highlight specific sections. One area where NMHSs should be involved is in the analysis of the level of global temperature change which becomes *dangerous* in their country.

1. We underline that climate change is one of the greatest challenges of our time. We emphasise our strong

[104] United Nations Framework Convention on Climate Change. Bali Action Plan. 2007. Pgs 2, 3. http://www.unfccc,int

[105] Underlining added for emphasis in the context of this report; both in Bali Action Plan and Copenhagen Accord.

[106] See Copenhagen Accord in Documents of UN FCCC CoP15. http://www.unfccc.int

political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities. To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change. We recognize the critical impacts of climate change and the potential impacts of response measures on countries particularly vulnerable to its adverse effects and stress the need to establish a comprehensive adaptation programme including international support.

3. Adaptation to the adverse effects of climate change and the potential impacts of response measures is a challenge faced by all countries. Enhanced action and international cooperation on adaptation is urgently required to ensure the implementation of the Convention by enabling and supporting the implementation of adaptation actions aimed at reducing vulnerability and building resilience in developing countries, especially in those that are particularly vulnerable, especially least developed countries, small island developing States and Africa. We agree that developed countries shall provide adequate, predictable and sustainable financial resources, technology and capacity-building to support the implementation of adaptation action in developing countries.

8. Scaled up, new and additional, predictable and adequate funding as well as improved access shall be provided to developing countries, in accordance with the relevant provisions of the Convention, to enable and support enhanced action on mitigation, including substantial finance to reduce emissions from deforestation and forest degradation (REDD-plus), adaptation, technology development and transfer and capacity-building, for enhanced implementation of the Convention. The collective commitment by developed countries is to provide new and additional resources, including forestry and investments through international institutions, approaching USD 30 billion for the period 2010-2012 with balanced allocation between adaptation and mitigation. Funding for adaptation will be prioritized for the most vulnerable developing countries, such as the least developed countries, small islands developing countries and Africa. In the context of meaningful mitigation actions and transparency on implementation, developed countries commit to a goal of mobilizing jointly USD 100 billion dollars a year by 2020 to address the needs of developing countries. This funding will come from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources of finance.

New multilateral funding for adaptation will be delivered through effective and efficient fund arrangements, with a governance structure providing for equal representation of developed and developing countries. A significant portion of such funding should flow through the Copenhagen Green Climate Fund.

10. We decide that the Copenhagen Green Climate Fund shall be established as an operating entity of the financial mechanism of the Convention to support projects, programme, policies and other activities in developing countries related to mitigation including REDD-plus, adaptation, capacity-building, technology development and transfer.

11. In order to enhance action on development and transfer of technology we decide to establish a Technology Mechanism to accelerate technology development and transfer in support of action on adaptation and mitigation that will be guided by a country-driven approach and be based on national circumstances and priorities.

12. We call for an assessment of the implementation of this Accord to be completed by 2015, including in light of the Convention's ultimate objective. This would include consideration of strengthening the long-term goal referencing various matters presented by the science, including in relation to temperature rises of 1.5 degrees Celsius.

Appendix III - The International Framework for Natural Hazards Actions and Research

World Commission on Environment and Development

The World Commission on Environment and Development (1987) defined sustainable development in the statement: "*Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs*".[107] This means that societies need to look to the future, making investments now that will allow future generations to meet their needs consistent with those of present generations. To look to the future and meet the needs for sustaining development, integrated, multi-disciplinary, science-based predictions of the future are essential. It is recognized that there is a literature on the problematic nature of prediction and accordingly, attention will be given to scenarios and interactive discussions about futures in appropriate balance with reliance on achieving and communicating predictions.

UN Framework Convention on Climate Change

In 1992, the UN Framework Convention on Climate Change (UN FCCC) was signed by most countries, with its objective, as stated in Article 2, of "*stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure food production is not threatened and to enable economic development to proceed in a sustainable manner*."[108] The objective is stated to be the avoidance of "dangerous" anthropogenic interference. In this context, the concept of danger is, in most citizen's minds, closely related to hazardous and extreme climate-related events, such as floods, droughts, severe storms and heat-waves. Despite the uncontrollable nature of these occurrences, the danger related to these events depends largely on the exposure and vulnerability of communities, an aspect which can be controlled and reduced by human actions. Under other Articles of the UN FCCC, there are commitments, such as Article 4(g) on "*… scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives … uncertainties regarding the causes, effects, magnitude and timing of climate change and the economic and social consequences of various response strategies.*"[109] [note ... means text omitted]The social consequences of response strategies include the impacts of climate-related hazards on communities.

World Summit on Sustainable Development

The 2002 World Summit on Sustainable Development and the related Millennium Development Goals (MDGs) led to a Johannesburg Plan of Implementation (UN Dept. of Economic and Social Affairs, 2002) which includes commitments by governments to:

"IV. Protecting and managing the natural resource base of economic and social development

37. An integrated, multi-hazard, inclusive approach to address vulnerability, risk assessment and disaster management, including prevention, mitigation, preparedness, response and recovery, is an essential element of a safer world in the twenty-first century. Actions are required at all levels to: *(h) Develop and strengthen early warning systems and information networks in disaster management, consistent with the International Strategy for Disaster Reduction;*

38. Change in the Earth's climate and its adverse affects are a common concern of humankind.

(a) Meet all the commitments and obligations under the United Nations Framework Convention on Climate Change...

…build upon relevant international commitments …including the Millennium Declaration, to strengthen global disaster reduction activities for the twenty-first century. Disasters have a tremendous detrimental impact on efforts at all levels to eradicate global poverty; the impact of disasters remains a significant challenge to sustainable development.

… intrinsic relationship between disaster reduction, sustainable development and poverty eradication, … importance of involving all stakeholders…"[110]

World Conference on Disaster Reduction and Hyogo Framework for Action

In 2005, governments attending the World Conference on Disaster Reduction (Kobe, Hyogo, Japan) agreed that:

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[107] World Commission on Environment and Development. 1987. "Chapter 2: Towards Sustainable Development." *Our Common Future*. Pg 1.www.un-documents.net/ocf-02.htm#1

[108] United Nations Framework Convention on Climate Change. "Article 2: Objective." 1992. Pg 1. www.unfccc.int

[109] United Nations Framework Convention on Climate Change. "Article 4: Commitments." 1992. www.unfccc.int

[110] World Summit on Sustainable Development. *Plan of Implementation of the World Summit on Sustainable Development.* 2002. Pgs 20, 21.

"*We can and must further build the resilience of nations and communities to disasters through people-centred early warning systems, risks assessments, education and other proactive, integrated, multi-hazard, and multi-sectoral approaches and activities in the context of the disaster reduction cycle, which consists of prevention, preparedness, and emergency response, as well as recovery and rehabilitation. Disaster risks, hazards, and their impacts pose a threat, but appropriate response to these can and should lead to actions to reduce risks and vulnerabilities in the future."*[111]

From the World Conference on Disaster Reduction and especially the agreed expected outcome and strategic goals, five priorities for action are stated as part of the Hyogo Framework for Action (2005b), together with some illustrative and research-specific sub-items:

5. Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation; and,
6. Identify, assess and monitor disaster risks and enhance early warning[112]

7. Use knowledge, innovation and education to build a culture of safety and resilience at all levels

(iii) Research

(n) Develop improved methods for predictive multi-risk assessments and socioeconomic cost-benefit analysis of risk reduction actions at all levels; incorporate these methods into decision-making processes at regional, national and local levels.

(o) Strengthen the technical and scientific capacity to develop and apply methodologies, studies and models to assess vulnerabilities to and the impact of geological, weather, water and climate-related hazards, including the improvement of regional monitoring capacities and assessments.

8. Reduce the underlying risk factors; and,
9. Strengthen disaster preparedness for effective response at all levels"[113]

The Chair's Summary of the First Session of the ISDR Global Platform on Disaster Risk Reduction (ISDR, 2007b), identified questions such as: "*Some cities and local authorities have successfully implemented risk reduction programmes, and these need to be documented and widely publicised by the ISDR system. All cities and local authorities should create and implement a disaster risk reduction plan, including multi-sectoral disaster preparedness plans with strong civil society participation.*" Research to identify and analyse successful risk reduction programmes is very important. Further, it was noted that: "*a core challenge in disaster risk reduction is to scale up proven practices".*[114]

In reference to climate change, the Summary noted that "*ISDR system partners should "promote the integration of risk reduction associated with existing climate change variability and future climate change into strategies for the reduction of disaster risk and climate change adaptability and actively disseminate and apply disaster reduction tools to support adaptation to climate change,"*[115] The UNFCCC has now had the benefit of four scientific assessments of climate change by the IPCC which has been able to draw upon the internationally-planned and coordinated scientific research programmes.

Integrated Research on Disaster Risk Programme

Recognizing the impacts of hazards on society, the International Council for Science (ICSU)[116], the International Social Sciences Council[117] and the United Nations International Strategy for Disaster Reduction (ISDR) are co-sponsoring a new international research initiative - Integrated Research on Disaster Risk (IRDR)[118] with a mandate to address the challenge of natural and human-induced environmental hazards. Focusing on disaster risk reduction, the research will be aimed at integrated risk analysis, including consideration of relevant human behaviour and decision-making processes in the face of risk. The IRDR is guided by three-broad research objectives: Objective 1. Characterization of hazards, vulnerability and risk; with sub-objectives: identifying hazards and vulnerabilities leading to risks; forecasting hazards and assessing risks; and dynamic modeling of risk; Objective 2: Understanding decision-making in complex and changing risk contexts with sub-objectives - identifying relevant decision-making systems and their interactions; understanding decision-making in the context of environmental hazards; improving the quality of decision-making practice; and Objective 3: Reducing risk and curbing

[111] United Nations International Strategy for Disaster Reduction. 2005. "Hyogo Declaration". World Conference on Disaster Reduction. Pg 2
[112] Underlining added for emphasis in this report.
[113] United Nations International Strategy for Disaster Reduction. "Hyogo Framework of Action". World Conference on Disaster Reduction. Pgs 14-20.
[114] Holmes, John. "Chair's Summary", *Global Platform for Disaster Risk Reduction* (Geneva, ISDR, 2007). Pg 4
[115] Ibid.
[116] ICSU, http://www.icsu.org
[117] ISSC, http://www.unesco.org/ngo/issc
[118] International Council for Science. *A Science Plan for Integrated Research on Disaster Risk: Addressing the challenge of natural and human-induced environmental hazards.* 2008 ISBN 978-0-930357-66-5

losses through knowledge-based actions. The IRDR research program fulfills the need for an international, multidisciplinary and an all hazard research program emphasized in the Hyogo Framework for Action. The added value of such a research program lies in its coupling of natural sciences' examination of hazards with socio-economic analysis of vulnerability and mechanisms for engaging the policy decision-making process. The IRDR will draw upon the expertise and scientific outputs of many partners in research with the Earth System Science Partnership[119] and the World Weather Research Program of the WMO.

An important cross-cutting theme of the IRDR Program is the capacity building efforts which will be done in collaboration with the Global Change System for Analysis Research and Training [START][120] project. A case study approach will help determine the most appropriate intervention strategies to enhance disaster risk reduction capacity. Mechanisms are needed for mainstreaming disaster reduction into development programmes. The legacy of IRDR will be an enhanced capacity around the world to address hazards and make informed decisions on actions to reduce their impacts.

[119] ESSP; URL http://www.essp.org
[120] START http:/www.start.org

Appendix IV - The World Climate Conference 3 and the Global Framework for Climate Services

The World Climate Conference – 3[121] (WCC-3) was held in Geneva, Switzerland, 31 August – 4 September 2009. The Conference Declaration stated that participants agreed to "establish a Global Framework for Climate Services (hereafter referred to as "the Framework") to strengthen the production, availability, delivery and application of science-based climate prediction and services."

The Expert Segment of WCC-3 reviewed the various challenges facing the climate service provider and user communities; considered the needs and capabilities for applying climate information in key climate-sensitive sectors, as well as for social and economic benefits; examined the scientific bases for climate information and prediction services; and concluded that:

• Great scientific progress has been made over the past 30 years, especially through the World Climate Programme and its associated activities, which already provide a firm basis for the delivery of a wide range of climate services; but that

• Present capabilities to provide effective climate services fall far short of meeting present and future needs and of delivering the full potential benefits, particularly in developing countries;

• The most urgent need is for much closer partnerships between the providers and users of climate services;

• Major new and strengthened research efforts are required to increase the time-range and skill of climate prediction through new research and modelling initiatives; to improve the observational basis for climate prediction and services; and to improve the availability and quality control of climate data.

The following are extracts from the outcomes of expert panels at the conference.

Climate information delivers economic value by providing users, whose activities are sensitive to climate conditions, with a basis for making decisions. The plenary presentations in the Expert Segment provided examples of the effective use of climate information to deliver economic value in different sectors. Seasonal climate prediction and information, for example, can prove valuable for agricultural planning and drought mitigation strategies. The estimates of the economic value of improved El Niño-Southern Oscillation predictions for the agricultural sector are not insubstantial.

With respect to longer time scales, the Conference was advised to consider climate change as a "threat multiplier", amplifying other potential stresses on economic and social systems. Climate variability and change can exacerbate existing vulnerabilities to the point of tipping systems into critical states. In this context, it is important to recognize costs associated not only with responding to climate change, but also with decisions not to act.

There are, however, many impediments to the effective use of climate information for socioeconomic benefits. The Conference learned these impediments include a lack of understanding about climate impacts, what climate information is most relevant, and how best to engage with users to define the right questions and involve them in the solutions. Several speakers stressed the challenges associated with acquiring, and sustaining resources.

The speakers and discussants canvassed the various challenges in removing the impediments to delivering greater socio-economic benefits from the use of climate services. Among the approaches advocated are the systematic application of "adaptation science" that is solution-focused, and the encouragement of multidisciplinary research. In addition, there was strong support for the following recommendations:

• *Madrid Action Plan.* High priority should be given to completing the actions identified in the March 2007 Madrid Action Plan on the Social and Economic Benefits of Weather, Climate and Water Services, incorporating the principles of climate risk management developed at the July 2006 Espoo Conference on 'Living with Climate Variability and Change';

• *Economic valuation of climate services.* The international agencies participating at WCC-3 should collaborate on assessing the value of various types of climate services and on ways and means of enhancing that value in the various climate-sensitive sectors of society;

• *Connecting with users.* Boundary organisations with sufficient capacity to integrate information from producers and mainstream services to users should be provided with sustained, cross-institutional support. Regional support institutions like development banks and insurers should be mobilized.

Nearly 80 per cent of disasters caused by natural hazards are linked to climate extremes. The IPCC

Fourth Assessment Report has provided scientific evidence on the increasing risks associated with these hazards as a result of human-induced climate change. Traditionally, many countries have been reactive to disasters. The adoption by 168 countries of the Hyogo Framework for Action 2005-2015: Building the resilience of

[121] Report of WCC3 – http://www.wmo.int

nations and communities to disasters, however, has led to a new paradigm in disaster risk management focused on prevention and preparedness. The UNFCCC Bali Action Plan has stressed the need for disaster risk management as a critical component of climate risk management in all countries.

Since the adoption of the Hyogo Framework for Action, initiatives are underway to bring together the scientific and technical agencies, disaster risk management and other relevant ministries and sectors (such as agriculture, health, environment, development) to coordinate the development of national disaster risk management strategies.

The Conference discussed that effective disaster risk management must be founded on quantification and understanding of risks associated with natural hazards. In many countries, institutional capacities and cooperation for risk identification need to be developed. Climate information is critical for the analysis of hazard patterns and trends. This must be augmented, however, with socio-economic data and analysis for vulnerability assessment (for example, casualties, construction damages, crop yield reduction and water shortages). With this risk knowledge, countries can manage risks using: (1) early warning systems and preparedness; (2) medium and long-term sectoral planning (such as land zoning, infrastructure development, agricultural management); and, (3) weather-indexed insurance and financing mechanisms. Early warning systems are effective tools for reducing loss of life. Climate forecasting tools could, however, be used to develop warnings with longer lead times for improved sectoral planning. Analysis of hazard patterns from historical data is necessary; but changing patterns of climate hazards are posing challenges with longer-term investments in areas such as infrastructure planning and retrofitting based on building codes and specifications, derived only from historical records (a 100-year flood may become a 30-year flood, for example).

In light of various experiences, the experts recommended:

• *Identification of requirements.* There is need for a systematic demand-driven approach to identify requirements of various user-communities including the level of integration of climate services in disaster management policies within different sectors of disaster risk management. This would require partnership and two-way cooperation between the climate information providers and targeted users. The coordinated framework of disaster risk management under the Hyogo Framework for Action is crucial for bridging the user interface;

• *Scaling up of pilot studies.* Development and utilization of relevant climate information for managing risks in some sectors have been piloted. These efforts need to be identified, evaluated and scaled up through a coordinated and operational institutional framework;

• *Increased investments in data.* Historical and real-time climate data are critical, but there is a pressing need for increased investments in NMHSs for strengthening observing networks, and data maintenance systems);

• *Climate forecasting technologies.* Climate forecasting technologies (seasonal, interannual and decadal) provide an unprecedented opportunity for improved sectoral planning for disaster risk reduction at different timescales (tactical to strategic planning). There is need, however, for coordinated research to improve these tools for providing relevant information for disaster risk management (such as predictions of trends and patterns of droughts, tropical cyclones, floods and heat waves at longer time scales). There is a need to make these tools operational to ensure sustainable delivery and utilization of information in sectoral planning;

• *Decision-maker awareness.* Utilization of climate information must be augmented with systematic public and decision-maker awareness programmes;

• *Developing tools to support* the application of climate services in disaster risk reduction. Appropriate tools to help decision-makers integrate climate services into disaster response and prevention (disaster risk maps, indices for monitoring hazards, signals for appropriate response, for example) need to be developed.

Climate information is already widely used in many countries and in many socio-economic sectors, and at many levels of society. Nevertheless, the urgency of adaptation to climate change, to which there is no alternative, elevates a need for climate information to a new level. In the absence of adaptation, scarce resources planned for national development activities will continue to be massively redirected to disaster response and recovery actions. Of paramount importance for policy and decision-makers are the following questions:

• What is the “adaptation field”, that is, where are the likely impacts that can probably not be avoided by mitigation?

• How much of this adaptation field can we afford to adapt, and how much would different levels of adaptation cost?

• How should we handle ‘residual impacts’ not addressed by adaptation?

A broad framing of the adaptation processes from awareness to mainstreaming in current activities, together with reorganization due to transformations in risk, suggests different entry points for information for decision-makers and for vulnerable populations. Conditions of vulnerability and available financial mechanisms are relevant factors. This approach includes the practical involvement of communities and governments in the implementation of climate risk reduction strategies and in the improvement of resilience to climate risks. Each country will have to develop its own adaptation policies, actions plans, programmes and measures. These must be integrated into the ongoing development processes and might also involve the coordination of needs between neighbouring countries.

The efficient use of climate information becomes an essential requirement in mainstreaming climate change into policy and development.

The experts highlighted:

• *Mainstream climate information.* The urgent need to assist developing countries in mainstreaming local and regional information on climate change and variability into planning and policy development;

• *Availability of adequate information.* Existing challenges related to availability of adequate information for adaptation to climate change in the most vulnerable regions such as Africa, low lying Asian mega-deltas, and small islands;

• *Learning from experience.* The importance of learning from the successes and positive and negative experiences of addressing challenges in the use of the available climate information;

• *Integrating knowledge.* The value of creating and integrating knowledge bases on local and regional climate hazards, on impacts, and especially on the economics of adaptation;

• *Improved understanding and data.* The central role of accurate and detailed prediction of the consequences of climate change at timescales and geographical scales corresponding to society and people's needs, and the corresponding requirement for improved understanding of the climate change and for sustained efforts in climate research and observation.