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BACKGROUND PAPER

Prepared for the 2015 Global Assessment Report on Disaster Risk Reduction

SYNTHESIS OF THE STATUS AND TRENDS WITH THE DEVELOPMENT OF EARLY WARNING SYSTEMS

A Contribution to the Global Assessment Report 2015
Priority for Action (PFA) 2 – Core Indicator (CI) 3: Early Warning Systems are in Place for all Major Hazards with Outreach to Communities

World Meteorological Organization (WMO)

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1 Introduction

The topic of early warning received a boost in attention after the 26 December 2004 Tsunami. In 2005, at the request of the United Nations Secretary-General, a global survey of early warning systems (EWS) was undertaken with a perspective of advancing the development of a global early warning system for all natural hazards (UN, 2006). The survey report concluded that while some warning systems are well advanced, there are numerous gaps and shortcomings, especially in developing countries and in terms of effectively reaching and serving the needs of those at risk. The survey report recommended a set of specific actions towards building national people-centred EWS, filling in the main gaps in global early warning capacities, strengthening the scientific and data foundations for early warning, and developing the necessary institutional foundations.

In response to the call for establishing a suitable framework for advancing early warning as an essential risk management tool, the International Early Warning Programme (IEWP) was proposed at the Second Early Warning Conference (EWC II) in 2003. As a facilitator, the Platform for the Promotion of Early Warning (PPEW) was established in 2004 with support from the Government of Germany, to facilitate the implementation of the proposed IEWP, to sustain the dialogue on early warning and to mobilize resources to strengthen partnerships and capacities at all levels. The IEWP was formally launched at the World Conference on Disaster Reduction in January 2005 that also adopted the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (hereafter referred to as HFA).

The second high-priority area of the HFA stresses the need for, "identifying, assessing and monitoring disaster risks and enhancing early warning". The HFA further highlights that EWSmust be an integral component of any nation's disaster risk management strategy, enabling governments from national to local levels as well as communities to take appropriate measures towards building resilience in anticipation of disasters.

Various assessments (for example, UN, 2006; UNEP, 2012; and Villagrán de León et al., 2013) and the outcomes of the mid-term review of the HFA (UNISDR, 2011) have revealed that many nations around the globe operate EWS for various natural and human-induced hazards. However, the governmental priority, stage of development and overall effectiveness of these EWS at national to local levels, vary widely. Many countries, especially those at highest risks but with the least resources, remain highly challenged in building and sustaining their EWS from the national level down to the level of communities.

The report from WMO was prepared as a background paper to the Global Risk Assessment Report 2015 (GAR15). The Global Assessment Reports on Disaster Risk Reduction (GARs) are biennial global assessments of disaster risk reduction and comprehensive review and analysis of the natural hazards that are affecting humanity. The GARs have contributed to achieving the HFA through monitoring risk patterns and trends and progress in disaster risk reduction while providing strategic policy guidance to countries and the international community. The GAR15 main document will be the product of efforts of many partners that contributed the building blocks of the GAR. These components are addressed through a series of activity streams coordinated by the United Nations Office for Disaster Risk Reduction (UNISDR) and with partners including the World Meteorological Organization (WMO),the United Nations Environment Programme (UNEP), the United Nations Development Programme (UNDP), the World Bank, the World Food Programme (WFP), the Food and Agricultural Organization (FAO), a wide range of specialized technical and academic institutions, regional intergovernmental organizations, non-governmental organizations (NGOs), governments, and many others.

This paper addresses five primary objectives: (1) document country, regional and global coordinated initiatives for development of EWS underpinned by the HFA; (2) assess the current state of implementation of EWS at the country level spanning governance, key drivers (e.g., risk-based), institutional coordination (local, national and international), sectoral penetration, and operational and technical aspects; (3) assess current state of (sub) regional efforts, for development of inter-operable national EWS; (4) evaluate different approaches among countries and fundamental principles that have led to the implementation of effective EWS, irrespective of different governance and institutional structures and socio-economic and cultural aspects as a way to develop a framework for monitoring and measuring performance at the country level; and (5) latest trends and expected future developments of EWS.

In the following sub-sections, the document explaines the methodology and sources used to arrive at the information presented in the following sections and presents a definition of EWS, highlighting five aspects that compose EWS at the national, regional and international levels. The document further provides an overview of the status of EWS at the national, regional, and international levels prior to the adoption of the HFA (Section 2); a review of progress with the implementation of EWS after the adoption of the HFA (Section 3); an analysis of the overarching trends in the development of EWS since the adoption of the HFA including challenges and successes in the institutionalization of EWS (Section 4). The last Section (5) presents a summary of the status of EWS along with conclusions for the further development of EWS under the post-2015 framework for disaster risk reduction.

1.1 Methodology and sources

The synthesis provided in this chapter is based on two types of sources: primary and secondary sources.

Primary sources:

October 2013 UNISDR call for submission of collaborative abstracts related to Priority for Action2/Core Indicator 3 (PFA 2/CI 3):

Following the procedures established by UNISDR, their 2013 October call encouraged submissions in collaboration with partners (e.g. disaster risk management authorities, socio-economic ministries and other national and regional agencies).

The call highlighted three issues to be addressed by the submitted abstracts, including:

1. What changes have been observed since the adoption of the HFA in 2005 in terms of development of Multi-Hazard Early Warning Systems (MHEWS) in your country, and what has been the impact in terms of reduction of risks to society?

2. To what extent has the HFA facilitated development of policies, financing and development of MHEWS; what have been other critical factors affecting these decisions?
3. What elements related to MHEWS and emergency preparedness will need to be considered for inclusion in the successor framework to the HFA?

To guide the responses to the UNISDR call, a template for review and documentation of EWS was provided as a means to ensure a consistent review and response (Annex 1). After review of the abstracts, invitations were extended to develop full GAR15 input papers and those papers constitute the primary sources. Submitted papers are listed in the References (Section 6.1).

Secondary sources:

A number of secondary resources were utilized for this report and are provided in the References (Section 6.2). These resources provided the main corpus of information on the status of the EWS prior to and since the adoption of HFA.

In November 2013 a survey was developed by WMO (Annex 2) and administered by UNISDR. This survey provided results consistent with review of documents, however only 9 countries responded to the survey (sometimes only partly): Comoros, Syria, Virgin Islands, Mozambique, Algeria, Portugal, Guinea, Bahrain, and New Zealand. Therefore, the main additional sources considered in arriving at the conclusions in this section were the GAR 2009 (UN, 2009) and GAR 2011 (UN, 2011) surveys, the Southeast Europe assessment of capabilities (WMO, 2012a) and the Caribbean Multi-Hazard Assessment (WMO, 2011).

1.2 What is an Early Warning System?

According to the UNISDR terminology (UNISDR, 2009), an EWS can be defined as:

> *"The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss. (UNISDR, 2009) '*

The objective of people-centred EWS is to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner so as to reduce the possibility of personal injury, loss of life, damage to property and the environment and loss of livelihoods (UNISDR, 2006). An EWS is an integral component of any nation's disaster risk management strategy, enabling governments at national to local levels and the communities to take appropriate measures toward saving lives and property, and building resilience in anticipation of disasters (WMO, 2009).

The Second International Conference on Early Warnings (EWC-II, 2003) concluded that effective EWS are comprised of:

- **Risks knowledge:** Risks are analyzed and this information is incorporated in the warning messages;

- **Monitoring and warning service:** Hazards are detected, monitored, and forecasts and hazard warnings are developed;
- **Dissemination:** Warnings are issued (by one national designated authoritative source) and disseminated in a timely fashion to authorities and public at-risk;
- **Emergency response capacity:** Community-based emergency plans are activated in response to warnings, to reduce potential impacts on lives and livelihoods.

These components must be underpinned by appropriate legislative, legal frameworks and policies, organizational coordination and cooperation mechanisms, feedback mechanisms to improve the system over time and appropriate allocation of resources. Implementation of these components requires coordination across many agencies at national to local levels for the system to work. Many good practices around the world have demonstrated that EWS should be developed with a multi-hazard, multi-sectoral and multi-level (national to local) approach. Failure in one component or lack of coordination across them could lead to the failure of the whole system. The issuance of warnings is the responsibility of the government; thus, roles and responsibilities of various public and private sector stakeholders for implementation of the EWS should be clarified and reflected in the national to local regulatory frameworks, planning, budgetary, coordination, and operational mechanism. Best practice EWS also have strong inter-linkages and effective communication channels between all of the elements (UNISDR, 2006) (Figure 1).

Figure 1: WMO Schematic of the four operational components of effective EWS

Risk knowledge:

Quantitative risk assessment combines information about hazards with exposures and vulnerabilities of the population or assets across various economic sectors and communities (e.g., agricultural production, infrastructure and homes, etc.).This means that hazard analysis must be augmented with socio-economic data that quantifies exposure and vulnerability (e.g., casualties, construction damages, crop yield reduction and water shortages). Depending on the types and levels of decisions (local, national, regional and global levels), this analysis requires different data resolutions (temporal and spatial). Furthermore, risk information may need to be tailored to address sectoral and inter-sectoral issues if to be used in decision-making. Equipped with the quantitative risk information, countries can develop risk reduction strategies using: (i) EWS to reduce casualties; (ii) medium and long-term sectoral planning and risk management (e.g., land zoning, infrastructure development, water resource management, agricultural planning) to reduce economic losses and build livelihood resilience, and, (iii) risk financing and transfer (e.g., insurance) to transfer and/or redistribute the financial impacts of disasters. This must be underpinned by effective policies, legislation and legal frameworks, and institutional coordination mechanisms as well as information and knowledge sharing, education and training.

Hazard events are characterized by magnitude, duration, frequency, location and timing. Calculating the probability of occurrence of hazard events in terms of these characteristics is the key task in fully documenting the hazard component of potential disaster impacts. These defining characteristics can be extracted from observational datasets. A fundamental requirement of risk assessment is therefore the availability of, and access to, high-quality historical data. This requires:

- Ongoing, systematic and consistent observations of hazard-relevant hydro-meteorological, geophysical and other environmental parameters;
- Quality assurance and proper archiving of the data into temporally and geographically referenced and consistently catalogued datasets and related metadata;
- Ensuring that the data can be located and retrieved by users; and,
- Availability of hazard mapping and analysis tools.

However, as the characteristics of weather, climate and hydrological hazards are changing as a result of climate change (and human development/global change), analysis of historical hazard data is no longer sufficient in itself. For instance a flood or drought with a return period of 100 years may become a one in 30 years or less flood or drought. Simply said, more severe events could happen more frequently in the future. In addition, hazards are occurring in areas where historically they did not occur. Thus nations may not have anticipated developing their EWS and emergency preparedness measures for these new hazards. This points to the urgent need for advancements in forward-looking approaches (scenarios, modelling, etc.) to identifying characteristics of hazards, exposure and vulnerability to enable risk-informed decision-making for investments in development of EWS.

Box 1: The Thailand floods of 2011

In the second half of 2011, Thailand was struck with severe flooding that impacted 65 of the 77 of Thailand's provinces. The floods were caused by the persistent monsoonal rains combining with the remnants of a series of tropical cyclones that impacted northern and central Thailand from late July to October of 2011. The heaviest rains occurred across the northern and central sections of Thailand, before swollen rivers and floodwaters began to shift southward towards the greater Bangkok metropolitan area. The flooding persisted in some areas until mid-January 2012 and resulted in a total of 815 deaths and 13.6 million people affected. Over 20,000 square kilometres of farmland was devastated and significant damage to Thailand's manufacturing industry where more than 1000 factories were flooded. Seven major industrial estates were inundated by as much as 3 meters of water which caused significant disruptions to manufacturing supply chains including the electronics industry which resulted in a global shortage of computer hard disk drives. The World Bank estimated that the total economic losses were 45.7 billion USD which ranks the disaster at one of the top five costliest in world history.

Furthermore, access to (near) real-time risk information would allow development of risk- and impact-based warnings which are more meaningful than mere weather warnings and can provide the basis for more focused decisions pertaining to evacuations and preparedness measures in advance of an event.

Monitoring and warning service:

Development of early warnings requires sustainable systematic and consistent real-time monitoring and detection of hazards, sufficient network of operational observation, detection, and monitoring capacities on a 24/7 basis, forecasting and modelling capacity to predict natural hazards, a well-defined capacity to disseminate hazard and risk information to appropriate partners and constituencies, and continual review and analysis of forecast and warning accuracy and relevance. These systems require regular maintenance and updates to remain operational.

Sustainability is often one of the greatest challenges in the development of monitoring and forecasting systems, particularly in developing and least developed countries, as the cost and specialization for such services may not be considered as part of the on-going financing of such networks and systems.

Staffing and equipment of hydro-meteorological and tsunami modelling and forecast centres must be adequate to support 24/7 operations. Staff requires ongoing training to enable them to remain up-to-date with the latest modelling, analysis and forecast techniques which is critical in the development of timely and accurate forecasts and warnings.

Critical to the success of any EWS is furthermore the level of confidence in the accuracy of warning messages. Application of sound science is fundamental in improving the accuracy of the warnings thereby increasing the likelihood of appropriate response when warning messages are disseminated. To accomplish this, adequate observation networks, computer and telecommunication resources, and/or collaboration and partnerships with other entities to support modelling, forecasting and development of warnings are necessary. Additionally, capacities for research and development and/or the ability to ingest sound scientific processes from the academia,   other governmental agencies and private sector are vital to the strength of the EWS.

An often overlooked part of the EWS process is a comprehensive post-event review. Such a review should include an analysis of observation, detection and forecast processes and accuracy, the timing, location and intensity of the event, documentation of impacts, with a focus on institutional coordination and cooperation. This review provides the basis for documenting lessons learned and for developing the future steps for improving the EWS.

Dissemination:

Once warning and forecast information are developed, it is critical that systems and procedures are in place to ensure that they are disseminated to decision makers in a timely and efficient manner. Even the best forecasts and warnings are not effective if they are not timely disseminated.

Effective dissemination systems must be available 24 hours a day, every day of the year. Issuance of warnings and dissemination to the authorities and the general public are national responsibilities or, under national coordination, those of subnational entities through a multi-level approach. The dissemination process should ensure that:

- Messages are readily identifiable as authentic and authoritative;
- Messages should reach authorities responsible for emergency preparedness and response at the national to community levels;
- The end_to_end systems should get the message to those at risk;
- Dissemination systems are sustainable, reliable and redundant; and,
- Dissemination systems provide update and cancellation capabilities.

Emergency response capacity:

The primary objective of the EWS is to enable the appropriate authorities to develop pro-active and timely emergency preparedness and response measures designed to avoid or limit negative/adverse impacts of hazards. To be effective in meeting that goal, it is important that the line of authority and decision-making processes are clear and understood by all EWS stakeholders. Additionally, all stakeholders must have a comprehensive understanding of the hazard risks and potential impacts. In this regard, emergency protocols and procedures should be developed from the national to the community level clearly defining roles and responsibilities. An important component in this process is outreach to and education of those at risk which involves the understanding of hazards and their impacts, hazard forecast uncertainties, and the EWS. Equally important are the organization of routine drills and practice scenarios to ensure that emergency response processes are practiced, lessons learnt are documented and the constituencies are prepared to act, and the conduct of post-event reviews to analyse successes and areas for improvement.

Policy, legislative, and institutional coordination aspects:

The EWS should be clearly defined through policy and legislation and ensure that roles and responsibilities of different agencies and authorities at national to local levels are clear and understood by all stakeholders (and very importantly by the public at risk), and that there is a mechanism for support and capacity development for all aspects of the EWS. A national response framework should be a part of this policy which enables all forecast and response partners to prepare for and deliver a unified national to community level response to disasters and emergencies. The framework should establish a comprehensive, national, Multi-hazard approach to incident response. Coordination between the National Meteorological and Hydrological Service (NMHS), geological, marine or any other relevant service and the disaster risk management agency should be strong and continuous and planned in advance. Synergies developed through extensive coordination will result in a more effective EWS (that is actually Multi-Hazard Early Warning System (MHEWS)) and avoid duplication of efforts and lack of clarity in roles and responsibilities during hazard events.

2 Status of Early Warning Systems prior to the adoption of the Hyogo Framework for Action

In 2006, the Global Survey of Early Warning Systems (UN, 2006) and the outcomes of the Third International Conference on Early Warning (EWC-III) concluded that although progress had been made, many gaps remained to be addressed to ensure that effective EWS are implemented in all countries, particularly in those with least resources. The 2006 Global Early Warning Survey Report cited challenges on legislative, financial, organizational, technical, operational, training and capacity development fronts. Furthermore, a global survey among NMHSs of national and regional capacities conducted by WMO[1] (WMO, 2006) concluded that nearly 70% of countries require new or revised disaster risk reduction policies, legislation, planning, and coordination mechanisms with focus on preparedness and prevention and clearer roles of the NMHSs; over 65% of NMHSs need modernization or strengthening of their core infrastructure for observation, telecommunication, and operational forecasting; nearly 80% of NMHSs need guidelines as well as management and technical training; and over 80% of NMHSs need strengthening of their strategic and operational partnerships with various disaster risk management stakeholders.

Box 2: 60 Years of international and regional cooperation in meteorology to support national Early Warning Systems

Prior to the adoption of the HFA, following over 60 years of international and regional cooperation in meteorology to support national Early Warning Systems (EWS), international cooperation, facilitated by the World Meteorological Organization (WMO), existed already. This involved coordinated research and an operational network, comprised of the WMO Global Observing System (GOS), Global Telecommunication System (GTS), and Global Data Processing and Forecasting System (GDPFS) that together enable monitoring, detecting, forecasting and exchange of weather-, water-, and climate-related information, engaging the National Meteorological and Hydrological Services (NMHSs) of 191 Members (in 2014)(Figure 2).

[1] The survey outcomes were based on 145 WMO Member responses. Link: http://www.wmo.int/pages/prog/drr/natRegCap_en.html

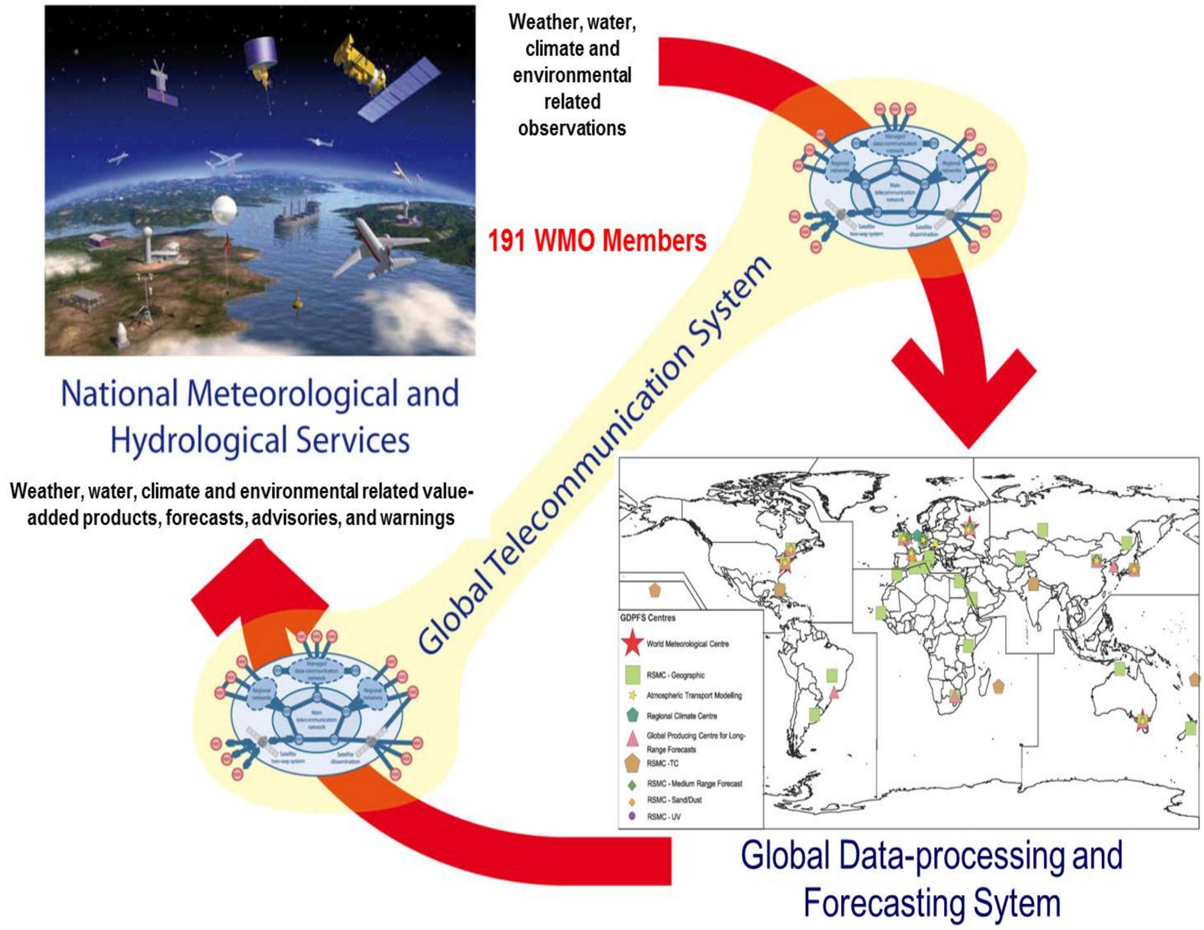

Figure 2: Internationally coordinated operational network of WMO involving the WMO Global Observing System (WIGOS), Global Telecommunication System (GTS), and Global Data Processing and Forecasting System (GDPFS) facilitating sharing of data, analysis, and forecasts across 191 WMO Members through their National Meteorological and Hydrological Services (NMHSs).

Through this coordinated operational network, a wide range of global and regional forecast products and services based on latest technologies and forecasting tools were provided to support the NMHSs with the development of national products and services such as hazard analysis and early warnings to support sectoral risk management decision-making. Examples include:

Tropical Cyclone Programme

The Tropical Cyclone Programme (TCP) of WMO is an example of cooperation using regional capacities to support national EWS to promote disaster risk reduction strategies. Through the Programme, six Regional Specialized Meteorological Centres (RSMCs) are dedicated to providing tropical cyclone analysis, forecasts, and alerts in support of NMHSs' operational warnings. These include: RSMC Nadi-Tropical Cyclone Centre, RSMC La Reunion-Tropical Cyclone Centre, RSMC New Delhi - Tropical Cyclone Centre, RSMC Tokyo-Typhoon Centre, RSMC Honolulu - Hurricane Center, and RSMC Miami - Hurricane Center. The Programme is supported by five regional committees, involving forecasters from the NMHSs, which ensure ongoing improvements in the tropical cyclone forecasting and warning systems (Figure 3). This has enabled availability of tropical cyclone warning capacities to all countries at risk.

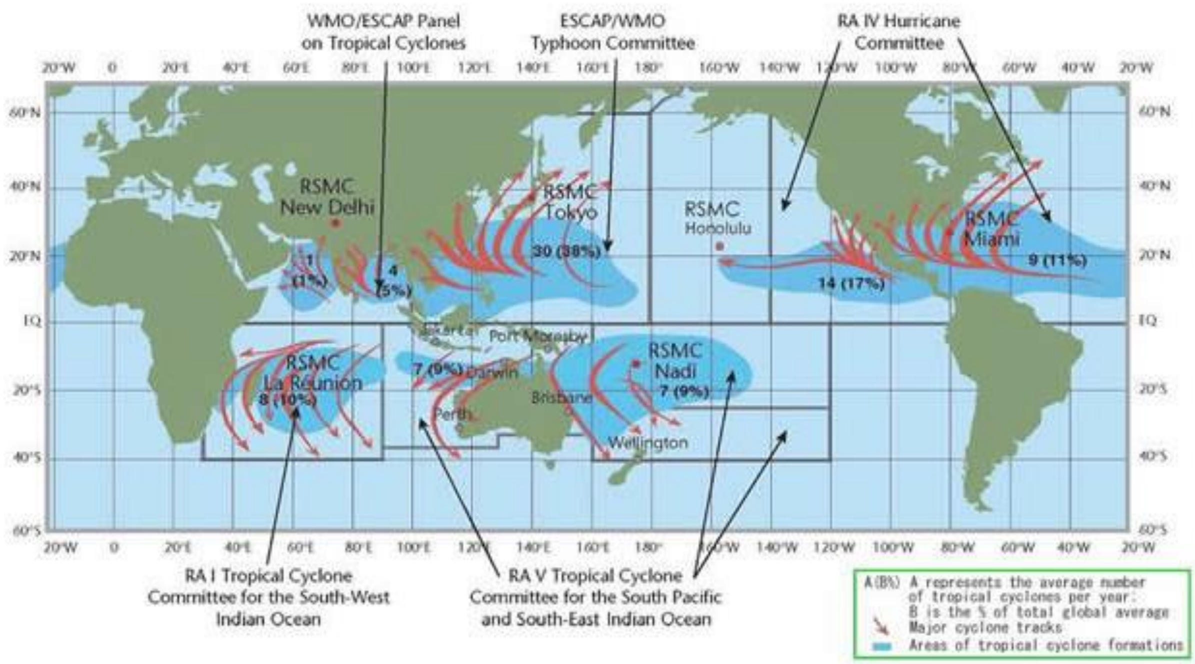

Figure 3: Globally and regionally coordinated Tropical Cyclone System
Source: WMO Tropical Cyclone Programme (https://www.wmo.int/pages/prog/www/tcp/organization.html)

Emergency Response Activities

WMO's Emergency Response Activities (ERA) Programme, established in 1986 to assist NMHSs, governments, and international organizations to respond effectively to environmental emergencies with large-scale dispersion of airborne hazardous substances, is another example of regional cooperation. The Programme is focused on nuclear facility accidents, but also provides meteorological support in emergency responses in relation to the dispersion of smoke from large fires, volcanic ash, dust, sand storms, and chemical releases from industrial accidents. The WMO operational network of global, regional, and national meteorological centres provides the infrastructure for specialized atmospheric dispersion-modelling that play a crucial role in assessing and predicting the spread of air- and water-borne hazardous substances. Some applications include:

Nuclear Accidents
The Chernobyl nuclear accident (April 1986) led to strengthened international cooperation in the event of a nuclear emergency through the Joint Radiation Emergency Management Plan of the international organizations. The plan is coordinated by the International Atomic Energy Agency in cooperation with international organizations including WMO, the World Health Organization (WHO), and the Food and Agriculture Organization (FAO). WMO maintains a system of eight Regional Specialized Meteorological Centres (RSMCs) which provide highly specialized computer-based simulations of the atmosphere that predict the long-range movement of airborne radioactivity to support environmental emergency response, when needed. These centres, which provide complete global coverage 24 hours a day, every day, are located in Beijing (China), Obninsk (Russian Federation) Tokyo (Japan), Exeter (United Kingdom), Toulouse (France), Melbourne (Australia), Montreal (Canada), and Washington (USA). This response system was activated on 11March 2011 in the aftermath of the Tōhoku earthquake and tsunami in Japan.

Volcanic Ash

Volcanic ash is a direct safety threat to jet transport aircraft, primarily because the melting point of ash is around 1100°C, while the operating temperatures of jet engines are around 1400°C. The ash melts in the hot section of the engines and then fuses on the turbine blades, potentially leading to engine stall. The International Civil Aviation Organization (ICAO) is responsible for coordinating the efforts of its member states and seven international organizations, including WMO, which comprise the International Airways Volcano Watch (IAVW). Under the IAVW, international ground-based networks, global satellite systems and in-flight air reports detect and observe volcanic eruptions and ash cloud and pass the information quickly to appropriate air traffic services units and Meteorological Watch Offices, which provide the necessary warnings to aircraft before or during flight. The warnings are based on advisory information supplied by nine Volcanic Ash Advisory Centers (VAACs) designated upon recommendation from WMO. The designated VAACs are located in Anchorage (USA), Buenos Aires (Argentina), Darwin (Australia), London (UK), Montreal (Canada), Tokyo (Japan), Toulouse (France), Washington (USA), and Wellington (New Zealand).

Wildfires

Following the worst smoke and haze episodes that affected Southeast Asia in autumn 1997, which impacted many socio-economic sectors including civil aviation, maritime shipping, agricultural production, tourism, and the health of populations, WMO joined with the Association of Southeast Asian Nations (ASEAN) to set up the ASEAN Regional Specialized Meteorological Centre in Singapore. This Centre provides smoke/haze information and forecasts to NMHSs to assist in environmental emergency situations. It also displays weather and hot spots using satellite images on its website. Satellite imagery can provide information on the dryness of vegetation, location and size of major fires and smoke plumes, energy released by fires, and air pollutants in the smoke plumes.

Using the Tsunami EWS as an example, we see that in 1949, the Seismic Sea-Wave Warning System was put into operation at the Seismological Observatory in Ewa Beach near Honolulu to warn Pacific coastal communities of the United States of America (USA) about impending tsunamis like the one three years earlier which originated from the Aleutian Islands and struck Hawaii by surprise with disastrous results[2]. In 1965, the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO) approved the offer made by the USA to strengthen this institution by establishing, on a permanent basis, the International Tsunami Information Center. Not long thereafter, the Observatory changed its name to the Pacific Tsunami Warning Center (PTWC) and became the operational centre for the Tsunami EWS in the Pacific.

Within the Pacific, less than ten countries had national tsunami warning centres in place by 2004: among them the USA tsunami warning centres at Ewa Beach, Hawaii, (PTWC) and in Palmer, Alaska, (WC/ATWC); the Russian Federation tsunami warning centres at Petropavlovsk-Kamchatskiy and Youzhno-Sakhalinsk; the Japanese tsunami warning centres at Sapporo, Sendai, Tokyo, Osaka, Fukuoka, and Naha; the French Polynesia tsunami warning centre at Papeete, Tahiti, and the National Tsunami Warning System of Chile headquartered at Valparaiso.

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[2] This section is largely based on the ITSU Master Plan, Third Edition, July 2004, IOC/INF.1124; SC.99/WS/36 REV. (Eng. only). [should go to References]

By July, 2004, EWS for tsunamis only covered some areas of the Pacific Ocean. The system of warning centres had clear gaps in its coverage for Southeast Asia, the Southwest Pacific, and Central and South America. These regions did not have regional tsunami warning centres.

The Indonesian Tsunami Early Warning Systems (InaTEWS) was established following the occurrence of gigantic tsunamis in the Indian Ocean, (with the Aceh Province in Northern Sumatra among the hardest hit) in December 2004. The establishment involved 16 domestic national institutions and 5 international donor countries coordinated by the Indonesian Minister of Research and Technology. The InaTEWS was, and is, daily operated by the Agency for Meteorology Climatology and Geophysics (BMKG, Indonesia) – the Indonesian NMHS, whose roles is to monitor, analyse, predict, and disseminate not only weather and climate information, but also earthquake and subsequent potential tsunami warnings. The development embraced an end-to-end approach covering two parts: upstream or structural part and downstream or cultural one. The structural part deals with all technical aspects of the system ranging from observation, communication, processing and dissemination subsystem. The downstream or cultural part addresses the response, be it from the government, or the public.

The Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and connected seas (NEAMTWS) project, launched by UNESCO- IOC in 2005 after the 2004 event in Southeast Asia, provides for the establishment of the risk of a tsunami warning system by operating in the Mediterranean and connected seas and the North Atlantic[3].

WMO's Global Telecommunication System (GTS), which is the backbone system for global exchange of data and information in support of multi-hazard, multipurpose early warning systems, disseminates tsunami related information and warnings.

Historical data for past tsunamis was available in many forms and for many locations. The forms included online tsunami databases, published and manuscript catalogues of tsunami occurrences, field investigative reports, personal accounts of experiences, newspaper accounts, and film or video records. One of the larger collections of this type is still maintained by the International Tsunami Information Center (ITIC) in Honolulu, Hawaii. Another major collection is maintained by the US NOAA National Geophysical Data Center (NGDC) in Boulder, Colorado. The NGDC hosts the World Data Center for Geophysics and Marine Geology, serving as the recognized archive for tsunami events, including sets of images illustrating tsunami effects and damage, and a variety of publications containing scientific data, records, photos, and information on historical and recent tsunami events.Tsunami catalogues had also been compiled by Australia, Chile, Mexico, Ecuador, Japan, and the Russian Federation for their own and/or nearby shores.

Often the only way to determine the potential run-ups and inundation from a local or distant tsunami is to use numerical modelling, since data from past tsunamis is usually insufficient. Models can be initialized with potential worst-case scenarios for the tsunami sources or for the waves just offshore to determine corresponding worst case scenarios for run-up and inundation. Models can also be initialized with smaller sources to understand the severity of the hazard for the less extreme but more frequent events. This information is then the basis

[3]http://www.ioc-tsunami.org/index.php?option=com_content&view=article&id=70:neamtws-home&catid=9&Itemid=14&lang=es

for creating tsunami evacuation maps and procedures. By 2004, such modelling had been carried out for a small fraction of the coastal areas at risk, and in the Pacific. UNESCO disseminated a numerical programme/application called the Tsunami Inundation Modeling Exchange (TIME) that provided the transfer of a numerical inundation model developed by Professor Shuto of Japan to Mexico, the USA, Republic of Korea, Turkey, Canada, Mexico, Greece, Colombia, Australia, Italy, Indonesia, Ecuador, Costa Rica, and Chile. Most importantly, it also provided training in the use of the model. Many countries, including Chile, Mexico, France, Japan, and the United States had established programmes to systematically model the potential tsunami inundation for their coastal areas at risk.

In summary, despite the available historical records and scientific knowledge, tsunami EWS were available only for a few countries by 2004.

2.1 Risk knowledge

Prior to the HFA many countries, especially high-income countries, had developed risk maps for selected geographical areas and for some hazards. Gaps in the development of multi-hazard assessments and maps were in part due to the fact that the preparation of hazard databases was rarely a legal requirement. Additionally, resources to develop this information were widely disparate and generally limited in developing countries. In many countries, risk assessments were carried out on an ad hoc basis and frequently tended to be developed only after a disaster occurred. In Africa only a few countries had prepared risk maps and they were mainly limited to hydrological phenomena. Some of the most significant gaps in risks knowledge included:

Inadequate emphasis on social, economic and environmental vulnerability and exposure- Risk assessments were predominately focused on hazards.

Data gaps - In many countries long historical records did not exist. In many cases data was only available in paper form and showed inconsistencies. The main challenges that existed were:

- Establishing and maintaining observing and data management systems;
- Maintaining archives, including quality control and digitization of the data;
- Obtaining social and environmental data; and,
- Securing institutional mandates for collection and analysis of vulnerability data.

Difficulty in accessing information - In addition to the challenges listed above and the lack of fully digitized data, in some areas there was an unwillingness to share data due to security concerns.

Lack of early warning indicators - There was a lack of internationally agreed and locally referenced measures of success and failure of EWS.

2.2 Monitoring and warning service

A summary of what was in place for specific hazards (UN, 2006) is provided in Annex 3.

Significant progress had been made in many countries on the technical aspects of monitoring and forecasting natural hazards, however many major overall gaps existed, particularly in the developing and least developed countries (as noted in Annex 3). Key issues included:

- Inadequate coverage and sustainability of observing systems for monitoring of hydrometeorological hazards;
- Inadequate level of technical capabilities (computer resources and operational warning services) and expertise capabilities (professional staff, training) in the operational technical agencies responsible for monitoring and forecasting of severe events, such as the NMHSs;
- Lack of public awareness on ability to predict most of hazards, especially hydrometeorological hazards was widespread;
- Lack of systems for many hazards such as dust and sand storms, severe storms, flash floods and storm surges, particularly for at-risk developing and least developed countries;
- Lack of internationally negotiated data-exchange policies and procedures to share essential data in a timely fashion among countries for the development of models and of operational forecasting and warning systems, such as for tsunamis and earthquakes;
- Inadequate access to information (forecasts and interpreted data) from countries outside of the region affected;
- Insufficient multi-disciplinary and multi-agency coordination and collaboration for improving forecasting tools such as for storm surge and floods and for integrating warnings into the DRR decision processes in a more effective and proactive fashion; and,
- Inadequate communication systems to provide timely, accurate and meaningful forecasts and early warning information down to the level of communities.

Systems existed to provide hazard forecasts and warnings against impending disasters induced by hydrometeorological hazards, but the scope of hazard coverage at the country level was highly variable and reflected countries' economic development level. Effective monitoring and forecasting systems were available for most hazards, including for complex hazards like drought, El Niño, and desertification. Effective improvements had occurred in tropical cyclone and windstorm warning systems. Systems were less well developed for tsunamis, landslides, wild fires and volcano-related hazards (e.g. eruptions and lahars). For many countries the sustainability of monitoring and warning systems was a major challenge.

Most EWS focused on hazard monitoring and forecasting but were not risk-based due to the exclusion or lacking availability of information on the assessments of vulnerability and exposure. A major need across the board was therefore the integration of risk information into hazard warning messages. This required strengthening collaboration between technical operational agencies such as the NMHSs, national agencies responsible for assessments of vulnerability and risks, and disaster management. Capacities for risk assessment needed to be developed at national and local levels, on methodologies, hazards, and various socio-economic data.

2.3 Dissemination

Prior to the HFA the warning dissemination chain often involved moving warnings from technical and scientific sources through government decision makers and the media to multiple receivers who may have also functioned as onward disseminators.Countries recognized the need for effective dissemination systems which leveraged traditional telecommunication systems as well as evolving dissemination systems such as social media networks. However for a variety of reasons in many countries such a system was not complete and was not effective for all hazards.Adequate resources for development and sustainment of dissemination systems were often a challenge.Even prior to the HFA, technical capacities for disseminating and communicating warnings had advanced with an explosion in the types and extent of information communication technology.Countries were at various stages of leveraging these advancements and application of these technologies was relatively slow.

The ability to quickly disseminate increased amounts of warning information was leading to confusion in the constituencies who relied on this information. Dissemination practices were not keeping up with advances in lead time and ability to predict and warn for hazards which made it necessary to provide a more continuous information flow. This resulted at times in confusion or inaction which indicated a need for standardization and clarification of warning terminology and responsibility, and education of partners and people impacted by the hazards. There was a need to increase multi-organizational collaboration, cooperation, and interaction to improve the dissemination process and make the warning messages more effective.

According to Global Survey of Early Warning Systems (UN, 2006) warning messages did not reach all persons, organizations, and sectors at risk. In developing countries this was largely a result of the underdeveloped dissemination infrastructure and systems, while in developed countries it was the incomplete coverage of systems. Resource constraints also contributed to a lack of necessary redundancy in services. The most significant gaps in dissemination processes are summarized below.

Inadequate institutional and legal arrangements - Warning services were limited in many developing countries due to the lack of formal institutional structures with requisite political authority to issue warnings. Clarity with respect to roles and responsibilities in the warning dissemination system was not in place in many countries.

Political failure to take action - At times political considerations (such as timing, lack of resources, fear of litigation, etc.) created breaks in the warning dissemination chain.

Lack of clarity and completeness in warnings issued - Partly due to a lack of standards within and across countries, warning messages were sometimes incomplete and therefore ineffective. There was a lack of clarity due to the missing link of vulnerability acknowledgement - warnings were not often impact based.

Need to strengthen telecommunication systems and technology, particularly for least developed countries - In some countries there were serious shortcomings with respect to updating equipment and linkages to the WMO GTS Regional Telecommunication Hubs. There also was a need to upgrade telecommunications facilities and capabilities in many countries.

Nationally and internationally inadequately standardized nomenclature, protocols and standards - There was confusion in warning dissemination when different issuers used varying protocols for issuing alerts and warnings. This was especially problematic across country borders.

Failure to address the public's interests and concerns - Messages often did not address the recipient's values, interests and needs. If the recipients do not view the warning as relevant they will not act.

Inadequate understanding of vulnerability - There was a need for better integration of risk knowledge in the official warnings. Due to the historical emphasis on the hazard phenomena there was inadequate emphasis on the impacts of the warnings. When the recipients clearly understand how the hazard impacts them they are much more likely to respond.

Proliferation of communication technologies and loss of single authoritative voice - Advances in communication technologies opened access to multiple sources of warning information. The results were untargeted and sometimes conflicting messages inducing incorrect responses.

Ineffective engagement of the media and the private sector - There was a need for training of technical agencies involved in the development of hazard warnings and their stakeholders (e.g. disaster risk managers, media and the public sector) to ensure that warnings are understood and effective actions can be generated.

Ineffective integration of lessons learned from previous warnings - In many countries there was no formal feedback process to ensure that the system continually evolves and improves based on previous experience.

2.4 Emergency response capacity

The success of early warning depends on the extent to which it triggers effective response measures. Prior to the HFA most countries had contingency plans, but often they mainly focused on post-disaster emergency response and recovery.Political momentum was beginning to move toward more preventive strategies where EWS were part of a coordinated process aimed at reducing disaster risks, but in many countries this was in immature stages. Emergency planning ranged from rather complete plans inclusive from national to local levels to nearly non-existent plans in some less developed countries.While there was an understanding of the importance of coordination between various government agencies, the private sector and non-government organizations, coordination was in need of strengthening in many countries. Community preparedness and education was generally in place in many developed countries, however it was lacking in a number of developing and least developed countries.

An important part of improving EWS is incorporating lessons learned by gathering post-disaster successes and failure. While some countries had post-disaster survey processes in place there were many shortcomings in this area. Recurring review and updating of preparedness strategies and plans for response were not universally occurring and rehearsal/drilling of these plans was often inconsistent.

The failure to adequately respond to warnings often stems from a lack of planning and coordination at the national and local levels, as well as a lack of understanding the risks. Some of the gaps and challenges in emergency response capacity were:

Lack of multi-agency collaboration and clarity of roles and responsibilities at national to local levels - Response plans often did not work due to a lack of coordinated reaction among the main actors, in part due to a lack of clarity in the lines of responsibility and authority.

Lack of public awareness and education for early warning response - In many countries response plans existed but were not known to the public because of weak public information and dissemination capacities.

Lack of simulation exercises and evacuation drills - Few countries regularly practiced their preparedness plans. This was one of the priority challenges to enhance warning effectiveness.

Limited understanding of exposure and vulnerabilities and of the public's concerns - Often there was no clear process for integrating risk information into emergency preparedness and response planning which led to people not gaining a full appreciation of the risk.

Need for a participatory approach and inclusion of traditional knowledge - Warnings often failed to induce the desired response because the language of the warnings was too technical or in a format that could not be understood by the stakeholders who were receiving the message. There was a lack of public as well as emergency management agency participation in the development of response strategies.

Need for long-term risk reduction strategies - Efforts to mitigate disaster losses through effective response to early warnings were sometimes ineffective because they focused exclusively on warning response rather than inducing long-term risk-reduction behaviour.

2.5 Policy, legislative, and institutional coordination aspects

Prior to the HFA in many countries there was inadequate political commitment to, and responsibility for, developing integrated EWS. Some of the gaps that existed were:

Lack of legal frameworks for EWS - In many countries the lack of policy and legal framework inhibited the development of EWS as there was no clear line of authority and responsibility.

Weak integration of early warning issues into national plans - Frequently the stimulus for EWS development was post-disaster rather than pro-active.

Inadequate recognition of the links between disaster risk reduction and development - As additional areas of countries were being developed there were significant impacts on EWS and disaster planning. Too often this development was not taken into consideration by NMHSs and other governmental planning agencies when establishing, or updating the end to end EWS.

Insufficient coordination among actors responsible for early warning - Coordination between technical warning agencies and response agencies in some countries was weak or non-existent.

Limited multi-hazard approach to EWS - For the most part EWS were developed to deal with natural hazards with increasing adaptation to human-induced hazards.

Lack of participatory approaches - Too often there was an over-reliance on centralized government direction and limited engagement with social science, NGOs, and the private sector.

3 Progress with the implementation of Early Warning Systems after the adoption of the Hyogo Framework for Action(to present)

There have been several advances in EWS since the adoption of the HFA, however significant challenges still remain. This section will discuss what progress has been made and outline which gaps and challenges remain.

Good practices and guidelines have been documented, synthesized and principals for effective EWS have been developed following ten principles common to the development of Multi-Hazard Early Warning Systems (MHEWS).

Many countries have built their MHEWS on the four operational components, but implementation of each MHEWS varies from country to country. However, a detailed synthesis of seven good practices in MHEWS (from Bangladesh, the megacity of Shanghai in China, Cuba, France, Germany, Japan, and the USA) revealed that, irrespective of political, social, cultural, environmental differences, and institutional factors in each country and despite the individualized approaches to the operation of their MHEWS, the countries/territories have incorporated 10 common characteristics that have led to reductions in losses of life and property from hydrometeorological hazards within their respective jurisdictions.

Additionally, the synthesis makes the case for greater integration of EWS in development, preparedness and planning at all levels of society. It provides the basis for a holistic and systematic approach to the mapping and evaluation of EWS including improvement and sustainability. It offers government officials, heads of agencies and their operational staff as well as other stakeholders in EWS detailed information on policy and legal frameworks, institutional coordination and collaboration, and operational aspects of EWS.

These ten common principles are:

1. There is a strong political recognition of the benefits of EWS reflected in harmonized national to local disaster risk management policies, planning, legislation, and budgeting.

2. Effective EWS are built upon four components: (i) hazard detection, monitoring, and forecasting; (ii) analyzing risks and incorporation of risk information in emergency planning and warnings, (iii) disseminating timely and "authoritative" warnings; and (iv) community planning and preparedness.
3. EWS stakeholders are identified and their roles and responsibilities and coordination mechanisms clearly defined and documented within national to local plans, legislation, directives, MoUs, etc.
4. EWS are supported by adequate resources (e.g., human, financial, equipment) across national to local levels and the system is designed and for long-term sustainability.
5. Hazard, exposure, and vulnerability information are used to carryout risk assessments at different levels as critical input into emergency planning and development of warning messages.
6. Warning messages are (i) clear, consistent and include risk information; (ii) designed with consideration for linking threat levels to emergency preparedness and response actions (e.g., using colours or flags) and understood by authorities and the population; and (iii) issued from a single (or unified), recognized and "authoritative" source.
7. Warning dissemination mechanisms are able to reach the authorities, other EWS stakeholders and the population at risk in a timely and reliable fashion.
8. Emergency response plans are developed considering hazard/risk levels and the characteristics of the exposed communities.
9. Training on hazard and risk awareness as well as emergency preparedness integrated in various formal and informal educational programmes with regular drills to ensure operational readiness.
10. Effective feedback and improvement mechanisms are in place at all levels of EWS to provide systematic evaluation and ensure system improvement over time.

3.1 Risk knowledge

Developed countries have made significant progress in expanding comprehensive multi-hazard risk assessments (UNISDR, 2009;UNISDR, 2011).Recent trends in those countries indicate expansion into multi-sectoral aspects as well expanded documentation for natural and human-made hazards. As an example, in Belgium flood risk management is integrated into river basin management (Cools,2013).In Italy recent revisions to flood plans in the Umbria region followed the same template and included an exposure analysis which defined the exposed population, critical infrastructures at risk, strategic structures or buildings at risk and vulnerable production sites (Molinari, 2013). As illustrated in the publication "Institutional Partnerships in Multi-Hazard Early Warning Systems" (WMO, 2012b), the seven countries documented that they all had a sound foundation in risk assessment across multiple hazards as a fundamental part of their plans. As another example, the European Commission (EC) developed and adopted guidelines for mapping and assessing risk based on a multi-hazard and therefore multi-risk approach (EC, 2007).

Progress in community level risk assessment has also been reported. As an example, in Egypt due to limited availability of flood data, local knowledge of the Bedouins communities has been used to develop the flood risk model (Cools, 2013).New technologies are being developed and research must continue into the applicability of using these tools such as crowd sourcing and GIS. A study has begun on the capacity of using GIS information in the collection and analysis of risks (Guru, 2013), and such research is a fertile ground for future developments.

Some of the most significant gaps in the risk knowledge part of an effective EWS have not changed much since the HFA (are still valid):

Inadequate emphasis on social, economic and environment vulnerability - While there have been limited advances in these areas since the adoption of the HFA considerable work remains to be carried out.

Data gaps - Producing reliable loss and impact information remains a challenge, especially after large disaster or in difficult environments. Most countries report limited data availability and difficulties connecting local disaster impact assessments with national monitoring systems and loss databases (UN, 2011).

Difficulty in accessing information - Countries reported an uneven level of progress depending on technical capacities and resources. At times there remains a reluctance to share this information due to national security concerns.

3.2 Monitoring and warning service

Progress has been made in advancing monitoring and forecast systems. International support and partnerships between government agencies and the private sector have increased capacity in observational networks. An example is the enhancement of telemetric monitoring systems installed at the Enguri Dam in Georgia which were used for research and the development of EWS related to dam failure (Chelidze, 2013).Observations for monitoring of natural hazards in Uzbekistan have been strengthened with improved documentation of dangerous hydrometeorological phenomena (Chub, 2013).This has led to advanced and more structured forecast processes in Uzbekistan. After the 2010 eruption of the MerapiVolcano the observation system for lahars was revitalized in partnership with the people at risk who were enlisted to guard against vandalism to the system (Hardjosuwarno, 2013). And in Italy the Umbria flood network is now capable of integrating early warning modelling systems for floods and landslides (Molinari, 2013).

The lack of adequate observation systems for tsunamis received significant attention in 2004, leading to significant investment in equipment after 2005. Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoys and tidal gauges were deployed not only in the Pacific but also in the Atlantic. While this equipment has been deployed, ongoing maintenance and high operational costs continue to be a challenge. Many significant gaps remain, particularly in developing and least developed countries. Key issues include:

- Inadequate coverage of observing systems;
- Inadequate technical capabilities in the operational technical agencies responsible for monitoring and forecasting of severe events;
- Difficulties in coordination, sharing information and adopting common data standards and methodologies when hazard monitoring is spread across multiple institutions;

- Gaps in monitoring systems for some hazards, particularly for at-risk developing and least developed countries;
- Lack of resources to acquire and maintain equipment;
- Need for improved internationally negotiated data exchange policies and procedures;
- Inadequate access to information concerning forecasts and interpreted data from countries outside of the region affected;
- Need for increased multi-disciplinary, multi-agency coordination and collaboration for improving forecasting tools;
- Need to better integrate risk and impacts into the warning process.

3.3 Dissemination

Technical capabilities to improve dissemination have advanced rapidly over the past several years. While taking full advantage of the new technologies in disseminating the warnings, the currently available dissemination methods can help minimize costs while developing and expanding the dissemination infrastructure.

In many instances these capabilities provide the ability for redundant dissemination and in some instances reduce infrastructure requirements. As an example, in Italy latest advancements in IT such as crowd-sourcing[4]is being tested for integration into the EWS. Leveraging these systems offers promise for overcoming weaknesses in dissemination systems such as the problems encountered when tsunami warnings were not able to reach people in very rural areas (Muhari, 2013). Institutional commitment to developing end-to-end warning systems for major and frequent hazards has improved. For instance, in Uzbekistan warnings are sent to the Ministry of Emergency Situations and other governmental organizations who are responsible for dissemination and activation of disaster risk reduction activities (Guru, 2013). Strong political recognition of the importance of MHEWS is required (WMO, 2012b). While advancements in this area have been made in many countries such acknowledgement is not yet universal. Outreach and education has become a part of enriching the dissemination system in many countries however further strengthening is required.

Some of the significant gaps remaining in enhancing dissemination systems are:

Inadequate institutional arrangements - Warning services were limited in many developing countries due to the lack of formal institutional structures with requisite legal authority to issue warnings. Clarity with respect to roles and responsibilities in the warning dissemination change is not yet in place in many countries.

Failure to take action - At times considerations (such as timing, lack of resources, fear of litigation etc.) created breaks in the warning dissemination chain.

Lack of clarity and completeness in warnings issued - Partly due to a lack of standards within and across countries warning messages were incomplete and therefore ineffective. There was a lack of clarity due to the missing link of vulnerability acknowledgement – warnings were not

[4]The term crowd-sourcing has different meanings depending on the context it is used as. The dictionary definition is: "The practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers".

impact-based. As an example, even in developed countries such as Belgium warning messages lack clarity and are difficult to interpret and use (Cools, 2013). In Italy, a review process of the 10 years of experience with national EWS has provided the means to document lessons learned and future steps for improving the EWS, as well as optimizing warning dissemination in order to achieve efficient, clear and effective messages to the population.

Need to strengthen telecommunication systems and technology, particularly for least developed countries - In some countries there remain serious shortcomings with respect to updating equipment and linkages to the GTS Regional Telecommunication Hubs. There also remains a need to upgrade telecommunications facilities and capabilities in many countries.

Inadequately standardized nomenclature, protocols and standards nationally and internationally - While progress has been made, there was confusion in warning dissemination when different issuers use varying protocols for issuing alerts and warnings. This was especially problematic across country borders. The international Common Alerting Protocol (CAP) can be used to standardize the warning message content and develop unified standards (ITU, 2007). When disseminating the warning messages, appropriate elements could be extracted from the CAP package for defining the content and format of the warming message.

Failure to address the public's interests and concerns - Messages often did not address the recipient's values, interests and needs. If recipients do not view the warning as relevant they will not act. There is trend toward the development of "impact-based warnings" that provide additional information on the potential impacts of the forecasted hazard.

Inadequate understanding of vulnerability - There remains a need for better integration of risk knowledge in the official warnings. When recipients clearly understands how the hazard impacts them they are much more likely to respond.

Inadequate understanding of forecast uncertainties -This can lead to a lack of reliability and credibility of the system.

Proliferation of communication technologies and loss of single authoritative voice - Advances in communication technologies opened access to potential sources of warning information. This has led to confusion by the recipient. A vital part of the dissemination of early warning messages is a partnership between all players to ensure that consistent and complementary messages are issued from a single recognized, official and "authoritative" source.

Ineffective engagement of the media and the private sector - There is a need for training of technical agencies involved in the development of hazard warnings and their stakeholders (e.g. disaster risk managers, media, and the public sector) to ensure that warnings are understood and effective actions can be generated.

Ineffective integration of lessons learned from previous warnings - In many countries there was not a formal feedback process to ensure that the system continually evolves and improves based on previous experience.

3.4 Emergency response capacity

Translating warning into concrete local action is crucial, even in countries with effective capacities for forecasting, detecting, and monitoring hazards and suitable technologies for disseminating advance warnings. In many countries even accurate timely early warnings are often not acted upon effectively (UN, 2011). Increasingly development is leading to multi-sectoral impacts from hazards, and to cascading hazard events such as the 2011 earthquake, tsunami and nuclear accident in Japan (Box 2). There has been good progress in integrating multi-hazard information into multi-sectoral plans but in many countries much work remains to be done (WMO, 2012b). There have been efforts in many countries to improve coordination, outreach and education between governmental agencies, NGOs, the private sector, and those at risk. This has led to a movement toward more effective early warning messages which contain information concerning the risks and impacts expected. As an example, in Brazil the National Civil Defence Secretariat participates in the UNISDR campaign called " Making Cities Resilient: My City is Getting Ready" as an effort to engage multi-sectors in developing emergency response plans (Araujo et al., 2013).

Box 3: Tohoku, Japan earthquake, tsunami and nuclear emergency of 2011

On Friday, 11 March 2011, a magnitude 9.0 (Mw) earthquake struck off the Pacific coast of the Tōhoku region of Japan. The earthquake was one of the most powerful to ever hit Japan as well as in world history. The earthquake triggered a massive tsunami which reached heights up to 40.5 meters in Miyako in Tōhoku's Iwate Prefecture, and which, in the Sendai area, travelled up to about 10 km inland. According to the latest estimates, 15,854 deaths, with 6,114 injured and 3,203 people were still missing. Damages included 146,000 homes and other buildings totally or partially destroyed. The tsunami caused nuclear accidents at three Japanese reactors in the Fukushima Daiichi Nuclear Power Plant complex which resulted in the evacuations of hundreds of thousands of people in the affected area.

The earthquake and tsunami caused over US$200 billion damage in Japan. The tsunami also caused damage over 16,000 km away at Isla Chiloe, Chile; US$6 million in losses to the fishing industry in Tongoy, Chile; US$30 million damage in Hawaii; and US$70 million damage in California, USA. The World Bank's estimated economic cost was US$235 billion, making it the most expensive disaster caused by natural and human-made hazards, in world history.

Sources:

NOAA, "March 11, 2011 Japan Earthquake and Tsunami": http://www.ngdc.noaa.gov/hazard/tsunami/pdf/2011_0311.pdfhttp://www.ngdc.noaa.gov/hazard/honshu_11mar2011.shtml

LA times: http://articles.latimes.com/2011/mar/13/world/la-fgw-japan-quake-insurance-20110314http://articles.latimes.com/2011/mar/21/world/la-fgw-japan-quake-world-bank-20110322

Munich Re Press Release: http://www.munichre.com/en/media_relations/press_releases/2012/2012_01_04_press_release.aspx

The Economist online, "Counting the cost": http://www.economist.com/blogs/dailychart/2011/03/natural_disasters

The ability to respond remains widely variable amongst countries. Many developing and least developed countries are challenged at the local level due to the lack of resources and coordination from the national to local level. While there has been improvement in many areas since the adoption of the HFA, some of the same gaps and challenges still include:

Lack of multi-agency collaboration and clarity of roles and responsibilities at national to local levels - Strengthening of coordination among the main actors continues to be a challenge, in part due to a lack of clarity in the lines of responsibility and authority in many countries.

Lack of public awareness and education for early warning response - In many countries response plans are in place but not known to the public because of weak public information and dissemination capacities.

Lack of simulation exercises and evacuation drills - While an increasing number of countries regularly practiced their preparedness plans, the need for this practice must be emphasized and acted upon.

Limited understanding of vulnerabilities and of the public's concerns **-** In many countries there still is no clear process for integrating risk information into emergency preparedness and response planning which led to people not gaining a full appreciation of the risk.

Weak linkage between technical capacity to issue warnings and localities capacity to respond - Despite increasing abilities to collect and process data and issue early warnings the accessibility of that information and resources to respond to the threats are not even in many countries.

Need for a participatory approach and inclusion of traditional knowledge - Language of warnings, even in some developed countries is too technical or in a format that could not be understood by the stakeholders who were receiving the message. There continues to be weak participation of the public as well as of emergency management agencies in the development of response strategies.

3.5 Policy, legislative, and institutional coordination aspects

Political commitments to, and responsibility for, developing integrated EWS are increasing, in all countries. This is driven in part due to the complexities associated with development that increases the exposure profile of communities and cities to hazards. There remains wide variation in the resources provided to develop and sustain an effective EWS.As laws, regulations and policy have been developed there has been an increasing sensitivity to the need for sufficient resource support and realization of the benefits of such investment. Attempts to share lessons learned have increased through WMO and other UN agencies, funds, and programmes which have been a strong benefit to all nations.

Continued strengthening of plans should follow national and/or regional guidelines to ensure a proper chain of command and integration of actors from national to local level. Under the guidance of the emergency response plans developed by higher authorities, governments at different levels can develop their plans according to their own conditions.

Some of the gaps which remain are:

Weak integration of early warning issues into national plans - Frequently the stimulus for EWS development was post-disaster rather than pro-active planning.

Inadequate recognition of the links between DRR and development - As additional areas of countries are developing there are significant impacts on EWS and disaster planning. Too often this development is not taken into consideration when establishing, or updating EWS. Another area of development impacting the effectiveness of EWS are changes in frequency and intensity of natural hazards due to climate change.

Insufficient coordination among actors responsible for early warning - Coordination between technical warning agencies and response agencies in some countries continues to need improvement.

Limited multi-hazard and multi-impact approach to EWS - While EWS planning is evolving a strong focus still remains on natural hazards. For a disaster which might trigger a chain reaction of disasters, relevant government agencies should discuss and develop a unified comprehensive emergency response plan. The warning dissemination strategy should be mainstreamed into the warming dissemination systems in order to achieve efficient warning dissemination.

Lack of sufficient participatory approaches - Too often there remains an over-reliance on centralized government direction and limited engagement with civil society and other actors. Fostering of partnerships should be expanded.

3.6 Regional and international levels

Since the adoption of the HFA significant progress has been achieved at the regional and international levels to support the development and strengthening of EWS at the national level, benefitting from advancements in science and technology. Examples of these developments include:

Observations:

It is important that there is standardization of observing practices, including the planning of networks on a regional basis to meet the requirements of users with respect to quality, spatial and temporal resolution and long-term stability. The WMO Integrated Global Observing System (WIGOS) provides a new framework for WMO observing systems and the contributions of WMO to co-sponsored observing systems. WIGOS is not replacing the existing observing systems, but is rather an over-arching framework for the evolution of these systems which will continue to be owned and operated by a diverse array of organizations and programmes. WIGOS will focus on the integration of governance and management functions, mechanisms and activities to be accomplished by contributing observing systems.

With the advancements in weather and marine models and weather forecasting (Global Data-Processing and Forecasting System – GDPFS, Box 4), hydrometeorological hazards can be forecasted with lead times ranging from a few minutes (enough to save lives) to several days (enough to save lives and property , for even longer periods at least for some phenomena). Weather forecasting is fundamental to an EWS for meteorological, hydrological, and climate-related hazards. Since the adoption of the HFA, advances in modelling and technology have made forecasts more accurate where 5-day forecasts today are as good as the 2-day forecasts 25 years ago (ECMWF, 2012).

This is exemplified by the WMO Severe Weather Forecasting Development Project (SWFDP), which has been successfully rolled out in five regions: Southern Africa, South Pacific, Eastern Africa, Southeast Asia, and Bay of Bengal (South Asia). It uses a "Cascading Forecasting Process" (global to regional, to national) that provides Forecasters of the NMHS with improved access, as well as effective utilization of existing and newly developed products and tools available through the advanced GDPFS centres. Information is integrated and synthesized by a RSMC, which, in turn, provides daily "guidance" concerning hazardous meteorological conditions and related hazards for the upcoming five-day period to NMHSs of countries in its geographical region. This daily guidance is used by NMHSs to issue alerts, advisories and severe weather warnings at national level for the public and for disaster management and civil protection authorities. The project has improved the ability of NMHSs in these regions to forecast severe weather events; improving the lead-time and reliability for alerts and improving interaction with disaster management and civil protection agencies. The data provided as part of the project enabled the NMHS of Mozambique, for example, to provide warnings of strong winds and heavy rain to the communities five days ahead of the arrival of Tropical Cyclone Favio in February 2007. The alerts have contributed to the significantly lower number of fatalities compared to the devastating floods in early 2000 caused by another tropical cyclone.

Box 4: WMO Global Data-Processing and Forecasting System (GDPFS)

The Global Data-Processing and Forecasting System (GDPFS) of WMO produces and disseminates weather and climate analyses and predictions to enable National Meteorological and Hydrological Services (NMHSs) to provide high-quality meteorological forecasts, warnings and other information services related to weather, water, environmental quality, and climate on a 24/7 basis. Its three-level system – World Meteorological Centres (WMCs), Regional Specialized Meteorological Centres (RSMCs), including Regional Climate Centres (RCCs), and National Meteorological Centres (NMCs) – support NMHSs and their early warning capacities (Figure 4). Improved skills and lead-time of predictions of high-impact weather events have made a major contribution to DRR.

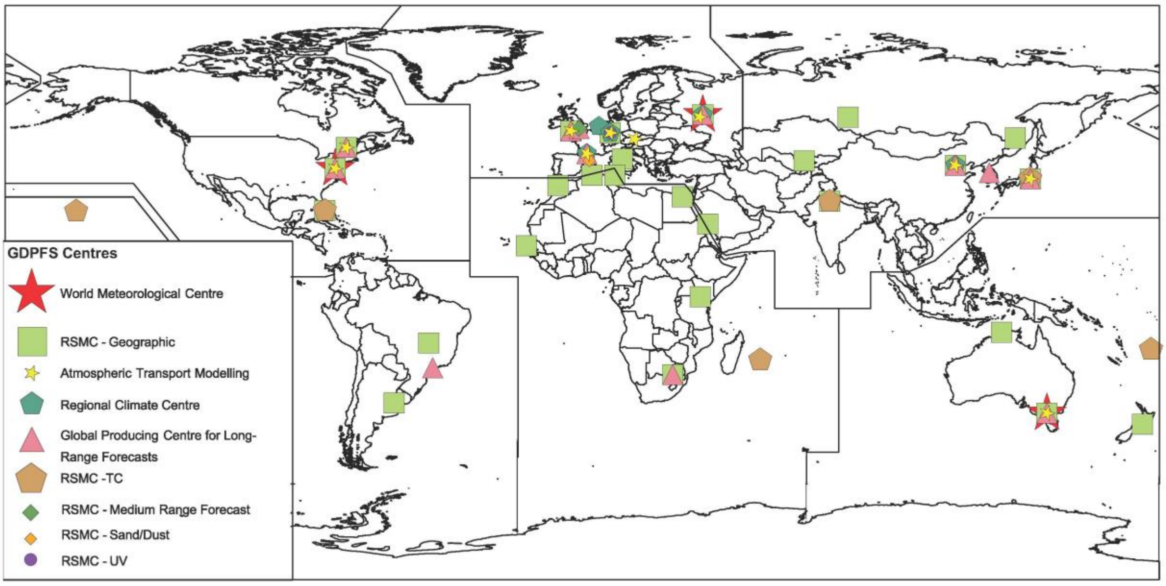

Figure 4: The Global Data-Processing and Forecasting System (GDPFS)

Costal Inundation Forecasting:

Coastal inundation is an increasing threat to the lives and livelihoods of people living in low-lying, highly populated coastal areas. The management of such risk represents a great challenge to scientists and policy-makers in the areas of meteorology, hydrology, oceanography, emergency management, and coastal planning. The WMO Coastal Inundation Forecasting Demonstration Project (CIFDP) was established in 2009 to facilitate the development of efficient warning systems to protect communities from coastal inundation in disaster-prone countries. It aims to build improved operational forecasts and warnings capability for coastal inundation that can be sustained by the responsible national agencies (WMO, 2014a).

The focus of CIFDP is on reducing vulnerability by improving operational forecasts and warning capability on probable risk and impacts by coastal inundation, caused by single or multiple hazards including storm surge, astronomical tides, waves, riverine flooding and sea surface elevation anomalies (Figure 5). Upon completion of national sub-projects of CIFDP, countries will implement an operational system for integrated coastal inundation forecasting and warning, providing objective basis for coastal disaster (flooding) management; contributing to saving lives, reducing loss of livelihood and property, and enhancing resilience and sustainability in coastal communities.

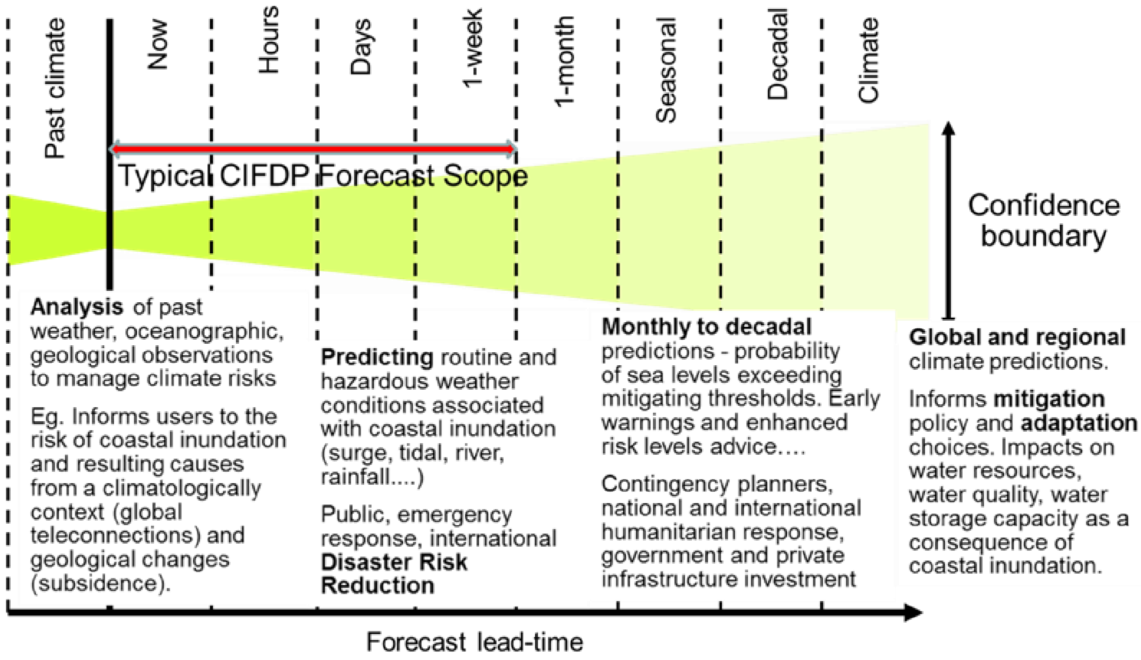

Figure 5: General scope of CIFDP service for forecasting and warning, in the temporal range of service offerings for meteorological, hydrological and oceanographic information for decision making

CIFDP is implemented through a series of sub-projects, based on users' requirements and operated / maintained by national operational agencies with the responsibility for coastal inundation warnings (Figure 6). Throughout the implementing phases of the Project, countries will be provided with valuable input to the assessment and awareness of the issues of coastal inundation management within its governments. At present, four CIFDP sub-projects are being implemented in Bangladesh, Fiji, Indonesia, and the Caribbean region.

CIFDP also offers the development of a seamless and integrated impact-based service that enables people (public), local communities and emergency responders to make timely and effective decisions to reduce the consequences of coastal inundation.

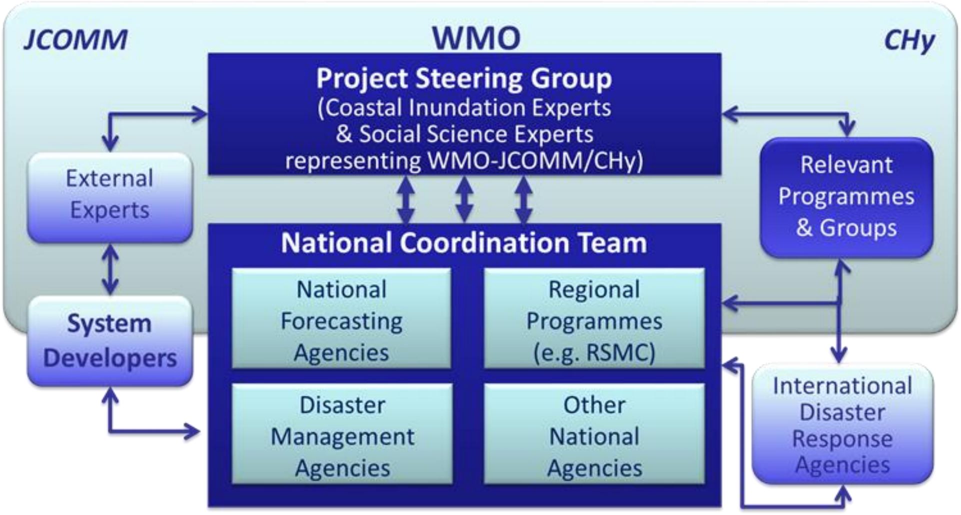

Figure 6: Collaboration of multi-disciplinary stakeholders for CIFDP implementation

Regional Climate Centres:

WMO Regional Climate Centres (RCCs) are Centres of Excellence that assist WMO Members in a given region to deliver better climate services and products including regional long-range forecasts, and to strengthen their capacity to meet national climate information needs. Climate change and its potential impacts have boosted social demands for tailored climate services. By the same time, advances in science and technology provide a multitude of opportunities to build up sustained routines for such services. Constant scientific progress increases humankinds' understanding and provides societies with more and more complex approaches. Accelerated technical advances offer to develop and run more and more sophisticated tools.

Climate analyses as well as seasonal and climate forecasting provide excellent examples of this evolution. Related research and operation requires huge amounts of resources in terms of, e.g. computer power, model research and know-how, IT expertise as well as interpretation capabilities. Therefore, networking and international specialization becomes more and more necessary. At the same time, this approach is a significant contribution to the sustainability of the process.

Regional Climate Outlook Forums (RCOFs): Consensus-driven predictions and outlooks:

Creating a climate forecast is not an easy task, and not all countries have the technology or capacity to create the valuable climate predictions and outlooks. For this reason, among others, in the late 1990's the WMO, NMHSs, regional institutions, and other international organizations initiated an innovative process known as the Regional Climate Outlook Forum (RCOF).

The forums bring together the experts from regions which are climatologically similar and provide consensus-based climate predictions and information. The information is usually based on the season which has the highest socio-economic significance. This information has been applied to reducing climate-related risks and supporting sustainable development. Such forums now exist in many regions across the world indicated in the map to the right.

These forums bring together national, regional and international climate experts, on an operational basis, to produce regional climate outlooks based on input from NMHSs, regional institutions, RCCs, and global producers of climate predictions. By bringing together countries with common climatological characteristics, the forums ensure consistency in the access to, and interpretation of, climate information. Through interaction with sectoral users, extension agencies and policy makers, RCOFs assess the likely implications of the outlooks on the most pertinent socio-economic sectors in the given region and explore ways these outlooks could be used.

Volcanic ash:

The eruption of Iceland's Eyjafjallajökull volcano in 2010 clearly demonstrated the vulnerability of aviation to volcanic eruptions that occur in or near to high density airspace. more than 100,000 commercial flights were cancelled during the volcano's eruptive phase and over US$5 billion in global GDP was lost due to what eventually became the largest shut-down of European air traffic since World War II. International Air Transport Association (IATA) estimated that its airlines alone lost US$1.7 billion due to this single volcanic event.

Advancements in climate prediction and warnings through the Global Framework for Climate Services:

Every year natural hazards cause significant loss of life, and erode or destroy development gains. From the ten most commonly reported disasters, nine are directly or indirectly related to weather or climate. Vulnerability to disasters is increasing as more people and assets locate in areas of high risk.

Over the past five decades, economic losses related to hydro-meteorological hazards have increased, but the human toll has fallen dramatically. This is thanks to scientific advances in forecasting, combined with proactive disaster risk reduction policies and tools, including contingency planning and EWS in a large number of countries.

The emergence of climate prediction provides opportunities to increase the lead times of early warnings. Historical data has traditionally been used for analysis of hazards patterns. But this is no longer sufficient, because hazard characteristics are changing as a result of climate change. Weather and climate services with forecasts from the next hour to seasonal through to decadal time scales are therefore needed to inform long-term investments and strategic planning.

Launched in 2009, the Global Framework for Climate Services (GFCS) aims to enable society to better manage the risk and opportunities arising from climate variability and change, especially in those countries which are most vulnerable to climate related hazards by developing and incorporating science-based climate information into planning, policy and practice (WMO, 2014b). GFCS three pronged approach is hinged on a cascading process from global to regional to national levels in support of provision of climate services. The global level benefits from a network of WMO Global Producing Centres (GPCs) while the regional component is ensured by the operationalization of the RCCs and RCOFs (see above) which provide regional mechanisms for users and providers to effectively interact. At national level, the National Climate Outlook Forums (NCOFs) play a key role in connecting users to providers to effectively use climate services for applications in climate-sensitive sectors.

Sophisticated climate services combine climate forecasts with information from other sectors to inform decisions on public health, agriculture, water management, disaster risk and other priorities. For example, forecasts of drier-than-average periods in the Sahel can be integrated with information about a population's health and maps of available health facilities to support the timely roll-out of vaccines ahead of a meningitis outbreak. The WMO/WHO Atlas of Health and Climate (WHO and WMO, 2012), combines data from the health and climate domains to demonstrate how climate variability and change can influence public health. A monsoon forecast plus information on past cropping decisions and market trends can support decisions on food security. Scenarios of future sea-level rise combined with population trends can shape long-term investments in coastal housing and infrastructure.

While the use of climate information and forecasts is growing rapidly, some 70 developing countries still lack the resources and expertise they need for their citizens to benefit from climate services. The GFCS assists these countries to develop and use climate services. It also promotes international collaboration, the pooling of resources and expertise, and the sharing of best practices. Recent activities include the Climate Services Adaptation Programme in Africa; projects in Haiti, the Caribbean and Asia; and a series of national and regional consultations.

UNESCO-IOC international tsunami standards(using the WMO Global Telecommunication System as the primary means of communication):

Following the 26 December 2004 tsunami in the Indian Ocean, IOC of UNESCO started to coordinate the development of warning systems for the Indian Ocean, the Caribbean and the North East Atlantic, the Mediterranean and connected seas, and continued the work initiated in the Pacific Ocean in 1965.

On the governance side a sustained coordination of the governance groups for the four tsunami warning systems, including its associated technical working groups, enabled the systems to develop. This fostered enhanced awareness and facilitated considerable national contributions in the tsunami warning systems. Many nations have indeed invested considerably in enhancing the up-stream components the tsunami warning system.

After six years of development, the Indian Ocean Tsunami EWS was launched on 12 October 2011.Operational responsibility was formally transferred on 31 March 2013 to the Tsunami Service Providers in Australia, India, and Indonesia from the Japan Meteorological Agency (JMA) and the Pacific Tsunami Warning Center (PTWC) that had provided an interim warning service since March 2005. For the North East Atlantic and Mediterranean Tsunami Warning System region, there has been steady progress towards the provision of tsunami watch services for the region. In July/August 2012 three nations (France, Greece and Turkey) officially announced that their national tsunami watch centres were operational and that they had the ability to act as Candidate Tsunami Watch Providers, pending their accreditation.

Training and awareness play a central role in the development of tsunami warning systems. From 2007 to 2013 IOC organized or co-organized more than 60 workshops on hazard assessment, Standard Operating Procedures (SOPs), coastal inundation modelling and tsunami modelling. It was accompanied by the production of a large set of manuals and guides in various languages helping to increase tsunami preparedness and awareness and best practices.

Another key component of warning systems is the scheduling of tests and exercises. These have now become a regular feature of tsunami warning systems. More tsunami exercises have been carried out and evaluated than at any point earlier in all basins. These exercises have contributed significantly to raising awareness within countries and have created better tsunami-ready citizens.

The tsunami detection network has been strengthened considerably. Many nations have upgraded their seismic and sea level networks and make these observations available in real time to tsunami warning centres. The increasing number of observations is helping to reduce the time for issuing tsunami alerts and helping to confirm or cancel a tsunami warning. As an example the number of sea level stations that contribute real time data to the Global Sea Level Observing System (GLOSS) Data Centres and the tsunami warning centres has increased from 80 to 784 and now 120 national institutions participate in this data exchange. These real time sea level stations contribute to the four regional tsunami warning systems and have enabled development of new tsunami warning products in the Pacific Tsunami Warning System. WMO's Global Telecommunication System (GTS) disseminates tsunami related information and warnings.

As a result of an agreement between IOC of UNESCO and the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in 2010, seismic data from the CTBTO International Monitoring System is now made available to 10 national tsunami warning centres and about 3.2 gigabytes of IMS primary seismic, auxiliary seismic, and hydro-acoustic data is sent in near-real time daily to these centres, providing the centres access to high accuracy seismic data with a close to 100% up-time availability due to advanced equipment and highly reliable data transmission systems.

Extensive training has been provided on SOPs to emergency managers and tsunami warning centre operators, to establish clear and redundant communication links between these two key actors of the warning systems. More than 400 staff members from all basins have been trained on SOPs and many countries now have SOPs in place that enable coordinated response in case of tsunami. National Tsunami Warning Centres have been established in Australia, Colombia, China, Ecuador, El Salvador, France, Greece, India, Indonesia, Italy, Malaysia, Mexico, Nicaragua, Pakistan, Peru, Portugal, Thailand, Turkey, and several other countries.

4 Trends with the developments of Early Warning Systems since the adoption of the Hyogo Framework for Action

Looking at the progress with the implementation of EWS after the adoption of the HFA the following trends are becoming apparent.

4.1 Risk knowledge

Advancements in technology, and development in countries, have led to an increased, shareable database of hazards and the risks inherent to them. Along with the increasingly sophisticated databases, significant effort has been put in to national, regional and international sharing of lessons learned along with access to data. While challenges remain in sharing data, including national security concerns, international cooperation in data sharing and accessibility has improved. Access to, and interoperability with hazard and risk databases is critical to improved modelling for forecasting and response in EWS planning.

Increasingly the emergency management community and academia are reviewing hazard events and publishing information concerning what happened, how well it was warned for, and what were the consequences and efforts required to recover from, and mitigate for the impacts. This information has led to improved EWS as end-to-end systems.

The ability to access and act upon the ever increasing risk knowledge varies widely among countries. Many reasons for this remain, including resources, infrastructure and political support variability within countries. As countries continue to develop, single hazards increasingly have multi-layer cascading impacts upon people, commerce, industry, and infrastructure. HFA has had a positive impact on the growth and sophistication of risk knowledge by focusing efforts on high return activities and generation of resources and support for enhancement of EWS risk knowledge applications. Additionally activities generated by the HFA have facilitated and coordinated development of national strategies and brought together regional working groups to develop and enhance EWS.

4.2 Monitoring and warning service

Scientific advancements -Weather forecasts have become increasingly accurate and available as a result of international co-operation, facilitated by WMO, involving coordinated research and an operational network for monitoring, detecting and forecasting of weather-related conditions engaging NMHSs of 191 Members.

This co-operation together with two major international agreements[5](signed in the 1990s) for the free exchange of "essential" meteorological and hydrological data and information among countries (WMO, 2005), have enabled the systematic collection and sharing of massive amounts of earth observation data, collected through various platforms, as essential input to weather research, modelling and forecasting. The advent of (expensive) space-based and Doppler Radar technologies and the improvement of supercomputers have been a significant factor in improving weather forecasting skills (accuracy). Enormous amount of data, weather forecasts, bulletins, reports, charts and digital products are processed and disseminated daily through the WMO Global Telecommunication System, which interconnects all countries

[5] Resolution 40, "WMO Policy and Practice for the Exchange of Meteorological and Related Data and Products Including Guidelines on Relationships in Commercial Meteorological Activities" was adopted by 12thWMO Congress in 1995 (WMO, 1995). Resolution 25 "Exchange Of Hydrological Data and Products" was adopted by the 13th WMO Congress in 1999 (WMO, 1999). These resolutions have underpinned the exchange of essential meteorological and hydrological data and information among countries in the past decade.

through their national meteorological services. These products are produced routinely by the WMO Global Data Processing and Forecasting System, involving three World Meteorological Centres (WMCs) (USA, Russian Federation and Australia), as well as 40 RSMCs (which are operated by NMHSs) and provided to all countries to support their meteorological services. This international cooperation has led to accessibility of the information developed based on latest technologies to the developing and least developed countries.

Weather-related information and forecasts have become an integral part of decision making in many sectors such as agriculture, food security and safety, transport (air, marine, land), tourism, urban development, energy, water resource management. Investments in national meteorological infrastructure including observing networks, 24/7 operational data management, forecasting and telecommunication systems is central to socio-economic development and EWS.

In recent years, seasonal forecasting has begun to show useful skill. Success in forecasting and analysing the effects of recurrent climatic regimes such as El Niño Southern Oscillation (ENSO) are potentially enabling forecasts with lead-times in the order of a few months in some places, for some time periods during the year, to support warnings and sectoral planning activities. Seasonal forecasting is not yet as useful as short-term weather forecasts, but this technology offers great promise in the future (Livezey and Mayes, 2006).

Partnerships - Increasingly scientific and technological agencies responsible for monitoring, detecting and forecasting hazards are engaging in relevant partnerships with agencies that maintain exposure and vulnerability information. This is leading toward risk-based warning and forecast services. With support from UN agencies, such as WMO and UNESCO-IOC, national capacities in areas such as severe weather, flash flooding and tsunami forecasting has improved. Developing and least developed countries have greater access to the latest technologies and products emerging from the meteorological, hydrological and tsunami communities. However, lack of institutional coordination mechanisms that engage these technical agencies with disaster risk management agencies at the national to local levels is creating a major hurdle for the utilization of these forecasting and warning services in emergency preparedness and response at the local level.

Other challenges include:

Ability to target sectors - In many countries scientific and technological agencies responsible for the issuance of warnings still do not have the capacity and resources to translate authoritative warnings for target sectors and special interest groups such as the tourism sector as an example.

Coordination and synthesis of observing networks - In many countries monitoring networks are expanding in both the government and private sectors, however coordination is lacking in accessing and archiving that information.

Sustainability - Local, national and international support to purchase monitoring equipment is not sufficiently coordinated to provide resources to sustain these systems. As a result valuable monitoring systems can fall into disrepair leaving significant gaps in the EWS.

Box 5: Guidance on Heat-Health Early Warning Systems

Effective climate services can facilitate climate-smart decisions that will, for example, mitigate the impacts of climate-related disasters, improve health and food security outcomes, enhance water resources management, and provide better outcomes in disaster risk reduction.

Heatwaves are among the most dangerous of natural hazards, but rarely receive adequate attention because they lack the spectacular and sudden violence of other hazards such as tropical cyclones or flash floods. Even the related death tolls are not always immediately obvious. For example, the European heatwaves in the northern hemisphere summer of 2003 were responsible for the deaths of tens of thousands of people.

There is an increasing recognition that heat-related risks can be reduced through systematic development of heatwave early warning systems (EWS), alerting decision-makers and the general public to impending dangerous hot weather and serving as advice on how to avoid negative health outcomes associated with hot weather extremes. Considering the need for close coordination between meteorological and health services in this regard, the World Meteorological Organization (WMO) and the World Health Organization (WHO) took the initiative to jointly develop and disseminate guidance on Heat–Health Warning Systems (HHWSs). The Guidance outlines issues surrounding the threat of heat waves; shows how an understanding of the biometeorology, epidemiology, public health and risk communication aspects of heat as a hazard needs to be integrated within EWS for heat waves; and how key players from climate, health, emergency response agencies, decision-makers as well as the media and general public can work together for effective management of heat as a health hazard.

4.3 Dissemination

Social media - The role of social media is evolving quickly to encompass getting hazard information out quickly as well as gathering feedback from the population experiencing the hazard, or hazard risk reduction activities. Social media also has the ability to aid with identification and location of people during emergency situations. There are challenges with the use of social media in the EWS including the authentication of incoming information and the use and propagation of that information. While many countries are beginning to use social media in their EWSs it is still in an early development status.

New technologies - The utilization of new technologies is reducing infrastructure requirements in some instances through a partnership with government agencies and the private sector. In some countries, private companies may provide warning dissemination services, not only to their dedicated customers but also to the general public via internet and mobile technologies.

Advances in dissemination protocols, such as the Common Alerting Protocol (CAP), are facilitating expanded dissemination through various means and partners. However there are limits in that technologies, such as SMS messaging, can be overwhelmed in case of major hazard occurrence. As such, redundancy via traditional dissemination systems is still required for the foreseeable future. The analysis in this chapter was not conclusive on the trends of what was being used indicating that more study is required.

Warning message content - A trend toward harmonization of the content in warning messages was evident in many countries. An example of this evolution is the MHEWS in Southeast Europe Project (WMO, 2012) (Box 6) which was developed through support of the WMO, UNISDR, the World Bank, and UNDP. Further examples are the Meteoalarm programme in Europe (www.meteoalarm.eu) and the MHEWS documented in WMO (2011). This trend is taking place at the local, national, regional and international levels.

Interpretation of probabilistic forecast and warning- As science has improved capacity to produce probabilistic forecasts and warnings there is a challenge in how to present that information. While there is a need for probabilistic information for more sophisticated constituencies in general the public responds best to deterministic information which will evoke the proper response.

4.4 Emergency response capacity

Emergency response capacity is improving in many countries. The greatest challenges remain in developing and least developed countries. Movement toward increasing political support and resources is evident in many countries; however least developed countries still face significant challenges which require international assistance. It should be noted that conducting response exercises at least yearly is critical to an effective EWS, including response programmes.

4.5 Policy, legislative, and institutional coordination aspects

Advances in policy legislation and legal frameworks - There has been a movement in many countries to formalize and more clearly define roles and responsibilities with respect to EWS. However this has not always been translated into operational systems linking national and local levels. There needs to be more emphasis on moving legislation and policy into operations.

Local level emergency planning - In many developing and least developed countries the lack of emergency plans at local levels impedes progress in EWS and risk reduction.It was observed that in cases where these plans do exist at the local levels, they are not aligned, linked and well leveraged with national plans.

Evolution of plans - In many places investments in updating plans, educating constituencies and rehearsing plans are not in place. Too frequently these plans do not target special interest groups whose special needs are not accounted for in the plans. There has been limited development of preparedness programmes.

Lack of multi-hazard/multi-sectoral planning - Many EWS plans are focused on single hazards rather than on multiple hazards. In some countries where local plans are multi-hazard, this is not translated to national levels. Local plans are developed based on community perceptions of local events as opposed to the larger range of events which occur on a larger scale. In many countries emergency plans have not been designed to consider complex emergencies from natural and man-made hazards. Even in some best case scenarios emergency plans have not been designed to consider the extent of risk. There also has been has been a lack of anticipation of emerging risk which arises from cascading events which are becoming increasingly multi-sectoral.

Regional coordination - There has been a trend toward increased international coordination where shared hazards exist across national boundaries.There are still challenges in some areas to fully share information due to national security concerns.

4.6 Overarching trends

The development of EWS primarily has been driven by several major events that have raised significant political awareness. However, it seems that an increasing number of countries are making decisions on developing EWS based on informed risk analysis as part of their development planning. Irrespective of the driver for development of EWS, a clear trend is that for those countries that have developed, and are developing these plans, every event is viewed as an opportunity to re-evaluate and improve their systems. Particularly in developed countries, EWS for natural hazards are being reframed as an integral part of systems that anticipate any threat to national security. These plans are being extended to span not only natural hazards, but also man-made hazards and protection of critical infrastructures in sectors such as energy, water, and food security.

In many countries, EWS have been developed at the national or local level without linkage. In many countries, EWS remains in the territory of disaster risk management agencies without penetration to socio-economic sectors that are fundamental both in the preparedness, response, rescue and recovery phases including; post-event support by organizations such as Red Cross/Red Crescent societies, evacuation, debris removal, agriculture, health, etc. This remains a main challenge for planning, development and effective implementation of EWS. While this planning is starting to gain traction, recent complex disasters demonstrated that even the best plans which anticipate layers and sectors can be challenged and need further development.

Changing characteristics of meteorological, hydrological and climate hazards (severity, location and frequency) associated with climate variability and change pose significant challenges to countries for further development and requisite expansion of EWS into areas that do not have historical exposure to such hazards. This reinforces the critical role of science and technology to advance modelling and forecasting methodologies that allow for improved models of changing risk patterns, and provide for longer lead times to facilitate risk reduction. While forecasting accuracy has improved there is still a reluctance in some government agencies or other authorities in utilizing forecasts and warnings in their emergency response systems. Many reasons exist for this doubt including a lack of understanding of the forecast uncertainties, and the associated costs of activating disaster risk reduction plans. There remains a challenge in identifying forecast uncertainties and the ability to communicate those uncertainties to stakeholders in a way that can be used to make informed decisions.

4.6.1 Multi-hazard, multi-layer, multi-sector approach to Early Warning Systems

At its foundation EWS were developed in response to threats and impacts from natural (meteorological, hydrological, climate-related, geological, etc.) and human-made (technological and chemical, etc.) events which were usually associated with a single hazard. As the ability for forecast and respond to these events has advanced, and increasing risk knowledge and communication abilities have blossomed, EWS have evolved into a system which now addresses multi-hazard, multi-layer and multi-sectoral risks and impacts. Since the adoption of the HFA this transition has accelerated rapidly in developed countries while a slower evolution has taken place in developing countries. The variation in advancement may be attributed to differences in political support, inter-agency coordination and fiscal resources.

As countries continued to evolve with increasingly sophisticated populations and infrastructures, there have been more inter-linkages as natural or human-made events occur. This has required EWS to evolve into a Multi-hazard approach which addresses cascading hazards (e.g. tropical cyclones which results in wind storm damage, flooding, damage and interruption to infrastructure, etc.) and complex natural and human-made events (e.g. the 2011 Tohoku earthquake, tsunami and nuclear accident). As the world has developed and experienced natural and human-made hazardous events it has become clear that inter-relationships between the event and its immediate hazards are becoming more far-reaching. A single event has often cascading impacts which threaten the population, infrastructure and in some cases national security.

In several countries political support and legislation have been enacted to provide a framework upon which to build multi-level, multi-agency, and multi-hazard EWS. There also have been concerted efforts to provide adequate resources to support EWS at national and local levels. In other countries there is usually increasing recognition that political support and legislation is essential to building a strong EWS which can deal with multiple hazards. Multiple efforts have taken place to share best practices to lend credence and support to governments as they tackle the challenges of advancing EWS. These efforts need to be continued and expanded.

Following are examples of significant successes in EWS since the adoption of the HFA:

The Bangladesh Cyclone Preparedness Programme: Saving Lives through an Early Warning System for Tropical Cyclones

In Bangladesh, following the tropical cyclones and storm surges in 1970 and 1991 that led to over 300,000 and 140,000 deaths, respectively, the Government worked together with UN organizations and the Red Crescent Society of Bangladesh to implement a Cyclone Preparedness Programme (CPP). The programme's effectiveness was well demonstrated by the much-reduced death toll – less than 3500 lives lost – during the similar November 2007 super cyclone, Sidr. The CPP uses a network of over 42,000 volunteers, along with a transceiver telecommunications system, to ensure rapid and timely delivery of tropical cyclone warnings produced by the Bangladesh Meteorological Department to the authorities and the public at risk in coastal regions. Over the last 30 years WMO has been working through its Tropical Cyclone Programme (TCP) to establish, with its Members, Regional Specialized Meteorological Centres (RSMCs) with expertise in tropical cyclone analysis and forecasting to support NMHSs. The RSMC-New Delhi works closely with countries at risk from tropical cyclones in South Asia to provide bulletins and forecasts to support NMHSs in developing the respective warnings.

Tsunami Warnings

Considerable progress has been made in the area of tsunami EWS: regional seismic events can be detected and monitored a few minutes after an earthquake may have generated a tsunami. Duty officers at nearly each endangered country can receive tsunami alert information and decide on actions to take at national level, including immediate evacuation or heighten watch status. Despite this progress there are three main areas of tsunami EWS that require additional work towards efficient warning and life-saving. The first one is on community preparedness and tsunami education, at school level, in particular for areas that are prone to local events that can reach the coast in less than 30 minutes. The second is a sustained and improved monitoring system for tsunami, considering recurrent cost for the maintenance and continued operation of sea level observation and seismic monitoring. The third area that still needs improvement is hazard assessment and tsunami modelling, which is critically dependent on near-shore high-resolution bathymetry.

Costa Rica Early Warning System for the Hydrometeorological Hazards Project

In Costa Rica, the SarapiquiRiver and several of its tributaries have a long history of recurrent overflows, generally related to the intensity of the rainy season in the Northern Caribbean. Many of the communities are exposed to the river flooding which is being exacerbated by the growing population in the flood prone areas, which increases the overall vulnerability of the community in the affected areas. On 8 January 2009 a 6.2 magnitude earthquake struck the Cinchona area of Costa Rica which changed the risk scenario in the Sarapiqui basin by changing the drainage patterns and creating new risk areas for flash floods and mudslides. For these reasons, it was necessary to identify the new risks and to support the organization of the communities in the areas of potential impact.

In this regard, WMO, the National Meteorological Institute (IMN), the National Commission of Risk Prevention and Emergency Response (CNE), and the Instituto Costarricense de Electricidad (ICE) combined their efforts to develop an early warning system (EWS) in the Sarapiqui basin and to support the strengthening of the local capacities for the prevention and response of these hazards, through the "Costa Rica Early Warning System for the Hydrometeorological Hazards Project". The project was funded by the World Bank's Global Facility for Disaster Risk Reduction (GFDRR) and was implemented by WMO.

The purpose of the Project was to develop an effective framework for an operational early warning system at the Pilot Site of the Sarapiqui river basin in order to: (a) strengthen cooperation efforts between IMN and CNE in collaboration with other national government agencies and non-governmental organizations at the local level; (b) promote replication at other sites; (c) integrate the Costa Rica legal framework and policy instruments with existing standard operational procedures and protocols; (d) develop a feedback mechanism aimed to improve the preventive approach, overall coordination and operation during its design and implementation; and (e) provide IMN and CNE with the necessary tools to optimize the information for decision making.

The overall objectives of the project were to:

- Carry out an analysis of threats, vulnerability and mapping of hydrometeorological events in the Sarapiqui River basin;
- Carry out the hydrological and hydraulic modelling of the basin and design a protocol based on the rain and flow thresholds that act as input to broadcast the early warnings for flash floods, avalanches and floods; and,
- Carry out an analysis and facilitate a community simulation exercise of the EWS and work with the local communities to ensure the EWS incorporates the additional information/data from the technical part of this project.

The project was completed in 2013 with the following accomplishments:

- Unprecedented level of coordination and cooperation among the three national agencies, IMN, ICE and CNE, at national level and with over 50 Sarapiqui River basin communities.
- A simulation exercise conducted on 28 February 2013 drew over 800 participants – some 500 volunteered to participate in an evacuation exercise coordinated by CNE, the police, the Red Cross and local authorities.
- Communication protocols were established between the scientific entity (IMN) and the CNE.
- Communication protocols between CNE and the communities were established.

Improvement of numeric model prediction used as input of the hydrological model; therefore, enabling the generation warnings with a 24 to 48 hour lead time.

Southeast Europe Project

Even though the Southeast Europe (SEE) region is highly diverse in terms of geography and climate, countries of Western Balkans and Turkey are exposed to a range of similar disasters caused by the impacts of natural hazards, including heavy precipitation causing floods and landslides, droughts and forest fires, earthquakes, prolonged cold and heat waves, and hailstorms. Disasters caused by hydrometeorological hazards already have a significant impact in the SEE region and might affect any country's economic standing and key sectors (agriculture, transport, water management, energy, tourism, finance). Besides their exposure to similar disasters, SEE countries are also often affected by cross-border disasters, as natural hazards do not know boundaries. Floods in transboundary rivers and fires in transboundary forests are frequently crossing borders in the region.

As part of the South Eastern Europe Disaster Risk Mitigation and Adaptation Programme (SEEDRMAP) initiated in 2007 by the World Bank, WMO, UNISDR, and UNDP developed two complementary project proposals that were funded together as the "Regional Programme on Disaster Risk Reduction in South East Europe" by the European Commission (EC) Directorate General for Enlargement, through its Instrument for Pre-Accession Assistance (IPA). This programme is targeting the following eight IPA beneficiaries: Albania, Bosnia and Herzegovina, Croatia, the former Yugoslav Republic of Macedonia, Montenegro, Serbia, Kosovo (as defined by UNSCR 1244/99) and Turkey and were initiated in March 2009. The aim of this project is to reduce the vulnerability of South-Eastern European countries to natural hazards such as drought, flood and forest fires.

The project focuses on building the national and regional capacity of the NMHSs in the provision of reliable weather, water and climate products and services such as hazard analysis to support risk assessment and forecasts and warnings with adequate lead time to support the disaster risk reduction activities of the IPA beneficiary countries and the region as a whole. Building better cooperation between the NMHSs, which are the providers of hydrometeorological information and services and the agencies responsible for civil protection and emergency response, with the main economic sectors, is a primary objective. The project was also intended to underpin a regional approach to DRR by enhancing the interoperability of the national systems and the cross-border exchange of information related to hydrometeorological hazards.

The project has completed an assessment phase and a capacity development phase (Phase I) which focused on building the national and regional capacity of the NMHSs in the provision of reliable weather, water and climate products and services and Phase II which is focused on developing or strengthening national capacities in this region along three components: (i) Disaster risk management institutional capacities and governance; (ii) NMHSs and their cooperation with sectors; and (iii) Financial risk transfer mechanisms, to assist the beneficiaries in reducing risks associated with natural hazards (See map).

The Global Flash Flood Guidance System

Flash floods strike quickly over small spatial scales – yet globally, numerous flash floods are happening at any moment. On average, 14 people die in flash floods every day, while extreme floods affect 500 million people per year. Unfortunately, climate change is expected to increase average temperatures, intensify extreme precipitation, and cause more flooding throughout the world. Yet, many countries still lack the capability to recognize, evaluate, and predict flash flooding, issue flood warnings, and coordinate disaster response. While developing countries suffer the most due to lack of resources, even developed countries have limited flash flood forecast capability in rural and mountainous areas.

Fortunately, the technology now exists to implement systems that empower local forecasters to effectively develop localized warnings for deadly flash floods throughout the world. For example, the Flash Flood Guidance System (FFGS) was designed and developed by the Hydrologic Research Center, a non-profit public benefit corporation located in San Diego, CA, USA, for use by meteorological and hydrologic forecasters throughout the world. The primary purpose of the FFGS is to provide operational forecasters and disaster management agencies with real-time informational guidance products pertaining to the threat of small-scale flash flooding throughout a specified region (e.g., country or portion of a country, several countries combined). Similar guidance systems for flash floods are now operative in some countries.

The FFGS provides the necessary products to support the development of warnings for flash floods from rainfall events through the use of remote-sensed precipitation (e.g., radar and satellite-based rainfall estimates) and hydrologic models. The FFGS outputs are made available to users to support their analysis of weather-related events that can initiate flash floods (e.g., heavy rainfall, rainfall on saturated soils) and then to make a rapid evaluation of the potential for a flash flood at a location. To assess the threat of a local flash flood, the FFGS is designed to allow product adjustments based on the forecaster's experience with local conditions, incorporation of other information (e.g., Numerical Weather Prediction output) and any last minute local observations (e.g., non-traditional rain gauge data) or local observer reports. The system supports evaluations of the threat of flash flooding over hourly to six-hourly time scales for stream basins that range in size from 25 to 200 km^2 in size. Important technical elements of the FFGS are the development and use of a bias-corrected radar and/or satellite precipitation estimate field and the use of land-surface hydrologic modelling. The system then provides information on rainfall and hydrologic response, the two important factors in determining the potential for a flash flood. The system is based on the concept of Flash Flood Guidance and Flash Flood Threat. Both indices provide the user with the information needed to evaluate the potential for a flash flood, including assessing the uncertainty associated with the data.

- Flash Flood Guidance is the amount of rainfall of a given duration over a small stream basin needed to create minor flooding (bankfull) conditions at the outlet of the stream basin. For flash flood occurrence, durations up to six hours are evaluated and the stream basin areas are of such a size to allow reasonably accurate precipitation estimates from remotely sensed data and in-situ data. Flash Flood Guidance then is an index that indicates how much rainfall is needed to overcome soil and channel storage capacities and to cause minimal flooding in a basin.
- Flash Flood Threat is the amount of rainfall of a given duration in excess of the corresponding Flash Flood Guidance value. The flash flood threat when used with existing or forecast rainfall then is an index that provides an indication of areas where flooding is imminent or occurring and where immediate action is or will be shortly needed.

In February 2009, a Memorandum of Understanding (MOU) was signed among WMO, the U.S. Agency for International Development/Office of U.S. Foreign Disaster Assistance (USAID), the U.S. National Oceanic and Atmospheric Administration/National Weather Service (NOAA/NWS), and the Hydrologic Research Center to work together under a cooperative initiative to implement the FFGS worldwide. The MOU is in effect through 2017. The 15th WMO Congress officially sanctioned the Flash Flood Guidance System through unanimous approval by representatives of all countries.

4.6.2 Challenges and opportunities for Early Warning Systems within a changing climate

Since the adoption of the HFA, countries have made advances in understanding linkages between short fused events and changes in the climate. Improvements in cataloguing details of events and the ability to share and analyze these databases has led to improved longer range forecasting, and more thorough risk analysis. Furthermore, improved inter-agency coordination at the national, state and local level has strengthened EWS as hydrometeorological agencies have become active, trusted partners in the development of risk management plans. This is especially true at the national to local level in developed countries. Progress has been slower in developing countries as they face challenges in resources and inter-agency coordination from the national to local level.

Although climate change is expected to change the intensity, frequency and duration of weather hazards in addition to exposure to these hazards, scientifically, no one single disaster can be attributed directly to climate change. Climate is only one of many complex factors contributing to disasters. Non-climatic factors such as lack of capacity, lack of governance, environmental and natural resource degradation, population growth, rapid urbanization, poverty, settlement in hazard prone areas and many other non-climatic factors determine whether a weather or climate-related hazard transforms into a disasters or not.

4.6.3 Role of science, technology, and engineering

The past decade has produced significant advances in monitoring, forecasting and cataloguing hazard events, especially in developed countries. International cooperation in studying the science behind detecting and forecasting natural and human-made hazards has led to advances in predictive accuracy and increased lead time (Figure 7). Rapid advances in information technology (IT) have aided these advances by providing the ability to process and share rapidly expanding datasets. These datasets are a result of improved and expanded monitoring systems, recognition of the value of post event analysis and more detailed risk analysis, both before and after events. EWS are now able to be based upon more data and stronger science.

With these improvements come challenges related to the uncertainties of longer term forecast hazard events. Since the adoption of the HFA, EWS have moved from a system which, especially in developing countries, was frequently detecting an on-going or imminent event, to an end_to_end system forecasting events out to days, weeks, months, and even longer in advance. As the lead time for an event warning increases, so do the possible future range. This has presented new challenges in how to best communicate the threat without unduly alarming those in harm’s way. Many developed countries have seen evolution of their EWS to more effectively communicate uncertainty. This can be seen at national to local levels, and in many areas of the globe EWS have seen regional collaboration designed to provide a more standard EWS methodology. Sharing of best practices from these EWS with developing countries has begun and should continue to be supported.

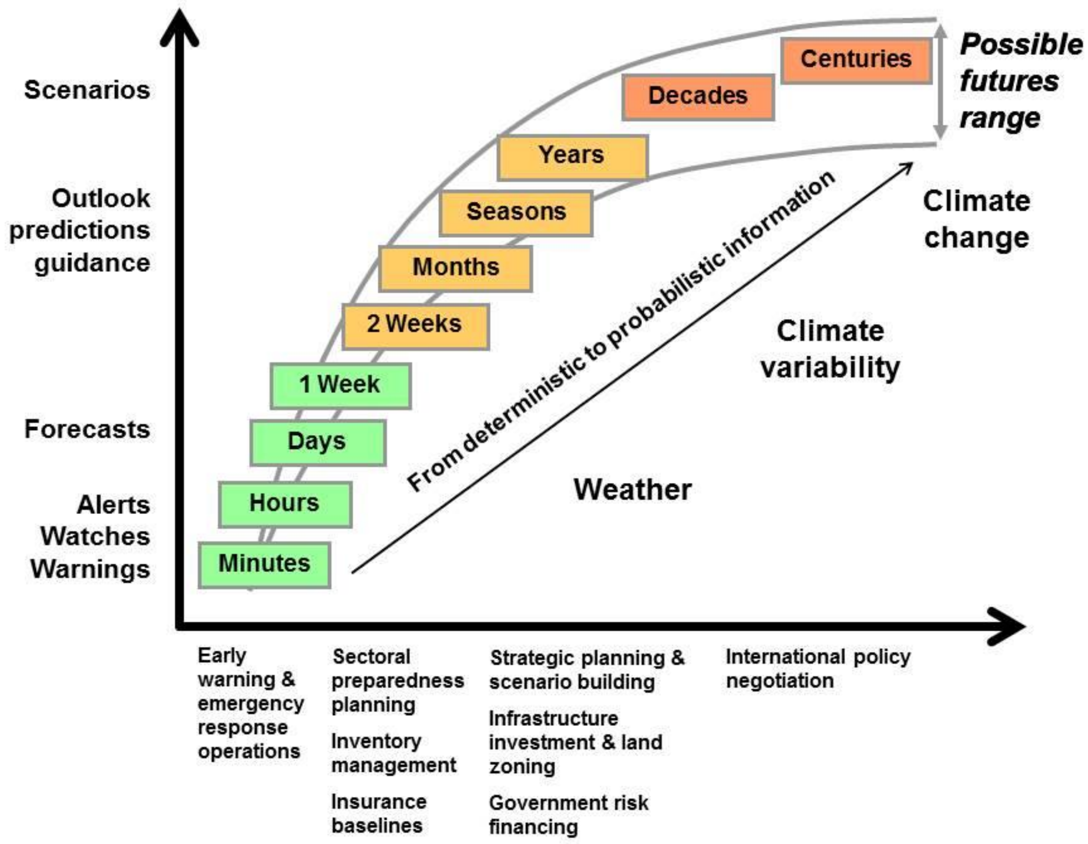

Figure 7: Seamless hydrometeorological and climate services for various risk management applications

Since the adoption of the HFA, there have been advances in making warning messages more impact-based with additional information on specific actions to be taken included. People respond much more readily when they clearly understand what an early warning message means to them and what they have to do to protect life and property. The evolution of warning messages from technical information into actionable warnings is not a trivial task. To accomplish this, strong multi-agency coordination from the national to local level is required to ensure consistent, understandable messages. Close collaboration between many governmental agencies, including emergency management, hydro-meteorological, geophysical, and infrastructure agencies, to name a few, is required.

Developed countries have seen many advances in communication technologies. These advances have been slower in developing countries where resources are more limited. While new communication technologies enable to transmission of more information more quickly, traditional communication systems are still effective in a number of countries. Since the adoption of the HFA, both traditional communications and new systems have been important players in effective EWS. While the advancements in communication, especially the Internet and mobile computing and communication devices have provided the ability to more quickly provide more information to the people affected by hazards, it also has provided challenges. Many different sectors including, government, media and private enterprise have access to these technologies. Without established protocols and regulations, there exists the possibility of conflicting and confusing information reaching those at risk. In countries where those protocols are in place through governmental and private sector coordination, and effective legislation, the EWS is working as one official voice. Management of official communication systems and protocols remains a top priority.

4.6.4 Institutionalizing Early Warning Systems

Attainment of maximum effectiveness of EWS requires implementation of respective policies, inter-agency coordination, monitoring and warning, risk analysis, communication and emergency planning and response measures. A first consideration is the recognition at the national to local level that governmental support and legislation play a key role in the evolution of an effective EWS. It is critical that roles and responsibilities are clearly defined, most effectively through legislation, and that all participants understand their role. The level at which emergency planning and response takes place varies among countries. Within those boundaries it is important that local emergency planners and responders feel empowered to receive EWS messages in ensure that initial actions are initiated to protect life and property.

While this requirement starts at the country level, trans-boundary large scale hazards such as basin level flooding, tropical storms, droughts, fires and tsunamis, require international and regional institutionalization. Since the adoption of the HFA, there has been progress, but more remains to be done, especially in developing countries and on an international and regional basis. Standardization of impact based warning messages, communication systems and response planning remains to be accomplished in some areas and for some hazards. Some examples of success in this area since HFA are international centres such as the tropical storm forecast centres and tsunami warning centres which play a key role in coordination for development and communication of warnings.

5 Summary and conclusions

There has been considerable progress in meeting the EWS goals of HFA, however many gaps and challenges remain. Especially noteworthy in the maturation of EWS is the trend to become more people-centred and risk- and impact-based. There are many factors supporting this improvement including improvements in risk assessments and mapping, scientific and technical advancements, supporting public policy and dissemination capabilities. Many international agencies, including WMO, have worked to support capacity building, technical transfer, sharing of best practices and development of regional and international partnerships. Additionally, countries have moved to strengthen multi-agency participation in the development and maintenance of EWS from the national to local level. As countries continue to move to a more risk and impact centred approach, EWS are evolving to a multi-hazard approach with an eye toward impacts on infrastructure and national security. The move toward impact based warnings has made the warning messages easier to understand, and there is evidence that this has led to increased response for the protection of life and property.

While considerable progress has been made in meeting the goals of HFA much work remains to be done, especially in developing and least developed countries. HFA 2005-2015 provided a sound framework to focus international activities to successfully support the expansion and improvement of EWS.

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7 Annex

Annex 1:

A Template for review and documentation of Early Warning Systems

1) Overview of Early Warning Systems (EWS)
2) Background in the establishment of EWS
3) Governance and institutional arrangements (national to local levels)
    a) Policy, intuitional and legal frameworks to support emergency planning and response
    b) National to local emergency planning and related linkages to EWS
    c) Organizational structure for implementing the plans
    d) Penetration in the sectors for coordination of emergency planning and response activities
    e) Institutional capacities and concept of operations (coordination and operational collaboration)
    f) Financial and budgetary aspects
4) Utilization of risk information in emergency contingency planning and warnings
    a) Organizational responsibilities and arrangements for the development of risk information
    b) Hazard assessment, quantification and mapping (national to local)
    c) Assessment of vulnerabilities and exposure (national to local)
    d) Storage and accessibility of disaster and national hazard risk information
    e) Development and utilization of hazard/risk information to support emergency planning and warnings
5) Hazard monitoring, forecasting, and mandates for warning development
    a) Organizational responsibilities for monitoring, forecasting and development of hazard warnings
    b) Organizational collaboration and coordination for development of hazard warnings
6) Development of understandable, authoritative, recognizable and timely warnings
    a) Warning message development cycle
    b) Warning message improvement cycle
7) Warning dissemination mechanisms (national to local)
8) Emergency preparedness and response activities (national to local)
    a) Disaster preparedness and response planning and emergency response activation
    b) Community response capacities
    c) Public awareness and education
9) Sustainability, resources and budgetary commitments
10) Improvement of overall operational framework of EWS through on-going drills and feedback and evaluations during and after an event

11) Examples of previous events where the operational EWS has led to improvements in emergency preparedness and prevention

12) Overall lessons learned and future steps for improving meteorological, hydrological and climate services contribution in EWS particularly focusing on institutional coordination and cooperation with the disaster risk management agencies and EWS stakeholders (public and private)

Annex 2:

WMO Questionnaire on Multi-Hazard Early Warning System Changes since 2005

November 2013

(Responses included for each question)

This survey is related to the initiatives of the United Nations Office for Disaster Risk Reduction (UNISDR) in collaboration with the World Meteorological Organization (WMO) and a number of other UN and international agencies for the development of the Global Risk Assessment Report 2015 (GAR15).GAR15 will be published prior to the Third UN World Conference on Disaster Risk Reduction in 2015, in which governments will adopt a successor framework to the Hyogo Framework for Action (HFA).

Nine countries/territories responded to the survey, including: Union des Comores, Syria, British Virgin Islands, Mozambique, Algeria, Portugal, Guinea, Bahrain, and New Zealand.

Survey questions:

1. Have there been enhancements to policy or institutional frameworks that support emergency preparedness and response planning?
   Yes 9
   No 0
   If yes what?
2. Coordination between national, regional and local governments:
   Remained the same 3
   Improved 6
   Lessened 0
3. Partnerships with the private sector have:
   Improved 7
   Remained the same 1
   Lessened 1
4. With respect to funding for MHEWS has it:
   Increased 3
   Decreased 1
   Remained the same 6
5. Have capabilities for monitoring hazards improved?
   Yes 8
   No 1
   If Yes how?
6. Have forecasting capabilities for hazard events improved?
   Yes 5
   No 4
   If Yes how?
7. Has hazard forecast accuracy and timeliness improved?

Yes	4
No	2

If Yes how?

8. Have there been improvements in communicating hazard warning information to governmental and private entities and people at risk?

Yes	7
No	0

If yes what?

9. Is there increased utilization of risk information in emergency planning and warning?

Yes	6
No	1

10. Have local governments increased their participation in identifying and planning for responding to hazard events?

Yes	6
No	1

If yes how?

11. Do cooperating partners routinely review and revise MHEWS processes as needed?

Yes	5
No	2

If yes how frequently?

12. Are adequate resources available to sustain monitoring of hazard information?

Yes	4
No	3

If No, what is needed?

13. Are adequate resources available to sustain forecasting and communication of hazard information?

Yes	4
No	3

If No, what is needed?

14. Are adequate resources available to sustain communication systems for hazard information?

Yes	3
No	3

If No, what is needed?

15. Is the catalogue of natural and man-made hazards more complete than in 2005?

Yes	6
No	1

16. Do you have a national to local hazard risk map?

Yes	5
No	2

17. After a hazard warning or event is there a review of successes and areas for improvement?If so, by what agency/agencies?

Yes	7
No	1

Who?

18. Partnering between NMHS and other governmental agencies involved in disaster planning and response has:

Improved	3
Remained the same	4
Lessened	0

19. Does your country feel your MHEWS is adequate to deal with all hazards? If no what areas need enhancement?

Yes	2
No	4

Enhancements needed:

Annex 3:

Capacities and gaps prior to HFA 2005-2015 (UN Global Survey of Early Warning Systems, 2006)			
Hazard Class	**Hazards**	**Capacities**	**Gaps**
Hydrometeorological	Floods	- Agencies responsible for monitoring flood events vary by country - Dedicated systems to monitor & forecast river basins were well established in developed countries	- Dedicated systems were much less widespread in developing countries - Sharing of data between countries was lacking in some areas
	Tropical Cyclones	- Tropical cyclones were globally monitored and forecast on a daily basis through the WMO Global Tropical Cyclone Warning System - There were six Regional Specialized Metrological Centres that provide forecasts, alerts and bulletins to NMSs	- In some countries improvements were required in disseminating the alerts - Coordination of response required strengthening
	Severe Storms	- Tornado warning systems were only operational in a few countries at risk - Windstorm warning systems were in place in many countries	- Operational warning systems for severe storm hazards were lacking in many countries and regions - Communication systems needed strengthening - Standardization of messages was not common
	Drought	- Traditional forecasting was an important source of drought information in many rural communities	- EWS for drought were relatively less developed globally however some countries had developed drought EWSs
	Extreme Temperatures	- The health sector normally issued warnings based upon	- Impact information not readily available in warning messages

Capacities and gaps prior to HFA 2005-2015 (UN Global Survey of Early Warning Systems, 2006)			
Hazard Class	**Hazards**	**Capacities**	**Gaps**
		NMHS observed and forecast data	- Dissemination improvements needed
	Air Pollution, haze and smoke	- Observation and forecasting of atmospheric conditions conducive to the formation and movement of these phenomena was occurring - Satellite observations were very useful in this process	- Improvements in dispersion modelling were needed - Impact information not included in warnings
	Dust and Sandstorms	- Satellite and ground observational data available in developed countries	- There was a need for up to date information on global climate patterns for monitoring weather conditions conducive to these phenomena - There was a need for development of dust and sand storm warning systems in most countries facing that risk. - Satellite and ground observational data not readily available in many at risk countries
	Snow avalanches and winter hazards	- Winter hazard warning services were well developed in many countries - Winter weather (heavy snow, blizzard, ice storms, etc.) were forecast as part of operational forecast and warning services	- Regional standardization of warning messages was not always occurring - Impact information not included in warnings
	Famine	- EWS for food security in many developing countries made use of information from the major international food security monitoring systems - The majority of food security warning systems operated in Africa, however they also cover parts of central Asia, of	- Food security warning systems needed in many countries at risk - Inter-agency coordination not as robust as required in some countries

Capacities and gaps prior to HFA 2005-2015 (UN Global Survey of Early Warning Systems, 2006)			
Hazard Class	**Hazards**	**Capacities**	**Gaps**
		Central America and of the Caribbean.	
Geological	Earthquakes	- Earthquake prone areas and plate boundaries had been identified and extensively studied - Regional earthquake monitoring systems had been installed in most earthquake prone regions	- Prediction capability for earthquakes was elusive and the location, timing and magnitude of occurrence could not be forecasted
	Tsunamis	- An ocean-wide warning system under the auspices of the IOC was operational in the Pacific region - Experimental warning systems existed in many parts of the world	- There was no global tsunami EWS - Technical monitoring capacity needed to be completed
	Volcanoes	- Prediction of timing had been accomplished - Satellite based systems for global monitoring were established by ICAO and WMO	- Size, duration and climax of an eruption could not be predicted - Capacity for monitoring varied globally especially in large areas of the developing world
	Landslides	- Modelling techniques were improving where real-time data was available	- Monitoring technology was only available in a few areas subject to landslide risk
Biological	Epidemics	- Surveillance systems for epidemics and pest infestations globally were at various stages of development and effectiveness	- Epidemic EWS were undeveloped in several developing countries - The most pressing need for malaria EWS was in Africa, south and east Asia and South America
	Locust Swarms	- Warnings were based on biological modes,	- WMO was working with NMHSs to enhance monitoring

Capacities and gaps prior to HFA 2005-2015 (UN Global Survey of Early Warning Systems, 2006)			
Hazard Class	**Hazards**	**Capacities**	**Gaps**
		observations and meteorological data - Desert Locust Information Service of FAO prepared medium and long-term forecasts	
Environmental	Desertification	- Difficult to predict due to complexity of the interaction of multiple driving forces	- Knowledge gaps in translating broadly accepted principles of EWS into action-oriented modalities
	Wildland fire	- Fire danger ratings in use in many areas of the world	- No international fire warning system existed