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WMO OMM

Weather • Climate • Water
Temps • Climat • Eau

Наш исх.: № WDS/DRR/GAR15-2 ЖЕНЕВА, 23 сентября 2014 г.

Приложение: 1 (имеется только на английском языке)

Вопрос: Предложение рассмотреть проект справочного документа ВМО и представить по нему комментарии

Уважаемый господин/Уважаемая госпожа!

Ссылаясь на циркулярное письмо PR-6718 от 23 августа 2013 г., в котором содержалось предложение представить тезисы материалов к Глобальному докладу об оценке рисков 2015 г. (ГДО15), рад сообщить Вам, что в настоящий момент ведется процесс рассмотрения, координируемый Международной стратегией Организации Объединенных Наций по уменьшению опасности бедствий (МСУОБ ООН).

Являясь совместной инициативой учреждений Организации Объединенных Наций, международных банков развития, правительств, организаций гражданского общества, университетов и экспертных учреждений, этот двухгодичный доклад представляет глобальные модели рисков, тенденции и прогресс в деле уменьшения опасности бедствий. Его целью является информирование по вопросам разработки политики и принятия решений правительствами и неправительственными организациями в процессе уменьшения опасности бедствий. ГДО15 будет выпущен на третьей Всемирной конференции по уменьшению опасности бедствий в марте 2015 г. в Сендае, Япония.

В этой связи в качестве вклада в ГДО15 ВМО выпускает справочный документ по системам заблаговременного предупреждения и обслуживанию «The Status and Trends with Development of Early Warning Systems for All Major Hazards and Outreach to Communities» (Состояние и тенденции развития систем заблаговременного предупреждения для всех основных видов опасных явлений и оповещение населения). Он послужит важным справочным материалом для написания ГДО15.

Был бы признателен, если бы Вы рассмотрели и представили комментарии, а также дополнительную информацию к прилагаемому проекту справочного документа.

Постоянным представителям (или директорам метеорологических или гидрометеорологических служб) стран – членов ВМО (PR-6795)

Копии: Советникам по гидрологии постоянных представителей

Буду признателен, если Вы отправите свои комментарии по вышеупомянутому проекту до **3 октября 2014 г.** включительно в Секретариат ВМО, вниманию д-ра Сю Танга, директора Департамента по метеорологическому обслуживанию и уменьшению опасности бедствий (xtang@wmo.int).

С уважением,

(Дж. Ленгоаса)
за Генерального секретаря

SYNTHESIS OF THE STATUS AND TRENDS WITH THE DEVELOPMENT OF EARLY WARNING SYSTEMS FOR ALL MAJOR HAZARDS AND OUTREACH TO COMMUNITIES

A CONTRIBUTION TO THE GLOBAL ASSESSMENT REPORT 2015 FOR PRIORITY FOR ACTION (PFA) 2 – CORE INDICATOR (CI) 3: EARLY WARNING SYSTEMS ARE IN PLACE FOR ALL MAJOR HAZARDS WITH OUTREACH TO COMMUNITIES

WMO

8/28/2014

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Introduction

The second high-priority area of the Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (hereafter referred to as HFA) stresses the need for, "identifying, assessing and monitoring disaster risks and enhancing early warning." The HFA further stresses that Early Warning Systems (EWS) must be 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 building resilience in anticipation of disasters. The Second International Conference on Early Warnings (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, forecasted, and hazard warnings are developed;
- **Dissemination:** Warnings are issued (by a 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.

Indeed, 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. Implementation of these components requires coordination across many agencies at national to local levels for the system to work. Failure in one component or lack of coordination across them could lead to the failure of the whole system. The issuance of warnings is a national responsibility; 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.

Various assessments and the outcomes of the mid-term HFA review in 2010 have revealed that many nations around the globe operate EWS for various natural and man-made hazards. However, the governmental priority, stage of development and overall effectiveness of the EWS at national to local levels, vary widely. Many countries, especially those with the highest risks and least resources, remain highly challenged in building and sustaining their EWS at national to community levels.

The Global Risk Assessment Report 2015 (GAR15) input on this core indicator will serve five primary objectives, including, (1) document country, regional and global coordinated initiatives for development of EWS underpinned by HFA (2) assess current state of implementation of EWS at the country level spanning governance, key drivers (e.g., risk-based), institutional coordination (national and local), sectoral penetration, operational and technical aspects, (3) assess current state of (sub) regional efforts, for development of inter-operable national EWS, (4) evaluate different approaches among developed and developing countries and fundamental principles that have led to the implementation of effective EWS, irrespective of different governance and institutional structures, socio-economic, cultural aspect as a way to develop a framework for monitoring and measuring performance at the country level, and (5) latest trends and future developments of EWS.

Following this introduction, Section 2 explains the methodology and sources used to arrive at the information presented in the following sections. Section 3 defines the five aspects that compose an early warning system at the national, regional and international levels. Section 4 presents the status of EWS at the national, regional and international levels prior to the adoption of HFA while Section 5 reviews progress with the implementation of EWS after the adoption of HFA. In Section 6, the overarching trends in the development of EWS since the adoption of HFA are discussed. Challenges and successes in the institutionalization of EWS will be detailed in Section 7. Section 8 will present a summary of the status of EWS along with conclusions. Finally, Section 9 will provide a list of references utilized in this chapter and Section 10 contains the Annexes.

Methodology and Sources

The synthesis provided in this chapter is based on two types of sources including primary sources 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 the 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). After review of the abstracts invitations were made to develop full GAR15 input papers and those papers have constituted the primary sources. Submitted papers are listed in the References (Section 9) References.

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 HFA has 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)

Secondary Sources:

A list of secondary resources was utilized for this report and is provided in the References (Section 9). These resources provided information on status of the EWS since the adoption of HFA.

Several sources were used to determine the progress since HFA, however recent documents were limited as the UNISDR call for papers resulted in only 9 submissions. In November 2013 a survey was developed by WMO (Annex 2) and administered by UNISDR. That survey provided results consistent with review of documents, however only 9 countries responded to all or part of the survey (Union Des Comores, Syria, British Virgin Islands, Mozambique, Algeria, Portugal, Guinea, Bahrain and New Zealand). 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, 2012) and the Caribbean Multi-hazard Assessment (WMO, 2011).

What is an Early Warning System?

National Level

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 (Golnaraghi, 2009). The Second International Conference on Early Warnings (2003) defined four components of EWS, as illustrated in Figure 1, including:

- **Risk knowledge:** Risks are analyzed and this information is incorporated in the warning messages;
- **Monitoring and warning service:** Hazards are detected, monitored, forecasted, and hazard warnings are developed;
- **Dissemination:** Warnings are issued (by a 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.

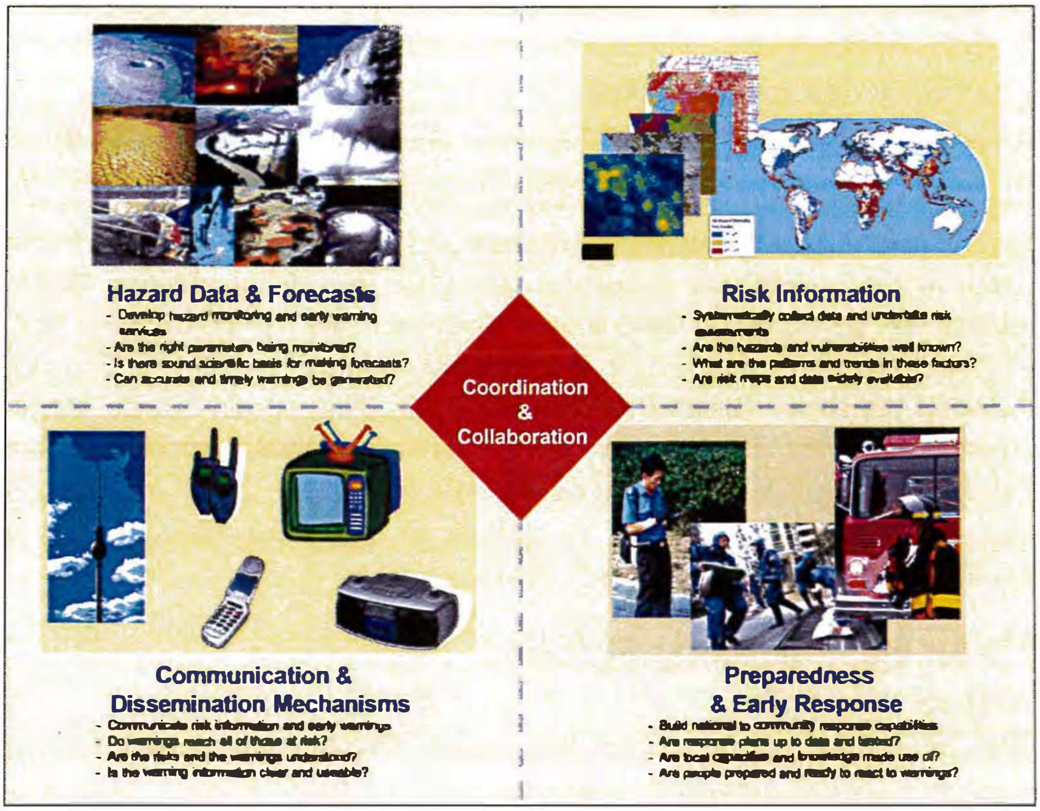

Figure 1: Four components of an Early Warning System as defined in the Second International Conference on Early Warnings (2003)

For an EWS to be effective, it is critical that countries develop policy, legislation and institutional coordination and define formally roles and provide support for development and sustainability of such systems. Implementation of the four components requires coordination across many agencies at national to local levels. Failure in one component or lack of coordination across them could lead to the failure of the whole system. The issuance of warnings is a national responsibility; 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, budgets, coordination, and operational mechanism.

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.). 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 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. 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 (Figure 1).

Hazard events are characterized by magnitude, duration, 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 disaster impacts. These defining characteristics provide a basis for extracting information on hazard frequency and severity from observational datasets. A fundamental requirement of risk assessment is the availability of, and access to, high quality historical data. This requires:

- Ongoing, systematic and consistent observations of hazard-relevant hydro-meteorological 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 (i.e., severity, frequency, location) are changing as a result of climate change, analysis of historical hazard data serves as a benchmark, and is no longer sufficient. For instance a 100-year flood or drought may become a 30-year flood or drought or, simply said, more severe events could happen more frequently in the future. In addition, hazards are occurring in regions where they did not occur based on the past records and thus nations have not anticipated to develop EWS and emergency preparedness measures. Thus, there is need for advancements in forward looking forecasts and analysis of characteristics to enable informed decision-making for investments in development of EWS.

Furthermore, access to (near)real-time risk information would allow development of risk-based warnings which are more meaningful and can inspire sound and more focused decisions, pertaining to evacuations, and preparedness measures before an event.

Monitoring and warning service:

Development of early warnings requires systematic and consistent real-time monitoring and detection of hazards, operational forecasting and observation capacities on a 24/7 basis, forecasting and modelling capacity to predict natural hazards, the capacity to disseminate that information to appropriate partners and constituencies, and continual review and analysis of forecast and warning accuracy. Maintenance of such a system is resource intensive, but it is critical to a successful EWS.

A sufficient network of monitoring and detection systems and reliable communications to collect and process that data is required. Maintenance and updated requirements to keep these systems operational should not be overlooked. 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 of hydro-meteorological and tsunami modelling and forecast centres must be adequate to support 24/7 operations. Another underlying resource factor is sufficient training enabling this staff to remain current with the latest modelling, analysis and forecast techniques. This is critical in the development of timely and accurate forecasts and warnings.

Adequate computer resources, and/or collaboration and partnerships with other entities, to support modelling, forecasting and development of warnings are necessary. Along with that is the need to provide the ability for research and development, and/or the ability to ingest sound scientific processes from the private sector, academia or other governmental agencies. Critical to the success of any EWS is the level of confidence in the accuracy of the 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.

Once forecast and warning information is developed it is critical that systems are in place to allow that information to get to partners and constituencies responsible for taking emergency actions to respond to the threats. Even the best forecast and warnings are not effective if they are not timely disseminated.

An often overlooked part of the EWS process is the timely 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, and a focus on institutional coordination and cooperation. This review provides the means to document lessons learned and future steps for improving the EWS.

Dissemination:

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. 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 system should get the message to those at risk
- Dissemination systems are sustainable, reliable and redundant
- 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 impacts of disasters. To be effective in meeting that goal it is important that there is a good understanding of the line of authority and decision making processes. Additionally all stakeholders must have a comprehensive understanding of the hazard risks and impacts. In this regard, emergency protocols and procedures should be developed from the national to community level clearly defining roles and responsibilities. An important component in this process is outreach and education of those at risk. Equally important is the conduct of routine drills and practice scenarios to ensure that information reaches those that need to know, and that impacted constituencies are prepared to act.

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 understood by all stakeholders (and very importantly by the public at risk), and that there is a mechanism for support and capacity building 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, all-hazard approach to incident response. Coordination between the National Meteorological and Hydrological Services (NMHS) and disaster risk management agencies should be planned in advance, strong and continuous. Synergies developed through extensive coordination will result in a more effective EWS and avoid duplication of effort and lack of clarity in roles and responsibilities during hazard events.

Status of Early Warning Systems prior to the Adoption of HFA

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

Using the Tsunami Early Warning System (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 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 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

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

[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).

Tsunami Warning Center (PTWC) and became the operational centre for the Tsunami Warning System in the Pacific.

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.

Outside the Pacific region no tsunami warning centres were available, although the tsunami hazard exists on both sides of the Atlantic Ocean, in the Indian Ocean, and in the Caribbean and the Mediterranean and Black Seas.

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 Center at Papeete, Tahiti, and the National Tsunami Warning System of Chile headquartered at Valparaiso.

Historical data for past tsunamis was available in many forms and for many locations. The forms included on-line 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 still 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 tsunami 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 for creating tsunami evacuation maps and procedures. By 2004, such modelling had only been carried out for a small fraction of the coastal areas at risk, and only in the Pacific. UNESCO disseminated a numerical program 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, 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 well before 2004 programs to systematically model the potential tsunami inundation for their coastal areas at risk.

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

National Level

Risk knowledge:

Prior to HFA many counties, especially high income countries, had developed risk maps for selected geographical areas for some hazards. Gaps in the development of multi-hazard assessments 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 assessment was ad hoc and frequently tended to be developed only after a disaster occurred. In Africa only a few counties had prepared risk maps and they were mainly limited to hydrologic phenomena. Some of the most significant gaps in risks knowledge include:

Inadequate emphasis on social, economic and environmental vulnerability - 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 there were 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
- 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 full 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.

Monitoring and warning service:

A summary of what was in place for specific hazards (UN Global Survey of Early Warning Systems, 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 include:

- Inadequate coverage and sustainability of observing systems for monitoring of hydro-meteorological hazards;
- Inadequate level of technical capabilities (resources, expertise and operational warning services) in the operational technical agencies responsible for monitoring and forecasting of severe events, such as the NMHS;

- 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 modelling and for operational forecasting and warning systems, such as for tsunami and earthquake;

- Inadequate access to information (forecasts and interpreted data) from countries outside of the region affected;

- Insufficient multi-disciplinary, multi-agency coordination and collaboration for improving forecasting tools such as for storm surge and flood forecasting and for integrating warnings into the disaster risk reduction decision processes in a more effective and proactive fashion;

- Inadequate communication systems to provide timely, accurate and meaningful forecasting and early warning information down to the level of communities.

Overall, systems existed to provide hazard forecasts and warnings against impending disasters induced by hydro-meteorological 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 Nino, food security and desertification. Some improvements had occurred in tropical cyclone and windstorm warning systems. Systems were less well developed for tsunami, landslides, wild land fires and volcano-related hazards (eruptions and lahars). For many countries the sustainability of monitoring and warning systems was a major challenge.

Overall most EWSs focused on hazard monitoring and forecasting but were not risk based due to the exclusion of vulnerability assessments. A major need across the board was 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 vulnerability and risk assessment, and disaster management. Capacities for risk assessment needed to be developed at national and local levels, on methodologies, hazards and various socioeconomic data.

Dissemination:
Prior to HFA the typical warning dissemination chain 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 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 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 which made it necessary to provide a more continuous information flow. This led to confusion or inaction which indicated a need for standardization and clarification of warning terminology, 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 (2006) warning messages did not reach all 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 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 incomplete and therefore ineffective. There was a lack of clarity due to the missing link of vulnerability acknowledgement - warnings were not 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 GTS Regional Telecommunication Hubs. There also was a need to upgrade telecommunications facilities and capabilities in many countries.

Inadequately standardized nomenclature, protocols and standards nationally and internationally - 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 recipients values, interests and needs. If the recipient does 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 recipient clearly understands 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 result was untargeted 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 not a formal feedback process to ensure that the system continually evolves and improves based on previous experience.

Emergency response capacity:

The success of early warning depends on the extent to which it triggers effective response measures. Prior to HFA most countries had contingency plans, but traditionally they mainly focused on post-disaster emergency response and recovery. Political momentum was beginning to move toward more preventive strategies where EWSs 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 in developed countries 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 that coordination was in need of strengthening in many countries. Community preparedness and education was in place in developed countries, however it was lacking in 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 inconsistent.

The failure to adequately respond to warnings often stems from lack of planning and coordination at the national and local levels, as well as a lack of understanding about 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 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 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.

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 developing there were significant impacts on EWS and disaster planning. Too often this development was not taken into consideration when establishing, or updating EWS. Another area of development impacting the effectiveness of EWS was changes in frequency and intensity of natural hazards due to climate change and variability.

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 was developed to deal with natural hazards with increasing adaptation to man-made 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.

Box 1: 60 Years of International and Regional Cooperation in Meteorology to support National Early Warning Systems

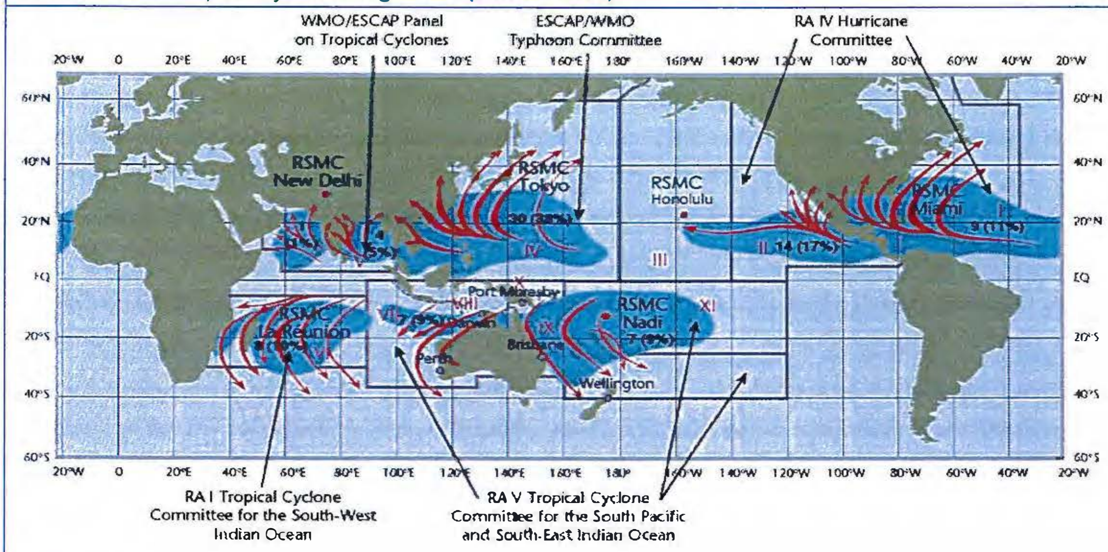
Prior to the adoption of HFA, following over 60 Years of International and Regional Cooperation in Meteorology to support National Early Warning Systems there was international co-operation, facilitated by the World Meteorological Organization (WMO). This involved coordinated research and an operational network, comprised of the WMO Global Observing System (GOS), Global Telecommunication System (GTS) and Global Data Processing and Forecasting System (GDPFS) that enable monitoring, detecting, forecasting and exchange of weather, water and climate related information, engaging the National Meteorological and Hydrological Services (NMHS) of 189 Members. 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 NMHS, supporting them with the development of national products and services such as hazard analysis, early warnings and other products and services to support sectoral risk management decision-making. Examples where this coordinated network was supporting the WMO Member States include:

Tropical Cyclone Programme

The Tropical Cyclone Programme is an example of cooperation using regional capacities to support national warning systems to promote disaster risk reduction strategies. Through the Program, six Regional Specialized Meteorological Centres (RSMCs) are dedicated to providing tropical cyclone analysis, forecasts and alerts in support of National Meteorological Services' 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 Program is supported by five regional committees, involving forecasters from the NMHSs, which ensure ongoing improvements in the tropical cyclone forecasting and warning systems. This has enabled availability of tropical cyclone warning capacities to all countries at risk.

Figure 2: Globally and regionally coordinated Tropical Cyclone System

Source: WMO Tropical Cyclone Programme (www.wmo.int)



Emergency Response Activities

The WMO programme of Emergency Response Activities (ERA) 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 program is focused on nuclear facility accidents, but also provides for meteorological support in emergency response to the dispersion of smoke from large fires, volcanic ash, dust and 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

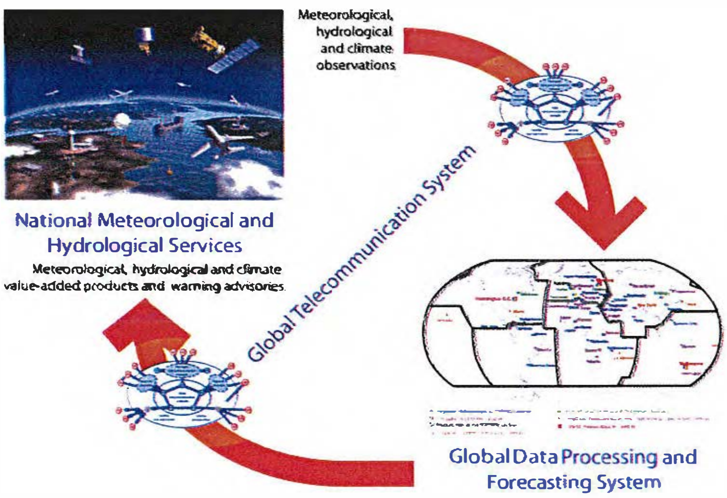
The Chernobyl nuclear accident (April 1986) led to strengthened international cooperation in the event of a nuclear emergency through the Joint Radiation Emergency Management Plan of the International Organizations. The plan is coordinated by the International Atomic Energy Agency in cooperation with international organizations including WMO, the World Health Organization, and the Food and Agriculture Organization. WMO maintains a system of eight 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 12 March 2011 in the aftermath of the earthquake 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, eventually leading to engine stall. The International Civil Aviation Organization 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 advice from WMO. The designated VAACs are located in Anchorage, Buenos Aires, Darwin, London, Montreal, Tokyo, Toulouse, Washington, and Wellington.

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.



Internationally coordinated network of WMO involving Global Observing System, Global Telecommunication System and Global Data Processing and Forecasting System facilitating sharing of data, analysis and forecasts across 191 WMO Members through their National Meteorological and Hydrological Services.

Progress with the Implementation of Early Warning Systems after the Adoption of HFA to Present

National Level

At the national level there have been several advances in the EWS since HFA, however significant challenges still remain. This section will discuss what advances have been made and outline what gaps and challenges remain.

Risks knowledge:

Developed countries have made significant progress in expanding comprehensive multi-hazard risk assessments (Global Assessment Report, 2009, Global Assessment Report, 2011). Recent trends in those countries indicate expansion into multi-sectoral aspects as well expanded documentation for natural and man-made hazards. As an example in Belgium flood risk management is strongly 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 documented in "Institutional Partnerships in Multi-Hazard Early Warning Systems" (Golnaraghi, 2012) the seven countries documented that they all had a sound foundation in risk assessment across multi-hazards a fundamental part of their plans. As another example the European Commission developed and adopted guidelines for mapping and assessing risk based on multi-hazard and multi-risk.

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, GIC, etc. 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 warning system have not changed much since the HFA.

Inadequate emphasis on social, economic and environment vulnerability - while there has been limited advances in these areas since HFA considerable work remains.

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.

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 hydro-meteorological phenomena (Chub, 2013). This has led to advanced and more structured forecast processes in that country. After the 2010 eruption of the Merapi Volcano 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).

Many significant gaps remain, particularly in developing and least developed countries. Key issues include:

- Inadequate coverage and sustainability 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

Dissemination:
Technical capabilities to improve dissemination have advanced rapidly over the past several years. 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 [3]is being tested for integration into the EWS there (Molinari, 2013). 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 the activation of disaster risk reduction activities (Guru, 2013). Strong political recognition of the importance

[3] 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".

of multi-hazard EWS is required as documented in the 2012 book "Institutional Partnerships in Multi-Hazard Early Warning Systems" (Golnaraghi, 2012). 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 political authority to issue warnings. Clarity with respect to roles and responsibilities in the warning dissemination change is not yet 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 incomplete and therefore ineffective. There was a lack of clarity due to the missing link of vulnerability acknowledgement - warnings were not impact based. As an example even in developed countries like Belgium (Cools, 2013) and Italy (Molinari, 2013) warning messages lack clarity and are difficult to interpret and use.

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.

Failure to address the public's interests and concerns - Messages often did not address the recipient's values, interests and needs. If the recipient does 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 the recipient clearly understands 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. 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 complimentary messages are issued.

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 not a formal feedback process to ensure that the system continually evolves and improves based on previous experience.

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 increases in cascading hazard events such as the 2011 earthquake, tsunami and nuclear accident in Japan (Box 2). As documented in the "Institutional Partnerships in Multi-Hazard Early Warning Systems" (Golnaraghi, 2012) there has been good progress in integrating multi-hazards into multi-sectoral plans but in many countries much work remains to be done. 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 supports a campaign called "Constructing Resilient Cities: My City is Preparing" as an effort to engage multi-sectors in developing emergency response plans (Araujo, 2013)

Box 2: Tohoku, Japan earthquake, tsunami and nuclear emergency of 2011

On Friday, 11 March 2011, a 9.0 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 (133 feet) in Miyako in Tōhoku's Iwate Prefecture, and which, in the Sendai area, travelled up to 10 km (6 mi) 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. The World Bank's estimated economic cost was US$235 billion, making it the most expensive disaster caused by natural and man-made hazards, in world history.

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

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 weakness of public as well as emergency management agency participation in the development of response strategies.

Policy, legislative and institutional coordination aspects:

Political commitment to, and responsibility for, developing integrated EWS is increasing, especially in developed and developing countries. This seems to be 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 has been developed there has been an increasing sensitivity to the need for sufficient resource support, however fiscal challenges remain. Attempts to share lessons learned have increased through WMO and other UN agency programs which has been a strong benefit to developing and developed nations.

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 disaster risk reduction 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 approach to EWS - While EWS planning is evolving a strong focus still remains on natural hazards.

Lack of sufficient participatory approaches - Too often there remains an over-reliance on centralized government direction and limited engagement with social science, NGS and the private sector. Fostering of partnerships should be expanded.

Regional

Since the adoption of the HFA significant progress has been achieved at the regional and international levels to support the development and strengthening of national EWS. That development includes:

- Tsunami-UNESCO IOC international standards, GTS as the primary communications

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 WGs, 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 early warning system was launched on October 12, 2011. Operational responsibility was formally transferred on 31 March 2013 to the Tsunami Service Providers in Australia, India, 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 centers 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 2007-2013 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 120 national institutions now 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.

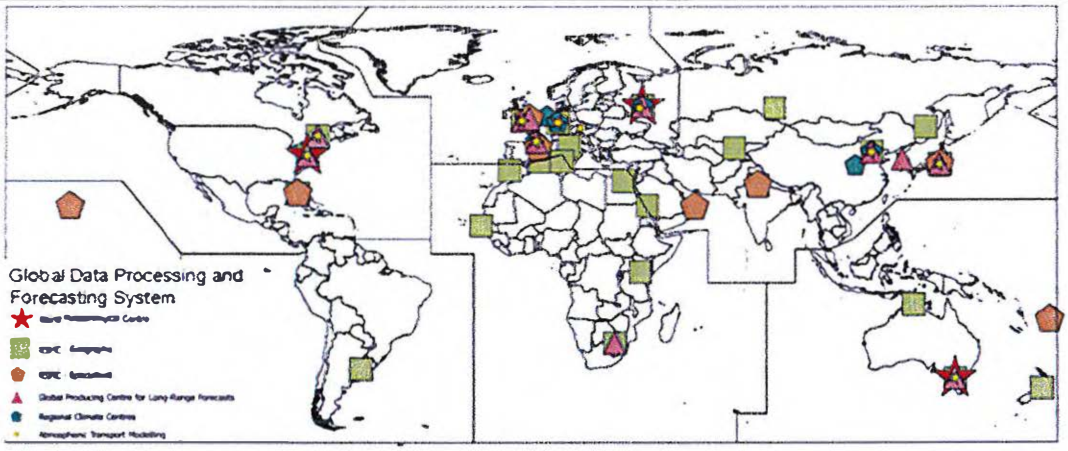
As a result of an agreement between IOC of UNESCO and the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in 2010, seismic data from the CTBTO International Monitoring System is now made available to 10 national tsunami warning centres and about 3.2 gigabytes 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 center 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.

- Expansion of the WMO system to WIGOS, WIS and GDPFS to include SWF Centres and RCCs and Volcanic ash

Box 3: The Global Data-Processing and Forecasting System (GDPFS)

The Global Data-Processing and Forecasting System (GDPFS) produces and disseminates weather and climate analyses and predictions to enable NMHSs to provide high-quality meteorological forecasts, warnings and other information services related to weather, 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. Improved skill and lead-time of predictions of high-impact weather events have made a major contribution to DRR.



Additionally good practices and guidelines have been documented, synthesized and principals for effective EWS have been developed following ten principles common to development of MHEWS (Box 4).

BOX 4: Ten principles common to development of Multi-Hazard Early Warning Systems.

Many countries have built their Multi-Hazard Early Warning Systems (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 (Bangladesh, megacity of Shanghai in China, Cuba, France, Germany, Japan and the United States of America) 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 meteorological and hydrological hazards within their respective jurisdictions (Golnaraghi et al, 2010; Golnaraghi, 2012).

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 early warning systems (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 characteristics include:

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 capacities 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 carry-out 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 colour, flags) and understood by authorities and the population, (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 with consideration for hazard/risk levels, characteristics of the exposed communities.
9. Training on hazard/risk/emergency preparedness awareness 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.

Trends with the Developments of Early Warning Systems since the Adoption of HFA

Looking at the progress with the implementation of EWS after the adoption of HFA there are several trends which are apparent. Following is a look at those trends.

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 end to end systems.

The ability to access and act upon the ever increasing risk knowledge varies widely between developing and developed countries. Many reasons for this remain, including resources, infrastructure and political support variability between countries. As countries continue to develop, single hazards increasingly have multi-layer cascading impacts upon 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.

Monitoring and warning service

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 international 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 most 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 tourist 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.

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. However there are limits in that new technologies, such as SMS messaging as an example, 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 Multi-hazard EWS in Southeast Europe (WMO, 2012) which was developed through support of the WMO, UNISDR, World Bank and UNDP. Further examples are the Meteoalarm program in Europe and Multi-hazard EWSs documented in the Institutional Partnerships in Multi-Hazard Early Systems (Golnaraghi, et.al, 2011). This trend was taking place at the local, national, regional and international levels.

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.

Policy, legislative and institutional coordination aspects

Advances in policy legislation and legal frameworks - There has been 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 only limited development of preparedness programs such as StormReady in the USA.

Lack of multi-hazard/multi-sectoral planning - It was found that many EWS plans are single focused rather than on multi hazards. In some countries where local plans are multi-hazard that 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. Especially in developing and least developed 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. There are still challenges in some areas to fully share information due to national security concerns.

Over-Arching Trends

The development of EWS primarily has been driven by one or several major events that have raised significant political awareness. However, it seems that increasingly more 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, 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 threats to national security. These plans are being extended to span not only natural hazards, but also for man-made hazards, protection of critical infrastructures such as energy, banking, water, food and ultimately national security.

In many countries EWS have been developed at the national or local level without linkage. In most 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 such as Red Cross/Red Crescent, 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, hydrologic 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 lack of trust in some government agencies in utilizing forecasts and warnings in their emergency response systems. Many reasons exist for this doubt including a lack of understanding of the forecast inaccuracies, 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.

Multi-Hazard, Multi-Layer, Multi Sector approach to Early Warning Systems (linking natural and man-made hazards with hazards posing risk to national security)

At its foundation EWS was developed in response to threats and impacts from natural (meteorological, hydrological, climate-related, geological, etc.) and man-made (Chemical, biological, industrial, 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 has evolved into a system which now addresses multi-hazard, multi-layer and multi-sectoral risks and impacts. Since 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 become more inter-linkages as natural or man-made events occur. This has required EWS to evolve into an all hazard approach which addresses cascading hazards (e.g. Tropical Cyclone which results in wind storm damage, flooding, damage and interruption to infrastructure, etc.) and complex natural and man-made events (e.g. the Japan Earthquake, Tsunami and nuclear accident). As the world has developed and experienced natural and man-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 has cascading impacts which threaten the population, national infrastructure and in some cases national security.

Both developed and developing countries are approaching these challenges. In developed countries political support and legislation has been enacted to provide a framework upon which to build multi-level, multi-agency EWS. There also have been concerted efforts to provide adequate resources to support EWS at national, state and local levels. In developing countries there is increasing recognition that political support and legislation is essential to building a strong EWS which can deal with multi-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.

The following boxes provide examples of the evolution of EWS since HFA.

Box 5: Costa Rica Early Warning Systems for Hydro-Meteorological Hazards Project

In Costa Rica, the Sarapiqui river 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 the 8th 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, the World Meteorological Organization (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 a 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 Hydrometeorological Hazards Project". The project was funded by the World Bank Global Facility for Disaster Risk Reduction (GFDRR) and was implemented in close coordination with the United Nations Development Programme (UNDP).

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.
- Carry out an analysis and facilitate a community simulation exercise of the early warning systems and work with the local communities to ensure the early warning system incorporates the additional information/data from the technical part of this project.

The project was completed in 2013 and has led to a 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 of 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.

Box 6: South East Europe Project (SEE)

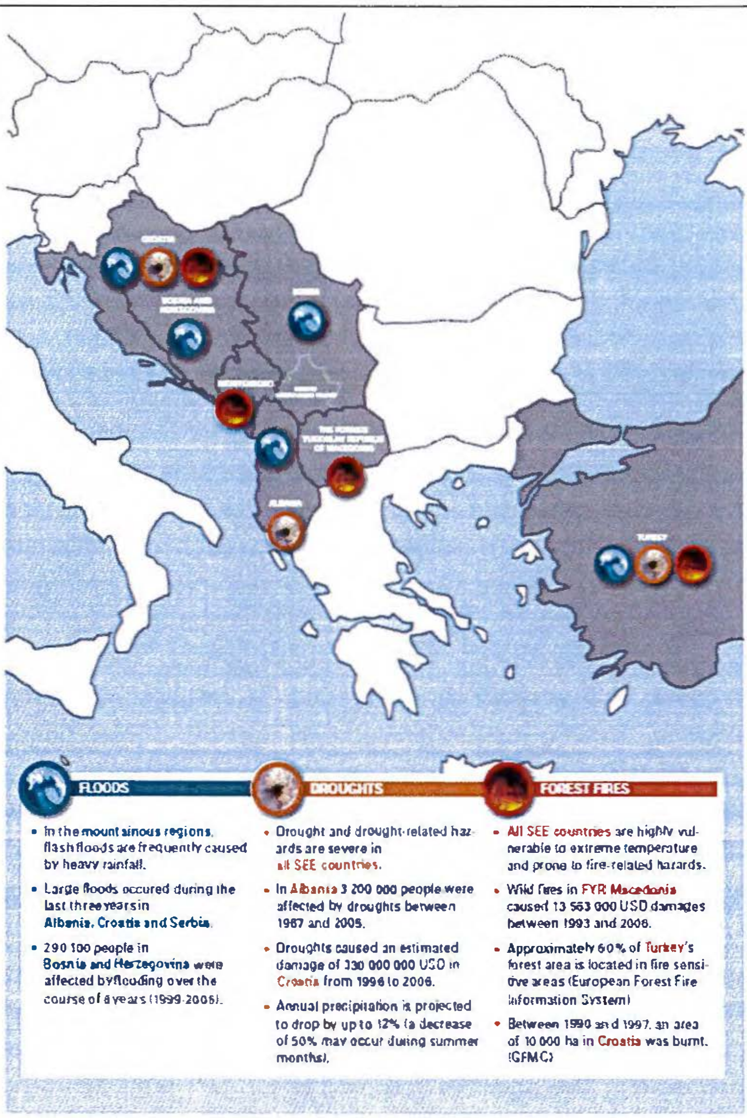
Even though the South East Europe (SEE) region is highly diverse in terms of geography and climate, countries of Western Balkans and Turkey are exposed to a range of similar disasters caused by the impacts of natural hazards, including heavy precipitation causing floods and landslides, droughts and forest fires, earthquakes, prolonged cold and heat waves, and hailstorms. Disasters caused by hydrometeorological and climate-related 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, the World Meteorological Organization (WMO) and the United Nations Strategy for Disaster Risk Reduction (UNISDR), World Meteorological Organization (WMO) and United Nations Development Programme (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 National Meteorological and Hydrological Services (NMHS) 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 (DRR) activities of the IPA beneficiary countries and the region as a whole. Building better cooperation between the NMHS, 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 NMHS in the provision of reliable weather, water and climate products and services

Currently the project has begun the second capacity development phase (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) Hydrometeorological services and their cooperation with sectors; and (iii) Financial risk transfer mechanisms, to assist the beneficiaries in reducing risks associated with natural hazards. See map on following page.


FLOODS
DROUGHTS
FOREST FIRES
• In the mountainous regions, flash floods are frequently caused by heavy rainfall.
• Large floods occured during the last three years in Albania, Croatia and Serbia.
• 290 100 people in Bosnia and Herzegovina were affected by flooding over the course of 4 years (1999-2005).
• Drought and drought-related hazards are severe in all SEE countries.
• In Albania 3 200 000 people were affected by droughts between 1987 and 2005.
• Droughts caused an estimated damage of 330 000 000 USD in Croatia from 1996 to 2006.
• Annual precipitation is projected to drop by up to 12% (a decrease of 50% may occur during summer months).
• All SEE countries are highly vulnerable to extreme temperature and prone to fire-related hazards.
• Wild fires in FYR Macedonia caused 13 563 000 USD damages between 1993 and 2008.
• Approximately 60% of Turkey's forest area is located in fire sensitive areas (European Forest Fire Information System)
• Between 1990 and 1997, an area of 10 000 ha in Croatia was burnt. (GFMC)

Box 7: Tohoku, Japan earthquake, tsunami and nuclear emergency of 2011

On Friday, 11 March 2011, a 9.0 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 (133 feet) in Miyako in Tōhoku's Iwate Prefecture, and which, in the Sendai area, travelled up to 10 km (6 mi) 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. The World Bank's estimated economic cost was US$235 billion, making it the most expensive disaster caused by natural and man-made hazards, in world history.

Box 8: 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 nearly 300 000 and 140 000 deaths, respectively, the Government worked together with 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 3 500 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.

Box 9: Iceland Eyjafjallajökull volcano eruption

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 $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 $1.7 billion due to this single volcanic event.

Box 10: 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 (7,700 sq. mi) of farmland were 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 (10 feet) 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.

Box 11: Tsunami Warning Programme

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.

Challenges and opportunities for EWS within a changing climate

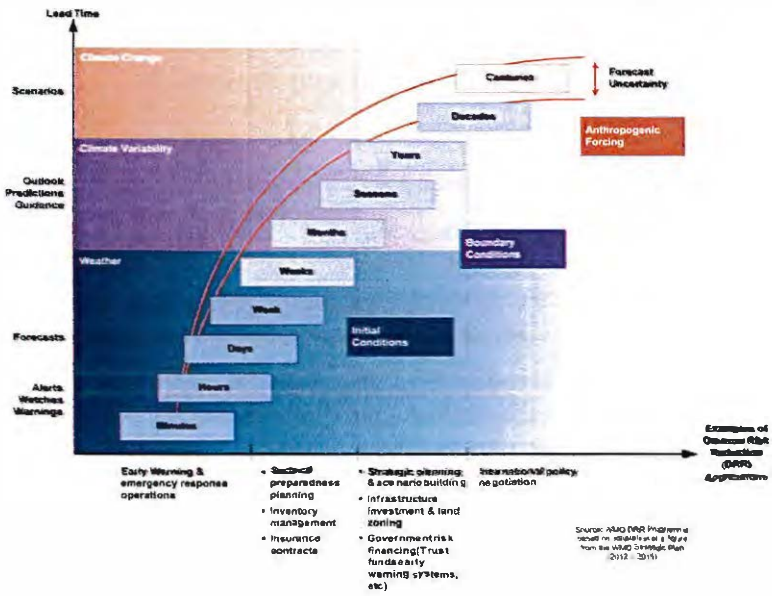


Figure 3: Seamless hydrometeorological and climate services for various risk management applications

Since 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 hydro-meteorological 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.

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 man-made hazards has led to advances in predictive accuracy and increased lead time. 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 HFA, EWS has 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 uncertainties. 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 has 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.

Prior to HFA some EWS messages were extremely technical which made understanding and response from the populace difficult. Since HFA there have been advances in making EWS 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 does this EWS warning mean to me and what do I have to do to protect life and property." Evolution of warning messages from technical information into actionable warnings was not a trivial task. To accomplish this strong multi-agency coordination from the national to local level was required to ensure consistent, understandable messages. Close collaboration between many governmental agencies including, emergency management, hydro-meteorological, infrastructure agencies, to name a few, is required.

Developed countries have seen significant 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 developing countries. Since 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 possibly 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, EWS is working as one official voice. Management of official communication systems and protocols remains a top priority.

Institutionalizing Early Warning Systems

Attainment of maximum effectiveness of EWS requires implementation of policy, 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 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.

Summary and conclusions

As illustrated in the preceding sections 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 impact based. As detailed in previous sections 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 develop EWS has migrated 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 a lot has been accomplished 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. The successor to HFA should continue to focus on the gaps and challenges that still exist.

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Box 11: Tsunami Warning Programme

Annex 1:

A Template for review and documentation of EWS

1) Overview of the 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 of International Strategy for Disaster Reduction (UN-ISDR) 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 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 responded to the survey including: Union des Comores, Syria, British Virgin Islands, Mozambique, Algeria, Portugal, Guinea, Bahrain, New Zealand.

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 NMHS observed and forecast data	- Impact information not readily available in warning messages - Dissemination

Capacities and gaps prior to HFA 2005-2015 (UN Global Survey of Early Warning Systems, 2006)			
Hazard Class	**Hazards**	**Capacities**	**Gaps**
			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 Central America and of the Caribbean.	- 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**
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, observations and meteorological data - Desert Locust Information Service of FAO prepared medium and long-term forecasts	- 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**
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

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