This report summarizes how to implement multi-hazard early warning systems based on best practices in the hydrometeorological community

Implementing Hazard Early Warning Systems

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Contents

Acknowledgements

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1. Introduction

The purpose of this report is to provide guidance to World Bank staff involved in the implementation of hydrometeorological-related early warning systems through the modernization of National Meteorological and Hydrological Services (NMHSs). The principle sources of information for warning systems are the International Strategy For Disaster Reduction (ISDR), the World Meteorological Organization (WMO) and countries that have implemented early warning systems successfully.

The Hyogo Framework for Action (ISDR 2005), which was adopted by the World Conference on Disaster Reduction in Hyogo, Japan in 2005, identified five priority areas:

1. Ensure that disaster risk reduction (DRR) is a national and local priority with a strong institution basis for implementation;
2. Identify, assess and monitor disaster risks and enhance early warning;
3. Better knowledge management for building a culture of safety;
4. Reducing the underlying risk factors; and
5. Enhance preparedness for an effective response

Weather hazards and related events such as hurricanes, heat waves, cold waves, windstorms, floods, and droughts jointly cause more economic damage and loss of life than other natural disasters. In recent decades such damage has shown a growing trend, and climate change may make such events even more dangerous. Weather extreme also contributes to impacts on food security, food price volatility and health. Strengthening weather and climate information and decision support systems is a key aspect of implementing the priority to enhance early warning systems highlighted under the Hyogo Framework.

At its Fourteenth Session in 2009, the World Meteorological Organization (WMO) Commission for Basic Systems (CBS) requested the WMO Public Weather Service Program (PWSP) to continue to focus on assisting WMO Members to improve their national Public Weather Service programs by providing guidance on nowcasting and multi-hazard warnings with the aim of strengthening NMHSs to reduce the impact of disasters (WMO 2010). The 2010 WMO report highlights the role of NMHSs in disaster management and what makes meteorological and hydrological warning systems effective. The present report reviews this information and reproduces the check list developed by ISDR for the development of warning systems (ISDR 2006); it considers the practical implementation of multi-hazard early warning; and how some of these best practices in multi-hazard early warning can be adapted to the World Bank's clients in developing and least developed countries. A detailed example of good practice is described in an annex.

2. The Role of NMHSs in Early Warning and Disaster Management

The role of NMHSs in early warning and disaster risk management is critical since so many natural hazards, which cause floods, heat waves, cold waves, wind storms, wildfires, droughts landslides, epidemics and the resulting social and economic losses are weather-related[1] (ISDR 2006a) and likely to become more common due to climate change (IPCC 2007).

A systematic approach to managing the "risks" associated with disasters can prevent or mitigate their impact. The process must consider the likely effects of natural hazards and the measures by which they can be minimized.

The concept of disaster risk is used to describe the likelihood of harmful consequences arising from the interaction of natural hazards and the community. Two elements are essential in the formulation of disaster risk: the probability of occurrence of a hazard, and the vulnerability of the community to that hazard.

Risk = Hazard Probability x Vulnerability

A closer look at the nature of hazards and the notions of vulnerability allows for a better and more comprehensive understanding of the challenges posed by disaster mitigation:

i. Nature of hazard - By seeking to understand hazards of the past, monitoring of the present, and prediction of the future, a community or public authority is poised to minimize the risk of a disaster. The NMHSs play a key role in this aspect of risk management of weather-related natural disasters; and,
ii. Notions of Vulnerability – The community vulnerability is the susceptibility and resilience of the community and environment to natural hazards. Different population segments can be exposed to greater relative risks because of their social and economic conditions[2]. Reducing disaster vulnerability requires increasing knowledge about the likelihood, consequences, imminence and presence of natural hazards, and empowering individuals, communities and public authorities with that knowledge to lower the risk before severe weather events occur, and to respond effectively immediately afterwards.

The importance given to social and economic vulnerability as a rapidly increasing factor of risk in most of today's societies underlines the need to encourage the participation of a wide spectrum of stakeholders in hazard and risk reduction and response activities.

Stakeholders are those people or organizations who may affect, be affected by, or perceive themselves to be affected by, a decision or activity. In developing a disaster risk management system, no single

[1] Here weather-related hazards is assumed to include water-induced and climate-related hazards
[2] Implicitly the poor are the most vulnerable. They are also likely to benefit the most from early warning systems since large protective infrastructure projects designed to reduce vulnerability, often result in the dislocation of poor residents to other risk prone places (World Bank 2010, Rogers and Tsirkunov 2011).

agency can provide a fully comprehensive solution. It is essential that agencies work together and with stakeholders to narrow knowledge gaps and to develop disaster risk management plans using a coordinated approach (WMO 2010). Well-developed governance and institutional arrangements support the successful development and sustainability of sound early warning systems. They are the foundations upon which early warning systems are built, strengthened and maintained.

Good governance is encouraged by robust legal and regulatory frameworks and supported by long-term political commitment and effective institutional arrangements. Effective governance arrangements should encourage local decision-making and participation which are supported by broader administrative and resource capabilities at the national or regional level.

Vertical and horizontal communication and coordination between early warning stakeholders is also essential.

Framework of Risk Management

NMHSs play a role in:

i. In risk identification element: Systematic observation and monitoring of hydrometeorological parameters; provision of quality-assured archived and real-time data; hazard analysis and mapping; as well as forecasts of hazards, their changing patterns and impacts;
ii. In risk reduction element: Provision of hazard forecasts and early warnings related to specific impacts (e.g., a flood or heat-health) to support emergency preparedness and response; climate data and forecasts (probabilistic information on hazards and their changing patterns) to support medium and long-term sectoral planning; and,
iii. In risk transfer element: Provision of historical and real-time hazard data and analysis to support catastrophe insurance, bonds and weather-indexed risk transfer mechanisms.

Partnerships

The design and operation of severe weather warning systems must be based on a commitment to cooperation and information exchange and the concept of partnership in the overall public interest (WMO 2010). The benefits of such partnerships include:

i. drawing expertise from a wide range of disciplines, such as social science, community planning, engineering, etc.;
ii. accomplishing tasks that cannot be managed by a single agency or organization;
iii. demonstrating to government budget planners a commitment to work together towards a common goal and making better use of scarce financial resources;
iv. leveraging resources for research, awareness, preparedness, etc.;
v. sharing costs, knowledge, and lessons learned;
vi. ensuring a consistent message (the warning bulletins and other outreach material) from multiple credible sources; and

vii. yielding wider distribution of the message through multiple outlets and receiving feedbacks from a whole range of users.

To identify and evaluate the weather information needs of the users, NMHSs need to build relationships and work in partnership with users in both the public and private sectors. NMHSs partners include:

1. other government agencies with missions involving the protection of life and property, such as the National Hydrological Services (NHSs) where they are separate agencies from National Meteorological Services (NMSs), national, regional or local emergency management agencies, first responders, and infrastructure managers (dams, transportation departments, bridges);
2. the media;
3. Non-Government Organizations (NGOs);
4. emergency relief and humanitarian organizations, such as the International Red Cross and Red Crescent Society (IFRC);
5. academic institutions and schools;
6. trained volunteers associated with NMHSs, such as cooperative observers, storm spotters, and amateur radio operators;
7. meteorological societies and other professional associations in risk management disciplines;
8. private sector weather companies, and,
9. utility services, telecommunication operators and other operation-critical or weather-sensitive businesses.

NMHSs must understand the decision-making processes being made by all of the sectors impacted by the hazard to ensure that information is tailored to the specific needs of the user. This involves efficient and timely synthesis and elucidation of weather-related data and information and its effect on the users' operations and objectives. These will likely vary widely for each stakeholder for the same weather event. It also includes a quantitative understanding of the social and economic cost and benefit of warnings (Rogers and Tsirkunov 2010). Maximizing the benefit depends on understanding the uncertainty in the warning, the decisions that depend on the warning, and the level of acceptance of false alarms. Good communication is essential to develop an effective high value warning system.

3. Effective Early Warning Systems

A warning system must empower individuals, communities and businesses to respond timely and appropriately to hazards in order to reduce the risk of death, injury, property loss and damage. Warnings must get the message across and stimulate those at risk to take action.

Increasingly precise warnings are required by disaster mitigation decision-makers. These require improvements in weather warnings (Gunasekera 2004):

i. extending the lead time of warnings;
ii. improving the accuracy of warnings;
iii. greater demand for probabilistic forecasts;
iv. better communication and dissemination of warnings;
v. using new techniques to alert the public;
vi. targeting of the warning services to relevant and specific users (right information to right people at right time and right place); and
vii. warning messages are understood and the appropriate action taken in response.

Longer lead times should be considered together with the need to reduce false alarm rates and a balance should be struck between the two whereby decisions can be based on optimum lead times for warnings (Rogers and Tsirkunov 2010).

People Centered Early Warning Systems

There is general agreement on the structure of people centered early warning systems; namely, risk knowledge, monitoring and warning service, dissemination and communication, and response capability (Fig. 1) (ISDR 2006b).

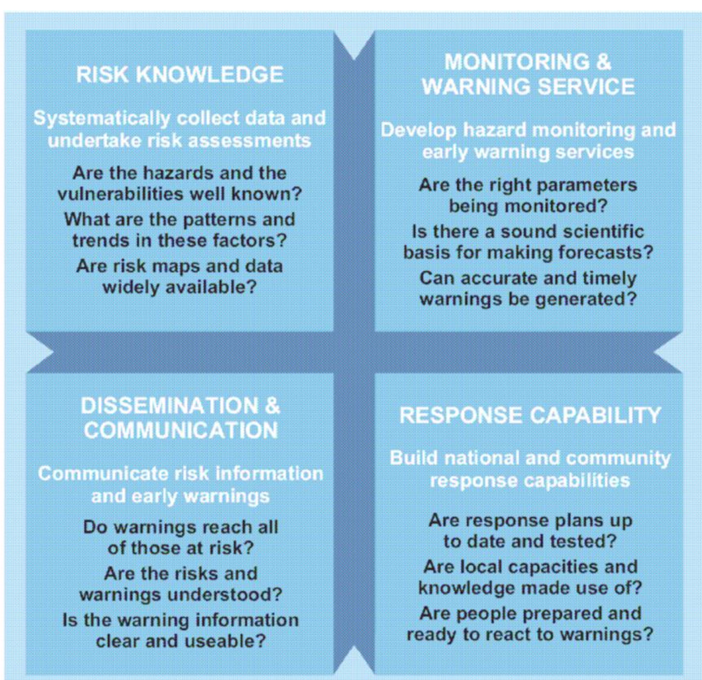

Fig. 1. Elements of a people centered early warning system (ISDR 2006b)

Since the concept was introduced the capacity to provide tailored information to individuals has increased along with an ever expanding access to mobile technology. Thus it is now possible to be increasingly specific about warnings to individuals at risk, increasing the importance of the concept of people centric warning systems. It also means that individuals need to be more aware of their risks and the warning systems must increasingly support forecasts of impacts so that those at risk can fully understand the consequences and actions that need to be taken.

Risk Knowledge

Risks arise from the combination of hazards and vulnerabilities at a particular location. Identification and assessments of risk require systematic collection and analysis of data and should consider the dynamic nature of hazards and vulnerabilities that arise from processes such as urbanization, rural land-use change, environmental degradation and climate change. Risk assessments and maps help to motivate people, prioritize early warning system needs and guide preparations for disaster prevention and responses.

Monitoring and Warning Service

Warning services lie at the core of the system. There must be a sound scientific basis for predicting and forecasting hazards and reliable forecasting and warning systems that operate 24 hours a day[3]. Continuous monitoring of hazard parameters and precursors is essential to generate accurate warnings in a timely fashion. Warning services for different hazards should be coordinated where possible to gain the benefit of shared institutional, procedural and communication networks. This can be achieved through a multi-hazard early warning system that coordinates and integrates the needs of different stakeholders.

In the past NMHSs have focused on provided warning information directly linked to the hydrometeorological forecasts that they calculate; however, the impact of heavy precipitation, for example, will vary over a catchment area depending on many factors that contribute to the vulnerability of people. Some will have little risk others may be in life-threatening situations. It is very important to make sure that those at risk are properly informed and actions are taken to protect them. Targeting those at risk also creates a more effective response and reduces the risk of warning fatigue and false alarms.

Dissemination and Communication

Warnings must reach those at risk. Clear messages containing simple, useful information are critical to enable proper responses that will help safeguard lives and livelihoods. Regional, national and community level communication systems must be pre-identified and appropriate authoritative voices established. The use of multiple communication channels is necessary to ensure as many people as possible are warned, to avoid failure of any one channel, and to reinforce the warning message.

[3] The accuracy of warnings of high impact weather is improved by the routine day-to-day forecasting operations of a National Weather Service. Forecasting skills remain high when exercised frequently and when training related to specific extreme events is part of the routine forecaster activities. For example, the US National Weather Service ensures that forecasters are well-prepared for the hurricane and severe convective seasons by the NWS National Hurricane Center and NWS Storm Prediction Center.

Response Capability

It is essential that communities understand their risks; respect the warning service and know how to react. Education and preparedness programs play a key role. It is also essential that disaster management plans are in place, well-practiced and tested. The community should be well informed on options for safe behavior, available escape routes, and how best to avoid damage and loss to property.

Cross-cutting Issues

Involvement of Local Communities

People-centered early warning systems rely on the direct participation of those most likely to be exposed to hazards. Without the involvement of local authorities and communities at risk, government and institutional interventions and responses to hazard events are likely to be inadequate.

A local, 'bottom-up' approach to early warning, with the active participation of local communities, enables a multi-dimensional response to problems and needs. In this way, local communities, civic groups and traditional structures can contribute to the reduction of vulnerability and to the strengthening of local capacities[4].

Consideration of Gender Perspectives, Cultural Diversity and Disability

In developing early warning systems it is essential to recognize that different groups have different vulnerabilities according to culture, gender or other characteristics that influence their capacity to effectively prepare for, prevent and respond to disasters. Women and men often play different roles in society and have different access to information in disaster situations. In addition, the elderly, disabled and socio-economically disadvantaged are often more vulnerable.

Information, institutional arrangements and warning communication systems should be tailored to meet the needs of every group in every vulnerable community.

A Multi-Hazard Approach

Where possible, early warning systems should link all hazard-based systems. Economies of scale, sustainability and efficiency can be enhanced if systems and operational activities are established and maintained within a multipurpose framework that considers all hazards and end user needs.

Multi-hazard early warning systems will also be activated more often than a single-hazard warning system, and therefore should provide better functionality and reliability for dangerous high intensity events, such as tsunamis, that occur infrequently. Multi-hazard systems also help the public better understand the range of risks they face and reinforce desired preparedness actions and warning response behaviors.

Housed within a National Meteorological or Hydrometeorological Service is the ideal solution since the main elements of the system can be exercised as part of the routine forecasting and analysis functions

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[4] Practical Action has demonstrated the importance of community involvement in early warning systems in Nepal. See for example, Scaling up Early Warning Systems in Nepal – Case studies and good practices.

of the service. Thus in many countries disaster risk reduction activities are the responsibility of public weather services.

4. The Checklist

The checklist on developing early warning systems was developed as a contribution to the Third International Conference on Early Warning by ISDR (ISDR 2006b).

Risk Knowledge

1. Organizational Arrangements Established

- Key national government agencies involved in hazard and vulnerability assessments identified and roles clarified (e.g. agencies responsible for economic data, demographic data, land-use planning, and social data).
- Responsibility for coordinating hazard identification, vulnerability and risk assessment assigned to **one** national organization.
- Legislation or government policy mandating the preparation of hazard and vulnerability maps for all communities in place.
- National standards for the systematic collection, sharing and assessment of hazard and vulnerability data developed, and standardized with neighboring or regional countries, where appropriate.
- Process for scientific and technical experts to assess and review the accuracy of risk data and information developed.
- Strategy to actively engage communities in local hazard and vulnerability analyses developed.
- Process to review and update risk data each year, and include information on any new or emerging vulnerabilities and hazards established.

2. Natural Hazards Identified

- Characteristics of key natural hazards (e.g. intensity, frequency and probability) analyzed and historical data evaluated.
- Hazard maps developed to identify the geographical areas and communities that could be affected by natural hazards.
- An integrated hazard map developed (where possible) to assess the interaction of multiple natural hazards.

3. Community Vulnerability Analyzed

- Community vulnerability assessments conducted for all relevant natural hazards.
- Historical data sources and potential future hazard events considered in vulnerability assessments.
- Factors such as gender, disability, access to infrastructure, economic diversity and environmental sensitivities considered.
- Vulnerabilities documented and mapped (e.g. people or communities along coastlines identified and mapped).

4. Risks Assessed

- Interaction of hazards and vulnerabilities assessed to determine the risks faced by each region or community.
- Community and industry consultation conducted to ensure risk information is comprehensive and includes historical and indigenous knowledge, and local information and national level data. Activities that increase risks identified and evaluated.
- Results of risks assessment integrated into local risk management plans and warning messages.

5. Information Stored and Accessible

- Central 'library' or GIS database established to store all disaster and natural hazard risk information.
- Hazard and vulnerability data available to government, the public and the international community (where appropriate).
- Maintenance plan developed to keep data current and updated.

Monitoring and Warning Service

1. Institutional Mechanisms Established

- Standardized process, and roles and responsibilities of all organizations generating and issuing warnings established and mandated by law.
- Agreements and interagency protocols established to ensure consistency of warning language and communication channels where different hazards are handled by different agencies.
- An all-hazard plan to obtain mutual efficiencies and effectiveness among different warning systems established.
- Warning system partners, including local authorities, aware of which organizations are responsible for warnings.
- Protocols in place to define communication responsibilities and channels for technical warning services.
- Communication arrangements with international and regional organizations agreed and operational.
- Regional agreements, coordination mechanisms and specialized centers in place for regional concerns such as tropical cyclones, floods in shared basins, data exchange, and technical capacity building.
- Warning system subjected to system-wide tests and exercises at least once each year.
- A national all-hazards committee on technical warning systems in place and linked to national disaster management and reduction authorities, including the national platform for disaster risk reduction.
- System established to verify that warnings have reached the intended recipients.
- Warning centers staffed at all times (24 hours per day, seven days per week).

2. Monitoring Systems Developed

- Measurement parameters and specifications documented for each relevant hazard.
- Plans and documents for monitoring networks available and agreed with experts and relevant authorities.
- Technical equipment, suited to local conditions and circumstances, in place and personnel trained in its use and maintenance.
- Applicable data and analysis from regional networks, adjacent territories and international sources accessible.
- Data received, processed and available in meaningful formats in real time, or near-real time.
- Strategy in place for obtaining, reviewing and disseminating data on vulnerabilities associated with relevant hazards.
- Data routinely archived and accessible for verification and research purposes.

3. Forecasting and Warning Systems Established

- Data analysis, prediction and warning generation based on accepted scientific and technical methodologies.

- Data and warning products issued within international standards and protocols.
- Warning analysts trained to appropriate international standards.
- Warning centers equipped with appropriate equipment needed to handle data and run prediction models.
- Fail-safe systems in place, such as power back-up, equipment redundancy and on-call personnel systems.
- Warnings generated and disseminated in an efficient and timely manner and in a format suited to user needs.
- Plan implemented to routinely monitor and evaluate operational processes, including data quality and warning performance.

Dissemination and Communication

1. Organizational and Decision-making Processes Institutionalized

- Warning dissemination chain enforced through government policy or legislation (e.g. message passed from government to emergency managers and communities, etc.).
- Recognized authorities empowered to disseminate warning messages (e.g. meteorological authorities to provide weather messages, health authorities to provide health warnings).
- Functions, roles and responsibilities of each actor in the warning dissemination process specified in legislation or government policy (e.g. national meteorological and hydrological services, media, NGOs).
- Roles and responsibilities of regional or cross border early warning centers defined, including the dissemination of warnings to neighboring countries.
- Volunteer network trained and empowered to receive and widely disseminate hazard warnings to remote households and communities.

2. Effective Communication Systems and Equipment Installed

- Communication and dissemination systems tailored to the needs of individual communities (e.g. radio or television for those with access; and sirens, warning flags or messenger runners for remote communities).
- Warning communication technology reaches the entire population, including seasonal populations and remote locations.
- International organizations or experts consulted to assist with identification and procurement of appropriate equipment.
- Multiple communication mediums used for warning dissemination (e.g. mass media and informal communication).
- Agreements developed to utilize private sector resources where appropriate (e.g. amateur radios, safety shelters).
- Consistent warning dissemination and communication systems used for all hazards. Communication system is two-way and interactive to allow for verification that warnings have been received.
- Equipment maintenance and upgrade program implemented and redundancies enforced so back-up systems are in place in the event of a failure.

3. Warning Messages Recognized and Understood

- Warning alerts and messages tailored to the specific needs of those at risk (e.g. for diverse cultural, social, gender, linguistic and educational backgrounds).
- Warning alerts and messages are geographically-specific to ensure warnings are targeted to those at risk only.
- Messages incorporate the understanding of the values, concerns and interests of those who will need to take action (e.g. instructions for safeguarding livestock and pets).

- Warning alerts clearly recognizable and consistent over time and include follow-up actions when required.
- Warnings specific about the nature of the threat and its impacts.
- Mechanisms in place to inform the community when the threat has ended.
- Study into how people access and interpret early warning messages undertaken and lessons learnt incorporated into message formats and dissemination processes

Response Capacity

1. Warnings Respected

- Warnings generated and distributed to those at risk by credible sources (e.g. government, spiritual leaders, respected community organizations).
- Public perception of natural hazard risks and the warning service analyzed to predict community responses.
- Strategies to build credibility and trust in warnings developed (e.g. understanding difference between forecasts and warnings).
- False alarms minimized and improvements communicated to maintain trust in the warning system.

2. Disaster Preparedness and Response Plans Established

- Disaster preparedness and response plans empowered by law.
- Disaster preparedness and response plans targeted to the individual needs of vulnerable communities (Increasingly it is possible to target vulnerable individuals).
- Hazard and vulnerability maps utilized to develop emergency preparedness and response plans.
- Up-to-date emergency preparedness and response plans developed, disseminated to the community, and practiced.
- Previous disaster events and responses analyzed, and lessons learnt incorporated into disaster management plans.
- Strategies implemented to maintain preparedness for recurrent hazard events.
- Regular tests and drills undertaken to test the effectiveness of the early warning dissemination processes and responses.

3. Community Response Capacity Assessed and Strengthened

- Community ability to respond effectively to early warnings assessed.
- Response to previous disasters analyzed and lessons learnt incorporated into future capacity building strategies.
- Community-focused organizations engaged to assist with capacity building.
- Community and volunteer education and training programs developed and implemented.

4. Public Awareness and Education Enhanced

- Simple information on hazards, vulnerabilities, risks, and how to reduce disaster impacts disseminated to vulnerable people, communities and decision-makers.
- Community educated on how warnings will be disseminated and which sources are reliable and how to respond to different types of hazards after an early warning message is received.
- Community trained to recognize simple hydro-meteorological and geophysical hazard signals to allow immediate response.

- On-going public awareness and education built in to school curricula from primary schools to university.
- Mass media and folk or alternative media utilized to improve public awareness.
- Public awareness and education campaigns tailored to the specific need of each audience (e.g. children, vulnerable people, emergency managers, and media).
- Public awareness strategies and programs evaluated at least once per year and updated where required.

5. Good Practice in Warning Systems

Government Leadership

Throughout the previous sections, acceptance and leadership at high levels of government has been emphasized as a critical step in the development of effective warning services, especially MHEWS. In China, for example, government leaders called for multi-agency coordination, cooperation and participation in disaster prevention mechanisms including Multi-hazard Early Warnings. This is essential because an effective warning system depends on a coordinated response from many different agencies including those responsible for managing disasters, the transportation networks, schools and public safety, health services, agriculture, water resources and so on. By focusing on detection and warning, hydrometeorological services are the first link in the chain of disaster prevention and mitigation, and they also play a supporting role in prevention and mitigation, as well as rescue.

Laws help to identify the responsibilities of government administrative departments in emergency response to disasters, multi-agency coordination and cooperative activities. The legal framework for emergency response and the role of the meteorological and other agencies removes the uncertainty from an essential chain of command in an emergency situation. In general this framework establishes management responsibilities and coordination mechanisms across all levels of government. The law or regulation, for example, should establish who is responsible for providing a flood control agency with real-time information on weather, hydrology, and storm surges. It should identify which departments, such as telecommunications, transportation, electric power, and material supply should support flood control efforts.

Some countries have laws governing the provision of meteorological services and warnings, many do not. Meteorological laws and regulations are intended to define responsibilities for the provision of warnings about disastrous weather and establishing a communication protocol with other departments throughout a country. The regulation should define the responsibility of the NMSs to organize joint detection and their role in the provision of preventative measures, assessments and analysis on the impact of weather disasters, in order to provide governments with information in support of their decision-making process.

Depending on the country, multi-agency coordination for disaster prevention and mitigation involves, as a minimum, agriculture, fisheries, flood control, fire control, environmental protection, public health, education, harbor and maritime management, traffic and transportation, police, civil administration, and tourism.

Communication departments, such as radio, television and official government websites, as well as transportation operators, such as airports, railway stations, harbors, tourist attractions and traffic control should be required to follow the directives of the weather service and provide resources to facilitate the distribution of early warning information in a timely fashion. In the case of lightning disaster prevention, all enterprises, social groups or organizations (such as schools and community centers) should follow the advice of the weather service.

Coordination of Warning and Response Messages

Ensuring that warning information is consistent across different departments is important, especially when each has a joint, but differentiated responsibility for issuing warnings. The China Meteorological Administration (CMA), for example, issues fourteen categories of warning signals: tropical cyclones, heavy rain, heavy snow, cold surges, strong wind, dust, heat waves, droughts, thunder and lightning, hail, frost, heavy fog, haze, icy roads. In addition, the Shanghai Meteorological Service (SMS) issues ozone warnings and it is in the process of developing health warnings for specific weather-sensitive diseases (Fig. 1). The CMA is responsible for creating weather disaster prevention planning for multi-agency implementation. For example, emergency response categories (I, II, and III) have been developed for flood and typhoon prevention based on weather warning categories (blue, yellow, orange and red); for air pollution, CMA and the Ministry of Environmental Protection co-issue air quality status and 24-hour predictions; for geological disasters, CMA and the Ministry of Land and Resources co-issue geological disaster warnings; for drought relief, CMA and the Ministry of Agriculture issue drought warnings for agricultural departments; CMA distributes daily traffic and weather information and co-issues with the Ministry of transport warnings as needed; and so on.

Fig. 1 Examples of various warnings issued by CMA and SMS (Tang and Zou, 2009)

This coordinated approach ensures that warnings have the authority of both the meteorological service and the agencies responsible for the particular sector affected.

Similarly, it is important that warnings are consistent between countries that share common borders or are part of a economic coumminity with considerable cross border exchange of people, goods and services. This has been successfully developed in Europe through an initiative called meteoalarm[5]. Meteoalarm is aimed at anyone travelling through Europe. Pictograms and colour-coded maps of Europe show at a glance where the weather might be, or soon become, dangerous. Gales, torrential rain, snow and ice, thunder and lightening, fog, and extreme temperatures are all indicated as well as weather conditions that could lead to increasesd risk, such as storm surges and high waves, forest fires, and avalanches. The level of risk is colour coded (Table 1).

Green	Is your country colored green? Then there is nothing to worry about
Yellow	Yellow mean potential danger. The weather is unlikeoly to be extreme but care is called for in activities that are dependent on the weather. Keep an eye on the information.
Orange	Orange means danger. There is severe weather that may cause damage or accidents. Keep in minde that the weather bring risks. Be careful and keep abreast of the latest developments in the weather. Take head of all advice given by the authorities
Red	Red means great danger from extremely severe weather. Major damage and accidents are likely. In many cases with threat to life and limb, over a wide area. Be extremely careful, pay constant attention to bulletins and obey the instructions and advice given by the authorities under all circumstances. Keep in mind that exceptional measures may be taken.

Table 1. Explanation of Meteoalarm colors

Developing a common weather awareness is a challenge for many countries; however the experience with Meteoalarm is generally positive linking the underlying national warning infromation into a regional framework (Fig 2).

At this stage, Meteoalarm focuses mostly on meteorological phenomena, rather than issuing flood warnings for example. The basic system closely follows Météo-France's development of early warning systems for meteorological hazards using vigilance charts with color-coded hazards according to severity, which they applied to each of the 100 French departments (administrative regions). In 2003,

[5] www.meteoalarm.eu is the website that integrates all important severe weather information originating from the official National Public Weather Services across a large number of European countries. This information is presented consistently to ensure coherent interpretation as widely as possible throughout Europe. www.meteoalarm.eu is developed for EUMETNET, the Network of European Meteorological Services. This initiative is strongly supported by WMO the World Meteorological Organization.
The participating countries:
Austria, Belgium, Switzerland, Cyprus, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, Greece, Croatia, Hungary, Ireland, Iceland, Italy, Luxemburg, Latvia, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Sweden, Slovenia, Slovakia, United Kingdom

however, having a good forecast of the extreme heatwave that struck Europe and France during August was not good enough (Fig. 3). In the absence of a well prepared health care system capable of acting on the information, there were major public health consequences (Rogers et al. 2010) with between 50 000 and 70 000 extra deaths during a 16-day period throughout Europe. About 15 000 of these occurred in France alone, corresponding to a 60 per cent increase in expected mortality in France (Fouillet and others, 2006a).

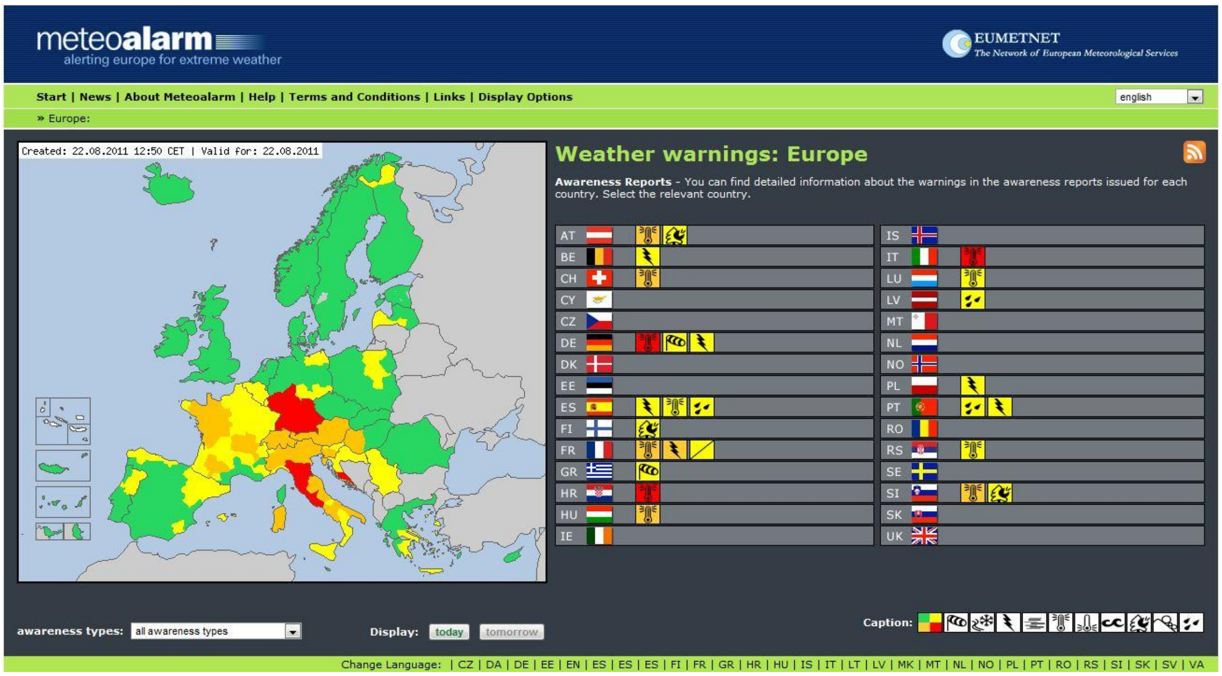

Fig. 2 Example of meteoalarm. Pictograms and color-coded maps show at a glance where the weather mingt be, or soon become dangerous.

This led the French Institute for Public Health Surveillance (InVS), in close cooperation with Météo-France, to define and implement a heat health watch warning system based on bio-meteorological indicators. The warning system operates from 1 June to 31 August (level 1, seasonal surveillance period). When the alert criteria are fulfilled, the departments declare a new action level (level 2). A third level, which results in maximum mobilization, is implemented if the impacts of the heatwave overwhelm the health system or include power cuts, drought, management problems in funeral centers or heavy air pollution (Josseran and others, 2009). The alert system aims to give the public authorities three days' prior warning that a heatwave may occur, in order for the National Heat Wave Plan (NHWP) measures to be put into operation (Pascal and others, 2006). The preventive measures are aimed at modifying the behavior of people, health institutions and health authorities with regard to high summer temperatures. They include television and radio spots, special assistance to people at risk (many of them being previously registered at their town halls), or facilities to access clinical information on recent morbidity or mortality.

This level of cooperation between the health and meteorological services, led by the health sector and where the meteorological warning works as a “trigger” for local action, is a good example of a multi-hazard early warning system enabling different sectors to work effectively with the climate community to support operational warning and response systems (Fig. 4).

The impact of this National Heat Wave Plan (NHWP) was evaluated during the July 2006 heatwave, which happened to be the second hottest month in France (since 1950) only three years after August 2003. During these 18 days of heat, the NHWP was exercised fully, including local care to elderly or sick people and daily health advice in all media. Two thousand extra deaths were observed, showing that additional deaths cannot be fully eradicated. Nevertheless, the detrimental effect of the heatwave was reduced significantly when compared with the effects of previous similar events such as in 1976 when there were 9000 additional deaths.

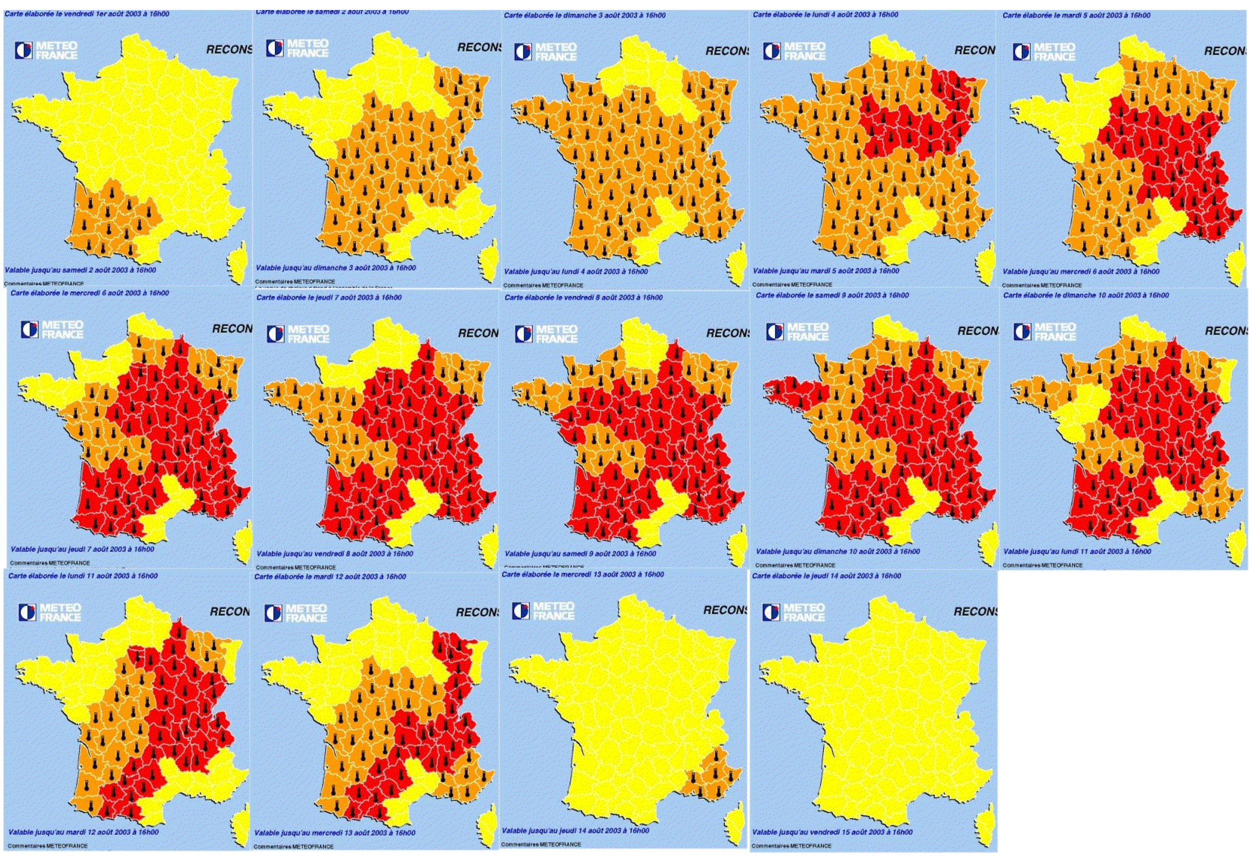

Fig. 3 MétéoFrance Cartes de Vigilence for the heat wave during August 2003

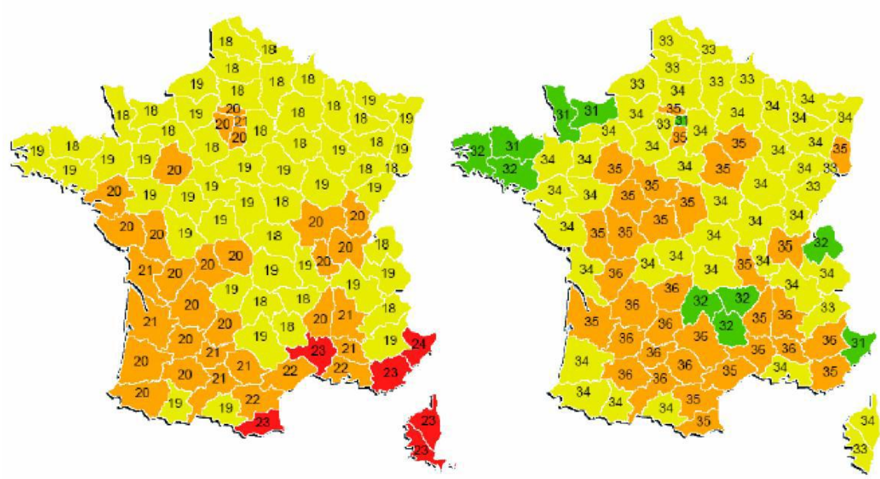

Fig. 4. Geographical variation in the minimum (left) and maximum (Right) Temperature thresholds by department for the French National Heat Health Warning System (InVS 2005)

Similar multi-hazard warning systems have also been developed for major cities. As a mega-city, Shanghai is particularly vulnerable to any hazard, such as typhoons, rainstorms, high temperatures, cold waves, thunder and lightning, and heavy fog, which can affect the lives of livelihoods of millions of people very quickly. The urban environment also creates a multiplicative effect where one hazard results in another; for example fog leading to traffic accidents, or heat waves and cold snaps that result in public health emergencies, which highlights the importance of multi-agency coordination and cooperation. This has been achieved in Shanghai through the establishment of a Multi-Hazard early warning System, which takes 'Multi-Agency Coordination" as the concept and technical core of the system to enhance the capacity of disaster prevention and mitigation in Shanghai.

The Shanghai Multi-Hazard Early Warning System (MHEWS) is jointly supported by the WMO, CMA, and the Shanghai Municipal Government (SMG). It is technically led by the Shanghai Meteorological Service and the Shanghai Municipal Emergency Response Management Office, and jointly developed by relevant local government agencies. The Shanghai MHEWS integrates diverse advanced technologies to support multi-hazard warning, multi-agency coordination and provides a multi-link to emergency response and rescue activities. The Shanghai MHEWS was invaluable in support of EXPO 2010, ongoing weather-related hazards, and will be a critical operational system in support of health forecasting, surveillance and early detection of health threats. It is planned to be the foundation for a broader city-wide hazards warning system.

A detailed explanation of this warning system based on the presentation of Tang and Zou (2009)[6] is given in Annex 1.

[6] http://www.wmo.int/pages/prog/drr/events/MHEWS-II/Presentations/Session%201/Shanghai/ShanghaiMHEWS.pdf

6. Adapting Good Practices in EWS in Developing Countries

At the heart of an effective early warning system is the capacity to predict hazards in a timely and accurate manner to provide useful information to decision-makers. The foregoing section highlighted the importance of multi-agency engagement and “buy-in” at senior levels of government. It also highlighted the critical importance of user engagement at all levels including communities and individuals.

Developing the capacity to observe and predict hazards and map vulnerabilities requires technological investment in observing networks, forecasting systems, communication and dissemination platforms; in other words – modernized NMHSs.

Nowcasting

A critical element is the capacity to provide nowcasts, which are forecasts for the following few hours via the analysis and extrapolation of weather systems as observed on radar, satellites and in situ sensors, such a rain gauges, and via the application of short-range numerical prediction. The techniques are applied to small-scale weather systems such as thunderstorms, which cause flash floods, lightning strikes and destructive winds. In the last two decades techniques have been developed digitize and merge remote sensing data with in situ observations and with numerical weather prediction forecasts. Radar is a particularly valuable tool since it provides the size, shape, intensity, speed and direction of movement of individual storms on a continuous basis. This ability to forecast precipitation amount or probability of hazardous weather at a given location and in a given time is particularly useful for the development of early warning systems for intense convective systems, which often result in a lot of damage. Active research continues into nowcasting systems, but several leading NMHSs and research laboratories have developed fully operational systems that could be adapted to World Bank client countries’ needs (WMO 2010).

These systems include:

- Beijing Auto Nowcaster and NCAR VDRAS (BJANC) (Beijing Meteorological Bureau, China, and National Center for Atmospheric Research, USA)
- Canadian Radar Decision System (CARDS) (Environment Canada)
- GRAPES-based Severe Weather Integrated Forecasting Tools (GRAPES-SWIFT) (Guangdong Provincial Meteorological Bureau and Chinese Academy of Sciences, China)
- Niwot (National Center for Atmospheric Research, USA)
- Short-Term Ensemble Prediction System (STEPS) (Bureau of Meteorology, Australia and Met Office, UK)
- Short-range Warning of Intense Rainstorms in Localized Systems (SWIRLS) (Hong Kong Observatory, Hong Kong, China)

From the output of these systems, useful nowcasting services can be developed to enable the public and users to take mitigating action to reduce risk of damage and loss caused by approaching high impact weather. An example of the BJANC output from the World Expo Nowcasting System (WENS) (WMO 2010) is shown in Fig. 5.

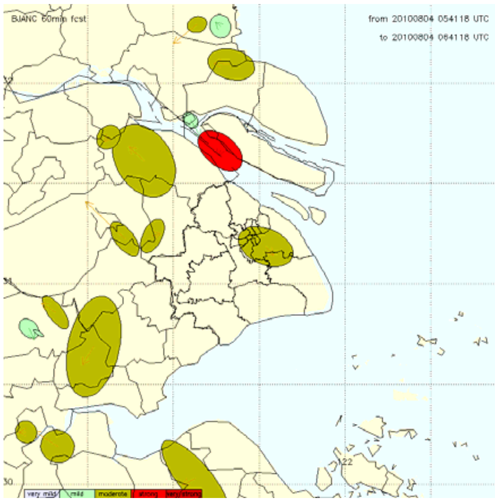

Fig. 5. T+60 minute thunderstorm nowcasting generated by BJANC (WMO 2010).

Creating Effective Service Delivery

Effective service delivery is also a key component of early warning that all NMHSs must and can adopt. Effective services should be:

- Available: at time and space scales that the user needs;
- Dependable: delivered regularly and on time;
- Usable: presented in user specific formats so that the client can fully understand;
- Useful: to respond appropriately to user needs;
- Credible: for the user to confidently apply to decision-making;
- Authentic: entitled to be accepted by stakeholders in the given decision contexts;
- Responsive and flexible: to the evolving user needs,
- Sustainable: affordable and consistent over time, and,
- Expandable: to be applicable to different kinds of services.

The following are prerequisites for an effective warning service

Step 1: Focus on the User

a) Identify the users

The purpose of preparing and delivering services to users is to enable them to make better decisions by using weather and climate information. User engagement and feedback is essential in designing and delivering effective services. For the implementation of a successful service delivery mechanism, it is very important to identify specific users that your Service will be serving, and to engage with them appropriately. Generally, users may be divided into five main groups as follows:

- The hazards community - The mission (shared with the NMHS) of these organizations is to ensure safety of life, livelihood and protection of property. The NMHS should consult and coordinate closely with them, know their specific requirements and give them high priority. The public safety, emergency and civil defense agencies constitute this important group. Their mandate and responsibilities make them major players in planning for and responding to most emergency situations. It is clearly in the interest of NMHSs to ensure that coordination with these important organizations be given a high priority.

- Government authorities – Governments are the most important users of the services and information provided by NMHSs. The most important users are usually the host ministry where the NMHS is situated. It is important to ascertain the requirements of this group and to maintain formal communication with them.
- Weather-sensitive economic sectors – Public Weather Services can be of significant value to weather-sensitive sectors of the economy such as agriculture, forestry, fishing, marine, air and land transport, energy production, construction, sport, tourism and outdoor entertainment. Many NMHSs also provide specialized meteorological, climatological and hydrological services. The needs of this user group can be very specific, ranging from long-range forecasts and climate information for planning purposes to short range forecasts and warnings for daily operations.
- Media (print, radio, TV and others) - The media is the most important user and partner of NMHSs products and services. Different media types and outlets have well defined expectations in regards to the final product they require from NMHSs. The final forecast product would need to be tailored to suit the media delivering the product.
- The public – The general public is the largest user group of NMHSs. The most important need of the public concerns warnings of severe weather so as to take prompt action to preserve life and secure property. Their routine needs relate to travel, leisure and general convenience. The requirements of general public are not as precise and well-defined as those for other user sectors and have to be better ascertained through establishing feedback mechanisms including comprehensive, fact-finding surveys.

(b) Determine user needs

Different users have different needs and the only way to determine their exact requirement is through consultation and gathering information. The starting point should be to ask very clearly how the currently available weather information is used in daily decision making by users, how they apply it and what would be the negative impact of lack of such information. The following lists a number of techniques that can be applied to gather such information:

- Surveys, questionnaires, interviews and in-depth case studies to identify a broad overview of the users' needs and expectations. Expertise outside of NMHSs, such as professional survey designers may be required for this type of information gathering;
- Fora and workshops with users' participation in order to learn their requirements and to explain to them of the capabilities of the NMHS;
- Pilot projects in collaboration with users to develop products and services on a longer term to meet the stated requirements;
- Monitoring feedback of user response through press clippings, letters, phone-calls, fax, suggestion boxes or the Internet;

- Interaction with users during Open Days, World Meteorological Day and activities of the NMHS outreach program;
- Regular meetings with government agencies and emergency managers to ascertain their information needs.

(c) Ensure that users are aware of NMHS services

It is important that users be made aware of the services that an NMHS can deliver as well as understand the limitations of forecast and warning products. Hosting discussion and short training events by NMHSs for different user groups helps to make them aware of how weather and climate products are prepared. Operational forecasters should be involved in such training for fruitful dialogue with users. Table 2 shows user groups and suggested approaches to educate or reach out to them.

User Groups	***Training Courses***	***Seminars***	***Informal***	***Leaflets / Pamphlets***	***Media***	***One-to-One***
Politicians / Senior Public Servants			x		x	x
Emergency Managers		x	x			x
Water Managers		x				x
Transport Authorities		x				x
Power Supply Engineers		x				x
Media	x		x			x
Farmers		x		x	x	
Fishermen		x		x	x	
Schools	x			x	x	
General Public				x	x	

Table 2: User groups and suggested approaches to educate or reach out to them

Step 2: Focus on internal organization of NMHSs

(a) Get NMHSs ready to deliver service

Delivery of effective public weather services needs an organization-wide commitment involving the NMHSs' leadership, technical systems and those directly involved in service delivery. An enthusiastic and motivated focal point or team of officers trained in different aspects of service delivery such as consultation and communication with user groups and with skills in dissemination and presentation of NMHSs' products would be a necessity for effective service delivery. Where possible, a Public Weather Services (PWS) office or unit should be established for this purpose.

(b) Ensure that NMHSs' staff is aware of the user needs

This step requires that members of staff in charge of service delivery are informed in detail of the requirements of different users and NMHSs' processes for preparing and delivering the required services.

This may require training, to be conducted within NMHSs so that all staff would follow the same rules and regulations and 'read from the same page' as they serve users.

(c) Develop an effective warning program

Since preparing and issuing warnings of hazardous weather is one of the most essential activities of NMHSs, it is crucial to develop an effective warning program. NMHSs' staff in charge of forecasting and public weather service provision should be involved in the development of the program as they are aware of the realities on the ground in terms of strengths and limitations of their Service. To be successful, a warning program strives to ensure that everyone at risk must:

- Receive the warning;
- Understand the information presented;
- Believe the information;
- Personalize the information;
- Make correct decisions; and,
- Respond in a timely manner.

The ideal warning process has to take into account each of the above components to be successful. It takes training and planning as well as strong collaboration with other partner agencies such as the disaster management and media, to implement a warning program.

Step 3: Improve communication skills of NMHSs' Staff

Communication is one of the most necessary skills for a forecaster, but it is a skill rarely taught during academic training in Meteorology. Communication, at its most fundamental, involves the transmission of thoughts, emotions and meaning from one person to another. While words (written or spoken) are usually thought of as the primary medium of communication, studies have shown that many other factors (tone of voice, inflection and body language) play a significant role in aiding (or impeding) communication. Effective two-way communication implies listening skills as well as speaking skills. Confidence is an important element in communication, and this cannot be taught directly, but must be developed within each person. Formal communication training courses for forecasters (in whatever medium they are required to operate – telephone, radio, television, etc.) are crucial in developing communication skills, but they should be augmented with mentoring and feedback schemes and with regular refresher training.

Step 4: Engage users

(a) Formalize NMHS working relationship

Formalize the working relationship with the user and agree on the following:

- Detailed description of products and services needed by the users;
- Detailed description of products and services provided by the NMHS;
- Service delivery procedures including product formats and delivery times;

- Responsibilities of the NMHS – ensuring high quality products and timely delivery;
- Responsibilities of the user – providing regular feedback on the quality of the services. (This is important to the NMHSs for use in service improvement);
- Training that may be required for users, including schedules;
- Assigning NMHS and user focal points who would: be easily accessible; capable of responding to concerns that may arise and; oversee the success of the mutual engagement.

(b) Engage and educate the media

Many NMHSs have difficulties in working successfully with media organizations. However, there is a substantial common interest between NMHSs and the media in providing a quality weather service to the public. Therefore, a dialogue needs to be established with media representatives through which NMHS personnel can gain a full understanding of the media concerns while the media representatives can gain an appreciation of the services that the NMHS can deliver. This is best achieved by a combination of formal (seminars, training courses) and informal contacts such as social events, familiarization visits, etc. In order to kick off media engagement where it has not existed before, training by internationally-respected experts, organized through WMO is recommended. NMHSs may learn the following from the media:

- How to write appropriate press releases for use by the media;
- How to organize proper press conferences, press briefs etc;
- How to perform effectively during radio, television or newspaper interviews etc.

The media may learn the following from the NMHS:

- Understanding and interpreting basic weather terminologies;
- Understanding and interpreting forecasts, advisories and warnings correctly;
- The limitations associated with the accuracy of weather forecasts;
- Communicating forecast uncertainty and confidence etc.

Step 5: Conduct Service Evaluation for Improvement

(a) Verification

This involves assessing the accuracy of forecasts and warnings from a technical point of view. It serves to inform the NMHS about the skills of its forecast procedures and the aspects of forecasting that need improvement. If no verification procedure exists in the NMHS, start with very simple steps to verify one or two elements (e.g., rainfall, temperature) in a few key locations, and use many available WMO resources to have staff trained on more advanced verification methodologies.

(b) Assessing user satisfaction and perception

Service evaluation determines whether services are meeting user requirements and ascertains whether users understand the products and services provided and are making optimum use of them. Some of items to consider include the language used in communicating forecasts (non-technical and simple for non-meteorologists), the timeliness of forecasts, presentation formats, and communication and dissemination methods. Evaluation must include an assessment of what value the users gained from NMHSs products and services and how such services helped them with making informed decisions. The evaluation process should be kept simple with the aim of having some results available when talking to decision-makers and in response to media enquiries. Annexes to this document provide examples of service delivery evaluation surveys.

Step 6: Make a PWS implementation / Improvement Plan

(a) Timelines

A Service Delivery Plan for NMHSs, should include an implementation program in the form of a table of activities to be carried such as meetings with respective users or user groups, training seminars or workshops, the agreements to be entered into etc. The plan should take into account the realities of the situation on the ground, including budgetary and personnel matters. These considerations are essential in helping to fix realistic timelines for achievement of milestones of the implementation of the plan.

(b) Action persons

A good plan is specific, not just on the actions to be taken, but also on the person to take the action. Contact details of the action persons should be included as appropriate. The action people should include focal points from the user organization(s) engaged in the project.

With these elements in place, NMHSs should be in a position to begin developing more effective warning services leading to the development of MHEWS.

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Annex I – Shanghai Multi-Hazard Early Warning System

The following is intended to provide the reader with a detailed example of how a multi-hazard warning system is developed and implemented starting with an explanation of the problem that the warning system is intended to address.

Multi-Hazard Classification

About 90% of natural disasters in Shanghai are of meteorological origin. There are three categories of hazards: 1) weather and climate hazards, which include typhoons, severe convective weather, heavy rainfall, heavy fog, snow and icing weather; 2) weather- and climate-related hazards, which include storm surges, urban inundation, heat wave and human health, epidemic diseases, bacterial food poisoning, strong haze and air pollution, transportation, energy consumption, and aeronautical hazards; and 3) other hazards, which include fire accidents, human accidents, and chemical gas leaks.

Risk Analysis

Good risk analysis information is essential for emergency response preparedness. The following shows the distribution of severe convective weather between 1994 and 2004 (Fig. 1).

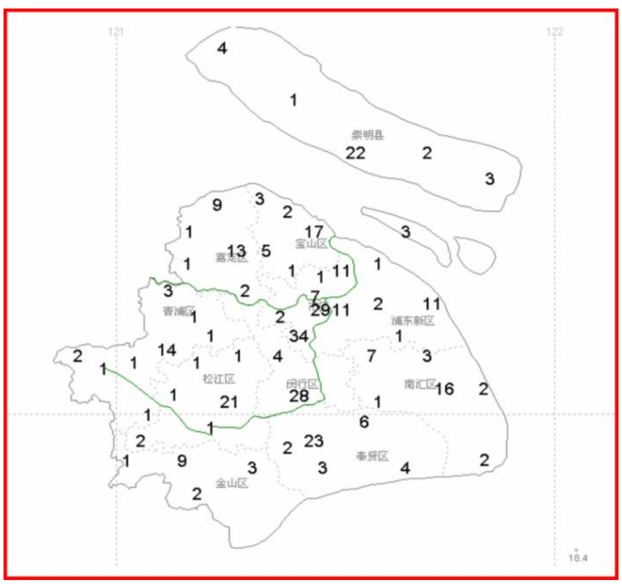


Fig. 1. Distribution of severe convective weather in Shanghai (1994 – 2004)(after Tang and Zou 2009)

This is useful for emergency response planning because it identifies “hot-spots” where severe convection is more likely to occur and therefore it can be used to develop a spatial warning standard. Similarly, a lightning risk map can be developed based on historical lightning disasters with damage reports over a long period, historical lightning and thunder data, and exposure information (e.g., number of tall buildings) (Fig. 2).

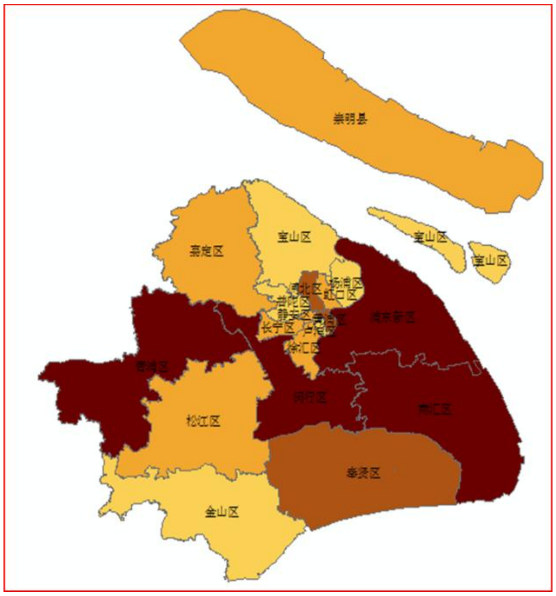


Fig. 2. Lightning risk map, based on historical damage, historical lightning detection, and exposure information (Tang and Zou 2009)

Factors such as regional total rainfall, drainage capacity, topography and vulnerabilities are integrated to provide a comprehensive risk map of torrential rain and flooding (Fig. 3).

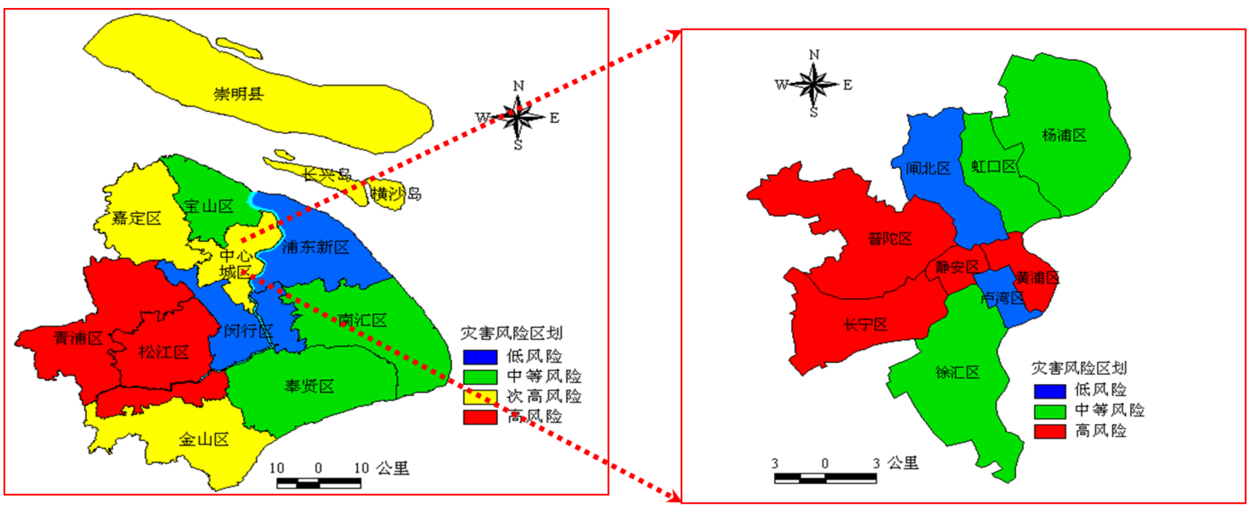


Fig. 3. Flood risk maps of greater Shanghai (left) and city center (right) (Tang and Zou 2009)

The flood risk map contributes to guidelines for land use planning and strengthening the infrastructure for specific regions, and provides guidance for multi-agency cooperation and coordination. Other agencies also identify potential risks; for example, The Safety Administration map risks related to dangerous chemical sources and The Real Estate Department provide risk surveys and maps of buildings and houses, which are vulnerable to disasters.

MHEWS in the Structure of the Emergency Management System

The follow illustrates the role of the Shanghai MHEWS in the Emergency Management System (EMS) (Fig. 4).

Fig. 4. Role of Shanghai MHEWS in the Structure of EMS (Tang and Zou 2009)

MHEWS, as one of the two technical centers in Shanghai, provides support to the Shanghai Emergency Response Management Platform and guidance to decision-makers for emergency events. The MHEWS warning and dissemination platform also acts as the municipal-level platform for disseminating emergency response information (Fig. 5).

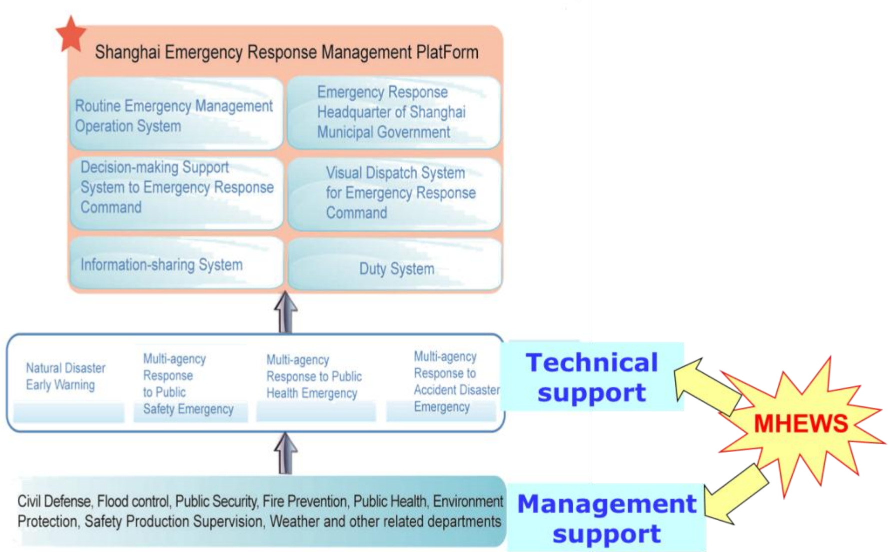


Fig. 5. The role of MHEWS in the Shanghai Emergency Response Management Platform (Tang and Zou 2009)

The Shanghai Meteorological Service is a member of the Emergency Management Committee and is responsible for lightning hazard emergency response, MHEWS development and integration within the central emergency management, and the daily operations of MHEWS. The organizational structure for the implementation of emergency management plans is shown in Fig 6.

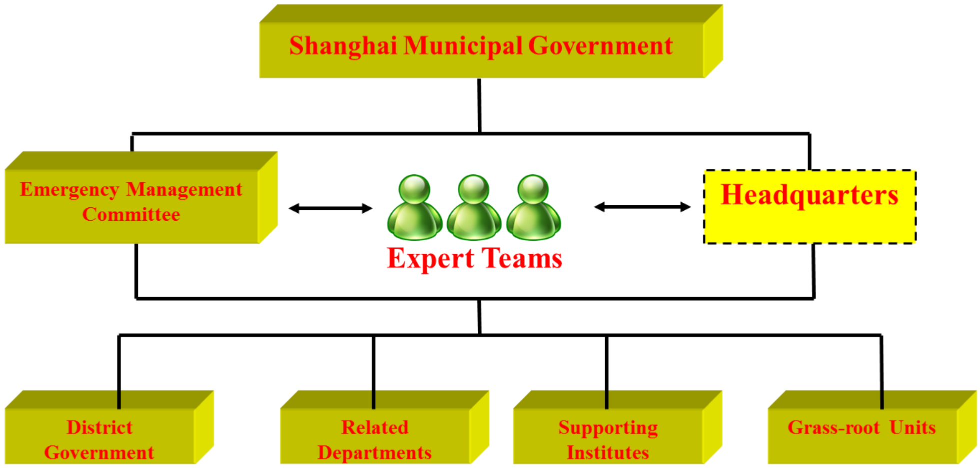


Fig. 6. Organizational structure for implementing emergency management plans (Tang and Zou 2009)

Coordination Mechanisms

An important element of a coordinated response to a hazard is the development of a Joint response, which includes warnings and standard response actions. For example, when SMS issues a typhoon blue warning, the relevant warning for flood and typhoon control is issued by the Flood Control Headquarters and related joint defense actions are implemented immediately (Fig 7).

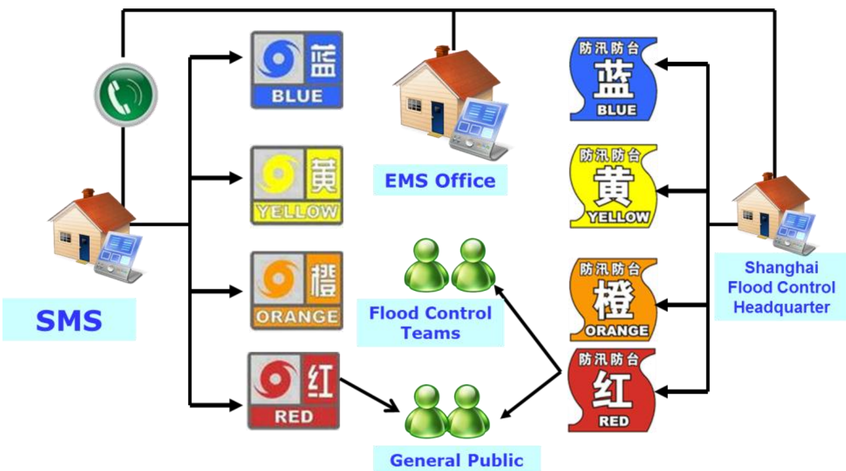


Fig. 7. Joint response for flood control. An important element is that both the Shanghai Meteorological Service and Flood Control Headquarters issue warnings using the same multi-color warning system, although each is providing different information. SMS provides typhoon-related information, while flood-related information is issued by the flood control headquarters (Tang and Zou 2009).

For heat waves and related health warnings, these are developed jointly by SMS and the Public Health Authority and jointly issued (Fig. 8).

Fig. 8. Health warnings are an example of joint production and joint issue of warning and guidance (Tang and Zou 2009).

A third coordination mechanism focuses on supporting efforts; for example special plans for accident disasters, such a chemical spills. In this case, SMS provides specialized support alongside public security, fire control, rescue teams, environmental services, and medical teams.

A fourth coordination mechanism is joint dissemination. Here warnings and guidance are issued to the Urban Grid Management System, related departments and the general public with a dissemination mechanism in each sector (Fig 9).

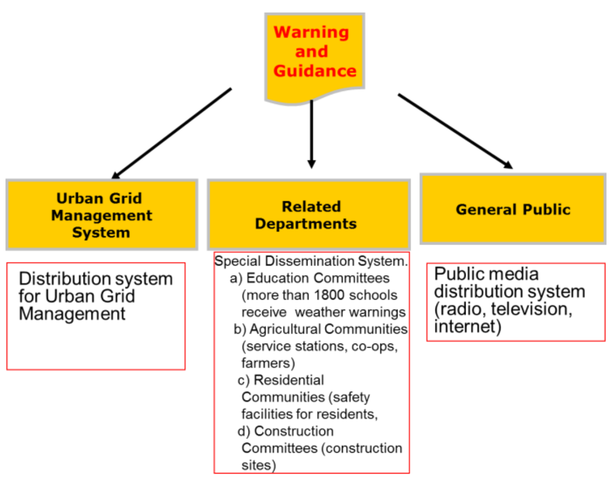


Fig. 9. Joint dissemination (Tang and Zou 2009)

Throughout the early warning system process there is a need for coordinated actions between different agencies in the fields of

- Information sharing;
- Joint generation of early warning information;
- Joint dissemination of early warning information;
- Coordination and cooperation of emergency response deployment; and
- Joint research and training.

The following table (Table 1) highlights the complexity of the process and number of different bodies that must be involved in each of these fields.

Activity	Responsible Organizations
Data and Information Sharing	Emergency Response Management Office, Emergency Response Center, Urban Grid Management Center, Marine Board, Traffic Bureau, Water Affairs Bureau, airports, Civil Affairs Bureau, Electric power company, Food and Drug Supervision Administration, Fire-risk Prevention Bureau Administration……
Joint development of technology	Public Health Bureau, Food and Drug Supervision Administration, Agriculture Commission, Construction & Transportation Committee, Environmental Protection Administration, Electric power company…
Joint Dissemination of Emergency Information	Emergency Response Management Office (early communication before warning) Daily Air Quality (Environmental Protection Administration), Bacterial food poisoning warning (Food and Drug Supervision Administration)…
Joint Response	Flood control departments, Education Commission, Construction & Transportation Committee, Communications Authority, Marine Board, Electric power company…

Table 1. Collaboration and Coordination in Early Warning Systems (Tang and Zou 2009)

Response Levels

An example of the type of response for each warning level is shown in Table 2.

Early Warning Grades	**Response Levels (Implemented by Shanghai Flood Control Headquarters)**
BLUE	Organize a consultation meeting to strengthen flood monitoring and flood control supervision, report the situation to Municipal Flood Control Headquarters and notify the Emergency Response Center of Shanghai Municipal Government.
YELLOW	Organize a consultation meeting to strengthen flood monitoring and flood control supervision, propose specific preparation requirements, report the situation to the Shanghai Municipal Government and notify the Emergency Response Center.
ORANGE	Deputy commander-in-chief for Municipal Flood Control Headquarters will chair the consultation meeting to strengthen flood monitoring and flood control supervision, to direct counter-measures, and report the situation to the leaders of the Shanghai Municipal Government. If necessary, an emergency response meeting will be held to plan flood and typhoon control more efficiently.
RED	Commander-in-chief of the Municipal Flood Control Headquarters will chair the consultation meeting, participating in planning flood and typhoon control guidelines. If necessary, the leaders of the Shanghai Municipal Government will deliver a speech on Television or radio to encourage all the military and civilians to devote themselves to disaster resistance and rescue. Report the situation to the State Council and related state-level departments according to National General Emergency Response Readiness and other related regulations.

Table 2. Example of early warning grades and responses for flood control (Tang and Zou 2009).

In the case of bacterial food poisoning, the SMS and Shanghai Food and Drug Administration share meteorological information and cases, and develop joint research on early warning technology. This includes the development of research on the relationships between bacterial food poisoning and meteorological conditions; and joint research in the development of warning models, and standardized warning levels and preventative measures. The output of the warning model is used by both organizations to issue jointly warnings to the public and food vendors.

Warning Dissemination

Warnings are disseminated by a variety of methods to ensure that everyone who needs the information receives it (Table 3).

No.	Issuing methods	Receivers
1	File Transmission Protocol (FTP)	the public
2	BGU transmitting system	community supervisors
3	Cell-Phone Dissemination System	municipal decision makers, various government agencies, residential community managers, basic response units managers (i.e. school, hospital, park, construction sites), the public
4	FM Subsidiary Communication Authorization (SCA)	special users
5	Radio Broadcasting	the public
6	Public Electronic Billboards	the public
7	Mobile Media TV	passengers in taxi, bus, and subway
8	Warning Calls	basic response units office
9	Dedicated Lines	municipal decision makers, city affairs management departments, and special users
10	Other Public Media (i.e. newspaper, TV)	the public

Table 3. Methods of warning dissemination (Tang and Zou 2009)

Technical Components of MHEWS

The Shanghai MHEWS consists of six technical components:

1. Early Detection and Monitoring Platform, which includes multi-hazard integrated monitoring, disaster tracking and trend warning;
2. Forecast and Prediction Information Generation Platform, which includes various subsystems involving meteorology, traffic, electricity and power security, agriculture, human health and other related fields;
3. Decision-Making Support Platform, which implements the multi-agency cooperation processes, measures and disaster prevention guidelines;
4. Warning Information Dissemination Platform, which corresponds to the Shanghai municipal emergency warning information dissemination platform;

5. Multi-Hazard Information Database, which provides multi-agency real-time monitoring information collection, disaster information and historical data sharing, as well as disaster impact assessments; and
6. Multi-agency coordination network system.

There are three management components:

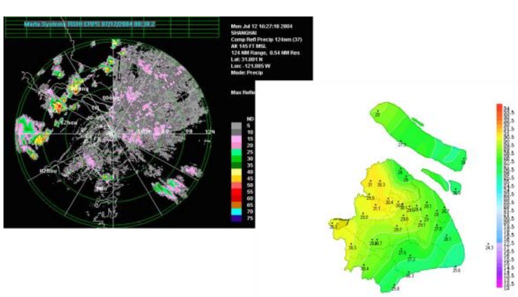
1. Multi-agency coordination and cooperation mechanisms;
2. Safe community protection system for local communities; and
3. Inter-city and inter-provincial disaster prevention mechanism.

Monitoring and Detection Platform

The monitoring and detection platform provides 24/7 monitoring of potential disasters and developing trends. Color codes are used to differentiate between – Outlook (yellow), Watch (orange) and Warning (red). This method is used to track the potential risk from high impact weather, such as typhoons (fig. 10).

Fig. 10. Monitoring and detection of high impact weather. Colors indicate severity of situation (Tang and Zou 2009).

Detailed information is provided by weather radar (Fig. 11a), lightning detection networks and automatic weather stations (Fig 11b).



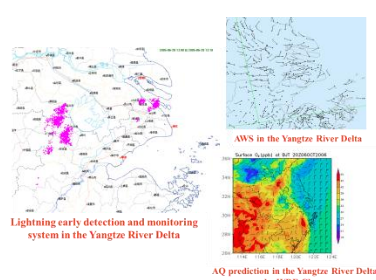


Fig 11. a) Weather Radar, b) lightning detection, air quality prediction and automatic weather stations (Tang and Zou 2009)

These and other tools are combined into a composite multi-product monitoring and early warning interface (Fig. 12).

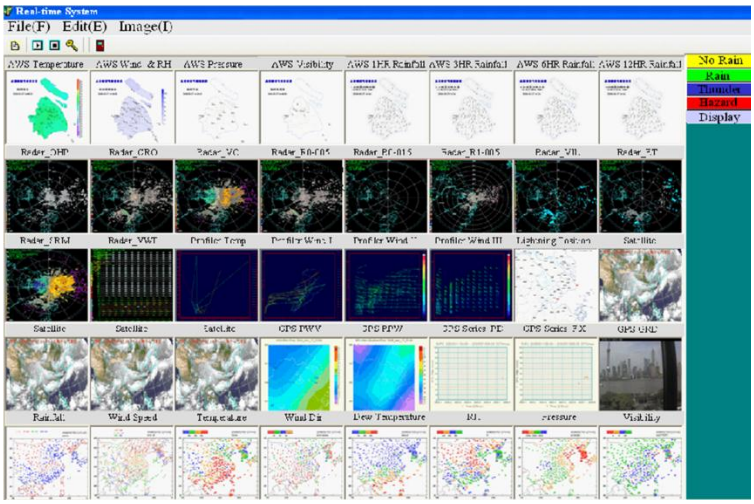


Fig. 12. Multi-product monitoring and early warning interface (Tang and Zou 2009).

Forecast and Warning Information Generation Platform

The traditional weather forecast has been extended to weather-related disaster prediction and warning threat. The service provided by SMS has become the start-up and critical support to the whole procedure of MHEWS and the city emergency management system. The Forecast and Warning Information Generation Platform provides weather analysis, related disaster forecasts and warning products to many fields, such as transportation, power, chemical, agriculture and public health (Fig 13).

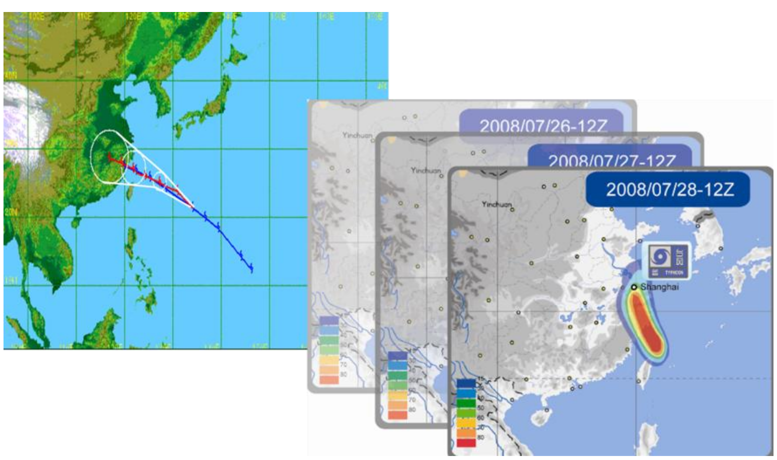


Fig. 13. Example of weather forecast and analysis related to typhoon landfall (Tang and Zou 2009).

The EWS forecast and information generation platform consists of many subsystems (Fig. 14) to provide forecasts of extreme weather related to severe convective weather, tropical cyclones, heavy fog, snow and freezing raining. The system also provides forecasts of weather-related hazards including heavy haze and static stability, marine meteorological hazards, wind hazards, lightning hazards, agricultural hazards, urban traffic, aeronautical risks, potential fire hazards, bacterial food poisoning, heat waves and human health, dangerous gas diffusion, urban inundation, energy security and infectious diseases.

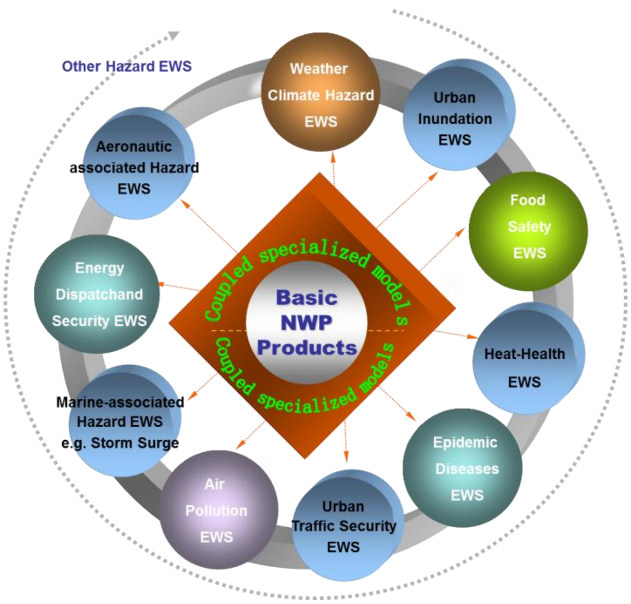


Fig 14. EWS forecast and Warning Information Generation Platform Subsystems (Tang and Zou 2009)

The urban inundation early warning subsystem, for example, is built on a partnership between SMS and the Shanghai Water Affairs Authority. The subsystem consists of an inundation simulation model, a geographic information system (GIS), and meteorological data inputs, including high-resolution output from numerical weather prediction (NWP) models, automatic weather station observations, radar data and hydrological data. The subsystem provides precipitation forecasts and utilizes risk assessment maps of the inundation area (Fig. 15).

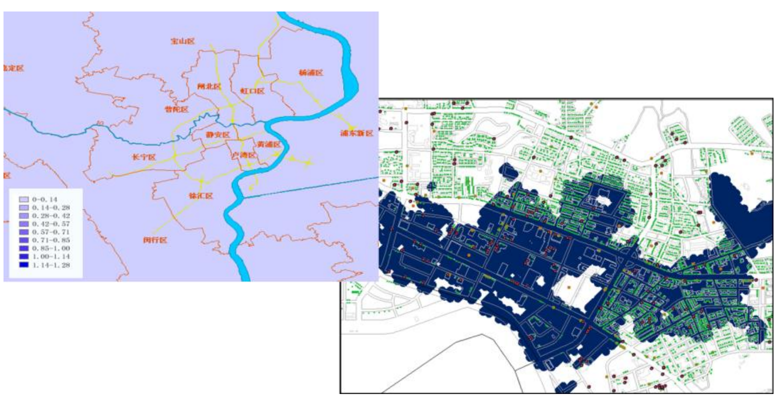


Fig. 15. Precipitation forecast and map of risk of inundation (Tang and Zou 2009)

The inundation early warning system includes a gridded map of Shanghai with 4600 grid points according to topographic features, and the area forecast system feeds the urban inundation model to provide forecasts of inundation at very high resolution (Fig. 16).

Fig. 16. Urban Inundation Early Warning Subsystem (Tang and Zou 2009)

Another example is the heat-health warning subsystem. Developed in cooperation with the Shanghai Public Health Bureau, it provides early warning of dangerous health conditions associated with prolonged periods of hot weather. The framework for this system is shown in Fig. 17.

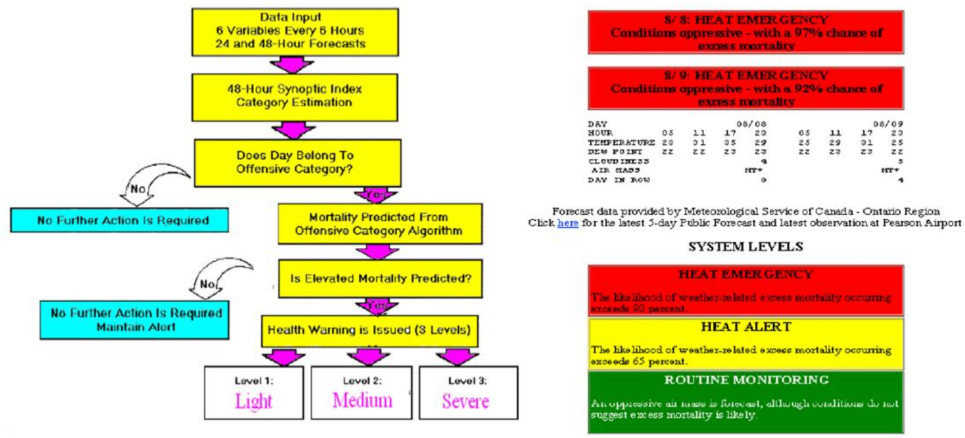


Fig. 17. Heat-health early warning framework (Tang and Zou 2009)

Decision-Making Support Platform

The decision-making support platform is a physical environment designed to facilitate coordination and cooperation between staff from the various agencies involved to determine the appropriate level of disaster response. The facility is the command center for early warning. Lead by a chief service officer it integrates all of the information from the various forecasting subsystems (Fig. 18).

Fig. 18. EWS Decision-Making Support Platform (Tang and Zou 2009)

Warning Dissemination Platform

The warning dissemination platform operates at multiple levels – city, department and public. At the city-level, the Municipal Emergency Office issues management information to 3000 staff in 76 different departments based on the Weather Information Dissemination Platform. At the Department-level, the cell phone messaging system of the Met Service sends warnings concerning water affairs, flood prevention, sunstroke, food poisoning and community management. This warning dissemination subsystem covers more than 800 residential areas, 1780 junior and primary schools and 300 agricultural units. At the public-level, information is disseminated several ways. Shanghai has constructed a community warning light system, which is being extended to the tallest buildings in each district (Fig. 19a). Mass coverage using cell-phone messaging and cell broadcast has also been implemented (Fig. 190b) along with a public warning dissemination network consisting of more than 50,000 public electronic screens (Fig. 19c), 2000 billboard TV screens, and 1000 electronic road signs.

Fig. 19a. Community warning light system

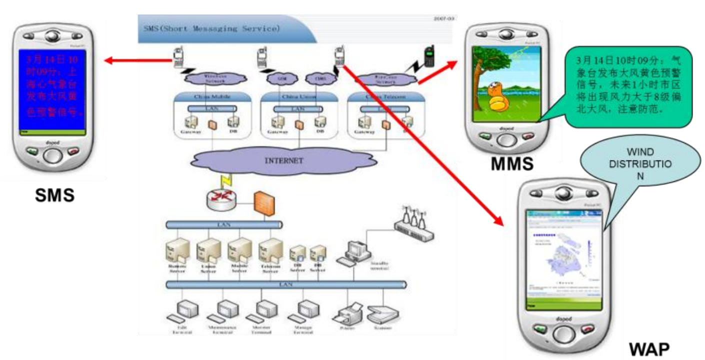


Fig. 19b. Cell-phone dissemination (SMS, MMS, WAP) supported by a layered user database.

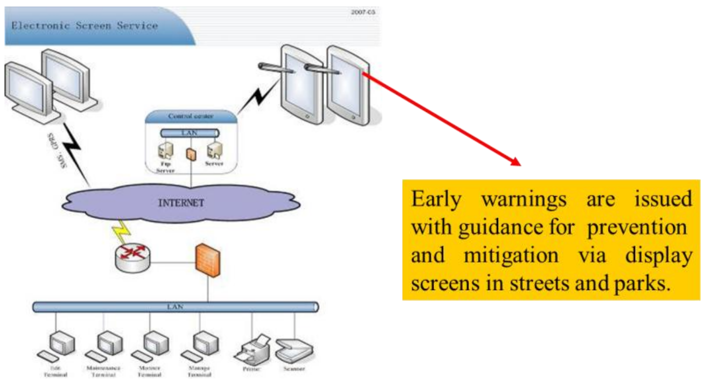


Fig. 19c. Public Electronic Screen Dissemination (Tang and Zou 2009)

Multi-Hazard Information Data Base

The data base for the MHEWS provides all platforms real-time monitoring information, disaster risk information and historical data (Fig. 20).

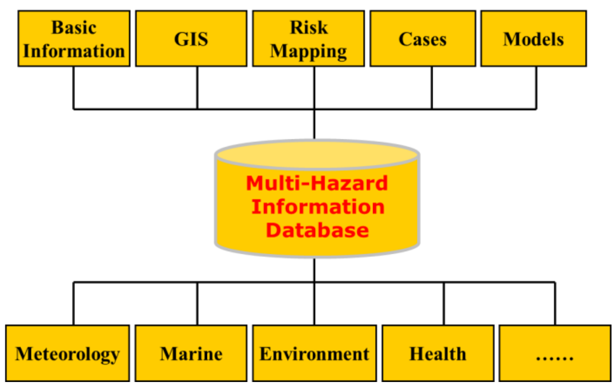


Fig. 20. Multi-hazard information data base that supports all of the platforms (Tang and Zou 2009).

Multi-Agency Coordination Network System

This component is established to ensure information sharing between agencies and helps monitor response to the warning information. There are about 36 joint response mechanisms which are initiated by the government covering 25 government departments and including the entire infrastructure of the city to ensure efficient cooperation in emergency management. The multi-agency coordination ensures early briefing to the agencies that need to respond quickly. It provides for early consultation with users to exploit uncertainty information within probabilistic weather forecasts to better understand the available risk information, and therefore the opportunity to deploy early to take effective action.