WEATHER AND ITS CONSEQUENCES TO EMERGENCIES

Ivan Obrusnik[1]
Czech Hydrometeorological Institute

Keywords: Early warning, forecast, multi-hazard, disasters, meteorology

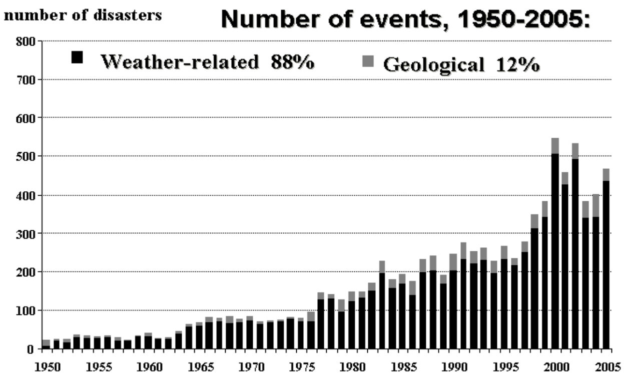
Abstract

Weather is rather important factor in many disasters and practically almost 90% of natural disasters taking place every year are connected with weather, climate or and water. Main weather related disasters are floods, tropical cyclones, tornadoes, severe weather and many others. Some of the disasters are connected with variability of climate. Most of weather - related events are fast and need appropriate and quick early warning (EW). National Meteorological and Hydrological Services (NMHSs), which should be an integral part of state emergency systems usually, issue such warnings. They utilize all available modern technology for observations including satellites and radars, numerical weather or hydrological modeling and data and information dissemination. All warnings should be accurate, timely and should reach responsible authorities, communities and finally the public. Activities of NMHSs have been supported and coordinated on international scale by the World Meteorological organization (WMO). Examples of early warning for natural hazards like tropical cyclone, flood, and drought, environmental hazards like forest fires as well as man made hazards provided by NMHSs connected to emergency systems are shown. Finally, a multi-hazard approach to early warning and disaster reduction is introduced.

Natural disasters of meteorological or hydrological origin

The number of natural disasters as well as their impact has been showing increasing tendency last 10 or 15 years. Most of these disasters, almost 90%, are weather-, climate- and water-related events (CRED, 2006).

Fig 1: Number of disasters in the last 50 years

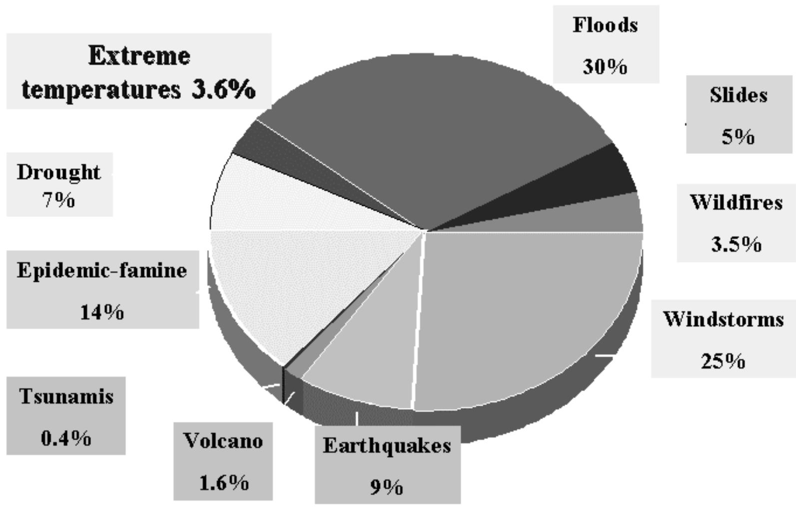


[1] Na Sabatce 17, 143 06 Prague 4, Czech Republic

It is a reason why both *National Meteorological and Hydrological Services (NMHSs*) on national and the World Meteorological organization (WMO) on international levels have been more and more involved in disaster reduction nowadays. Disaster reduction in general should always strongly involve activities of NMHSs and WMO especially in its early warning part. Last decade has shown many examples of well functioning NMHSs as well as some drawbacks in activities of NMHSs before and during disasters. NMHSs play an important role in weather-related disasters, which can be both very fast like tornado but also relatively slow like drought.

A distribution of weather-related and other types of hazards is shown in Fig 2.

Fig 2: Types of hazards leading to disasters



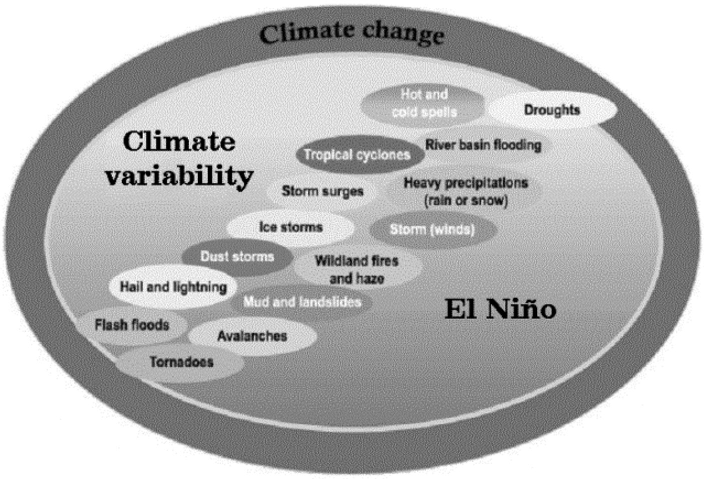
Early warning (EW) for such hazards covers a wide time span – from the shortest lead time for warning in the case of tornadoes, flash floods, hails and lightning (minutes or tens of minutes) up to relatively long lead time in the case of spells of hot and cold air or droughts (months). In recent years, climate variability and possible climate change can have a strong influence on number and range of weather extremes and consequent disasters (see Fig. 3). Each of the above-mentioned types of hazards needs a special approach to prepare an accurate and timely warning. NMHSs responsible for warnings have to utilize all data and information available and create forecasts and warnings tailored for emergency systems as well as for direct communication of warnings to the public by means of media, the Internet or mobile phones.

Role of the World Meteorological Organization in disaster reduction

The World Meteorological Organization coordinates observations, data processing and other activities of NMHSs towards reduction of life and property from natural and human induced disasters. Space and land-based hydrometeorological observations provide data and information needed for the forecasts and early warnings enabling preparedness for emergency relief and response. To affect relief efforts in humanitarian crises, the WMO-24-hour national operational contacts offer services including general briefings on the emergency's environmental conditions, weather advisories and seasonal outlooks.
Observing systems on platforms ranging from satellites, weather radars to buoys measure a variety of data. More than 10 000 manned and automatic surface weather stations, 1 000 upper- air stations, some 7 000 ships, 100 moored and over 1 000 drifting buoys and

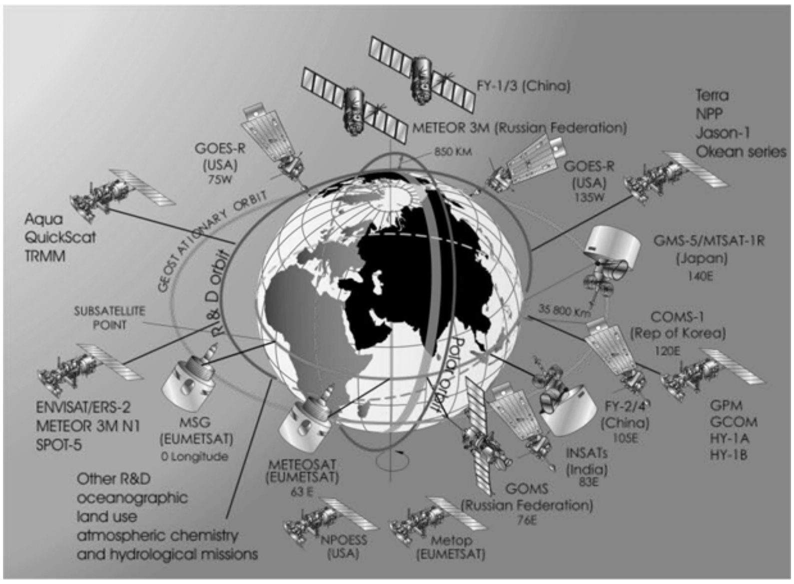
hundreds of weather radars measure every day key parameters of the atmosphere, land and ocean surface. In addition, over 3 000 commercial aircraft provide more than 150 000 observations daily.

Fig. 3: Weather-, climate- and water- related hazards (Jarraud, 2006)



The Environmental Observation Satellite network included five operational near-polar-orbiting satellites and six operational geostationary environmental observation satellites as well as several Research and Development satellites.

Fig 4: Network of meteorological satellites (WMO, 2004)



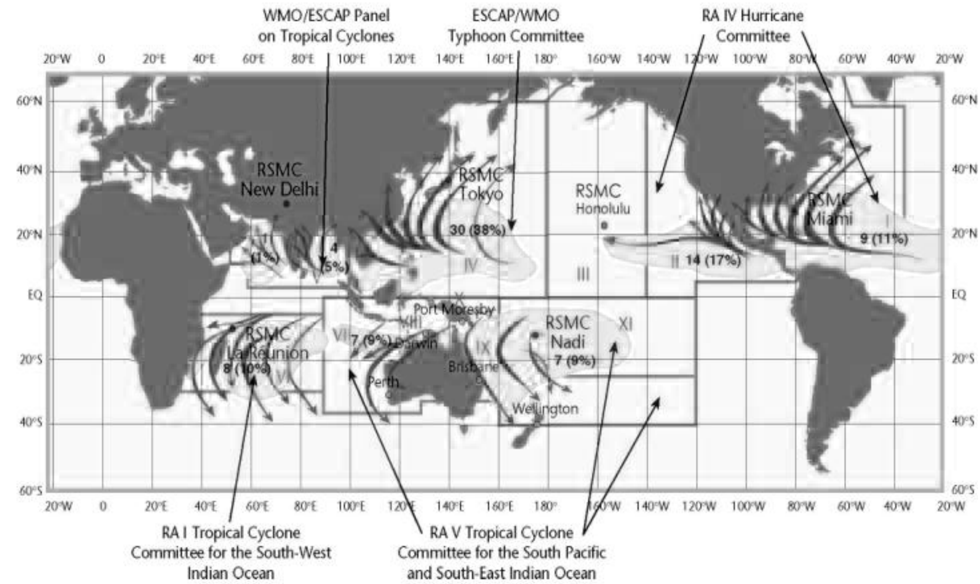
Polar orbiting and geostationary satellites are normally equipped with visible and infrared imagers and sounders, from which one can derive many meteorological parameters. Geostationary satellites can be used to measure wind velocity in the tropics by tracking clouds and water vapor. Satellite sensors, communications and data assimilation techniques are evolving steadily so that better use is being made of the vast amount of satellite data. Improvements in numerical modeling in particular, have made it possible to develop increasingly sophisticated methods of deriving the temperature and humidity information directly from the satellite radiances. Research and Development (R&D) satellites comprise the newest constellation in the space-based component of the Global Observing System (GOS).

The Global Telecommunication System (GTS) internationally exchanges the resulting data and information from observations, as well as the forecasts and warnings generated. Specialized weather and climate modeling centers process data and make model outputs and products available for use by all the nations. Some centers produce weather analyses, forecasts, advisories and warnings. Others produce monthly, seasonal and inter-annual analysis and forecast products, and also specialized products. Moreover, many NMHSs compute daily regional weather models with higher resolution giving more precise forecasts but for shorter lead-time than global models from the specialized modeling centers. For over 50 years, WMO has facilitated worldwide cooperation in establishing observation networks and has promoted the provision of meteorological and related services.

Tropical Cyclones

Tropical cyclones (Bulletin, 2006) are one of the most devastating of all natural phenomena. They form over all tropical oceans. In the western North Pacific, mature tropical cyclones are known as *typhoons*, in the western hemisphere are called *hurricanes* and *tropical cyclones* in other areas. The potential for creating destruction caused by their violent winds, torrential rains and their size, severity, and frequency of occurrence and vulnerability of the vast areas they affect compound associated storm surge.

Fig 5: Regional Specialized Meteorological Centers for tropical cyclone warning



Thanks to international cooperation and coordination by WMO, and with the aid of meteorology and modern technology, such as satellites, weather radars and computers, all tropical cyclones around the globe are now being monitored from their early stages and throughout their lifetime by relevant centers of NMHSs and by six Regional Specialized Meteorological Centers (RSMCs) located in Honolulu, Miami, Nadi (Fiji), New Delhi, Tokyo and La Réunion. Most of the damage inflicted by tropical cyclones is usually caused by storm surge and flooding. A typical example could be hurricane Katrina, which caused severe damage and losses in Louisiana and New Orleans especially by flooding despite a well-predicted trajectory and strengths of the hurricane itself.

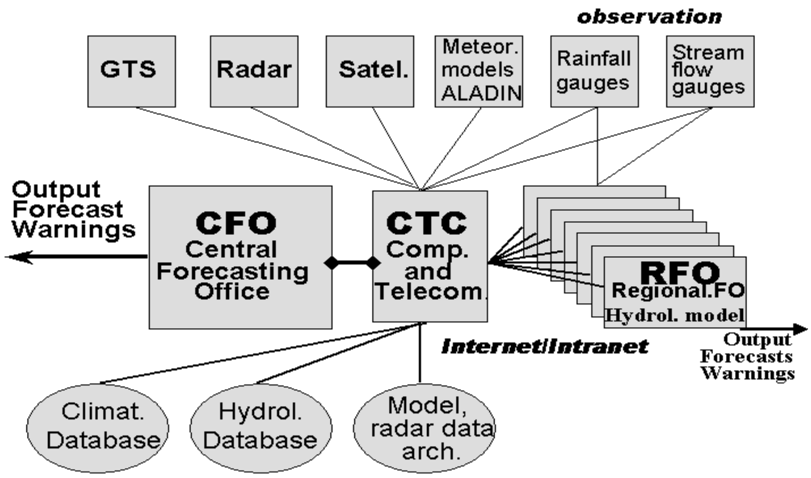
Similarly, NMHSs with the help of coordination and methodological support from WMO have been issuing forecasts and warnings for many other types of disasters of hydrometeorological origin like various types of storms including snowstorms, tornadoes and hails, torrential rains, heat and frost waves and also droughts, etc. However, the most frequent hazards causing enormous damages all over the world are floods.

Forecasting and warning system for floods

Flood forecasting and warning is relatively difficult task, which needs a close cooperation between meteorologists and hydrologists and good cooperation with other parts of emergency systems. In general, an accurate and timely forecast of forthcoming flood, its progress in time as well as forecasting the end of such event is a good, even though rather difficult example of involvement of NMHSs in early warning.

One example of a fully integrated approach to flood forecast and warning could be found in the Czech Republic, which passed through three big floods during last decade (in 1997, 2002 and 2006 years). During this decade an early warning system for floods had to be improved from both the point of view of an application of recent scientific and technological tools and by the use of rather advanced and efficient organization of Forecasting and Warning Service (FWS). Organization of such a system is shown in Fig. 6.

Fig 6: Simplified scheme of Forecasting and Warning System for floods

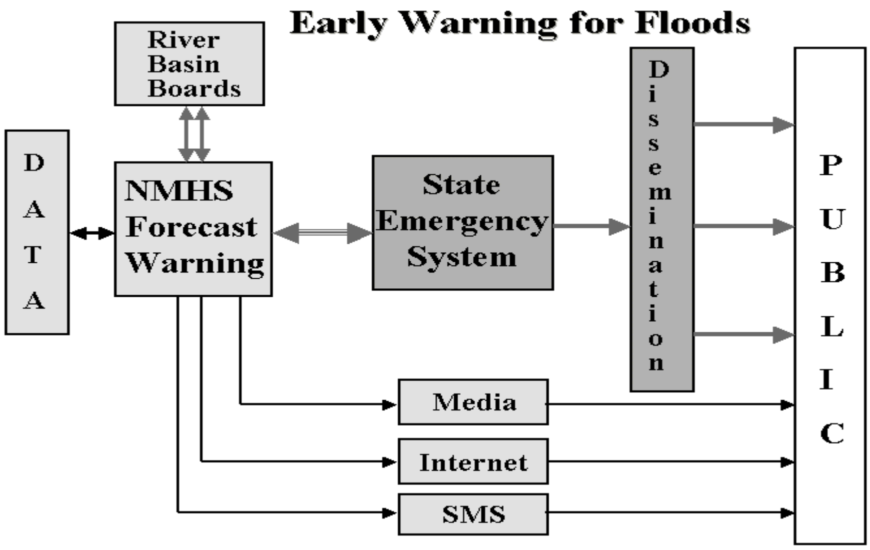


This FWS system involves the Central Forecasting Office (CFO) and six Regional Forecasting Offices (RFOs) and is based on *a multi-sensor observation input* (precipitation, river flow, and data from the WMO Global Telecommunication System (GTS)).

The system is based on *modern remote sensing systems like weather radars and satellites* (especially for nowcasting). Moreover, the system also routinely uses data from *numerical weather models* for heavy precipitation forecast and permits flood forecasts with a longer lead-time. The system uses also hydrologists both at CFO and RFOs equipped with *hydrological models* producing forecasts of water levels and discharges in river profiles. Potentially, GIS images of flooded zones would be added. The development of the hydrological part of the system, especially the models and river gage networks, together with information about reservoirs has been coordinated with River Basin Authorities.

However, FWS run by NMHS should be cooperating with *River Basin Boards* (there are five of them in the country) and connected with the state emergency system. Fig. 7 shows the warnings are disseminated to lower levels of the system like regions, districts, communities, and finally, to the public by this system with the help of the *Main Office of Fire and Rescue Service.*

Fig 7: Integration of Forecasting and Warning Service of NMHS in a state emergency system



All activities should be in accordance with flood mitigation plans and under a direct supervision of the *Flood Authorities*. When the flood reaches a disastrous level, then *crisis management staffs* would take over command and lead instead of the flood authorities. The minister of interior has the command and responsibility for the Central Crisis Management Staff in all non-military emergencies and disasters in the country. Fig.7 also shows that in many urgent cases an additional dissemination of warnings directly via media; the Internet and SMS messages via GSM should efficiently be used.

Climate

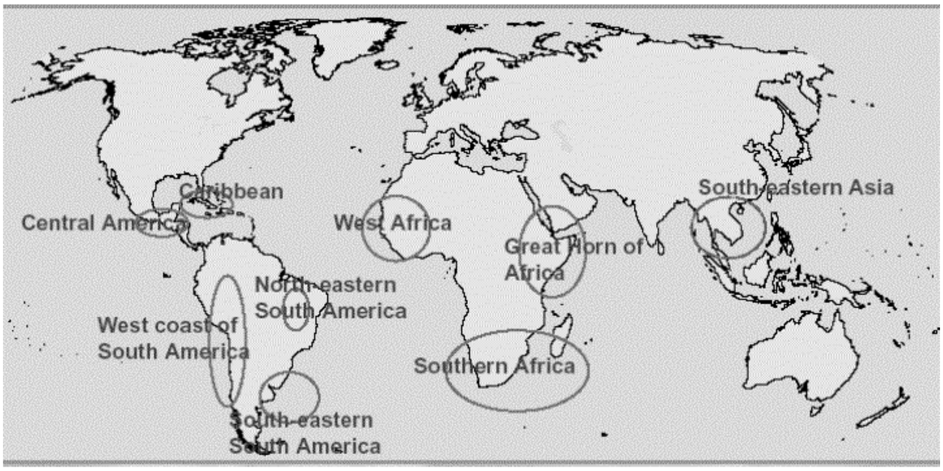
Climate variations at all timescales can have major impacts on numerous human activities. Prediction of such variations and events bring about major humanitarian and economic benefits. The need for systematic climate observations for the understanding and prediction of climate trends and variability, for the detection and attribution of climate change, and for providing guidance on mitigation and adaptation measures is now widely recognized. WMO and NMHSs contribute to fulfilling this need, and especially to meeting the requirements of the United Nations Framework Convention on Climate Change (UNFCCC) for climate information. Early warning for climate extremes allows sufficient lead-time for authorities and the public to act and to reduce losses on property and lives. NMHSs provide such forecasts and warnings in a timely manner by application of climatological and hydrological knowledge and in cooperation with emergency and relief agencies.

a) El Niňo
One rather dramatic phenomenon among Earth's climatic variations is the El Niño/Southern Oscillation (ENSO). An *El Niño* strikes every three to seven years, when trade winds in the tropical parts of the Pacific Ocean weaken or reverse their usual route. The winds then blow surface water warmed by the tropical Sun to the eastern Pacific Ocean and the equatorial west coast of South America. Rain follows the current, and eastern South America may then experience flooding, while Australia, southern Africa and Indonesia may have drought. A La Niña event is the opposite, with warmer waters in the western Pacific and cooler waters off the west coast of South America.

The prediction of El Niño/La Niña events up to several months ahead based on a careful monitoring of the sea-surface temperatures of the Pacific Ocean is a top priority for NMHSs around the world enabling to diminish impacts of this climatic phenomenon.

Regional Climate Outlook Forums (RCOFs) established in some areas (see Fig. 8) prior the 1997-1998 El Niňo event could provide advance information on the likely climate features of the upcoming season. RCOFS stimulate the development of climate capacity in NMHSs of the area, and can be helping to generate decisions and activities towards mitigation of adverse impacts of climate and climate variability.

Fig. 8: Regional Climate Outlook Forums in the world (CLIPS, 2006)



b) Heat waves
Heat waves, higher maximum temperatures and an increase in the number of hot days are already happening. The risks are significant: some heatwaves are associated with pollution; they kill or affect more people than tornadoes, earthquakes or hurricanes. Cities are hardest hit because even small increases in global temperatures can be amplified via the "heat island" effect. In the urban environment, concrete, tarmac and tall buildings absorb solar radiation and release it to the air, while the relative lack of vegetation means there is less cooling by evaporation. Deaths from heatstroke in large cities could become much higher. An example is a high level of human losses in France during a heat wave in summer 2003. Away from the cities, livestock and wildlife can suffer from heat stress, crops fail, and tourism may decline.

c) Droughts
Drought could be the most devastating climate extreme. Without proper management droughts can trigger other human-made tragedies such as famine, widespread displacement and death especially in developing countries. Drought predictions dependent on monitoring observed patterns of monthly and seasonal rainfall, streamflow, groundwater levels, snow cover and other parameters. Some NMHSs have developed drought EW systems capable of integrating reports and data from various sources and of identifying the start of drought period. Droughts in many countries have been linked to El Niňo. However, in some parts of the world like Europe without so strong phenomena like E Niňo seasonal forecasts from modeling and drought warnings have been more difficult.

d) Forest fires
Forest Fires are uncontrolled fires occurring in vegetation more than 1.8 m in height, which have become rather frequent in the past decade in many parts of the world. When combined with lightning strikes and human actions drought conditions produce thousands of forest or wildland fires. The use of models to simulate duration, spread and intensity of fire is an effective tool for fire management and some NMHSs produce warnings and forecasts for

such fires. A modern approach is the use of satellite remote sensing for wildfire monitoring and fire danger assessment.

e) Locusts
Locusts in large numbers can devastate large areas and cause big losses in agriculture especially in some developing countries. Accurate meteorological information is crucial for understanding locust outbreaks, upsurges and plaques and for eventual control operations. NMHSs in locusts affected areas of Africa, the Middle East and Asia provide necessary information and forecasts when required. At international level the Desert Locusts Information Service of FAO maintains a global overview and prepares medium- to long-term forecasts for all countries within the distribution areas of the desert locust.

Environmental emergency

WMO assists NMHSs and other national and international authorities to respond effectively to environmental emergencies involving the large-scale dispersion of airborne hazardous substances, caused, in particular, by nuclear and radiological incidents. Preparedness programs are of particular importance for rapid and effective meteorological support required to mitigate the disastrous consequences of a nuclear emergency.

The International Atomic Energy Agency/WMO Joint Radiation Emergency Management Plan commenced for an international nuclear exercise to test the full operation of the emergency information-exchange procedures with the help of WMO's Regional Specialized Meteorological Centers, Regional Telecommunication Hubs and NMHSs at national levels.

NMHSs and WMO have also been supporting emergency response to the dispersion of smoke from large fires, ash and other emissions from volcanic eruptions and chemical releases from industrial accidents. Some of NMHSs are responsible also for smog forecasting and warning.

Another important problem where meteorology plays a key role is *ozone depletion*. The stratospheric ozone layer protects plants, marine life, animals and people against harmful effects of solar ultraviolet B (UV-B) radiation. In the mid-1980s, the discovery of a "hole" in the stratospheric ozone layer over the Antarctic lead to intensive research of the chemistry and transport of ozone in the atmosphere. Increased UV radiation harms DNA in animals, inhibits photosynthesis in plants and damages the plankton forming the base of the marine food chain.

The subsequent finding, based on monitoring, that chlorofluorocarbons from industrial and cooling processes, along with other anthropogenic chemicals, were responsible for this catastrophic thinning of ozone prompted the drawing up of the 1985 Vienna Convention on the Protection of the Ozone Layer and the 1987 Montreal Protocol on Substances that Deplete the Ozone layer and its subsequent Amendments. Both NMHSs and WMO have been involved in these activities and issuing warnings and forecasts of dangerous levels of the ozone layer and solar UV-B radiation.

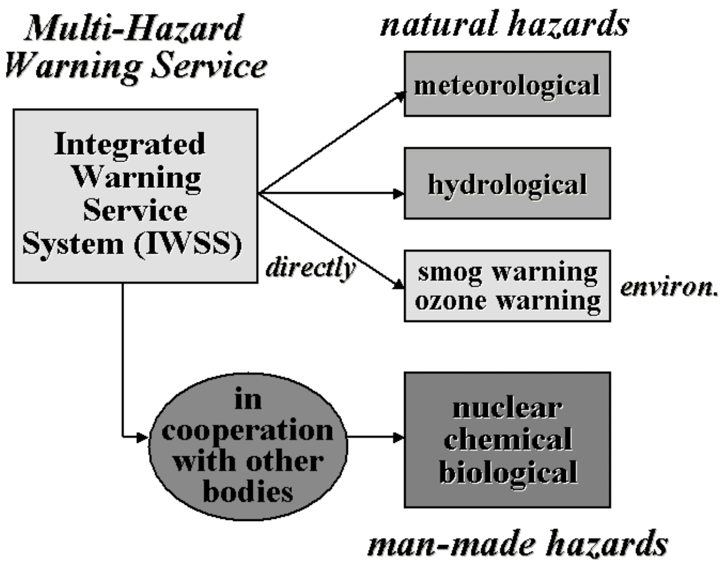
Role of NMHSs and WMO in Multi-hazard early warning

Many disasters in the last decade have shown an urgent need for early warning for a wider range of hazards both natural and man-made. This multi-hazard approach cn efficiently utilized infrastructures of NMHSs, WMO and other agencies on international, regional and national scales. A system established in the Czech Republic shown schematically in Fig. 8 can serve as an example of such approach.

This system produces early warning for meteorological, hydrological, environmental and man-made hazards and cooperates closely with other parts of the state emergency system. The very close cooperation of the Czech NMHS with crisis management authorities has lead step by step to acknowledgement of CHMI as official authority (single voice) for issuing meteorological, hydrological and air pollution warnings and information. At the same time, CHMI has become a standard part of the state emergency system.

Similarly, global early warning systems, including national alert-and-response mechanisms based on a multi-hazard approach, could avert disasters like the Indian Ocean tsunami of December 2004.

Fig. 9: Multi-hazard warning service used by NMHS in the Czech Republic (Obrusnik, 2001)



WMO's Global Telecommunication System (GTS) provides end-to-end capabilities for data collection and the development and dissemination of early warnings internationally. The GTS is already used by the Pacific Tsunami Early Warning System, which is coordinated by the International Coordination Group for the Tsunami Warning System in the Pacific of the Intergovernmental Oceanographic Commission (UNESCO), and has proved to be highly effective. The Pacific Tsunami Warning Center, operated by NMHSs from USA and Japan, will use the GTS for issuing tsunami early warnings to the Indian Ocean Rim countries, while the Indian Ocean Tsunami Early Warning and Mitigation System is being developed. The GTS will serve as a critical telecommunication mechanism for the exchange of tsunami related data and warnings in the longer term. WMO is taking action to ensure that the GTS will be fully operational for tsunami and seismic applications in the Indian Ocean and other areas at risk. It is building on the telecommunication and staffing infrastructure, which is already in place for tropical cyclone and storm-surge warnings.

Conclusions

Meteorology and hydrology play an important role in decreasing losses of human life, destruction of social and economic infrastructure and degradation of already fragile ecosystems caused by various kinds of natural and man-made disasters. WMO and the National Meteorological and Hydrological Services contribute significantly, at international and national levels, in the identification, assessment and monitoring of disaster risks and the provision of early warnings. They need to cooperate with national emergency systems and authorities, scientific communities, intergovernmental and non-governmental organizations, the private sector, the media and the public to be aware of the role of NMHSs and WMO and ensure that they have the capacity to contribute to the mitigation of disasters.

References

Bulletin (2006). Preventing and Mitigating Natural Disasters, Vol. 55, No. 1, World Meteorological Organization, Geneva, Switzerland.

CLIPS (2006). Climate Information and Prediction Services Program. World Meteorological Organization, Geneva, Switzerland. http://www.wmo.int. Last Accessed 15 April 2006.

CRED. (2006). EM-DAT:OFDA/CRED International Database. Centre for Research and Epidemiology of Disasters, Brussels, Belgium. http://www.cred.be.emdat. Last Accessed 25 March 2006.

Jarraud, M. (2006). Framework for Multi-Hazard, Multi-Purpose Early Warning Systems. In presentation at the Third International Early Warning Conference (EWC III), Bonn, Germany.

Obrusnik, I. Nemec, J. (2001): Role of NMHSs in Early Warning Systems, Bulletin, Vol.50, No. 1, pp 30-40, WMO, Geneva, Switzerland.

WMO (2004). Working Together for a Safer World. Natural Disaster Prevention and Mitigation Programme. WMO-No.976. World Meteorological Organization, Geneva, Switzerland.