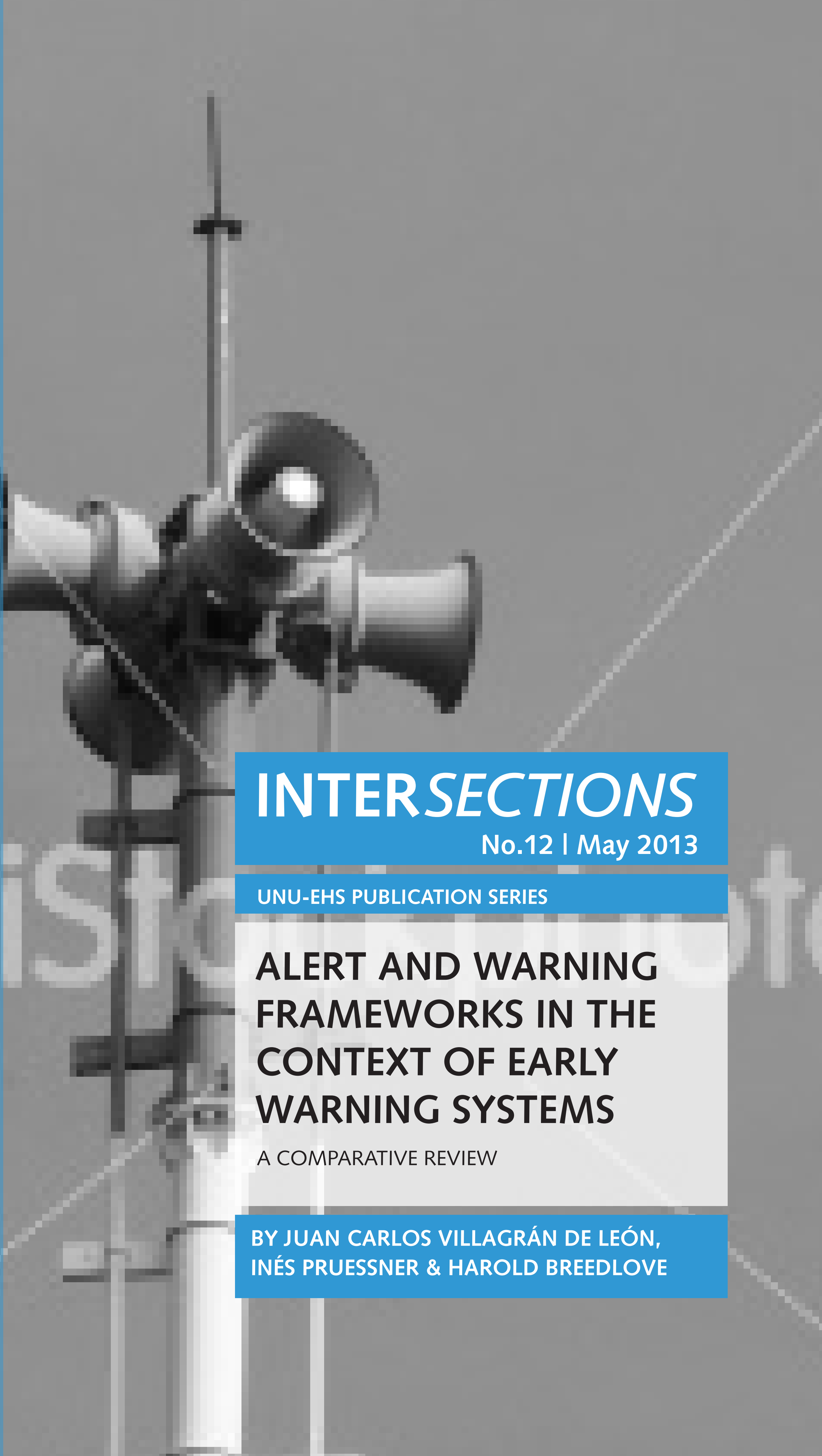

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ALERT AND WARNING FRAMEWORKS IN THE CONTEXT OF EARLY WARNING SYSTEMS

A COMPARATIVE REVIEW

BY JUAN CARLOS VILLAGRÁN DE LEÓN, INÉS PRUESSNER & HAROLD BREEDLOVE

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Not all frameworks in operation in all countries of the world are covered in this publication, and there has been a need to interpret terms and phrases based on the fact that information is supplied in different languages. All responsibility remains with the authors, who have done their best to capture and present the data and the information in the most professional way possible.

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Alert and Warning Frameworks in the Context of Early Warning Systems

A comparative review

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Foreword

The growing frequency and magnitude of extreme environmental events such as floods, droughts, tsunamis and earthquakes is increasingly becoming a threat to sustainable development, particularly in less wealthy countries or regions. As an important pillar in mitigating the risks and impacts of such events, Member States around the world have set up early warning systems, which allow those at risk to seek shelter before the manifestation of such events and to minimize losses. Within a broad set of measures for disaster risk reduction, early warning systems are particularly attractive for at least two reasons: first, they generally have a favourable cost-benefit ratio; and second, their flexibility making them particularly attractive in view of adaptation to different future climate change scenarios. The Hyogo Framework for Action (HFA), which stands as the international cornerstone to promote disaster risk reduction as the way to build the resilience of nations and communities to disasters, stresses the importance of early warning systems as an essential element of disaster risk reduction. In a similar fashion and in the aftermath of the Indian Ocean tsunami in December 2004, the United Nations called for the establishment of a globally comprehensive early warning system.

The benefit of early warning systems depends heavily on a careful assessment of the type and level of risk, the vulnerability of communities and their preparedness and response capabilities. In the international arena, the United Nations and other regional and international organizations have joined forces to promote and to contribute to the establishment of early warning systems and to facilitate the exchange of experiences and lessons learned among experts and professionals being in charge of operating such systems.

In this essay, the authors present a comparative review of early warning systems which have been established by Member States around the world for a variety of hazards from the perspective of their alert and warning frameworks. The authors urge us to recognize existing differences among these systems which arise as a consequence of the need to adapt such systems to the dynamics of environmental events. These differences are manifested in the number of danger and risk levels which are employed within different systems, the criteria used to define such levels as well as the nomenclature employed to differentiate the levels.

This UNU-EHS InterSections underlines the need to access the topic of early warning from different viewpoints as a way to provide policy relevant advice concerning early warning systems to Member States, and to contribute to the efforts of the United Nations in addressing international cooperation and development of generally applicable standards. This essay complements other UNU-EHS early warning system-related publications and articles. With its globally comparative review it aims to offer options and suggestions to those involved in the design and routine operation of such systems.

Disasters reveal vulnerability, lack of coping capacity and resilience. Ensuring human security requires a paradigm shift in the concept of disaster risk reduction. It is with this perspective that UNU-EHS has been undertaking its work as a way to provide policy relevant advice to Member States worldwide in their efforts to achieve human security through preparedness measures.

J. Rhyner

Prof. Dr. Jakob Rhyner
Director, UNU-EHS

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Abbreviations and acronyms

CENAPRED	*National Disaster Prevention Centre, Mexico*
CONRED	*National Coordinating Agency for Disaster Reduction, Guatemala*
COPECO	*Permanent Contingencies´ Commission, Honduras*
CRED	*Centre for Research on the Epidemiology of Disasters*
DEMA	*Danish Emergency Management Agency*
EU	*European Union*
EUMETNET	*European Meteorological Network*
FAO	*Food and Agriculture Organization, UN*
FEWSNET	*Famine Early Warning Systems Network*
GFMC	*Global Fire Monitoring Centre, Germany*
GIEWS	*Global Information and Early Warning System on Food and Agriculture, FAO*
HFA	*Hyogo Framework for Action*
HPSC	*Health Protection Surveillance Centre, Ireland*
ICGP	*Irish College of General Practitioners, Ireland*
IDEAM	*Institute of Hydrology, Meteorology, and Environmental Studies, Colombia*
IDNDR	*International Decade for Natural Disaster Reduction, UN*
INDECI	*National Civil Defence Institute, Peru*
INETER	*National Institute of Territorial Studies, Nicaragua*
ISDR	*International Strategy for Disaster Reduction*
ISDR-PPEW	*Platform for the Promotion of Early Warning, ISDR*
JMA	*Japan Meteorological Agency*
MFEWS	*Mesoamerican Famine Early Warning System*
NEAM TWS	*Tsunami Early Warning and Mitigation System for the North-Eastern Atlantic, Mediterranean, and Connected Seas*
NGOs	*Non-Governmental Organizations*
NMS	*National Meteorological Service*
NOAA	*National Oceanographic and Atmospheric Administration, United States*
OFDA	*Office of Foreign Disaster Aid, United Stated*

PTWC	*Pacific Tsunami Warning Centre, NOAA and UNESCO-IOC*
SOPs	*Standard Operating Procedures*
UN	*United Nations*
UNDP	*United Nations Development Programme*
UNEP	*United Nations Environment Programme*
UNDP-BCPR	*Bureau of Crisis Prevention and Recovery, UNDP*
UNESCO	*United Nations Educational, Scientific and Cultural Organization*
UNESCO-IOC	*Intergovernmental Oceanographic Commission, UNESCO*
UNU	*United Nations University*
UNU-EHS	*United Nations University Institute for Environment and Human Security*
USGS	*United States Geological Survey, United States*
US-AID	*Agency for International Development, United States*
WFP	*World Food Programme, UN*
WHO	*World Health Organization, UN*
WMO	*World Meteorological Organization*

INTRODUCTION

During the Third International Early Warning Conference held in Bonn, Germany in 2006, the International Strategy for Disaster Reduction presented the results of its *Global Survey of Early Warning Systems*. The survey highlighted notable advances in the capacity of agencies in many countries to forecast potentially catastrophic events, as well as the fact that early warning systems have been implemented for a broad variety of hazards. However, the survey also noted that there were differences in the degree of advancements from region to region and from country to country, and numerous gaps and shortcomings still persisted, especially in developing countries. In many developing countries, warning systems lack infrastructure, adequately trained staff and resources. As a suggestion to improve this situation, the report offered several recommendations including the development of a globally comprehensive early warning system, rooted in existing early warning systems and capacities. To this end, the survey recommended a detailed assessment of gaps and needs in order to develop plans for the systematic strengthening of early warning capacities. Such an assessment would provide the information needed to fill such gaps in global early warning capacities.

A year later, the second meeting of the Intergovernmental Coordination Group for the Tsunami Early Warning and Mitigation System for the North-Eastern Atlantic, Mediterranean, and Connected Seas (ICG/NEAM TWS) held in Bonn, Germany, in 2007, brought to light a concern which had already been mentioned in the global survey of early warning systems: the lack of a globally-standardized framework related to alert or warning levels. Such a concern stems from two factors:

- Frameworks employed in early warning systems throughout the world vary from one type of hazard to another.
- Frameworks employed in early warning systems throughout the world targeting the same hazard may vary from country to country.

The notion of a globally comprehensive early warning system as requested in 2005 by Mr. Kofi Annan, former Secretary-General of the United Nations, demands an analysis regarding its feasibility. Mr. Annan's reference to such a system took into account the lack of a tsunami early warning system for the Indian Ocean in 2004. The comparative review and systematization of existing warning and alert frameworks presented in this publication will contribute to the discussion regarding the feasibility of implementing such a global early warning system as proposed by Mr. Annan.

The systematization effort is based on a review of more than 150 early warning and alert frameworks implemented by local, national, regional, and international agencies around the world. The review focuses on hydro-meteorological, geological and biological hazards, forest fires and other hazards. Data on these frameworks has been extracted from institutional web pages on the internet and from interviews with Directors of agencies operating such systems in different countries. It is important to stress from the start that this publication by no means constitutes a survey of all early warning systems operated in all countries of the world, but a sample of such systems. For example, language limitations have impeded the compilation and systematization of early warning systems operated by institutions in all countries of the world. In addition, this publication is based on those frameworks which have been published in web-pages or those for which information has been gathered through personal interviews. Therefore, it is meant to provide a summary of early warning practices to national agencies and regional and international organizations that are focusing on disaster preparedness around the world and designing and implementing early warning systems.

At the global level, this systematization can be seen as a contribution to Key Priority Area 2 of the Hyogo Framework for Action, which focuses on the identification, assessment and monitoring of disaster risks and on enhancing early warning. The Hyogo Framework for Action was the outcome of the World Conference on Disaster Reduction held in Kobe in January 2005. This framework sets the stage for a coordinated approach to disaster reduction with the aim of building the resilience of nations and communities to such disasters. Key Priority Area 2 targets the topic of early warning explicitly, and calls for research on a variety of issues to enhance early warning capacities worldwide.

The systematization effort began with the compilation of information on early warning and alert frameworks for a variety of hazards around the world. An initial analysis of the frameworks was then conducted focusing on each hazard separately. Frameworks have been characterized in terms of:

- The number of levels employed in each framework;
- The ways in which levels are labelled in each framework (either through the use of different colour, terms, numeric classes or other labels);
- The criteria employed to define the levels.

This initial analysis provided information on several issues such as the number of levels and the type of labels most frequently used in such frameworks and the criteria most commonly used to characterize levels.

Once this initial effort was completed, a subsequent analysis was conducted through a comparison of the results as a way to deduct similarities and differences among the frameworks targeting such hazards. Based on this systematization effort, conclusions and recommendations have been elaborated, some of them targeting national institutions which operate early warning or alert systems, others targeting the international organizations such as the International Strategy for Disaster Reduction.

This publication includes separate sections for all hazards that were addressed and tables that compile information on the frameworks which were analysed. Links to websites have been included so that the reader may find additional information on all frameworks that have been documented. Subsequent sections are dedicated to a comparison of all frameworks and to the conclusions and recommendations which have emerged from the analysis.

Recognizing the diversity of frameworks employed in many countries for a variety of hazards, an initial recommendation is made to the national agencies operating such systems to explore ways to harmonize, to the best possible extent, the number of levels, the criteria employed and the labels used, while understanding the types of hazards that are being addressed through such early warning and alert systems. At the more global level, if the notion of a global early warning system is envisioned, then international organizations such as the International Strategy for Disaster Reduction (ISDR), the World Meteorological Organization (WMO) and others should devote efforts to identify how to harmonize existing systems, taking into consideration existing differences which will be documented in this publication.

As a way to institutionalize early warning efforts, this publication also addresses the need to assess governance issues and the need to conduct research in communities at risk; focusing on the identification of the best combination of the number of levels, criteria and labels to be employed to ensure that such communities will respond timely in case a warning or an alert is issued.

As stated earlier, this systematization effort aims to contribute to the improvement of early warning efforts worldwide, thereby contributing to the goals established in the Hyogo Framework for Action. In addition, the effort aims to contribute to the mission of the United Nations University Institute for Environment and Human Security (UNU-EHS) through a knowledge-based approach that aims to increase the capability of early warning systems as a way to strengthen human security worldwide.

GENERAL NOTIONS REGARDING EARLY WARNING

In generic terms, early warning constitutes a process whereby information generated from tailored observations of natural phenomena is provided to communities at risk or to institutions which are involved in emergency response operations so that certain tasks may be executed before a catastrophic event impacts such communities. The goal is to minimize the impacts manifested through fatalities, injuries, damages and losses of various kinds. While the provision of such information may have begun thousands of years ago, it started with the systematization of observations that lead observers to identify the patterns and precursors that allowed them to forecast the manifestation of certain events. The sustainability of such a process in communities exposed to hazards from generation to generation over the centuries has depended on the sharing of stories and historical cases.

For example, during the 26 December 2004 tsunami, traditional knowledge concerning sudden changes in the behaviour of animals and of the sea in coastal areas allowed the people from the *Simeulue* tribe in Indonesia to reach safe grounds before this tsunami hit the coast of their island, minimizing loss of lives (ISDR, 2007a). A similar success took place in the case of the *Moken* tribe in Thailand, where the elders ordered an evacuation prior to this tsunami, saving all but one life (ISDR, 2007b). In both cases, the observation of the unusual withdrawal of the sea in coastal areas was recognized by the elderly as a tsunami warning sign leading to an order for people to evacuate to high ground, which was the key to successfully saving lives.

In Tanzania, the *Maasai* elders use traditional observations of goats and the behaviour of other animals to foresee the amount of rainfall which may be expected in a given season. As mentioned in the webpage of the United Nations Environment Programme (UNEP) on early warning (UNEP, 2011):

"The observation of a higher than normal frequency of goats mating in August to September suggests that the season is going to have a lot of rain; this is because the goats are assured that their young will survive as they will have plenty to eat. Goat guts are examined by a specialized Maasai elder, and if they are found to be having watery cysts on them in August, this means that the coming season will be characterized by good rains. Certain features of the small and large goat intestines as observed in September or October are taken as tell tale signs of the occurrence of natural phenomena related to the weather. For instance, if the small intestine is observed to have a lot of dung, or if the large intestine is coiled in the form of a Maasai homestead layout, this means that there will be plenty of rain hence no famine."

Advances in observation and measurement techniques, in natural sciences, mathematical modelling and computing capacities have allowed institutions such as meteorological offices to improve the accuracy of their observations and to generate and disseminate more accurate warnings in a more timely way. The scientific revolution which began several centuries ago has paved the way for scientists to model such events and to forecast their manifestation through the use of models and theories such as those found in meteorology and hydrology. For example, in the area of public health, the systematization of observations concerning epidemics and diseases has led to the provision of timely information concerning potential outbreaks. Research efforts are leading to the identification of additional measures that may allow national agencies in charge of public health to reduce the risk of diseases such as malaria, dengue, cholera and epidemics such as influenza, to name a few.

The institutionalization of the early warning process within countries through early warning or alert systems was likely based on the responsibility of the governments to protect their citizens from external threats or hazards. Such systems implied the designation of an official agency in charge of monitoring such external threats or hazards and a means to communicate to the population at risk the potential manifestation of such a threat. A typical example during the Second World War would be the warning system in case of bombing by enemy aircraft. Sirens would alert the population in cities so that those at risk could take refuge in shelters. As Zillman (2003) points out, in an increasing number of countries governments have implemented meteorological and hydrological warning systems as a way to reduce the impact of disasters. These types of systems can be seen as top to bottom approaches.

A comprehensive review of many relevant issues related to early warning systems was undertaken and presented by Mileti and Sorensen in 1990. According to these authors:

"A warning system is a means of getting information about an impending emergency, communicating that information to those who need it, and facilitating good decisions and timely response by people in danger."

In their review, the authors paid attention to important aspects such as the factors which affect how people receive and perceive warning information. Thus, they stress the need to focus not only on issues related to the emission of such information, but also on how that information is presented to individuals in order to ensure an adequate response – thereby minimizing the impacts provoked by such events. A few years later, the ISDR Secretariat convoked scientists from around the globe to establish the Early Warning Programme of the International Decade for Natural Disaster Reduction (IDNDR). The International Expert Group on Early Warning, which convened the programme, presented the following statement regarding the objective of early warning (IDNDR, 1997):

"The objective of early warning is to empower individuals and communities, threatened by natural or similar hazards, to act in sufficient time and in an appropriate manner so as to reduce the possibility of personal injury, loss of life and damage to property, or to nearby and fragile environments."

Another view with respect to early warning within the scope of this early warning programme was expressed by Maskrey (1997). He stated that an early warning system should be viewed as:

"An information system designed to facilitate decision-making in the context of national disaster management agencies, in a way that empowers vulnerable sectors and social groups to mitigate the potential losses and damages from impending hazard events.

In 2005, Reid Basher, former Director of the Platform for the Promotion of Early Warning established by ISDR in 2003 (ISDR-PPEW), defined early warning to mean:

"The provision of information on an emerging dangerous circumstance where that information can enable action in advance to reduce the risks involved. Early warning systems exist for natural geophysical and biological hazards, complex socio-political emergencies, industrial hazards, personal health risks and many other related risks."

More recently, within the Glossary of Terms prepared and published by ISDR (2009), an "early warning system" is defined as:

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

In conclusion, the notion of early warning refers to the provision of timely information to an individual, an institution or a community at risk regarding the imminent manifestation of a particular event capable of provoking losses of various kinds. For example, meteorological departments or offices in many countries of the world issue forecasts concerning potential events such as tropical storms that could lead to floods or high winds, which may be capable of damaging or destroying infrastructure and livelihoods. The first critical issue to be considered in this context is whether the information is getting across from its source to the recipients or end-users. This issue was highlighted by Mileti and Sorensen (1990) and later by Lee and Davis (1998) in the context of the *Flagship Programme on Forecasts and Warnings* sponsored by the United Kingdom's National Coordination Committee for IDNDR. These authors commented that (Lee and Davis, 1998):

"Despite the progress made in new scientific and technological development to cope with natural disasters, many lives are lost because forecasts of such disasters are not effectively communicated to the population at risk…"

More recently, other authors point out the need to ensure that those at risk and those who have to respond in case of a warning understand the warning messages (Paton et al., 2008; Haynes et al., 2008; Kelman, 2006). One of the most recent cases regarding such a failure in communication was the 26 December 2004 Indian Ocean tsunami, where thousands of people lost their lives in coastal cities and communities due to a lack of an efficient and timely warning (Chang Seng, 2010; UN, 2006; UNESCO-IOC, 2006; ISDR, 2006; ISDR-PPEW, 2005a).

But how people at risk and authorities perceive and make use of that information is another story. As stated by Maskrey (1997), "*the usefulness of an early warning system should be judged, less on the warnings that are issued per se, but rather on the basis of whether such warnings facilitate appropriate and timely decision-making by those* people who are most immediately at risk."

In this context, Mileti and Sorensen (1990) identified four sequential processes which should take place once the warning is issued:

1. People receive the warning message;

2. The warning message is understood;

3. The warning message is believed;

4. The warning is then personalized.

According to Mileti and Sorensen, only when the warning is personalized and those at risk deem it necessary should one expect people to react via the execution of specific activities such as an evacuation. However, whether or not people believe the warning message will depend initially on the degree of credibility or trust concerning the imminent event (such as a flood, tornado or landslide, etc.) which people assign to the institution or source of the information that is provided (Patton, 2008; Haynes et al., 2008). Therefore, credibility is essential if institutions expect people to react to the warnings they may issue. Indeed, as has happened on several occasions, people have disregarded such warnings because they did not trust the information provided by the institution. As expected, credibility is gained through accurate forecasts and may be lost on account of false alarms.

In addition, people may react to warnings in situations where they believe that an event is imminent and could have severe consequences. However, there are also situations where people may not necessarily be aware of the degree of risk they are exposed to, and consequently may not respond to such a warning. An important and critical issue, which is being addressed by ISDR and other agencies, relates to whether people understand the warnings or not. Warnings may be issued in a format which may or may not be understood by those who need to respond. A case in point may be the recent 26 December 2004 tsunami. The "warning sign" manifested by the sea through its recession prior to its landfall was likely only understood by a few. As stated in the Global Survey of Early Warning Systems published by ISDR (UN, 2006), the dissemination of warnings using different alert stages or levels varies from hazard to hazard, from country to country, and such an inconsistency may also lead to confusion regarding how to respond in case of an event.

Nevertheless, important examples regarding the positive reaction from authorities and communities at risk have been witnessed on several occasions in the context of hurricanes in Cuba and more recently in Mexico and Mauritius. In comparison with other countries of the world, Cuba has a tremendous capacity to mobilize people to safe areas when hurricane warnings are issued by the Cuban Meteorological Department. This was demonstrated during the hurricane seasons in 2005 and 2008, when severe hurricanes battered the nation.

As stated by ISDR-PPEW (2005a; 2005b) and by Villagran de Leon et al. (2006), there are four basic elements which must be incorporated into every early warning system to make it effective:

- Prior knowledge of the risks faced by communities;
- Technical monitoring and warning service for these risks;

- Dissemination of understandable warnings to those at risk; and
- Knowledge and preparedness to act.

The authors further introduced a linear structure to illustrate the operational aspects of early warning systems in terms of four sequential phases (Villagran de Leon, 2003, 2005; Villagran de Leon et al., 2006):

- Monitoring of precursors;
- Forecasting events;
- Warning: declaration and dissemination;
- Anticipated Response.

While this linear structure depicts the most relevant tasks required when operating such systems, it is important to recall two facts: the first one being that in selected cases such as earthquakes and avalanches, systems do not really monitor precursors but rather all potential events. Therefore the systems issue a warning as quickly as possible in case the events trigger a disaster. The second fact is that early warning systems also encompass cross-cutting aspects such as:

- Governance issues which are necessary to ensure horizontal and vertical cooperation, including private stakeholders;
- Legal mandates which delegate responsibilities on specific agencies or institutions to carry out monitoring and forecasting phases and emission of warnings;
- Perceptions and expectations on the type and degree of response expected from institutions and from the people at risk once different levels of warnings or alerts are issued;
- Operational aspects of particular relevance to these systems, such as communication systems and formats to exchange information among the different agencies involved and dissemination schemes used to communicate the warnings to those at risk;
- The particularity of specific systems which emanate from the type of hazards or events being targeted for early warning.

It is important to recognize at this stage that there can be different views regarding what type of information is provided in the context of early warning. The previous paragraphs depicting the four phase system refer to the traditional view of early warning which focuses on the provision of information concerning a specific event that may trigger a disaster. However, there are other views not related with the forecast of specific, isolated events which will take place in a specific region of the world at a particular time. This is the case of information presented in the format of hazard maps targeting earthquakes, volcanic eruptions, or other hazards; these maps represent the current state of knowledge in terms of probabilities of occurrence of events associated with particular periods of return, in particular geographical areas of the world. For example, maps depicting the potential extent of floods that have a period of return of 100 years, or maps that depict the expected peak ground acceleration corresponding to earthquakes that have a period of return of 500 years. Nevertheless, within the scope of this publication, an early warning system is defined as a system that is set up to warn the population at risk in a timely and effective manner concerning any specific event that can trigger a disaster, so that actions can be taken by those at risk to reduce the extent of losses and damages. This definition is aligned with the one proposed by ISDR that was cited earlier.

Within the scope of the third and fourth phases in the linear structure of early warning systems (monitoring, forecasting, warning dissemination and anticipated response), many institutions around the world have designed and established frameworks incorporating various levels of warnings or alerts which include actions to be taken according to each level. In many cases these frameworks are formalized through Standard Operating Procedures (SOPs). For example, within the National Coordinating Agency for Disaster Reduction of Guatemala (CONRED), a hierarchical framework based on four alert levels (here, the explicit translation of the Spanish term “alerta” is being introduced as “alert” in English) is used for a variety of hazards, formatted using four colours: green, yellow, orange and red. For each alert level there is a set of procedures and tasks which need to be executed by personnel within this agency at the national, departmental and municipal levels. Table 1 describes the levels of alert and the actions that need to be conducted at each level.

Level of alert	Condition	General implications for the staff of CONRED
Green	Normal situation.	• Personnel of the Executive Secretariat of CONRED (ES-CONRED) carry out activities targeting risk reduction and preparedness according to the mission and strategic objectives.
Yellow	Some probability of event taking place.	• Vigilance and monitoring of the evolution of the event. • Verification of availability of equipment, resources, and personnel in case of response. • Coordinate the activation of CODRED, COMRED, and COLRED. • Elaboration of information bulletins for distribution to Mass Media, Authorities at the Departmental and Municipal levels and within the System of Institutional Liaisons. • Alerting Radio Bases of the CONRED Network. • Execution of activities according to the Standard Operating Procedures of ES-CONRED for this level of alert.
Orange	High probability of event taking place.	• Permanent and detailed monitoring of events. • Mobilization of equipment, resources, and personnel. • Activation of Immediate Response Team – IRT– according to the particular needs. • Coordination of activation of Institutional Response Plans of Emergency Operation Centres at various levels (Departmental, Municipal, Local). • Activation of the Information Unit of ES-CONRED. • Partial activation of the National Emergency Operation Centre, depending on the characteristics of the event.

Level of alert	Condition	General implications for the staff of CONRED
		• Elaboration of information bulletins for distribution to Mass Media, Authorities at the Departmental and Municipal levels and within the System of Institutional Liaisons. • Coordination of activation of Shelters. • Voluntary evacuation of areas at risk. • Execution of activities according to the Standard Operating Procedures of ES-CONRED for this level of alert.
Red	Complications arising as an impact of an event. Events of sudden or rapid onset manifestation.	• Activation of the National Emergency Operation Centre. • Coordination of activation of Institutional Response Plans of Emergency Operation Centres at various levels (Departmental, Municipal, Local). • Ensure availability and allocation of resources according to the needs and requests from areas impacted by the event. • Execution of activities according to the Standard Operating Procedures of ES-CONRED for this level of alert.

Table 1: Alert stages used by the National Coordinating Agency for Disaster Reduction of Guatemala (CONRED). Source: Institutional Response Plan, Executive Secretariat, CONRED (2007).

A review of more than 150 warning and early warning systems operated in the context of different natural hazards in many countries in all regions of the world yields the following results:

- The majority of systems employ hierarchical setups based on three or four levels, but some frameworks use from one to seven levels;
- Different frameworks may employ different criteria to differentiate levels. Typical criteria include the potential magnitude or severity of the event, time for the event to impact a community or a geographic area, the likelihood of an event or benchmarks that can be linked to such events;
- The most common way to label different levels is through the use of different colours, basically those used in traffic light signals at intersections (green, yellow, and red – from low to high level). However, in some cases the green colour is replaced by blue. Several systems make use of sets of terms such as "advisory", "watch", and "warning", or sets of levels using a numerical scale. In addition, in some countries the levels are labelled using terms such as "classes", "stages", or "alert levels";
- In a few cases, an "all clear" message is issued to signal the end of the event and thus a return to normal conditions;
- Frameworks vary from country to country and within one country from hazard to hazard. In addition, frameworks may vary from continent to continent.

Such results can be traced to the fact that not all hazards can be dealt with using the same framework and that there are a wide variety of agencies which implement and operate early warning systems for different types of hazards. Nevertheless, as mentioned previously, the 26 December 2004 Indian Ocean tsunami prompted the former Secretary-General of the United Nations, Mr. Kofi Annan to request the establishment of a *global early warning system* (UN, 2005, 2006). In the report entitled *Global Survey of Early Warning Systems* (UN, 2006), this notion of a global early warning system was taken further with a conclusion that a *"globally comprehensive early warning system"* can be built, based on the many existing systems and capacities, using a format of a networked and coordinated assemblage of nationally owned and operated systems. However, as stated by Mileti and Sorensen (1990) *"… a single-system design will not work for all different hazards warning situations but some events with similar characteristics may fit the same warning implementation strategy"*.

However, even if it may be feasible to congregate an international network of observatories to monitor precursors related to potentially catastrophic events and to improve forecasting capacities through regional centres, a global early warning system may not have jurisdiction within a country or within a municipality to issue a warning or an alert and to ensure that the anticipated response is executed. To this end, what may be more likely is the establishment of international, continental or regional networks of observatories to monitor precursors and to improve forecasting capacities, linked through an efficient communication system that allows for fast and reliable exchange of data or information, and protocols to that end.

Whereas the notion of a global system has attracted the attention of the organizations of the United Nations, the notion of multi-hazard early warning systems has attracted the attention of agencies such as WMO (2007) and UNEP (2012). Such multi-hazard systems have been implemented in a variety of countries as reported by WMO. As in the case of a global early warning system, the issue of alert or warning frameworks is one which needs to be considered when designing such a multi-hazard system (Villagran de Leon, 2012).

On the more technical side of warning and alert levels, the review of systems undertaken as part of this research leads to the conclusion that a global effort would need to be undertaken by international and national organizations to achieve a consensus on:

- The number of levels to be employed in the context of each type of hazard;

- Whether levels should represent the likelihood of events, the magnitude or severity of the potential event, the interval of time until an event impacts a community or a certain geographic region, or thresholds which have been reached already in relation to an event or the potential for an event to take place;
- The use of colours, terms, or numbers to represent the different levels;
- Institutional responsibilities regarding the emission of warnings.

Inputs from the hazards

When considering the dynamics of events such as a flood, a forest fire or a harmful algae bloom, it is possible to identify different stages associated with the evolution of such events. An initial or embryonic stage can be linked to the manifestation of those conditions that may give rise to these events or as they begin to emerge. Subsequently, there is a growth stage when the event gradually evolves in terms of its magnitude or area of influence. A mature stage would represent the event as being capable of provoking a disaster in a particular geographic location; and finally a decaying stage would indicate the event is dissipating. As expected, the duration of these stages varies from hazard to hazard and from event to event. For example, in the case of floods one could envision the embryonic stage to last from hours to weeks, as weather conditions worsen over a basin and precipitation begins to take place. The growth stage is represented through an increase in discharge in the channel of the river that is detected as a rise in the level of the river. In the mature stage the flood manifests itself when the channel of a river can no longer contain the amount of water being discharged by the river. In the decaying stage the water recedes in flooded areas and the discharge is reduced to an amount that can be contained within the river channel.

In the context of early warning, the time lapse between the embryonic and the mature stage is determinant to the capacity to issue warnings. If this time lapse is large enough, hierarchical phases could be identified allowing for the establishment of several alert or warning levels.

For example, in the case of volcanic eruptions one may consider the rise of magma from the depths during the embryonic stage, followed by a growth stage where tremors begin to be detected and gaseous emissions can be seen in the crater. The eruption takes place during the mature stage. A similar process could be identified in case of floods, where changes in the climatic conditions at the embryonic state precede the rainfall that may trigger such floods. Figure 1 proposes a sketch of the evolution of an event in terms of these four stages:

- *Embryonic stage* – preliminary phase of the event;
- *Growth stage* – event begins to take shape;
- *Mature stage* – event triggers impacts and effects on communities and regions near its path;
- *Decaying stage* – the event loses strength or dissipates.

During the embryonic stage those conditions which are leading to the event begin to take shape. In the case of hurricanes for example, one may consider the disturbances within the Atlantic Ocean that give rise to such events. The growth stage would then encompass those processes related to evaporation of water from the ocean and the convective processes within the atmosphere that begin to shape such hurricanes. In the mature stage, one could see the hurricanes as fully manifested in terms of their typical characteristics such as very low barometric pressure, high wind speeds, storm surges, and precipitation. Finally, as hurricanes make landfall, they begin to weaken to the point that they cease to exist once they are fully inside large continental landmasses. In the case of forest fires, the process of vegetation drying could be considered as the embryonic stage; while local dry weather conditions may lead to the growth stage. In the mature case, lightning or human actions would be responsible for triggering the event. The decaying stage is related either to the extermination of the fire through its combat by firemen, or due to the combustion of the existing vegetation.

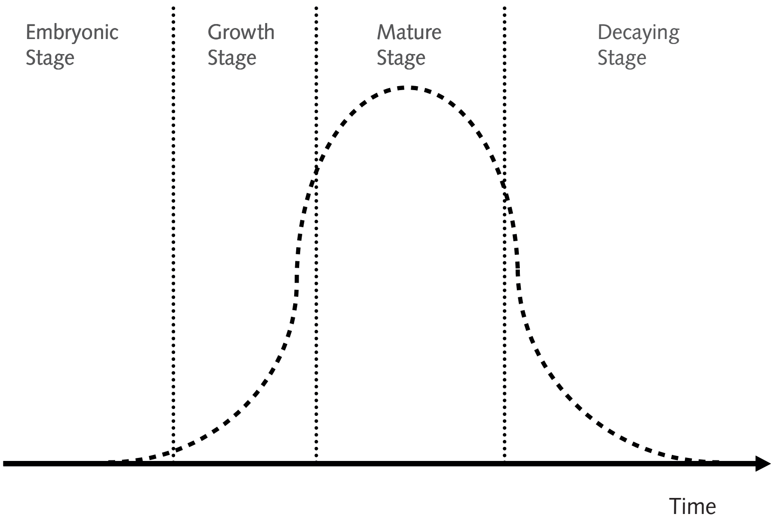


Figure 1: Stages of evolution of an event associated with a hazard. Source: authors.

In the context of weather, meteorologists use a variety of instruments to track the four stages of events such as hurricanes or storms, including: networks of satellites, airplanes retrofitted with instruments to fly through such hurricanes, buoys and weather stations. The combination of measurements allows meteorological agencies, such as the National Hurricane Centre in the United States, to be able to follow the path and the dynamics of such events, leading to forecasts of trajectories and places where such hurricanes may make landfall. Table 2 presents examples of these stages for events associated with different types of hazards.

The capacity to forecast an event capable of triggering a disaster is related to the type of hazard in question. In some cases the interval of time between the growth stage and the mature stage is so short that it is difficult to forecast events with sufficient lead time in order to issue a warning or to transfer the warning information into measures that limit damages and losses (such as the shutdown of processes and the evacuation of those at risk to safe areas). Therefore, it can be concluded that the peculiarities of different types of hazards force designers and operators of early warning systems to conceive the number of discrete levels of warnings or alerts to be included in the system and to clarify and communicate for which types of events no warning is possible.

In the particular case of industrial or technological accidents (such as toxic emissions into the air or into rivers, lakes or oceans), forest fires, epidemics and harmful algae blooms, scientists and technicians are only able to identify conditions which may predispose the environment to host such events or thresholds which may characterize particular instances of such events. In this case, the number of alert levels may be defined according to thresholds which are surpassed as events evolve. In the case of influenza, alert levels are based on the manifestation of episodes at the level of single individuals, at the level of episodes spanning communities or at the level of episodes spread throughout countries.

As it will be presented in subsequent chapters, alert or warning frameworks have been developed on the basis of different criteria:

Potential severity – In some frameworks, the level of alert or warning is based on the expected severity of an event. A low alert level implying a weak event, while a high alert level implies an event which may trigger a disaster or a catastrophe due to its high magnitude.

HAZARD	EMBRYONIC stage	GROWTH stage	MATURE stage	DECAYING stage
Hurricanes	Small weather disturbance takes place in the middle of the ocean.	Further evaporation from the oceans fuels the convective process. The event may be at the stage of becoming a tropical depression leading to a hurricane.	The event becomes a hurricane and makes landfall.	The hurricane dissipates inland or begins to track pole-wards over a cooler ocean surface, and begins to loose its strength.
Landslides	Local conditions of the slope may lead to susceptibility.	Intense rainfall may lead to extra weight on the soil, and may filter to the interface separating the immobile mass from the mass than can slide.	Landslide taking place.	Landslide stops moving.
Volcanic eruptions	Magma begins to rise to the surface, some tremors begin to appear.	Magma approaching the surface of the cone. Emanation of gases, frequency and magnitude of tremors increases.	Full, explosive eruption.	Eruptive activity decays to minimal stage or finishes.
Forest fires	Vegetation becoming dry.	Local weather conditions in terms of low humidity, high temperature and lack of rainfall lead to additional vegetation dryness. Weather conditions or human conditions favourable for the triggering of forest fires. Forest fires may begin to take place.	The fire is at the stage of consuming available dry vegetation.	Fire is diminished through human actions (fire fighting) or deple-tion of dry vegetation through its combustion.

Table 2: Examples of stages related to different types of hazards. Source: authors.

Likelihood – In some frameworks, the level of alert or warning is defined based on the likelihood of an event. Levels vary from low likelihood up until the case when the event is already taking place.

Thresholds – In some cases, the level of alert or warning are based on indicators and thresholds previously established. Levels are defined according to thresholds which are reached or surpassed.

Time to impact – In some frameworks, levels are assigned according to the interval of time before an event impacts a community, a city, or a country. For example, in several countries, low levels are selected when the event will impact a community 36, 48 or 72 hours later; while higher levels will be issued if the time interval is shorter (6, 12 or 24 hours, for example).

A tailored approach – In the particular case of Europe and in the context of coloured-schemes, European meteorological agencies have begun to establish a policy of enacting a red-level alert only one or two times a year. In this case, the aim is to minimize the use of this particular level, while making use of yellow or orange levels more frequently.

Terminology

An important aspect to highlight at this point is the terminology employed in the context of early warning and alert systems. For example, R. Hamilton (1997) made the following suggestions concerning particular terms typically used by scientists focusing on geologic hazards:

Prediction or Forecast – A statement that a geological hazard of a specified nature will occur with a given probability during a certain time-frame in a prescribed geographical area.

Warning – A recommendation or an order to take an action, such as an order to evacuate an area.

As Hamilton points out, predictions or forecasts are usually made by scientists and experts, and provide the basis on which warnings are issued by government officials. Handmer (2000) puts it slightly differently when he stated that "warnings constitute the mechanism whereby predictions or forecasts are turned into information in the form of an action statement."

In his introduction to the book entitled *Early Warning Systems for Natural Disaster Reduction*, Siebold (2003) commented that "predictions are defined to be largely based on statistical theory and historical records of past events resulting in average probabilities for future events". In contrast, he commented that forecasts "are based on well understood and monitored individual events". This notion, also shared by the seismological community, relates to the notion of predictions made on the basis of probabilistic assessments of potential events using historical catalogues of seismic events, and forecasts made using deterministic models.

In the METEOTERM terminology database of WMO (WMO, 2012), a forecast represents "a definite statement or statistical estimate of the occurrence of a future event". In the *International Glossary of Hydrology* published by the International Hydrological Programme of UNESCO and WMO (UNESCO, 2012), the following definitions are presented:

Flood forecasting – Estimation of stage, discharge, time of occurrence and duration of a flood, especially of peak discharge, at a specified point on a stream, resulting from precipitation and/or snowmelt.

Flood warning – Advance notice that a flood may occur in the near future at a certain station or in a certain river basin.

Alarm level – Water level (stage) at, or approaching, flood level which is considered to be dangerous and at which warnings should be commenced.

Forecast – Definite statement or statistical estimate of the occurrence of a future event.

Forecast (warning) lead time – Interval of time between the issuing of a forecast (warning) and the expected occurrence of the forecast element.

In the United States, the National Oceanographic and Atmospheric Administration (NOAA) uses the terms Advisory, Watch, and Warning, and may issue bulletins concerning particular events prior to issuing an Advisory, a Watch or a Warning. The glossary of terms presented in the institutional web page of NOAA presents the following definitions for these terms (NOAA, 2012):

Advisory – Highlights special weather conditions that are less serious than a warning. These are issued for events that may cause significant inconvenience, and if caution is not exercised, such events could lead to situations that may threaten life and/or property.

Watch – A watch is used when the risk of a hazardous weather or hydrologic event has increased significantly, but its occurrence, location and/or timing is still uncertain. It is intended to provide enough lead time so that those who need to set their plans in motion can do so.

Warning – A warning is issued when a hazardous weather or hydrologic event is occurring, is imminent or has a very high probability of occurring. A warning is used for conditions posing a threat to life or property.

A particular example regarding the use of these terms by NOAA in the context of tropical storms and hurricanes is presented in the following paragraphs:

Tropical storm watch – An announcement for specific coastal areas that tropical storm conditions are possible within 36 hours.

Tropical storm warning – A warning of 1-minute sustained surface winds of 48 kt (55mph or 88km/hr) or greater, predicted or occurring, not directly associated with tropical cyclones.

Hurricane watch – An announcement for specific coastal areas that hurricane conditions are possible within 36 hours.

Hurricane warning – A warning that sustained winds 64kt (74mph or 119km/hr) or higher associated with a hurricane are expected in a specified coastal area in 24 hours or less. A hurricane warning can remain in effect when dangerously high water or a combination of dangerously high water and exceptionally high waves continue, even though winds may be less than hurricane force.

This example is presented with the particular purpose of highlighting the difference between hurricanes and tropical storms which NOAA makes based on wind speeds. The difference is related to the potential magnitude or severity of the event (a storm as opposed to a hurricane); the interval of time for the event to reach the coast (24 or 36 hours); and the use of benchmarks (sustained surface winds related to tropical storms starting at 48 knots or 55 miles per hour and to hurricanes starting at 64 knots or 74 miles per hour respectively).

However, when it comes to the specific terms *alert* and *warning*, there seems to be no regional or global consensus on the difference between these two terms. At times they may be considered as synonymous, and in other cases both terms are included in the same framework. In some countries, government agencies or communities make reference to an *early alert system* rather than an *early warning system*. In the UK, the Meteorological Office (Met Office, 2012) made the following difference between the two terms in terms of lead time with respect to an event as follows:

- Alerts are issued more than 24 hours ahead;

- Warnings are issued up to 24 hours ahead.

In Central America the term "alert" is used in the majority of systems implemented in the event of floods and other types of hazards. In the case of volcanic activity, the Volcano Hazards Program of the United States Geological Survey (USGS) has adopted an *alert-notification system* nationwide characterizing the level of unrest and eruptive activity at volcanoes (USGS, 2012). However, in other countries the notion of *early warning systems* is more typical. In many Caribbean and Asian countries, national government agencies operate *flood early warning systems*. In addition, in recent decades the United States Agency for International Development (US-AID) has implemented both the Famine *Early Warning* Systems Network (FEWNET) targeting Africa and more recently the Mesoamerican Famine *Early Warning* System (MFEWS).

In an effort to explain the use of the terms alert and warning one may need to address the native language of the country where the system is implemented. In Latin America, the term "alerta" is used traditionally in the context of warning systems. A case in point would be the "Sistema de Alerta Temprana contra Tsunamis y Otras Amenazas Costeras en el Caribe y Regiones Adyacentes" as it is labelled by the Intergovernmental Oceanographic Commission of UNESCO (UNESCO-IOC). While in the English language, the same system by the same international organization is addressed as the "Tsunami and other Coastal Hazards *Warning* System for the Caribbean and Adjacent Regions", in the French language, the terms "*vigilance*" and "*alerte*" have been employed in early warning systems targeting floods, tropical cyclones and hurricanes, as well as in the case of extreme weather.

In this context of warnings and alerts it may be possible to conceive the notion that a warning may represent a message regarding the potential manifestation of a catastrophic event in the near future. This would be the case of a warning in case of a potential flood or a warning of an incoming hurricane. In contrast, an alert may represent a message that a certain threshold has been reached or surpassed with respect to particular conditions of an event or its impacts. For example, in many Latin American countries a red alert means that the event is already impacting a community or several communities. In the case of tsunamis, the detection of a very strong earthquake in coastal areas is used in some countries to trigger an alert. A subsequent issue of a warning or the cancellation of the tsunami alert will stem from subsequent observations made with deep-sea level buoys or tide gauges or through physical observations of the behaviour of the sea in coastal areas. Taking these inputs into consideration, it could be useful to think of warnings and alerts in the following ways:

Warnings – Statements issued by institutions to the population concerning the possibility of a catastrophic event which may impact such communities in the very near future.

Alerts – Statements issued by institutions to the general population that certain thresholds related to potentially catastrophic events have been reached or surpassed.

The survey

Based on the call to develop a global early warning system for all natural hazards and all communities by former Secretary-General of the United Nations, Mr. Kofi Annan – which was highlighted in ISDR-PPEW's Global Survey of Early Warning Systems (ISDR-PPEW, 2006a) – a web-based survey of early warning systems has been conducted with the aim of documenting and systematizing particular features of early warning systems, including the number of levels that such systems make use of; the criteria employed to characterize such levels; and the ways in which those levels are labelled. This web-based survey covered systems that are operated in many countries around the world targeting a variety of natural hazards. The information has been systematized on the basis of hazards and is presented in tables that summarize:

- The number of levels which such systems make use of;
- Whether levels are defined using colours, terms, numbers, etc.;
- Whether an "all clear" level is included or not in the framework;
- The criteria employed to define such levels (magnitude or severity, likelihood of event, threshold, time interval until impact, or period of return); and
- Links to web pages that contain the information on the systems.

Examples describing particular systems complement this systematization effort.

Taking into consideration the request made by the former Secretary-General of the United Nations concerning a "global early warning system targeting all hazards", subsequent systematization efforts has been conducted where the summaries of the frameworks for each type of hazard are compared as a way to identify similarities and differences as well as to identify critical elements to be considered when designing such a global early warning system. The survey then concludes with a set of recommendations for subsequent research and policy relevant advice.

EARLY WARNING FRAMEWORKS FOR HYDRO-METEOROLOGICAL HAZARDS

Hydrometeorological hazards include a wide variety of meteorological, hydrological, climate and ocean phenomena which pose a threat to life, property, and the environment. The evolution of an event from the embryonic to the mature stage can span roughly from a few hours in the case of tornadoes or flash floods in small basins, days in the case of hurricanes or months in the case of droughts and phenomena such as El Niño and La Niña which are triggered by interactions between the atmosphere and ocean in the tropical belt of the Pacific Ocean. In addition, events associated with these hazards can be accurately localized, as in the case of tornadoes and flash floods or may have a large geographical extent spanning several countries or even sub-continents as in the case of typhoons, hurricanes, El Niño and La Niña events.

In 1997, the Working Group on Hydrometeorological Hazards and Drought established by ISDR provided an initial list of these hazards. Table 3 presents this list classified in five categories (O´Neill, 1997).

Taking into consideration the spatial extent of these hazards, national weather services or offices have installed networks or arrays of dedicated sensors and infrastructure to measure a variety of parameters required to forecast both the time at which events may manifest themselves and their geographical area of influence. In addition, and taking into consideration the wide geographical nature of some of these hazards, national services or offices have joined forces to set up regional early warning systems such as Meteoalarm in Europe, which operates as a regional warning system benefitting from data supplied by national meteorological offices or departments.

At the more global level, WMO plays a leading role in promoting the use of satellites to track such events, and to ensure a rapid transmission of information among meteorological stations within countries as part of the monitoring phase. The World Information System serves as the institutional backbone for the transfer of information among Member States that belong to WMO. In addition, WMO operates the World Weather Watch Programme which combines observing systems, telecommunication facilities and data-processing and forecasting centres operated by Member States. The aim is to make available the meteorological and related environmental information needed to provide efficient services in all countries (WMO, 2008). Also, at this global level, the World Health organization operates a warning system targeting pandemics.

Forecasting in the context of meteorological and hydrological events span a time continuum ranging from less than one hour, through short and medium terms (hours to days) to seasonal and annual time scales. As expected, forecasting of tornadoes, severe thunderstorms and flash floods must be followed by a very rapid dissemination of warnings to the population in order for such early warning systems to be effective in reducing fatalities, injuries and losses. In such cases, a single warning or alert level may be the most recommendable, as the interval of time between the emission of such a warning and the impact of the event is too short for the incorporation of additional levels. Unfortunately, in many developing countries the advanced technology required to track such events, e.g., Doppler weather radar and real-time telemetry, is not available due to its high cost, and hence, forecasting such events remains a challenge.

In the case of larger scale weather systems such as hurricanes and tropical storms, forecasts can be elaborated several days in advance, allowing for the emission of different levels of warnings in a timely manner.

The emission of a warning, as reflected by O´Neill (1997), should be conducted in a consistent way, and preferably by the respective National Meteorological Service (NMS). Such an approach should ensure that only a single authority issues warnings within a given area.

Atmospheric	Cold weather	Hot weather	Wind	Rivers, lakes, oceans, waves
Tropical cyclone	Blowing snow	Drought	Tornado	Floods/Flash flood
Thunderstorm	Avalanche	Heat wave/ Excessive heat	Strong winds/Gale	Storm surge
Typhoon	Snow squalls		Wind chill	Waterspout
Hurricane	Freeze			Tidal wave
Heavy rainfall	Winter storm		Dust/Dust storm	Tsunami
High humidity	Heavy snowfall		Sand storm	
Fog/Dense fog	Frost/Glazed frost			
Lightning	Freezing rain/Sleet			
Thunder squall	Freezing drizzle			
Hail	Blizzard			
	Cold wave/Intense cold/Sudden temp. decrease			

Table 3: Examples of hydrometeorological hazards. Source: O´Neill (1997).

This segment of the survey includes information on the following hydrometerological hazards:

- Severe weather in general;
- Thunderstorms, tropical cyclones, hurricanes and typhoons;
- Severe storm;
- Floods;
- Winter storms/Extreme cold;
- Extreme heat;
- Tornadoes;
- Droughts and food insecurity;
- Coastal and high seas weather; winds, gales, storm surges.

The systematization of warning or alert frameworks in this case of hydrometeorological hazards is very difficult as there are several overlaps. For example, in some cases levels have been established using a combination of the severity of potential events, the specific thresholds which may be reached or surpassed and the interval of time until impact. In other cases, explicit frameworks have been defined only in terms of the time required for events to make landfall.

Severe weather in general

The survey developed in the context of this research found information on 21 frameworks which target severe weather in general. One of these frameworks relates to the regional system Meteoalarm, which targets 25 countries in Europe that make use of five levels represented using colours. The survey also identified a system in China which is not structured in terms of levels.

Country	Characteristics			Criteria for levels					
	Number of levels	Colours/ Terms	All clear *	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until impact	Period of return	Source of information
Canada	3	Terms	x		x		x		http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=C9A8D735-1
Colombia	4	Colours/ Terms	no		x		x		http://www.pronosticosyalertas.gov.co/jsp/loader.jsf?lServicio=Publicaciones&lTipo=publicaciones&lFuncion=loadContenidoPublicacion&id=750
England	4	Colours	no	x	x				http://www.metoffice.gov.uk/weather/uk/uk_forecast_warnings.html
The Netherlands	4	Colours	no	x	x				http://www.knmi.nl/index_en.html
Belgium	4	Colours	no	x		x			http://www.meteo.be/meteo/view/fr/112909-Carte+de+Belgique.html
Germany	5	Colour/ Terms	no	x		x	x		http://www.dwd.de/bvbw/appmanager/bvbw/dwdwwwDesktop?_nfpb=true&_pageLabel=_dwdwww_wetter_warnungen_warnungen&T169600781711254206874155gsbDocumentPath=Navigation%2FOeffentlichkeit%2FWetter__Warnungen%2FWarnungen%2FAmtliche__Warnungen%2FKriterien__node.htm
Austria	4	Colours	no					x	http://zamg.ac.at/wetter/warnung/mobile_version/
Switzerland	5	Colours/ Numbers	no	x				x	http://www.meteoschweiz.admin.ch/web/de/gefahren/gefahren.html
France	4	Colours	no	x					http://france.meteofrance.com/vigilance/Accueil

Country	Characteristics			Criteria for levels					
	Number of levels	Colours/ Terms	All clear *	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until impact	Period of return	Source of information
Spain	4	Colours/ Terms	no	x					http://www.aemet.es/es/eltiempo/prediccion/avisos
Portugal	4	Colours	no	x					http://www.meteo.pt/pt/otempo/tempopresente/
Romania	3	Terms	no				x		http://www.meteoromania.ro/index.php?id=98&lang=en
Antilles-Gyane	5–4	Colours/ Terms	yes	x	x				http://www.meteo.gp/
New Caledonia	4	Colours	no	x	x				http://www.meteo.nc/
Japan	2	Terms	no	x	x				http://www.bousai.go.jp/kyoryoku/soukikeikai.pdf
Malysia	3	Colours	no			x	x		http://www.met.gov.my/index.php?option=com_content&task=view&id=739&Itemid=1129
Australia	1	Terms	no	x	x		x		http://www.bom.gov.au/catalogue/warnings/WarningsInformation_SW_SWW.shtml
New Zealand	4	Terms	no			x	x		http://metservice.co.nz/default/help.php?subject=warning
Europe – Meteoalarm	4	Colours	x	x				x	http://www.meteoalarm.eu/
China	1	Terms	no	x					http://www.cma.gov.cn/en/WeatherForecast/
Taiwan, POC	2	Terms	no	x					http://www.cwb.gov.tw

** All clear in this context is related to the decaying phase, when the event is disappearing or displacing itself out of the territory or geographical region where the warning was issued. It is not related to the embryonic or growth stage, where some institutions make use of the level entitled "no severe weather".*

Table 4: Alert frameworks for general weather. Source: authors.

In the context of regions or continents, it can be concluded that for this type of hazard European and Australian institutions posted the most amount of information in their web pages, followed by institutions from Asia. Scarce information was found in the case of Latin America, the Caribbean and Africa.

As it can be seen in Table 4, the respective frameworks are structured in terms of levels spanning from one up to five levels, with four levels being the most common (in 12 out of 21 cases). With the exception of Romania, most European systems make use of four or five levels. In addition, most European frameworks make use of a colour-scheme with the exception of Romania. Nine frameworks make use of colours alone; several frameworks make use of the typical terms such as advisory, watch, and warning; and four frameworks combine the use of both terms and colours. The typical colours employed in four-level frameworks are green, yellow, orange and red.

Most frameworks are based on the potential severity of the event (in 15 of 21 cases); eight frameworks define their levels in terms of the likelihood of an event and seven frameworks define them in terms of the time required for such events to impact a specific geographic region. Most of them do not incorporate an "all clear" level. In terms of criteria employed to set up the different levels, it can be concluded that in many of these frameworks a combination of the criteria is employed, including the severity of the potential event, the expected time for impact in a given country or territory and the thresholds. However, in the case of some European countries, period of return are used as there is a tendency to make use of the red level only in the case of exceptionally intense events.

Countries like Antilles-Gyane present two parallel frameworks, one based on MeteoFrance using five colours (yellow, orange, red, purple and grey) and another one on the basis of the National Hurricane Centre of the United States for the Caribbean region. The latter is defined in terms of four levels which represent the interval of time necessary for a thunderstorm or a hurricane to make landfall in the territory. The Meteoalarm Framework established by the European Meteorological Network (EUMETNET) is presented in Example 1.

Alarm level	Event/Measures to be implemented
	No particular awareness of the weather is required.
	The weather is potentially dangerous. The weather phenomena that have been forecast are not unusual, but be attentive if you intend to practice activities exposed to meteorological risks. Keep informed about the expected meteorological conditions and do not take any avoidable risk.
	The weather is dangerous. Unusual meteorological phenomena have been forecast. Damage and casualties are likely to happen. Be very vigilant and keep regularly informed about the detailed expected meteorological conditions. Be aware of the risks that might be unavoidable. Follow any advice given by your authorities.
	The weather is very dangerous. Exceptionally intense meteorological phenomena have been forecast. Major damage and accidents are likely, in many cases with threat to life and limb, over a wide area. Keep frequently informed about detailed expected meteorological conditions and risks. Follow orders and any advice given by your authorities under all circumstances, be prepared for extraordinary measures.

Meteoalarm is a European early warning system which has been set up by the Network of European Meteorological Services targeting 25 European countries, and including hydrometeorological hazards such as wind, rain, snow/ice, thunderstorms, fog, extreme high and low temperature, coastal events such as storm surges, forest fires and avalanches (EUMETNET, 2008). The framework comprises four levels characterized in terms of colours. The respective web page presents warning levels at the country scale, and within each country a zoom option allowsusers to identify warnings for each province, as well as the type of hazard that is targeted with the warning. The level of warning assigned to each country corresponds to the highest level of warning that is in effect within all the provinces of every country.

One of the great strengths of Meteoalarm is the fact that it has been able to standardize information from almost all participating countries in the same format for many types of hazards, reaching a degree of unification that is not yet present in other continents or regions such as South East Asia or the Caribbean.

Example 1: EUMETNET – Meteoalarm. Source: http://www.meteoalarm.info/.

Tropical cyclones, hurricanes and typhoons

As stated by WMO, hurricanes, typhoons and cyclones are among the most devastating of all natural hazards. Every year, whether in Asia, Africa or the Caribbean, these events provoke loss of life, material losses, and disrupt routine activities and processes in those countries which are affected.

The embryonic, growth and mature stages of these events are controlled by the interaction between the atmosphere and the oceans in tropical waters. As it is well known, these stages may take from a few to days to a few weeks to be consolidated. In its mature state, a hurricane or a cyclone may vary its characteristics in terms of wind-speed and barometric pressure based on this interaction. The decay stage begins when the hurricane or cyclone makes landfall in a continental region (as opposed to making landfall within an island or an archipelago), or when the event travels to far north or south latitudes. Making use of advances in satellite technology, remote sensing, modelling and telecommunications; Meteorological Departments or Offices have improved their capacities to monitor, forecast and warn populations in the case of such events well in advance of their landfall. A crucial aspect behind this success has been the capacity for WMO to promote the generation and exchange of information among members states in different regions of the world, together with advances conducted by agencies within developed nations, such as NOAA in the United States. To this end, WMO has set up five Tropical Cyclone Regional Specialized Meteorological Centres located in Miami, Tokyo, New Delhi, La Réunion and Nadi.

The survey identified 23 frameworks including one for the South Pacific in the case of tropical cyclones. As expected, the systems are located in the areas where most tropical cyclones or hurricanes manifest themselves such as the Caribbean and North and Central America, South Eastern Africa; Eastern Asia, the South Pacific and Australia.

As can be seen in Table 5, these frameworks span from two to six levels; with three and four levels being the most common. The majority of frameworks make use of terms to label levels, with most countries employing advisory, watch, and warning. In contrast, three frameworks make use of numeric classes (Mauritius and Rodriguez, Hong Kong and the Philippines) and six frameworks make use of colours or a combination of colours and terms (Netherlands Antilles and Aruba, Mexico, Mozambique, French Polynesia, La Réunion and New Caledonia).

In the United States and in some other cases, separate frameworks are employed for tropical storms and for hurricanes. Taking into account the temporal dynamics of such events, most frameworks link their levels to the time required for such cyclones or hurricanes to make landfall in coastal areas. In other cases, levels are linked to wind-speed thresholds. For example, the Mexican Early Warning System for Tropical Cyclones makes use of a five-level arrangement, which is defined in relation to the leading edge of the tropical cyclone, characterized in terms of winds having a magnitude of 34 knots (63 km/h). The lower four levels are based on the time interval between the current position of this leading edge and the time required for such leading edge to reach land. The fifth level corresponding to red alert is established once the leading edge has reached the coastline.

In few cases an "all clear" level is employed. The use of thresholds related to specific parameters (wind-speed for example) is also a common practice in many of these frameworks. For example, wind-speeds are employed to characterize categories of hurricanes in the Caribbean, and are also used to trigger different warning levels. However, there is yet no consensus within this region of the Caribbean and North America on the use of a single framework.

Two interesting issues to highlight are the fact that in some countries such as Mozambique, the blue colour is used instead of green as the lowest warning level. While in contrast, in La Réunion the blue colour is used for the all clear level.

Example 2 presents some of the details of the framework employed by NOAA of the United States for hurricanes and tropical cyclones. As it can be seen in this example, a watch reflects the fact that conditions for a tropical storm or for a hurricane are possible within 36 hours, while a warning is described in terms of both a minimum wind speed and a timeframe of 24 hours or less.

Term	Definition/Description
Advisory	Official information issued by tropical cyclone warning centres, describing all tropical cyclone watches and warnings in effect along with details concerning tropical cyclone locations, intensity and movement and precautions that should be taken. Advisories are also issued to describe tropical cyclones prior to issuance of watches and warnings and subtropical cyclones.
Gale Warning	A warning of 1-minute sustained surface winds in the range 34 knots (39 mph or 63 km/hr) to 47kt (54mph or 87km/hr) inclusive, either predicted or occurring and not directly associated with tropical cyclones.
High Wind Warning	A high wind warning is defined as 1-minute average surface winds of 35 knots (40mph or 64km/hr) or greater lasting for one hour or longer, or winds gusting to 50kt (58mph or 93km/hr) or greater regardless of duration that are either expected or observed over land.
Storm Warning	A warning of 1-minute sustained surface winds of 48 knots (55mph or 88km/hr) or greater, predicted or occurring, not directly associated with tropical cyclones.
Tropical Storm Watch	An announcement for specific coastal areas that tropical storm conditions are possible within 36 hours.
Tropical Storm Warning	A warning that sustained winds within the range of 34 to 63 knots (39 to 73mph or 63 to 118km/hr) associated with a tropical cyclone are expected in a specified coastal area within 24 hours or less.

The NOAA of the United States uses a framework based on wind-speed and the expected time interval for the event to make landfall. In the context of wind-speed the framework makes reference to gales, high winds, storms, tropical storms and hurricanes. The following chart presents the framework and the characteristics of each level.

Example 2: NOAA in the United States. Source: http://www.nhc.noaa.gov/aboutgloss.shtml.

Country	Characteristics			Criteria for levels					
	Number of levels	**Colours/ Terms**	**All clear ***	**Magnitude/ Severity**	**Likelihood of event**	**Based on thresholds**	**Time until arrival**	**Period of return**	**Source of information**
Bahamas	2	Terms	n				x		http://www.bahamas-weather.org.bs/index.php?page=warningsystem
Cuba	4	Terms	y	x			x		http://www.insmet.cu/asp/genesis.asp?TB0=PLANTILLAS&TB1=OPTION&TB2=/contenidos/ciclones%20tropicales/generalidades/generalidades.htm
Jamaica	4	Terms	y	x		x	x		http://www.metservice.gov.jm/definitions.asp
St. Vincent and the Grenadines	3	Terms	n	x		x	x		http://www.meteo.vc/links/prepare.htm
Grenada	3	Terms	n			x	x		http://mypages.spiceisle.com/nadma/appendix3.html
Netherlands Antilles and Aruba	6	Colours/ Terms	y	x		x	x		http://www.meteo.an/include/Pub/documents/GuideTropicalCyclones.pdf
Cayman Islands	3	Terms	n	x					http://www.gov.ky/portal/page?_pageid=1142,1481967&_dad=portal&_schema=PORTAL
USA (gale/ wind, storm, hurricane)	3	Terms	n	x		Combination of threshold and time until arrival			http://www.nhc.noaa.gov/aboutgloss.shtml

Country	Characteristics			Criteria for levels					
	Number of levels	Colours/ Terms	All clear *	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until arrival	Period of return	Source of information
Canada	3	Terms	n	x		x	x		http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=D9553AB5-1
Mexico	5	Colours/ Terms	n	x		x	x		http://www.nl.gob.mx/pics/pages/sistema_alerta_base/SIAT_CT.pdf
Mozambique	3	Colours	n				x		http://www.inam.gov.mz
Mauritius & Rodriquez	5	Numeric Classes	y			x	x		http://metservice.intnet.mu/?cat=20
La Réunion	4	Colours/ Terms	y				x		http://www.meteo.fr/temps/domtom/La_Reunion/charte/pics/Alertes/tableau-alerte-cyclonique.html
India	4	Terms	n				x		http://www.imd.gov.in/ection/nhac/dynamic/faq/FAQP.htm#q85
Bangladesh	3	Terms	n				x		http://www.adrc.asia/publications/TDRM2005/TDRM_Good_Practices/PDF/PDF-2005e/Chapter3_3.3.2-1.pdf
Hong Kong	5 (incl. storm warning)	Numeric Signals	n	x		x	x		http://www.hko.gov.hk/publica/gen_pub/tcws.pdf
Taiwan, ROC	3	Terms	n	x		x	x		http://www.cwb.gov.tw/V7e/service/Meteorological_Regulations.htm
Philippines	4	Numeric Classes	n	x		x	x		http://www.pagasa.dost.gov.ph/genmet/psws.html
Australia	4	Terms	n				x		http://www.bom.gov.au/cyclone/about/warnings/

Country	Characteristics			Criteria for levels					
	Number of levels	Colours/ Terms	All clear *	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until arrival	Period of return	Source of information
French Polynesia	5	Colours	y					x	http://www.meteo.pf/vigi_cy-clone.php?557401742#bulvigi
New Caledonia	4	Colours/ Terms	y					x	http://www.meteo.nc/
Macau	5	Terms	n				x	x	http://www.smg.gov.mo/www/cvm/typhoon/fe_typhoonmain.htm
Fiji, South Pacific Area	2	Terms	n				x	x	http://www.met.gov.fj/index.php?id=152

Table 5: Alert frameworks for tropical cyclones/hurricanes. Source: authors.

Severe thunderstorms

In addition to frameworks focusing on tropical cyclones, information was also found on frameworks related to severe thunderstorms. NOAA and the Meteorological Service of Environment Canada operate a two-level framework using watch and warning terms. A watch is issued when there is a likelihood of such a thunderstorm taking place; while a warning is issued when severe thunderstorms have been reported by spotters or indicated by radar stations.

The Hong Kong Observatory, the Macao Meteorological and Geophysical Bureau and the Bureau of Meteorology of the Australian Government have presented one-level frameworks. In this case, a warning is issued to give a short-term notice of the likelihood of thunderstorms which may produce dangerous and damaging conditions.

In Europe Meteoalarm also includes thunderstorms in its four-level framework as indicated in Example 1.

Floods

Floods, triggered in many countries by storms or cyclones, manifest themselves in all continents of the world, provoking fatalities, injuries and losses of many kinds. As reported by the International Strategy for Disaster Reduction during its First Global Platform Meeting held in Geneva in June 2007 (ISDR, 2007b), most fatalities associated with floods occur in less developed regions, while most economic losses are concentrated in developed regions. Examples of this trend are the Nargis cyclone which killed over 80,000 people in coastal areas of Myanmar in May 2008; and hurricane Katrina, which provoked intense floods in New Orleans in August 2005. To this day, hurricane Katrina was the costliest disaster in the United States in recent history (Knabb et al., 2005).

Floods can manifest themselves rather quickly in the case of flash floods, within hours in other cases, and can take up to days to manifest themselves in the case of very large basins. Their growth stage is usually related to increasing runoff conditions within the basins triggered by rainfall. In the case of flash floods, the mature stage may last from a few to several hours; while in the case of floods in very large basins such as the Danube, Mississippi, Limpopo and the Yellow river, it can last for several days.

In the context of early warning, the same report by ISDR (2007b) indicates that through disaster preparedness and early warning, the impacts of floods can be reduced dramatically, as it has been demonstrated in the case of Cuba. The fact that most floods are preceded by intense precipitation, with a subsequent rise in the level of rivers, allows early warning systems to be designed and operated either as centralized systems managed by national meteorological or hydrological agencies; or as decentralized systems in the case of community-operated early warning systems in small basins.

The survey identified 23 frameworks, including three for Canada (a national framework plus two provincial frameworks: Alberta and British Columbia). As can be seen from Table 6, the majority of frameworks are designed to make use of three or four levels, although the number of levels varies from one to five. In the majority of cases levels are linked to the likelihood of floods (16 out of 23 cases), while in several cases the severity or magnitude of the expected floods is used and in few cases thresholds are employed. Furthermore, in many cases frameworks use combinations of several of these criteria to define levels. As it can be seen, in the case of Norway, the statistical period of return is used. In addition, the majority of frameworks do not make use of an "all clear" level to signal the end of the flood.

In most cases these frameworks use terms to represent levels, except in two cases where one finds numeric levels, and in the case of Colombia, France, China, the Czech Republic and Malaysia, where colours are used. In India and Bangladesh the terms Low, Normal, Moderate, High, Severe and Unprecedented Flood Situation are used.

European agencies make use of the internet to display information regarding their frameworks for a variety of hazards including floods. Information on frameworks from Asia is also considerable, although there is less information from the Caribbean and Latin America. Example 3 presents the framework employed by the Institute of Hydrology, Meteorology, and Environmental Studies of Colombia (IDEAM).

Winter storms/extreme cold

Winter storms and extreme cold temperature are typical examples of extreme weather in northern and southern latitudes and in the case of high-elevation mountain ranges (e.g., Alps, Himalaya, Andes). However, the notion of extreme cold temperature must be understood as a relative term according to the different conditions. For example, the Hong Kong framework for extreme temperature stipulates a warning when the temperature drops down to 12 degrees Centigrade or below.

Within the United States, NOAA has frameworks based on warnings for frost/freeze conditions and blizzards; and uses the traditional two-level scheme (watch and warning) in the case of winter storms. The Meteorological Service of Environment Canada issues a Cold-Wave warning when temperatures are expected to fall dramatically within 24 hours from above normal or near seasonal temperatures to very cold temperatures.

In the case of Europe, Meteoalarm, set up by the Network of European Meteorological Services, includes frameworks for snow/ice and extreme high and low temperature as presented in Example 1.

Country	Characteristics			Criteria for levels					
	Number of levels	Colours/ Terms	All clear *	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until arrival	Period of return	Source of information
USA	2	Terms	n		x		x		http://www.ready.gov/floods
Canada (Ontario)	2	Terms	n		x				http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@water/documents/document/264484.pdf
Canada (Alberta)	3	Terms	n	x		x	x		http://www.environment.alberta.ca/forecasting/FAQ/advisories.html
Canada (British Columbia)	3	Terms	n		x				http://www.rdn.bc.ca/cms.asp?wpID=904
Jamaica	2	Terms	n		x				http://www.metservice.gov.jm/definitions.asp
Colombia	4	Colours	n		x				http://pronosticos.ideam.gov.co/jsp/loader.jsf?lServicio=Publicaciones&lTipo=publicaciones&lFuncion=loadContenidoPublicacion&id=346
England	4	Terms	y	x	x				http://www.environment-agency.gov.uk/homeandleisure/floods/31620.aspx
Scotland	4	Terms	y	x	x		x		http://www.floodlinescotland.org.uk/floodsymbols/index.html
Norway	2	Terms	n		x			x	http://www.nve.no/en/Floods-and-landslides/Flood-forecasting-system/
Belgium	3	Terms	n		x				http://voies-hydrauliques.wallonie.be/opencms/opencms/fr/hydro/Gestion/Alerte/alerte.html

Country	Characteristics			Criteria for levels					
	Number of levels	Colours/ Terms	All clear *	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until arrival	Period of return	Source of information
Germany	3	Numeric levels	n	x	x				Personal communications, DWD
Czech Republic	4	Colours/ Numeric levels		x					http://hydro.chmi.cz/hpps/index.php?lng=ENG
France	4	Colours	n	x	x				http://www.vigicrues.ecologie.gouv.fr/
China	4	Colours	n		x		x		http://www.gfdrr.org/gfdrr/sites/gfdrr.org/files/Implementing_Early_Warning_Systems.pdf
India	4	Terms	n	x		x			http://www.india-water.com/ffs/Reports/SummFFSite.asp
Bangladesh	3	Terms	n	x					http://www.ffwc.gov.bd/
Hong Kong	1	Term	n	x	x				http://www.hko.gov.hk/wservice/tsheet/tsflwarn.htm
Japan	2	Terms	n	x					http://www.bousai.go.jp/kyoryoku/soukikeikai.pdf
Philippines	3	Terms	n		x	x			http://www.gov.ph/how-to-make-sense-of-pagasas-colour-coded-warning-signals/
Malaysia	4	Colours/ Terms			x				http://infobanjir.water.gov.my/yani.htm
Australia	5	Terms	n	x				x	http://www.bom.gov.au/hydro/flood/flooding.shtml
Viet Nam, Laos	3	Terms	n			x		x	http://ffw.mrcmekong.org/includes/stages.htm
Pakistan	5	Terms	n	x		x			http://www.apfm.info/pdf/case_studies/cs_pakistan_chenab.pdf

Table 6: Alert frameworks for floods. Source: authors.

The Institute of Hydrology, Meteorology, and Environmental Studies of Colombia (IDEAM) was established in 1995 to provide scientific and technical assistance to agencies conforming Colombia´s National Environmental System. IDEAM has established warning frameworks for a variety of hazards including floods using the format of colours to differentiate levels. The next chart presents the four-level framework designed for floods.

Colour	Definition/Description
Advice	Advice implies the presence of an event, but no immediate hazards are present and hence it is considered only as a message to inform the population. The issuing of advice implies that the population must be vigilant as conditions are likely to develop into an event.
Yellow	It is declared when the persistence and intensity of rainfall provokes the level of the river to rise and therefore, situations of risk may be likely and a flood may take place in a short time (days).
Orange	It is declared when the level of the river sustains an ascending tendency and the persistence of rainfall may imply imminent situations of risk and of floods which may begin to affect populated areas.
Red	It is declared when the level of the river has reached or surpassed critical levels provoking floods and is affecting populated areas.

Example 3: Flood warning framework, Colombia. Source: http://pronosticos.ideam.gov.co/jsp/loader.jsf?lServicio=Publicaciones&lTipo=publicaciones&lFuncion=loadContenidoPublicacion&id=346.

Humidex Index value	Degree of discomfort
20 – 29	No discomfort
30 – 39	Some discomfort
40 – 45	Great discomfort; avoid exertion
46 and over	Dangerous; probable heat stroke

Table 7: Humidex index of the weather office in Canada. Source: http://www.eohu.ca/segments/vocabulary_e.php?segmentID=3&topicID=292#616.

Extreme heat

The 2003 heat wave affected many countries in Europe provoking over 72,000 fatalities in 15 countries, revealing the hidden vulnerability of the elderly to such waves (CRED, 2009). Such an event triggered efforts in many countries to strengthen their early warning systems targeting extreme temperatures.

In the United States, NOAA uses a three-level framework for excessive heat: Outlook, Watch and Warning/ Advisory. The Outlook and Watch levels are established based on the potential for a wave to manifest itself in a particular geographical area within specific intervals of time (3 to 7 days and 12 to 48 hours respectively). In contrast, the Advisory and Warning levels are established when an excessive heat wave is expected in the next 36 hours and are based on the severity of the wave (the Advisory level reflects potential conditions of discomfort or inconvenience; while the Warning level reflects a more critical case of conditions posing a threat to life or property).

The Meteorological Service of Environment Canada has a framework which targets both heat waves and high humidity. The Humidex index has been defined according to the combined effect of high humidity and high temperatures on the human body. Table 7 presents values of the Humidex index and degree of discomfort. A Humidex Advisory is issued when temperatures are expected to reach or exceed 30 °C and the humidex values are expected to reach or exceed 40. According to Environment Canada the new Heat Health Alert system establishes two levels or stages: a heat alert, when a forecast projects a 65 per cent to 90 per cent chance of increased in mortality for Toronto city and an Extreme Heat Alert may be also issued when a forecast projects a chance greater than 90 per cent of increased mortality for Toronto residents. In contrast, the city of Kingston in the Province of Ontario uses a three-level framework using both the Humidex index and a SMOG advisory. The framework is based on thresholds and the levels (https://www.cityofkingston.ca/residents/environment/extreme/heatlevels.asp):

Level 1 – Heat alert

Level 2 – Heat warning

Level 3 – Heat emergency

In Europe, the National Weather Service of Switzerland (MeteoSwiss) uses a five level system in terms of a combination of colours and numbers based on the potential severity of the event. The German Weather Service uses a two-level framework based on the degree of thermal stress (Strong and Extreme Thermal Stress). The Meteorological Office of England uses a four-level framework based on numeric levels and corresponding terms which are presented in Example 4. The framework is based on the probabilistic forecast of the risk exceeding a certain percentage value. In Italy, the Epidemiology Department of Rome uses a four-level framework based on terms as well, but with a different nomenclature: normal, attention, alarm and emergency. Meteoalarm also targets this hazard for all European countries which are covered by this system. Table 8 summarizes these frameworks.

In Asia, the Hong Kong Observatory uses a one-level framework. A warning will be issued if the temperature may exceed 33 °C or higher. Most frameworks are defined in terms of two criteria: thresholds and magnitude or severity of the heat wave. None of them incorporate an "all clear" level. As it can be seen, around the world there are a variety of frameworks employed in the case of heat waves; which makes it complicated to suggest one single framework.

Country	Characteristics			Criteria for levels					Source of information
	Number levels	Colours/ Terms	All clear of (y/n)	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until arrival	Period of return	Website link
USA, NOAA	3	Terms	n	x			x		http://www.noaawatch.gov/themes/heat.php
Canada (Toronto)	2	Terms	n	x		x			http://www.ec.gc.ca/scitech/default.asp?lang=En&n=4B40916E-1&xsl=privateArticles2,viewfull&po=8D2706D0
Canada (Kingston)	3	Terms	n			x			https://www.cityofkingston.ca/residents/environment/extreme/heatlevels.asp
Switzerland	5	Colours/ Numbers	n	x					http://www.meteoschweiz.admin.ch/web/en/danger/danger.html
Germany	2	Terms	n			x			Personal communication
England	4	Numbers/ Terms	n			x			http://www.metoffice.gov.uk/weather/uk/heathealth/index.html#advice
Italy	4	Terms	n						http://www.epidemiologia.lazio.it/sitoDEP/bollettini_ondate_calore.php
Europe (Meteoalarm)	4	Colours	n	x				x	http://www.meteoalarm.eu/
Hong Kong	1	Term	n			x		x	http://www.wmo.ch/pages/prog/amp/pwsp/publications-guidelines_en.htm

Table 8: Alert frameworks for heat waves. Source: authors.

The Meteorological Office of England has established a four-level framework to deal with heat waves. The next chart presents a description of this framework.

Level	Designation	Comments
Level 1	Summer preparedness and long-term planning	This is the minimum state of vigilance during summer. During this time social and healthcare services will ensure that all awareness and background preparedness work is ongoing. The majority of the time the risk of a heat wave will be less than 50 per cent. However, when the risk exceeds 50 per cent this will be indicated by Level 1 - Summer preparedness - Increased risk.
Level 2	Alert and readiness	Triggered as soon as the risk is 60 per cent or above for threshold temperatures being reached in one or more regions on at least two consecutive days and the intervening night. This is an important stage for social and healthcare services which aim to ensure readiness and swift action to reduce harm from a potential heat wave.
Level 3	Heat wave action	Triggered as soon as the Met Office confirms threshold temperatures will be reached in one or more regions for one day and the following night, and the forecast for the next day is greater than 90 per cent confidence that the day threshold will be met. This stage requires social and healthcare services to target specific actions at high-risk groups.
Level 4	Emergency	Reached when a heat wave is so severe and/or prolonged that its effects extend outside the health and social care system. At this level, illness and death may occur among the fit and healthy, and not just in high-risk groups.

Example 4: Framework for heat waves in England. Source: http://www.metoffice.gov.uk/weather/uk/heathealth/index.html#advice.

Tornadoes

Tornados are frequent in the United States and may appear in Canada, Bangladesh and in other countries. However, the meteorological conditions required for such events are so unique that forecasting such events requires very sophisticated equipment and expertise. In the United States, Canada, Netherland Antilles and Aruba, a two-level framework is employed using the terms watch and warning.

Droughts and food insecurity

Droughts, like floods, have manifested themselves throughout the world with varying degrees of severity. However, in contrast to floods and other weather-related hazards, droughts are slow-onset hazards, lasting from months to years in extreme cases; and can affect a very large number of people in several countries or regions.

As stated by the Working Group on Hydrometeorological Hazards and Drought established by IDNDR (O'Neill, 1997), droughts evolve from a complex interaction of factors and, in many instances, can no longer be considered to be purely natural. Economic conditions, poor farming practices, inappropriate land use, water management practices, long term soil degradation and human influences due to population expansion beyond the immediate natural environment's carrying capacity, are factors which can have an effect on the processes related to the manifestation and persistence of droughts. The development and application of drought indices can contribute to both preparedness and response by assisting in the detection of emerging drought conditions and by providing an indication of their likely impacts.

Early warning in the case of droughts is conducted at the national, regional, and international levels. National Meterorological Services or Departments are now working through partnerships within regional and international organizations in Africa, Asia, and Latin America to share data in order to develop regional drought forecasts. In addition, a number of major international organizations such as the Food and Agriculture Organization's Global Information and Early Warning System on Food and Agriculture (FAO/GIEWS), the World Food Programme and USAID's Famine Early Warning System (FEWS) now conduct similar early warning efforts and are contributing to launch humanitarian assistance campaigns in those countries or regions affected by droughts.

In many cases, drought conditions are incorporated into early warning systems targeting food insecurity, particularly since drought has severe impacts on agriculture, which is essential for food security. Table 9 presents data on nine alert or warning frameworks for drought and food insecurity. Frameworks in this case incorporate three to seven levels. It is interesting to note that in the case of the United States, a framework based on colours is employed to complement the typical one based on terms. The reason is that such a framework also indicates the expected trend of the drought (whether the drought will persist, worsen or improve). In half the cases four levels are employed and in many cases the levels are assigned on the basis of the magnitude or severity of a drought or food insecurity event, or on thresholds related to impacts to livelihoods and assets of those at risk. In seven of the nine cases a combination of terms and colour are used, whereas in two cases only terms are used.

The Food and Agriculture Organization of the United Nations (FAO) operates a system based on a bi-polar status at the global level; either a country is experiencing drought or not. In contrast, the Famine Early Warning Systems Network (FEWSNET) makes use of five levels which employ a combination of colours and terms to identify whether there may be indications of possible incoming food security crisis, or whether it is already occurring.

Coastal and high seas, winds, gales and storm surges

Storm surges related to winds and gales are frequent in most coastal regions of the world. The survey identified information on 11 frameworks from eight countries and is summarized in Table 10. The number of levels in this case varies from one to four.

Country	Characteristics			Criteria for levels					
	Number of levels	Colours/ Terms	All clear *	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until arrival	Period of return	Source of information
USA, NWS	4	Colours/ Terms	y	x	x				http://www.cpc.ncep.noaa.gov/products/expert_assessment/seasonal_drought.html
USA, Drought Monitor	5	Colours/ Terms	n	x					http://droughtmonitor.unl.edu/
FEWSNET (Central America, East and West Africa, Central Asia)	5	Colours/ Terms	n	x					http://www.fews.net/ml/en/info/pages/scale.aspx
Central America (SERVIR MFEWS)	3	Colours/ Terms	n	x					http://servir.msfc.nasa.gov/fews/documents/Overview_Guatemala_Final_Espanol.doc
Africa (West, East, South)	4	Colours/ Terms	n			x			http://www.odi.org.uk/work/projects/pdn/drought/sommer.pdf
Kenya	4	Terms	n			x			http://www.odi.org.uk/work/projects/pdn/drought/sommer.pd
Kenya (Community-based EWS)	4	Terms	n			x			http://www.aridland.go.ke/inside.php?articleid=555
East Africa	7	Colours/ Terms	n	x					http://glews.tamu.edu/africa/pagesmith/2
Global - FAO	2	Colours/ Terms	n	x		x			http://www.fao.org/giews/english/index.htm

Table 9: Alert frameworks for drought and food insecurity. Source: authors.

Country	Characteristics			Criteria for levels					Source of information
	Number levels	**Colours/ Terms**	**All clear of (y/n)**	**Magnitude/ Severity**	**Likelihood of event**	**Based on thresholds**	**Time until arrival**	**Period of return**	**Website link**
Canada – storm surge	1	Terms	n		x				http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=D9553AB5-1#stormsurge
Canada – weather at sea	4	Terms	n	x		x			http://www.ec.gc.ca/meteo-weather/default.asp?lang=En&n=2EC4EC51-1&offset=11&toc=show
Finland – wind warnings	3	Terms	n	x					http://en.ilmatieteenlaitos.fi/warnings
Finland – wave warnings	3	Terms	n	x					http://en.ilmatieteenlaitos.fi/warnings
Finland – sea level warnings	3	Terms	n	x					http://en.ilmatieteenlaitos.fi/warnings
Japan – weather at sea	1	Terms	n	x	x				http://www.jma.go.jp/en/seawarn/
New Zealand – weather at sea	1	Terms	n	x		x			http://www.metservice.com/national/warnings/marine-warnings
Australia - coastal seas	4	Terms	n	x		x			http://www.bom.gov.au/marine/about/marine-definitions.shtml
Italy – coastal and high seas	3	Colours	n		x	x			http://www.meteoam.it/?q=meteomar/burrasca
United States – coastal weather	3	Terms	n	x					http://www.nhc.noaa.gov/aboutgloss.shtml
Hong Kong – coastal seas, weather	1	Terms	n		x				http://www.hko.gov.hk/wservice/tsheet/marine.htm

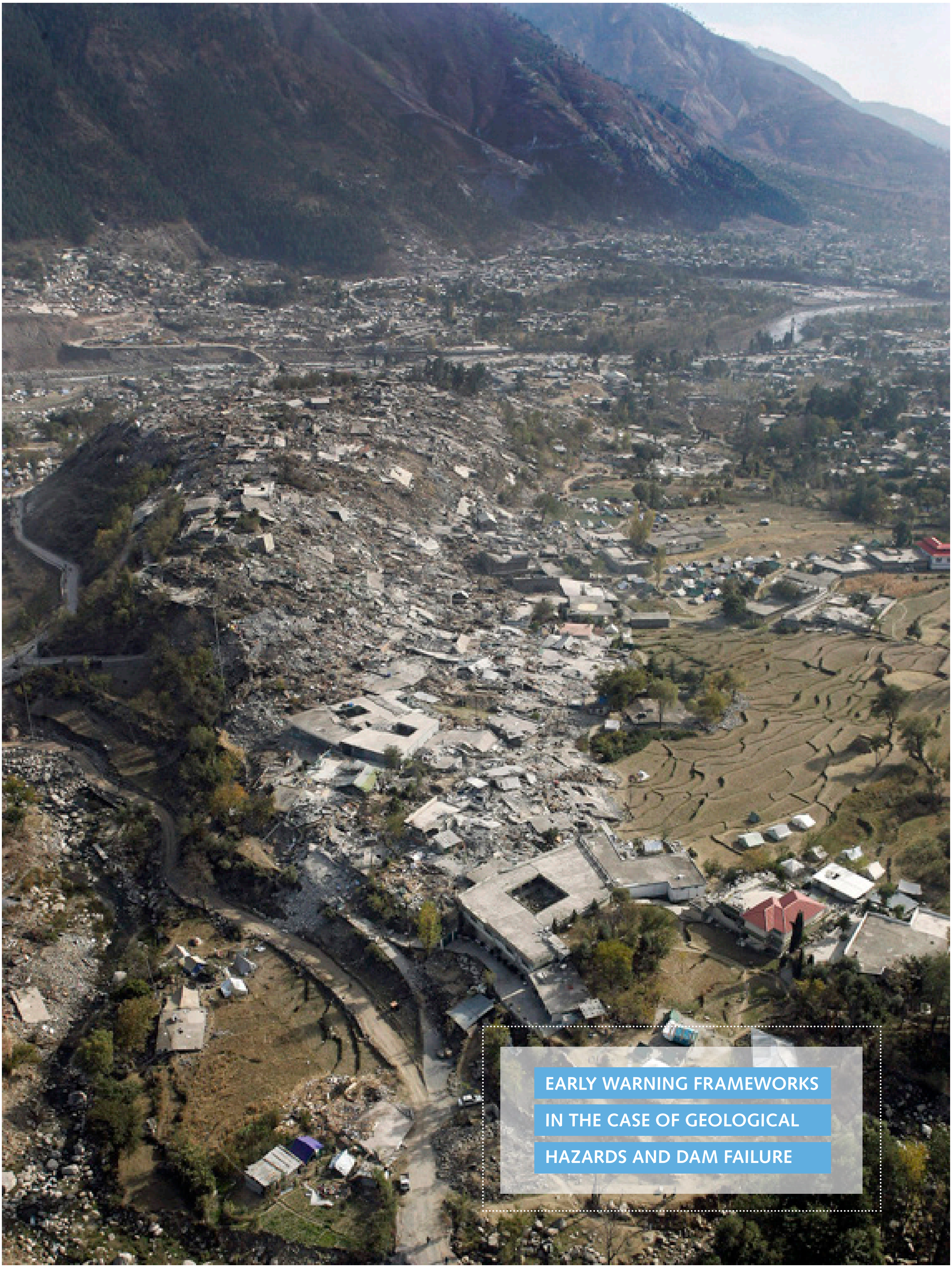
Table 10: Alert frameworks for storm surges, coastal and high seas weather. Source: authors.

x

As it can be seen from this table, four frameworks use a single-level scheme; five frameworks use a three-level scheme and two other frameworks make use of a four-level scheme. In several cases the frameworks are based on the magnitude or severity of the expected events, in other cases they are based on the likelihood of such events including storm surges, and also on thresholds. As in the case of other hazards, some frameworks are based on a combination of two criteria. In addition, no framework contemplates an "all clear" signal.

In the case of storm surges, the Meteorological Service Environment Canada uses a one-stage framework (warning) which is issued when a storm surge and/or high waves may result in significant flooding in coastal areas. However, in the case of weather at sea, the Meteorological Service uses a four-stage framework (strong wind warning, gale warning, storm warning and hurricane-force wind warning) based on the expected wind speed. In Finland, frameworks target wind warnings, sea level warnings and wave warnings as well. In the case of weather at sea, the Japanese Meteorological Agency and the National Meteorological Service of New Zealand employ a single-level framework (warning).

In Italy, the Meteorological Service employs a three-level framework based on colours for coastal and high seas (*blue colour:* no warning; *orange colour*: warning related to isolated thunderstorm; and *red colour*: warning related to distributed thunderstorms). In the case of the South China coastal waters, the Hong Kong Observatory uses a single-level framework (warning) in the case of strong winds, fog and hazardous weather. The Regional Offices of the Bureau of Meteorology of Australia, responsible for monitoring and forecasting coastal and high seas weather, employ a four-level framework based on the potential speed of winds in coastal waters. Finally, in the case of the United States, NOAA employs a three-level framework for coastal weather as described in Example 2.



EARLY WARNING FRAMEWORKS IN THE CASE OF GEOLOGICAL HAZARDS AND DAM FAILURE

This sections deals with geological hazards such as earthquakes, volcanic eruptions and landslides. In addition, it includes the specific case of dam failure.

Earthquakes

Earthquakes are the prime examples of plate tectonic activity. Such events liberate the energy that has been accumulated between tectonic plates over centuries. In doing so, these events may lead to major destruction in the geographical area near their epicentre and in the vicinity of fault-lines associated with the earthquake. Earthquakes can take place on every continent, although some regions within continents are more active than others. Typical examples are North and South America, where the Pacific coast is more active in terms of earthquakes than the Atlantic coast.

In the Great Eastern Earthquake that impacted Japan in March 2011, and which triggered a tsunami that affected many coastal cities, the earthquake warning system was employed which minimized losses, including those which could have been associated with the Japanese high speed trains.

The embryonic and growth stages leading to an earthquake may span centuries, while a very large earthquake may last from several seconds to a few minutes in its mature stage. Earthquakes are followed by replicas or aftershocks during the decaying stage, which manifest themselves in the days and months after the main shock. In addition, some large earthquakes may be preceded by foreshocks (Lin, 2003). Some of the very large earthquakes whose epicentres lie just below the surface of the bottom of the sea in shallow waters may generate tsunamis as was the case in Japan in 2011, in Chile in 2010 and 1960, in the Indian Ocean in 2004, and in Indonesia on many occasions. Earthquakes may also trigger landslides, displacing in some cases up to millions of cubic metres of rock, soil or debris.

While individual earthquakes cannot yet be forecast in terms of a specific date and a geographical epicentre, early warning systems have been set up to warn populations living hundreds to thousands of kilometres away from the epicentre within seconds to minutes before being struck by the earthquake. Such systems register potentially catastrophic earthquakes very quickly and make use of radio communications travelling at the speed of light to send signals to cities which may be impacted. Taking into consideration the faster speed at which radio communications propagate in comparison to the speed of seismic waves (Lee et al., 2003; Zschau et al., 2003), such systems allow authorities and institutions to quickly implement specific measures that will minimize impacts and losses, including shutting down electricity plants, stopping high-speed trains (as well as subway or metro trains) and mobilizing people to safe areas, particularly children in schools. Early warning systems of these kinds have been implemented in various countries including Mexico, Japan and Taiwan (Province of China), while similar alert or alarm systems are being implemented and tested independently in Canada, Italy, Greece and the United States.

However, as the interval of time between the arrival of the radio-transmitted signal and the earthquake is very short, it is not possible to have more than one warning level. The few systems which are in operation and those being implemented on a trial basis trigger an alarm as soon as a radio-transmitted signal is received. Furthermore, when the system is properly designed through standard operating procedures, operators of different types of facilities may react to such an alarm in diverse ways thereby minimizing losses in their facilities. Train operators would react by slowing down trains to a full stop, while operators of subways and metros may stop their subways at the next station to allow people to evacuate to the streets safely. Engineers operating electrical power plants may also shut down specific segments of the system to minimize subsequent damage to infrastructure due to short circuits. Directors or principals in schools may issue an order for children to take the necessary actions, whether mobilizing themselves under their desks or evacuating buildings to open areas, etc.

In the City of Mexico the Seismic Alert System tracks earthquakes in the Guerrero Seismic Area. The framework has been structured in terms of three levels which are based on the magnitude of the event. For earthquakes of magnitude 5.0 or less on the Richter scale, no alarm is triggered. For earthquakes whose magnitude is between 5.0 and 6.0 on the Richter scale, a preventive alert is issued targeting schools, hospitals and residential areas. For earthquakes whose magnitude is above 6.0 in this scale, a public alert is issued in subways, schools, radio stations, TV, houses, hospitals and to the public in general. Nicaragua uses a similar system based on three levels, where the levels again refer to the magnitude of the earthquake which has taken place. In Japan a system has been designed to target the region of Tokai, where major earthquakes have taken place regularly with an interval of 100 to 150 years. The Tokai warning system makes use of a three-level framework. The system is described in Example 5.

Volcanic activity

Volcanic activity includes a wide variety of phenomena such as eruptions, pyroclastic flows, lava flows, dome collapse, ash emissions, lahars, tremors, gaseous emanations and in rare cases tsunamis which can be triggered when there is a collapse of the dome of a volcano located next to the sea or underwater. For example, the Krakatau volcanic eruption in 1883 has been characterized as one of the most violent eruptions in recent history, and the collapse of the dome generated a destructive tsunami that impacted coastal areas as far away as Sri Lanka and India.

Level of alert	Type of observation that is used to assess the level of alert	Type of action suggested
Tokai Earthquake Report	1. A small anomaly is observed, but it is insufficient for interpreting whether it is directly relevant to the occurrence of the Tokai Earthquake. 2. Some anomalies are observed, which are interpreted to be irrelevant to the occurrence of the Tokai Earthquake (no risk of Tokai Earthquake)	Attention should be given to the information broadcast from TV/Radio. No further action is required.
Tokai Earthquake Warning	Some anomalies are observed, which may suggest that the possibility of an occurrence of the Tokai Earthquake is increasing.	Attention should be given to the information broadcast from TV/Radio. Follow notices from the government and the disaster management plan of the local governments.
Tokai Earthquake Warning	Anomalies are observed, which are interpreted to mean that the Tokai Earthquake is expected to occur.	Attention should be given to the information broadcast from TV/Radio. Act on the warning statement from the Prime Minister and the disaster management plan of local governments.

Example 5: Tokai Earthquake system. Source: http://www.jma.go.jp/en/quake_tokai/guide.html.

Colour	Level	Comments, instructions
(green)	NORMAL	Any type of activity can be conducted as programmed.
(yellow)	ALERT	Persons should be aware of further instructions by national and local authorities, and should follow the indications which such authorities may issue. Several preparedness measures need to be implemented at the household level.
(red)	ALARM	Exceptional conditions of volcanic activity may exist. Measures dictated by authorities should be followed.
	Return to Normality	

The National Secretariat of Civil Protection of Mexico, through its National Disaster Prevention Centre (CENAPRED), operates an early warning system targeting volcanic activity in the Popocatepetl Volcano. Based on the typical colours of a traffic street lights (green, yellow, red), the framework includes an all clear message, indicating a return to a calm state.

Example 6: Mexico: Popocatepetl volcano early warning system. Source: http://www.cenapred.unam.mx/es/Instrumentacion/InstVolcanica/MVolcan/Semaforo/.

Eruptions take place during the mature stage and are preceded by a rise of magma from large depths below the surface during the embryonic and growth stages, and by precursors such as an increase in tremors, increased emanations of gases such as water vapour, carbon dioxide, sulfur dioxide and other trace and toxic gases near the cone and small eruptions that can be perceived during the growth stage. Such precursors may be detected months prior to large eruptions. However, as Hugo Yepez, Director of the Geophysical Institute of Ecuador commented during the American Hemispheric Consultation on Early Warning, and later during the Second International Early Warning Conference in 2003, forecasting a large eruption is extremely difficult. Mr. Yepez was referring specifically to the volcanic activity which was manifested by Tungurahua and other volcanoes in Ecuador.

Several early warning systems employ colour schemes, while others use terms or numeric schemes. In New Zealand, a six-level framework is employed in the case of the reawakening of a volcano or in the case of frequently active volcanoes. The survey identified data on 14 frameworks, one of which is operated at the global level by the United States Geological Survey (USGS). As can be seen, while the number of levels can vary from three to six, the majority of frameworks are structured in terms of four levels. Five frameworks make use of colours, three make use of colours and numeric classes or terms, three make use of numeric classes, and the United States and La Réunion make use of terms.

As Table 11 displays, five frameworks are established using the potential severity or magnitude of volcanic activity while six frameworks make use of thresholds, the notion of likelihood or the interval of time until an eruption takes place. In addition, nine frameworks use a combination of two of these criteria.

Example 6 presents a summary of Mexico's Popocatepetl volcano early warning system which includes a three-level framework based on the typical colour-scheme of traffic lights to manage vehicle traffic in cities.

The respective web page presents warning levels and expected tasks to be conducted by citizens in each case. One of the great strengths of this framework is the link of its name to the standard name of traffic street lights in Spanish language (Semáforo del Popocatepetl).

Country	Characteristics			Criteria for levels					Source of information
	Number levels	Colours/ Terms	All clear of (y/n)	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until arrival	Period of return	Website link
United States	5	Terms	n		x				http://volcanoes.usgs.gov/activity/alertsystem/icons.php
El Salvador	4	Colours	n		x				http://issuu.com/moralesvalen/docs/ley_edicion_2011_ok?mode=window&backgroundColour=%23222222
Guatemala	4	Colours	n		x				Personal communication
Montserrat	5	Alert/ Numeric	n	x		x			http://www.mvo.ms/
Mexico	4	Colours/ Terms	y		x				http://www.cenapred.unam.mx/es/Instrumentacion/InstVolcanica/MVolcan/Semaforo/
Colombia	4	Numbers/ Colours	n		x		x		http://intranet.ingeominas.gov.co/pasto/Niveles_de_Actividad
Nicaragua	3	Colours	n	x		x			http://www.sinapred.gob.ni/index.php?option=com_content&view=category&layout=blog&id=61&Itemid=98
Italy	4	Colours	n			x	x		http://www.protezionecivile.it/minisite/index.php?dir_pk=250&cms_pk=1440&n_page=3
La Réunion (France)	4	Terms	n	x			x		Personal communication
Japan	5	Numeric	n				x		http://www.seisvol.kishou.go.jp/tokyo/STOCK/kaisetsu/English/level.html
Philippines	6	Numeric	n			x	x		http://www.phivolcs.dost.gov.ph/index.php?option=com_content&view=article&id=50&Itemid=86
Indonesia	4	Colours	n			x	x		Personal communication
New Zealand (frequently active)	6	Numeric	n	x		x			http://www.geonet.org.nz/volcano/alert-level.html
Global (USGS)	4	Colours/ Terms	y	x	x				http://volcanoes.usgs.gov/activity/alertsystem/

Table 11: Alert frameworks for volcanic activity. Source: authors.

Tsunamis

Tsunamis and tsunami early warning systems have received great attention recently. This is largely a consequence of the Indian Ocean tsunami of 26 December 2004 that affected many countries in South East Asia; the tsunami that impacted the coast of Chile in February 2010; and most recently the tsunami that impacted the eastern coast of Japan in March 2011. The attention directed towards Japan was further increased after the tsunami led to a subsequent nuclear disaster in the Fukushima nuclear plant.

Tsunamis can be triggered by undersea earthquakes; landslides which reach seas or oceans and underwater landslides; volcanic eruptions and dome collapse and meteorites. However, not all earthquakes trigger tsunamis, as it was the case during the Haiti earthquake that devastated this nation in January 2010.

The embryonic stage in case of tsunamis lasts a few minutes and is related to the mass movements underwater that give rise to them. The growth stage takes place in the interval of time between the mass movements triggered by an earthquake, underwater landslide or by an impact of a meteorite and the time the tsunami approaches the coastal area. In the mature stage the tsunami waves are impacting a coast and this phase may last for several hours, as there can be several waves associated with a single tsunami. The decaying stage takes place when there are no more tsunami waves and the sea level in the coast reaches its normal steady state.

Taking into consideration the fact that tsunamis can propagate along oceans and impact countries in different continents, regional tsunami watch centres are coordinated by the Intergovernmental Oceanographic Commission of UNESCO (UNESCO-IOC) and national counterparts. UNESCO-IOC recognizes the sovereignty of governments in context of the official issuing of warnings. To this end, these regional tsunami watch centres provide information bulletins that are expected to be used by decision makers in governments in order to decide which type of warning or alert to provide to coastal communities exposed to tsunamis. However, in the case of the Pacific Tsunami Warning system, since its establishment in the 1960s, countries in the Pacific Rim recognize that the Pacific Tsunami Warning Centre (PTWC) itself may issue warnings in case of potentially catastrophic tsunamis. For example, in 2006, 2011 and 2012, the PTWC disseminated bulletins issuing warnings to selected countries which could be affected by a tsunami. Example 7 presents a typical message sent by the PTWC in case of a potential tsunami, highlighting where warnings are in effect for particular countries.

Tsunami bulletins are sent to national focal points which operate on a 24/7 basis. In many countries, Meteorological Departments or Offices have been designated as the national focal points to receive such bulletins. WMO's Global Telecommunication System is used along with other means, such as the internet, fax and telephone communications, to send information to the national focal points. The need for national focal points was highlighted during the 2004 Indian Ocean tsunami, where the Pacific Tsunami Watch Centre, although aware of the tsunami, was not able to reach the relevant government agencies for several countries that were impacted by the wave, in time. Table 12 presents information on the regional tsunami warning systems being implemented.

Table 13 presents information on national warning frameworks employed in specific countries. As can be seen, such frameworks use between three and four levels with the exception of Hong Kong. Taking into consideration that tsunamis can be triggered by earthquakes, several early warning systems make use of seismic information to raise the level of warning or alert to a specific level. Then, based on the confirmation of a tsunami using data from buoys or other reports, such systems may opt to increase the level of warning or alert or cancel it in those cases where the earthquake did not trigger a tsunami. The emission of bulletins by regional tsunami watch centres is also triggered by earthquakes. The first bulletin usually presents information on the parameters of the earthquake (time of earthquake, epicentre coordinates, depth, location and magnitude). The evaluation segment of the bulletin will highlight whether or not there is a threat of a tsunami based on historical earthquake and any tsunami data that is available. Subsequent bulletins will also contain this information, as well as additional information on the readings of sea level changes in buoys in geographic regions where the tsunami may manifest itself. Such information on sea level changes is essential to confirm the presence of tsunamis.

In the case of Australia, warnings may be issued in case of potentially dangerous rips, waves and strong ocean currents in the marine environment, in the case of localised overflow onto the immediate foreshore and in those cases where land may be inundated by the tsunami.

TSUNAMI BULLETIN NUMBER 002

PACIFIC TSUNAMI WARNING CENTRE/NOAA/NWS

ISSUED AT 1525Z 05 SEP 2012

THIS BULLETIN APPLIES TO AREAS WITHIN AND BORDERING THE PACIFIC OCEAN AND ADJACENT SEAS... EXCEPT ALASKA...BRITISH COLUMBIA... WASHINGTON...OREGON AND CALIFORNIA.

THE EARTHQUAKE MAGNITUDE IS REDUCED TO 7.6

THE WARNING AREA IS REDUCED...SO THE WARNING IS CANCELLED FOR

EL SALVADOR...HONDURAS...MEXICO...COLOMBIA...ECUADOR...GUATEMALA AND PERU.

A TSUNAMI WARNING IS IN EFFECT FOR

COSTA RICA / PANAMA / NICARAGUA

FOR ALL OTHER AREAS COVERED BY THIS BULLETIN... IT IS FOR INFORMATION ONLY AT THIS TIME. THIS BULLETIN IS ISSUED AS ADVICE TO GOVERNMENT AGENCIES. ONLY NATIONAL AND LOCAL GOVERNMENT AGENCIES HAVE THE AUTHORITY TO MAKE DECISIONS REGARDING THE OFFICIAL STATE OF ALERT IN THEIR AREA AND ANY ACTIONS TO BE TAKEN IN RESPONSE. AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME – 1442Z 05 SEP 2012

COORDINATES – 9.9 NORTH 85.5 WEST

DEPTH – 46 KM

LOCATION – OFF COAST OF COSTA RICA

MAGNITUDE – 7.6

EVALUATION

IT IS NOT KNOWN THAT A TSUNAMI WAS GENERATED. THIS WARNING IS BASED ONLY ON THE EARTHQUAKE EVALUATION. AN EARTHQUAKE OF THIS SIZE HAS THE POTENTIAL TO GENERATE A DESTRUCTIVE TSUNAMI THAT CAN STRIKE COASTLINES IN THE REGION NEAR THE EPICENTRE WITHIN MINUTES TO HOURS. AUTHORITIES IN THE REGION SHOULD TAKE APPROPRIATE ACTION IN RESPONSE TO THIS POSSIBILITY. THIS CENTRE WILL MONITOR SEA LEVEL GAUGES NEAREST THE REGION AND REPORT IF ANY TSUNAMI WAVE ACTIVITY IS OBSERVED. THE WARNING WILL NOT EXPAND TO OTHER AREAS OF THE PACIFIC UNLESS ADDITIONAL DATA ARE RECEIVED TO WARRANT SUCH AN EXPANSION.

BULLETINS WILL BE ISSUED HOURLY OR SOONER IF CONDITIONS WARRANT.

THE TSUNAMI WARNING WILL REMAIN IN EFFECT UNTIL FURTHER NOTICE.

THE WEST COAST/ALASKA TSUNAMI WARNING CENTRE WILL ISSUE PRODUCTS

FOR ALASKA...BRITISH COLUMBIA...WASHINGTON...OREGON...CALIFORNIA.

Example 7: Example of message issued by the Pacific Tsunami Warning System in case of a potential tsunami.

Ocean/Sea	Continents/Regions			Comments on implementation	Source of information (website link)
Pacific	Asia	Asia Pacific	America	Implemented as a result of the Chile 1960 tsunami.	http://ptwc.weather.gov/index.php
Indian Ocean	South East Asia	Asia Islands and Africa	Indian Ocean	Implemented as a result of the 2004 Indian Ocean tsunami.	http://www.ioc-tsunami.org/index.php?option=com_content&view=article&id=8&Itemid=13&lang=en
Caribbean	Continental America	Caribbean		Implemented as a result of the 2004 Indian Ocean tsunami.	
North Eastern Atlantic, Mediterranean and Connected Seas (NEAMS)	Europe	Africa	Middle East	Implemented as a result of the 2004 Indian Ocean tsunami.	http://www.ioc-tsunami.org/index.php?option=com_content&view=article&id=9&Itemid=15&lang=en

Table 12: Regional tsunami watch systems. Source: authors.

Country	Characteristics			Criteria for levels	Source of information
	Number levels	Colours/ Terms	All clear of (y/n)	Comments on criteria employed	Website link
USA (NOAA)	4	Terms	y	Warnings initially issued based on earthquake parameters (magnitude, depth, etc), and are modified based on readings from tide gauges and DART buoys	http://www.prh.noaa.gov/ptwc/about_messages.php?region=0
Canada (West Coast & Alaska	4	Terms	y		http://ptwc.weather.gov/about_messages.php http://wcatwc.arh.noaa.gov/
Chile	4	Terms	y	Based on the earthquake parameters	http://www.snamchile.cl/
Nicaragua	3	Colours	n	Based on recommendations from INETER	http://www.sinapred.gob.ni/index.php?option=com_content&view=category&layout=blog&id=61&Itemid=98
Seychelles	3	Colours/ Numeric	n	Based on the parameters of earthquakes. Levels are also making reference to potential inundation depth	Personal communication
Hong Kong	1	Term	n	Based on warnings issued by PTWC	http://www.weather.gov.hk/gts/equake/tsunami_mon_e.htm
Japan	3	Terms	n	Warnings are based on expected height of tsunami (thresholds)	http://www.bousai.go.jp/kyoryoku/soukikeikai.pdf
Australia	3	Terms	y	Based on potential manifestation of event	http://www.bom.gov.au/tsunami/about/tsunami_warnings.shtml
Indonesia	4	Terms	y	Levels are based on seismic, tide gauge and DART buoy data	http://www.dews-online.org/c/document_library/get_file?uuid=6d4b8c64-

Table 13: National warning frameworks for tsunamis. Source: authors.

Landslides and snow avalanches

Landslides and other types of mass movements involve the movement of mass (rocks, soil, sand, debris) on a slope. While the force that drives and sustains any landslide or mass movement is gravity, such movements only take place when gravity is larger than the cohesion of the mass being moved with respect to the more stable material underneath that does not move. Landslide causes can be classified into four categories (Schwab et al., APA; USGS, 2005):

Geological causes – These include weak, weathered, sheared or fissured materials, adversely-oriented structural discontinuities (faults, unconformity, etc.), and contrasts in permeability and stiffness.

Morphological causes – These include tectonic or volcanic uplift, glacial rebound, fluvial, glacial or wave erosion of slope toe, or vegetation removal (forest fire, drought).

Physical causes – These include intense rainfall, rapid snow melt; earthquakes, volcanic eruptions, thawing and weathering (freeze and thaw or shrink and swell).

Human causes – These include excavation of the slope or its toe, loading of the slope or its crest, deforestation, irrigation, mining, artificial vibration and water leakage from utilities.

The most common trigger for landslides is water, generated through processes such as intense rainfall, snowmelt, increases in ground-water level and earth dams, etc. Water also plays a role in reducing cohesion within the soil that holds it in place. Also, water, when stored in the soil, may add weight to the soil itself, enhancing the force due to gravity.

Building on the fact that some landslides are triggered by intense rainfall, government institutions and NGOs are implementing early warning systems targeting such landslides. Table 14 presents information on three systems. While the United States continues to use the terms outlook, watch, and warning; in the case of Japan and Hong Kong, the framework is established using a single level. In all cases, the presence of extreme weather conditions is used as an indicator to issue the warning or to change levels of warning in the systems which make use of various levels.

Another type of mass movements is the snow avalanche. Table 15 presents information on four frameworks which have been established for avalanches. As with landslides, in the case of avalanches the likelihood of one occurring is used as the indicator by which levels are changed. Two interesting facts to note are the use of the "black" colour in the highest level and the equal use of frameworks in Europe, North America and New Zealand.

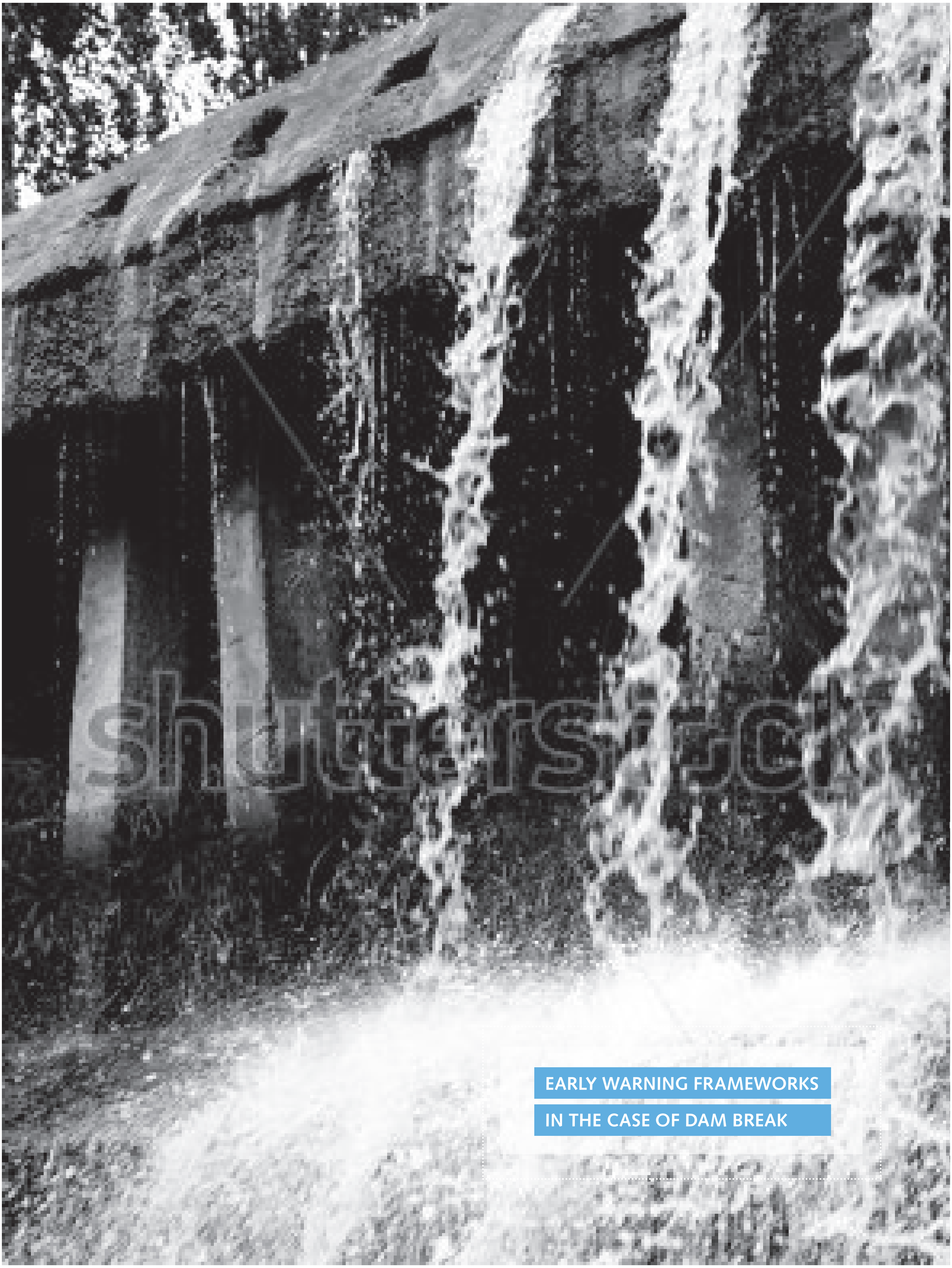
Other types of mass movements include debris flows and lahars. Lahars are particular events that are triggered when extreme rainfall takes place on the cone of active volcanoes or in case of eruptions. Debris flows can also take place when an eruption melts the snow cover of some volcanoes as in the case of the Nevado del Ruiz in Colombia in 1987. Such lahars find their ways into river channels and transport vast amounts of material to the flood plains, where it is deposited. Some countries with active volcanoes operate such early warning systems for lahars, but the survey did not find documentation on such systems in the internet.

Country	Characteristics			Criteria for levels	Source of information
	Number levels	Colours/ Terms	All clear of (y/n)	Comments on criteria employed	Website link
USA	3	Terms	n	Based on the likelihood of occurrence of a landslide due to extreme weather conditions or hydrological events	http://landslides.usgs.gov/advisories/
Hong Kong	1	Term	n	Based on the likelihood of a landslide due to heavy rain or in case a landslide has already occurred and is expected to continue in the next hours or days.	http://www.hko.gov.hk/wservice/tsheet/tsflwarn.htm
Japan	1	Term	n	Issued when there is an extremely high risk of landslides due to heavy rains in the next hours.	http://www.bousai.go.jp/kyoryoku/soukikeikai.pdf

Table 14: Warning frameworks for landslides. Source: authors.

Country	Characteristics			Criteria for levels	Source of information
	Number levels	Colours/ Terms	All clear of (y/n)	Comments on criteria employed	Website link
USA	5	Colours/ Terms	n	Based on the likelihood of an avalanche (very unlikely, unlikely, probable, likely and certain). The individual levels also describe the potential size of the avalanche.	http://www.nwac.us/education/olddangerscale/
Canada	5	Colours/ Terms	n		http://en.wikipedia.org/wiki/Canadian_Avalanche_Association
New Zealand	4	Colours/ Terms			http://www.avalanche.net.nz/index_aa.asp#mc
Europe	5	Colours/ Terms	n		http://www.slf.ch/lawineninfo/zusatzinfos/lawinenskala-europa/index_EN

Table 15: Warning frameworks for avalanches. Source: authors.



EARLY WARNING FRAMEWORKS IN THE CASE OF DAM BREAK

Dam breaks may trigger debris flows and floods. Example 7 presents information on the Finnish early warning system in case of dam break in the Kyrkoesjaervi reservoir. In addition to Finland, Portugal also operates a similar system for dam break using a four-level colour framework.

Alarm level	Event/Measures to be implemented
Internal alarm	Event: Abnormal situation. Serious natural flood situation; Water level of the reservoir is approaching a critical level (HW); Significant change in dam structure, but no failure; Problem caused by internal erosion or seepage; Other external threat (bomb warning, vandalism etc.). Measures: • Improve monitoring and preparedness; • Evaluation of an alarm level; • Repairing of a defect or damage.
Alarm Level 1	Event: Emergency call concerning a dam accident or damage; Only one emergency call; Emergency call is not given by person in charge of maintenance or safety of the dam, or by official; Seriousness of an accident cannot be defined on the basis of the call; Dispatcher suspects the call to be a prank call; Dam or hydroelectric plant failure does not require warning of population or evacuation; Dam failure is in such a location that is does not cause any danger to downstream areas. Measures: • Checking the emergency call; • Evaluation of an alarm level; • Repairing any damage.

Alarm level	Event/Measures to be implemented	
Alarm Level 2	Event:	Failure caused by internal erosion or slope break which is difficult to control or repair;
		Other structural or operational failure of dam that may lead to serious consequences in the areas downstream of the dam;
		Other dam failure upstream of the reservoir.
	Measures:	
		• Emergency repair of failure;
		• Warning of population and instructions to prepare for evacuation;
		• Evacuation of one and two hour flood areas;
		• Isolating the danger area.
Alarm Level 3	Event:	Total dam failure (not possible to repair);
		Serious dam failure that will probably lead to total failure and catastrophic consequences to the downstream area of the dam.
	Measures:	
		• Fast warning and evacuation of population from danger area;
		• Isolation of danger area;
		• Emergency repair of failure.

Example 7: A Finnish alarm system for dam break.
Source: http://www.environment.fi/downloadasp?contentid=13531&lan=EN.

The West Finland Regional Environment Centre and the Power Company operate this system in cooperation with the Emergency Response Centre of Finland. The system is based on alarm levels.

EARLY WARNING FRAMEWORKS IN CASE OF FOREST FIRES

Forest fires are processes that reduce the extent of forest through the combustion process of fire itself. Forest fires take place in all regions of the world except for the polar ice caps and can be affected by wind patterns and other weather conditions. According to the Global Fire Monitoring Centre (Goldammer, 2010), the heat wave that impacted Western Russia in 2010 fuelled forest fires consuming between 300,000 and 400,000 hectares of forests. These forest fires not only provoked fatalities and losses in areas exposed, but also impacted Moscow through the smoke arising from such fires. In fact, the smoke even travelled to neighbouring countries such as Ukraine.

As it was stated earlier, the embryonic phase in the case of forest fires takes place when vegetation is drying out as a consequence of high temperatures, lack of rainfall and low humidity. The growth stage is represented when the weather conditions are right; the fire has just started and is beginning to spread. In the mature stage the fire is consuming vast amounts of forest and in the decaying stage the fire is being extinguished or the fire has consumed all the existing vegetation.

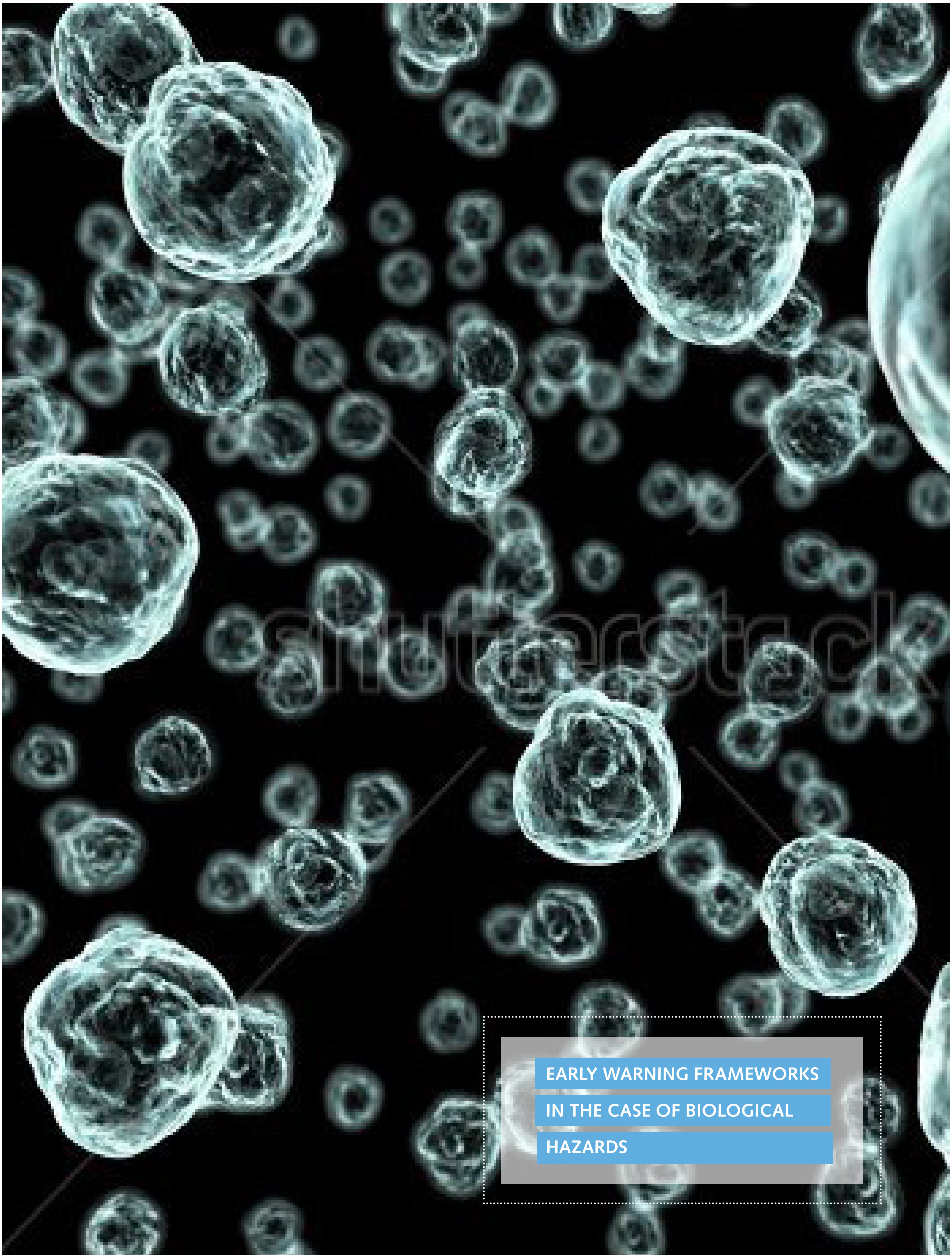
The results of this survey show that in most frameworks targeting forest fires are based on the magnitude or the severity of a potential fire. In 9 out of 17 frameworks, 5 levels are used. The lowest number of levels employed is 3 and the highest is 6 (Sweden and Australia). Basically all frameworks include both a term and a corresponding colour, with the exception of the ones for Germany and Malaysia, which are based only on terms. Table 16 presents data on these frameworks and Example 8 presents information on the framework employed in Portugal.

Class	Risk class
	Reduced
	Moderate
	Elevated
	Highly Elevated
	Maximum

Example 8: Fire risk index in Portugal. Source: http://www.meteo.pt/pt/ambiente/risco.incendio/.
The National Meteorological Institute of Portugal operates a Fire Risk Index based on five levels. This system was adopted from the Canadian Forest Service.

Country	Characteristics			Criteria for levels					Source of information
	Number levels	Colours/ Terms	All clear of (y/n)	Magnitude/ Severity	Likelihood of event	Based on thresholds	Time until arrival	Period of return	Website link
United States (US Forest Service)	5	Colours/ Terms		x	x				http://www.wfas.net/index.php/fire-danger-rating-fire-potential--danger-32/class-rating-fire-potential--danger-51?task=view
United States (NOAA)	3	Colours/ Terms	n		x				http://www.srh.noaa.gov/ridge2/fire/briefing.php
Canada	5	Colours/ Terms	n	x					http://cwfis.cfs.nrcan.gc.ca/en_CA/fwmaps/fdr
Cuba	5	Colours/ Terms	n	x					http://www.insmet.cu/asp/genesis.asp?TB0=PLANTILLAS&TB1=INCENDIO http://www.insmet.cu/asp/genesis.asp?TB0=PLANTILLAS&TB1=INCENDIO
Brazil	5	Colours/ Terms	n	x					http://www.cptec.inpe.br/products/queimadas/risco.html
Argentina	5	Colours/ Terms	n	x					http://www.smn.gov.ar/?mod=dpd&id=4
Sweden	6	Colours/ Terms	n	x					http://www.raddningsverket.se/templates/SRV_Page____826.aspx
Finland	3	Colours/ Terms	n	Warnings issued in case of forest fire and grass fire					http://en.ilmatieteenlaitos.fi/warnings
Germany	5	Terms	n	x					http://www.dwd.de/bvbw/appmanager/bvbw/dwdwwwDesktop?_nfpb=true&_pageLabel=dwdwww_result_page&gsbSearchDocId=752118
Poland	4	Colours	n	x					http://bazapozarow.ibles.pl/zagrozenie/
Italy	3	Colours/ Terms	n	x					http://www.protezionecivile.gov.it/resources/cms/images/Immagine_d0.JPG
Europe – Joint Research Centre	5	Colours/ Terms	n	x					http://effis.jrc.ec.europa.eu/
Korea	3	Colours/ Terms	n	x					http://www.fire.uni-freiburg.de/fwf/korea_fwf.htm
Malaysia	4	Terms	n	x					http://www.met.gov.my/index.php?option=com_content&task=view&id=4749&Itemid=1157
Australia	6	Colours/ Terms	n	x					http://www.bom.gov.au/catalogue/warnings/WarningsInformation_FW.shtml
New Zealand	5	Colours/ Terms	n	x					http://nrfa.fire.org.nz/fire_weather/weather/20070611/HTML/FireDanger.asp

Table 16: Alert frameworks for forest fires. Source: authors.



EARLY WARNING FRAMEWORKS IN THE CASE OF BIOLOGICAL HAZARDS

This section deals with hazards of biological nature including influenza and locust swarms.

Influenza

Taking into consideration recent episodes of influenza viruses, several national agencies and regional and international organizations have established alert systems for such biological hazards. In Ireland, the "Sentinel Surveillance Programme", a collaboration among the National Virus Reference Laboratory at the University College Dublin, the Health Protection Surveillance Centre (HPSC) and the Irish College of General Practitioners (ICGP), has led to the design of a four-level alert framework.

The four alert levels can be found at http://www.hpsc.ie/hpsc/A-Z/Respiratory/Influenza/PandemicInfluenza/Guidance/PandemicInfluenzaPreparednessforIreland/File,3254,en.pdf.

Alert Level 1: Cases only outside Ireland (countries which have extensive trade links with Ireland, countries which are frequently visited by Irish citizens or countries whose citizens travel extensively to Ireland).

Alert Level 2: New virus isolated in Ireland.

Alert Level 3: Outbreaks in Ireland.

Alert Level 4: Widespread activity in Ireland.

The European Centre for Disease Prevention and Control has also designed a four-level framework to operate in the context of European Union (EU) Member States (http://www.dohc.ie/publications/pdf/nationalfluplan.pdf?direct=1).

Level 1: Applies when there are no confirmed human cases infected with the pandemic virus in any EU Member State.

Level 2: Applies when there is one or more confirmed human case in any EU Member State.

Level 4: Applies when there is a confirmed outbreak in any EU Member State.

Level 4: Applies when there is widespread transmission in the EU.

At the global level, the World Health Organization (WHO) has established a global warning system based on six phases. As an international organization, WHO has been able to secure the support of national governments through parliamentary endorsements, allowing WMO to issue warnings in the case of specific countries experiencing problems related to influenza and other pandemic diseases. In the case of influenza, such as the avian influenza H5N1, the definitions of the six phases are as follows (http://www.who.int/influenza/preparedness/pandemic/h5n1phase/en/index.html):

Phase 1: No viruses circulating among animals have been reported to cause infections in humans.

Phase 2: An animal influenza virus circulating among domesticated or wild animals is known to have caused infection in humans, and is therefore considered a potential pandemic threat.

Phase 3: An animal or human-animal influenza reassortant virus has caused sporadic cases or small clusters of disease in people, but has not resulted in human-to-human transmission sufficient to sustain community-level outbreaks. Limited human-to-human transmission may occur under some circumstances, for example, when there is close contact between an infected person and an unprotected caregiver. However, limited transmission under such restricted circumstances does not indicate that the virus has gained the level of transmissibility among humans necessary to cause a pandemic.

Phase 4: Characterized by verified human-to-human transmission of an animal or human-animal influenza reassortant virus able to cause "community-level outbreaks". The ability to cause sustained disease outbreaks in a community marks a significant upwards shift in the risk for a pandemic. Phase 4 indicates a significant increase in risk of a pandemic but does not necessarily mean that a pandemic is a foregone conclusion.

Phase 5: Is characterized by human-to-human spread of the virus into at least two countries in one WHO region. While most countries will not be affected at this stage, the declaration of Phase 5 is a strong signal that a pandemic is imminent and that the time to finalize the organization, communication, and implementation of the planned mitigation measures is short.

Phase 6: The pandemic phase, as it is characterized by community level outbreaks in at least one other country in a different WHO region in addition to the criteria defined in Phase 5. Designation of this phase will indicate that a global pandemic is under way.

As can be seen, in these alert systems the levels are based on a threshold which may have been reached as opposed to the case when conditions for potential events or outbreaks may be possible. In this case, the embryonic phase would take place during phase 2 and phase 3; while the growth stage would take place in phase 4 and the mature stage would take place in phases 5 and 6.

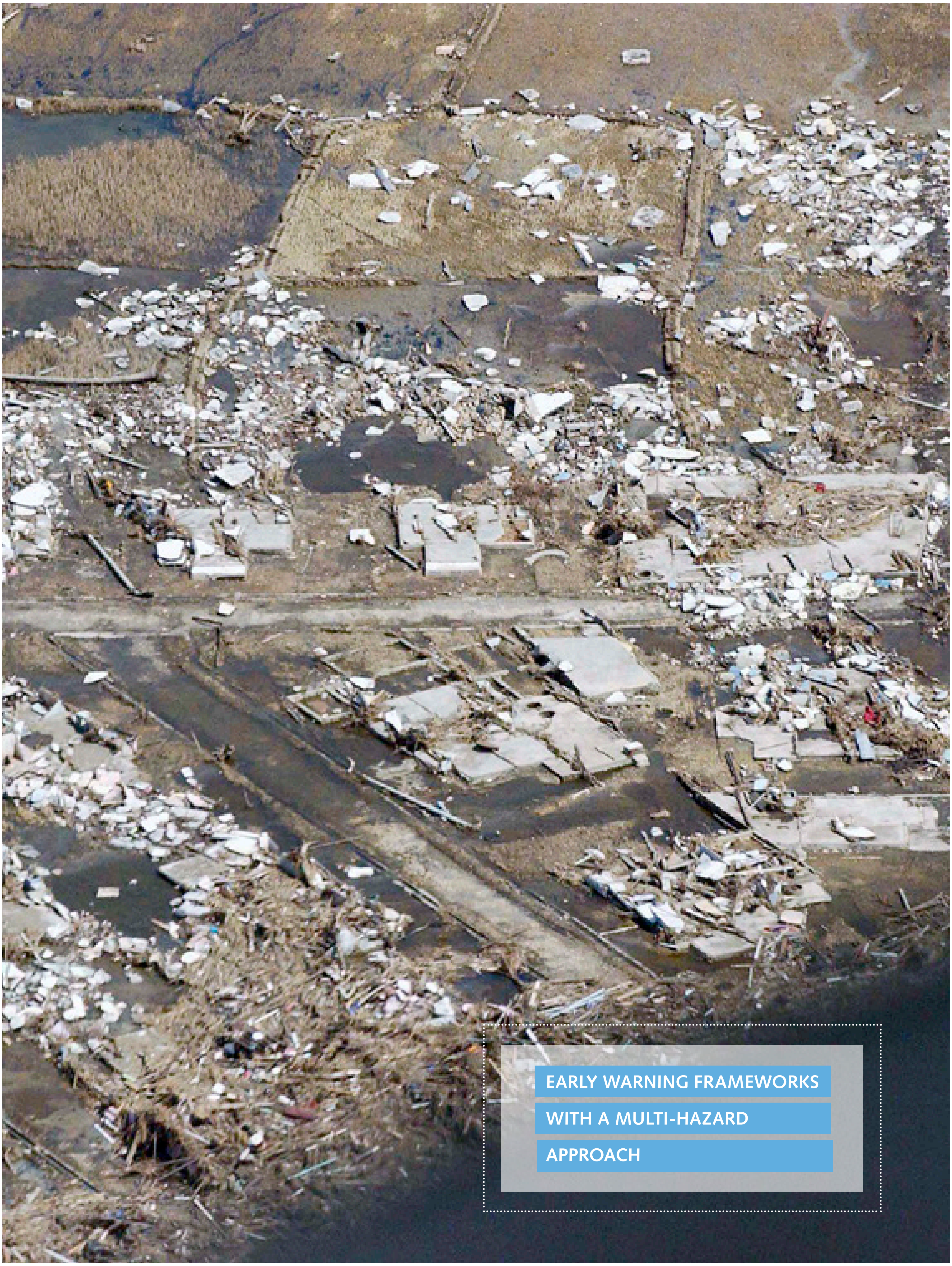
Locust swarms

FAO maintains an early warning system targeting locust swarms focusing on North East Africa. The four-level framework is presented in Example 9.

Alarm level	Measures to be implemented
Calm	Maintain regular surveys and monitoring; no threat to crops.
Caution	Increased vigilance is required, control operations may be needed; potential threat to crops.
Threat	Survey and control operations must be undertaken; threat to crops.
Danger	Intensive survey and control operations must be undertaken; significant threat to crops.

Example 9: FAO system for locust swarms. Source: http://www.fao.org/ag/locusts/en/info/info/index.html.

FAO has implemented this early warning system for locust swarms targeting North-East Africa. It is structured in four levels and indicates the actions that have to be executed at each level.



EARLY WARNING FRAMEWORKS WITH A MULTI-HAZARD APPROACH

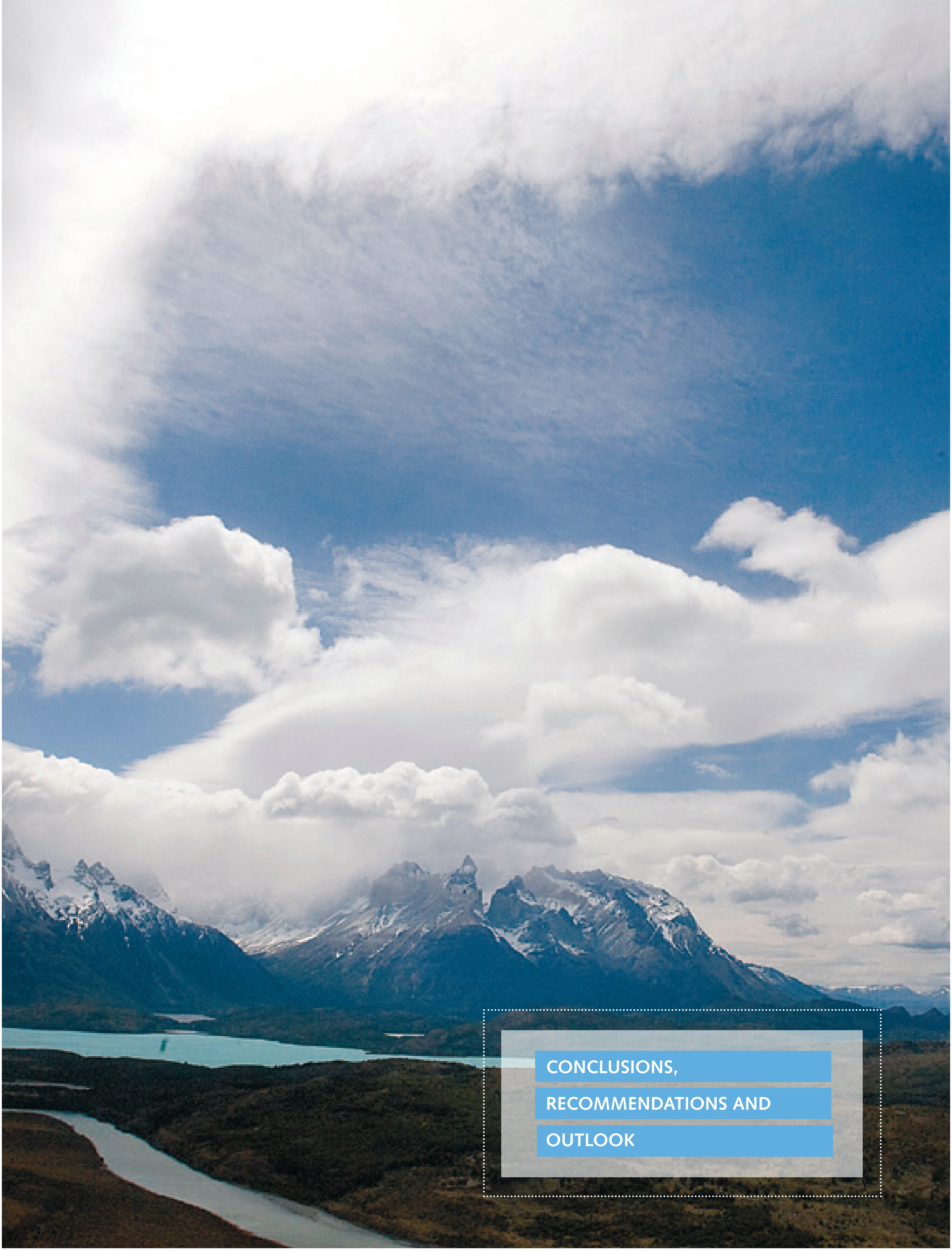
This section deals with those systems which have been set up mostly by civil protection or emergency response agencies and which are used to target multiple hazards. Table 17 presents a summary of early warning frameworks for eight countries which target a variety of natural hazards. Colour frameworks are used in the case of Latin America, and in several cases, levels are related to the interval of time for impact or on what actions need to be taken. In most cases, red alert implies that an event has already manifested itself, provoking impacts and losses. Unlike the European frameworks, Latin American frameworks do not impose a limitation on the number of red alerts that should be issued on a yearly basis.

Another type of multi-hazard warning system makes use of high-volume sirens. In the case of European countries, siren signals are implemented in order to make the population aware of actions they need to take in relation to a potentially catastrophic event.

In many countries, visual signs such as those in many roads are also used to make the population aware of potential events which may take place in selected places. Such visual signs include the possibility of slippery conditions, landslides, rock slides or avalanches in roads, etc. These would constitute one-level frameworks indicating the likelihood of the events they depict.

Country	**Agency**	**Characteristics**			**Criteria for levels**			**Source of information**
		Number levels	**Colours/ Terms**	**All clear of (y/n)**	**Magnitude/ Severity**	**Time until arrival**	**Based on thresholds**	**Website link**
Peru	INDECI	3	Colours	n		x		http://sinpad.indeci.gob.pe/UploadPortalSINPAD/Funcionamiento%20COEN1.jpg
El Salvador	Civil Protection	4	Colours	n		x		http://issuu.com/moralesvalen/docs/ley_edicion_2011_ok?mode=window&backgroundColour=%23222222
Guatemala	CONRED	4	Colours	n		x		http://www.conred.gob.gt/documentos/boletines/boletines_institucionales/Bolet%C3%ADn%20Institucional%20SE-CONRED%20No%2039.pdf
Honduras	COPECO	3	Colours	n		x		http://copeco.gob.hn/n/node/706
Sweden	Civil Protection	4	Signals	y	Levels indicate what type of action the population must carry out if a signal is issued			http://ec.europa.eu/echo/civil_protection/civil/act_prog_rep/public_warning_2.pdf
Denmark	DEMA	2	Siren Signal	y				http://brs.dk/eng/aboutus/Documents/Sounding%20of%20sirens.pdf
Austria	BWZ	3	Siren Signal	y				https://www.help.gv.at/Portal.Node/hlpd/public/content/295/Seite.2950031.html
China	Government Agency	4	Classes	n	x			http://www.gov.cn/english/2006-01/08/content_151081.htm

Table 17: Multi-hazard alert frameworks. Source: authors.



CONCLUSIONS, RECOMMENDATIONS AND OUTLOOK

As can be seen from this review of frameworks for individual hazards, warning or alert frameworks have been designed all over the world for a variety of geological and hydrometeorological hazards; for forest fires and dam failure; for influenza and other pandemics; as well as insect swarms such as locust. The main conclusions that can be gathered from this review include:

- Institutions in different countries and in different regions of the world use different criteria to design warning or alert levels for specific hazards;
- Different agencies use different criteria to select the number of levels to be used;
- In the case of specific countries, different agencies have established frameworks to target different types of hazards;
- The number of levels employed in these frameworks varies from one to seven levels. Nevertheless, as summarized in Table 18, the majority of frameworks employ three, four or five levels. Eight of the thirteen frameworks in Table 18 have been designed using four levels;
- Different systems use different labels to depict levels including: colours; numbers; terms like advisory, watch, warning, alert, alarm, emergency and danger; phases; stages; flags, signals; and specific labels such as low, moderate, high and unprecedented. In some cases, there are combinations of these terms and colours. In addition, in a single framework one may find different levels labelled using either alert or warning. In some cases these terms are combined with colour schemes;
- While some agencies may have established frameworks on the basis of colours, there are differences in the meaning of the colours and in some cases different colours are used to represent similar levels. For example, some systems make use of the colour green to represent the lowest level, while in other systems blue is used;
- In several countries efforts have led to the establishment of a single framework targeting a variety of hazards simultaneously. This seems to be the case where civil protection or civil defence agencies establish the levels or where one single agency deals with a variety of hazards;
- In the surveyed frameworks, the following criteria have been used to differentiate levels:

» Potential severity or magnitude of the event;

» Interval of time for the event to manifest itself in a particular geographic region;

» Likelihood of an event;

» A benchmark being reached or surpassed;

» The period of return or a statistical approach (Europe, avoiding the use of red level too frequently);

» In some cases the frameworks include an "all clear" level.

The adoption of the use of three or more levels instead of one or two is because in some cases either there is ample time between the growth and the mature stages, or the framework is targeting thresholds which can increase with time and it is important to use more than one or two levels. However, in very sudden events such as earthquakes, a single level is used to warn the population. Tsunamis, on the other hand, being triggered by earthquakes, may hit a coastal population within some minutes from the time of the earthquake or up to more than 20 hours later (as was the case in 1960, when an earthquake off the Chilean coast hit Hawaii 14 hours later and the coasts of Japan 22 hours later). To this end, in several countries an alert framework has been established based on the magnitude and depth of an earthquake and the subsequent confirmation of the alert. Its cancellation is decided based on data gathered from deep-sea buoys or tide gauges.

Hazard	Variation in number of levels	Most frequent number of levels	Most frequent type of labels	Criteria most often used to designate levels
General weather	1 to 5 levels	4	Colours/Terms	Potential severity of event
Tropical cyclones	2 to 6 levels	4	Colours/Terms	Interval of time remaining for arrival of event
Floods	1 to 5 levels	3 and 4	Colours/Terms	Potential severity of event
Drought	3 to 7 levels	4	Colours/Terms	Interval of time remaining for arrival of event
Heat waves	1 to 5 levels	3	Terms	Threshold reached
Storm surges	1 to 4 levels	1 and 3	Terms	Potential severity of event
Volcanic activity	3 to 6 levels	4	Colours and numeric levels	Interval of time remaining for arrival of event; likelihood, thresholds and magnitude or severity
Earthquake	3 levels	3	Terms	Interval of time remaining for arrival of event
Tsunami	1 to 4 levels	3 and 4 (including "all clear")	Terms	Mixed criteria for warning
Landslide	1 to 3 levels	1	Terms	Likelihood of event, but only regional average
Avalanches	4 to 5 levels	5	Colours/Terms	Likelihood of size or type of event, again only regional average
Forest fires	3 to 6 levels	5	Colours/Terms	Magnitude / severity
Influenza	4 to 6 levels	4	Colours/Terms/ Phases	Based on benchmarks being reached or surpassed
Multi-hazard	2 to 4 levels	4	Colours	Potential severity of event

Table 18: Summary of frameworks. Source. authors.

A look at this table allows one to identify the following issues:

- Frameworks span from one to seven levels. The majority of frameworks seem to make use of four levels, but it is also common to find frameworks making use of three or five levels.
- Criteria employed to define levels depend on the type of hazard. In the case of general weather, floods, storm surges and forest fires, the main criteria employed to characterize different levels is the potential severity or magnitude of the event. However, in the case of tropical cyclones, droughts, volcanic activity and earthquakes, the levels are defined more on the basis of the interval of time before an event will impact a community or a geographic area. And of course, in the case of influenza and heat waves, levels are defined according to thresholds which may be or have been reached.
- In some cases frameworks make use of terms, colours or numeric scales only, while in other cases these may appear in combination.

An initial recommendation stemming from this review is made to national civil protection agencies, emergency commissions or committees, or disaster preparedness organizations to host national workshops with the goal of harmonizing existing frameworks to the highest extent possible; recognizing that some hazards may require only a few levels while others may need more. Along the same lines, a parallel recommendation is made to ISDR to promote such efforts to harmonize frameworks at the international level.

An additional recommendation stemming from this comparative review is that subsequent research should be carried out to determine how people at risk view the frameworks being employed. In particular, to determine how the number of levels assist people in both believing the warning, personalizing it and taking action to minimize losses for each type of hazard. A similar recommendation is made in context of the use of terms, colours, phases or numeric levels. Furthermore, it is important to assess the advantages of using warnings to indicate the likelihood, severity or time to impact related to a potential event versus alerts indicating that thresholds have been reached or surpassed. These three recommendations are essential when considering the notions of multi-hazard and global early warning systems.

As can be seen, there is the need for a multidisciplinary approach to improve such frameworks. From this review it is clear that these frameworks have been developed mostly from a hazard perspective without paying close attention to social perceptions, behaviours, norms, etc. In the future it is important to address these social issues as a way to make early warning systems more effective, efficient and legitimate.

The "all clear" level is not included in many frameworks. However, in the case of tsunami there is a strong need to include it, based on the fact that tsunamis appear in sets of waves and it is up to authorities and operators of the tsunami early warning systems to determine when the danger is over and it is safe to return to coastal areas. Therefore, this review recommends that all early warning systems incorporate an "all clear" level in their frameworks.

In addition, it is important to look at the governance aspects concerning early warning systems. Topics requiring additional research include:

- Which agency has the mandate or authority to issue such warnings?
- Liabilities that stem from the declaration of such warning or alert stages.
- The level of integration of the different components of the early warning systems.

One key issue to address is related to the mandates or responsibilities regarding the issuing of early warnings. The Convenors of the International Expert Group on Early Warning of the Secretariat of IDNDR stated already in 1997 that national governments should exercise the sovereign responsibility to prepare and issue warnings within their territory in a timely and effective manner, and to ensure that such warnings should reach vulnerable populations. Within the Principles for the Application of Early Warning at the National and Local Levels elaborated by these Conveners, item 2 states:

"Within each country, the sole responsibility for the issuance of early warnings for natural disasters should rest with an agency, or agencies, designated by the Government."

An example regarding the recognition of such responsibilities concerning the issuing of warnings by national governments can be seen in the context of the Indian Ocean Tsunami Early Warning System. During the International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean conducted in the UNESCO Headquarters, France, 3–8 March 2005, representatives of governments from countries within the Indian Ocean agreed that Member States should have the responsibility to have control over the issuance of warnings within their respective territories (UNESCO-IOC, 2005). WMO also recognizes that the issuing of warnings is a national responsibility (Golnaraghi, 2011).

Another issue to consider relates to individual responsibilities or civil liberties once a certain level of warning is issued. For example:

- Whether warnings or alerts imply a mandatory evacuation to a safe area versus the choice to evacuate or not;
- Whether warnings or alerts targeting certain geographical areas should be considered as mandatory regulations to stay outside the perimeter of those areas or not, thereby restricting geographical movements in those areas.

A more critical issue is related to the liabilities that a government may incur when it issues warnings or alerts of different levels, although the predicted events manifest themselves they are not as predictable in terms of severity, time, arrival or likelihood.

Other aspects that need to be incorporated into a more comprehensive early warning review include those related to governance which may address the possible synergies among early warning systems that are operated by national agencies within one country. This can include meteorological departments that target hurricanes and tropical storms or cyclones and community-based early warning systems implemented in small basins targeting floods or in very specific mountainous regions targeting landslides.

From the point of view of multi-hazard warnings, this comparative review indicates that in some countries efforts have been conducted to standardize frameworks targeting several hazards into a single one. For example, within Europe, Meteoalarm has been able to standardize warning levels for a variety of hazards into a single framework. However, at the more global level such an approach may be more challenging given the differences that exist from country to country and from continent to continent. A case in point is the issuing of colours to represent certain stages. As it was shown in this review some frameworks use green as the lowest level while in other frameworks blue may be used as the lowest level. While a consensus may be reached concerning which colour to be used at the lowest level, a greater challenge will be faced when trying to unify frameworks that make use of terms when others make use of colours; as well, some frameworks are based on criteria such as severity, while others are based on expected interval of time to impact or on benchmarks.

While these issues will need to be resolved if efforts persist along the lines of a global system, international organizations operating at the global level may wish to facilitate efforts to harmonize frameworks by type of hazard. Such a harmonization of efforts would be a useful step as a way to promote synergies among early warning systems operating at a national level and would contribute to minimizing the loss of life and other types of losses that can be avoided through an efficient early warning system. However, as Chang (2010) points out, a multi-hazard approach has to confront institutional and organizational challenges.

This comparative review of early warning systems highlighting their hierarchical frameworks related to warnings or alerts has yielded very interesting findings in terms of features that are common to many of these systems, as well as the contrasting features among them. As such, this review complements the Global Survey of Early Warning Systems that was published by ISDR in 2006. In addition, this review provides information that is necessary to address two of the recommendations made by ISDR in 2006:

- Develop a globally comprehensive early warning system, rooted in existing early warning systems and capacities; and
- Develop the institutional foundations for a global early warning system.

This publication has provided information on one of the topics that has to be approached if such a globally comprehensive early warning system is to be implemented, particularly if it is to be rooted in existing early warning systems. It has advanced the notion that it is important to review the aspect of levels; and that at this time, there is no consensus on the number of levels to be used when targeting different hazards, nor a consensus on the criteria to be employed. However, while there have been considerable advancements such as Meteoalarm in Europe and the case of forest fires (Europe, North America, Australia), at the global level there will likely be challenges that need to be addressed.

This document's effort at systematization has also provided insights into other issues that need to be addressed in the context of warnings or alerts, namely the need to conduct research to identify which is the best combination of number of levels, the criteria on which to define those levels and the labels to be used to characterize the different levels (colours, terms, numeric scales, etc.) so that those at risk, whether individuals or institutions, react in a timely fashion and implement whatever measures are necessary to minimize losses before the event manifests itself.

For example, it is essential for designers of early warning systems to tailor the warning or alert messages in a language and format that allows those at risk to understand not only the nature of the potential event that is being forecasted, but also its potential impacts so that they may perceive such impacts appropriately and react properly.

More and more, early warning systems are being evaluated not only on the basis of the warnings that such systems issue, but in terms of the reduction of fatalities and losses that such systems provide. And while it is extremely difficult to assess how many lives an early warning system has saved, such as the one that is operated in Japan in the case of earthquakes and tsunamis, it is important to recognize that such early warning systems are indeed contributing to reducing the number of fatalities, as ISDR and other organizations have reported.

In conclusion, it is important to take note of the lessons learned from the outcomes of the survey regarding the need to become aware of the elements that have to be taken into consideration when designing, implementing and operating early warning systems. Such lessons, as well as those that emerge from emergency response efforts and those related to risk management, are essential in the road to sustainable development and human security.