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Global early warning systems for natural hazards: systematic and people-centred

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To be effective, early warning systems for natural hazards need to have not only a sound scientific and technical basis, but also a strong focus on the people exposed to risk, and with a systems approach that incorporates all of the relevant factors in that risk, whether arising from the natural hazards or social vulnerabilities, and from short-term or long-term processes. Disasters are increasing in number and severity and international institutional frameworks to reduce disasters are being strengthened under United Nations oversight. Since the Indian Ocean tsunami of 26 December 2004, there has been a surge of interest in developing early warning systems to cater to the needs of all countries and all hazards.

Keywords: early warning; natural hazards; disasters; vulnerability; warning systems; disaster reduction

1. Disasters and disaster trends

A disaster, precipitated by a natural hazard, can be defined as 'a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources' (ISDR 2004). A disaster thus arises from the combination of the hazard event or episode, the conditions of vulnerability to that hazard and the insufficiency of capacity or measures to cope with the hazard. From this perspective, the term 'natural disaster' is an oxymoron, as the vulnerability and coping factors in the equation are within human control to some degree and therefore are not 'natural'. Furthermore, the term implies a powerlessness that is inconsistent with human capacities to understand and reduce disasters.

The statistics of recorded disaster data (CRED 2005; IFRC 2005; ISDR 2005*a*) show that over the last decade (1995–2004) nearly 6000 disasters were recorded, accounting for about 900 000 dead, US$ 738 billion material losses and 2500 million people affected. Disasters have mostly hydro-meteorological origins, from extremes of wind, rainfall and temperature, but earthquakes figure high in the death rates, owing mostly to inadequate building design. Disasters disproportionately affect poor people and poor countries and are increasingly recognized as a major handicap to the development of many countries.

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Figure 1 shows the rising trend in the number of people affected by disasters over the last 35 years. Disaster impacts are generally increasing as a result of the combination of increasing populations, greater concentrations of people and assets in vulnerable areas, greater use of insurance and the modification and degradation of natural environments, such as floodplain settlement, coastal exploitation, wetland destruction, river channelling, deforestation, soil erosion and fertility decline. Vulnerability to hazards is exacerbated by poverty, disease, conflict and population displacement.

The estimation of long-term trends in disasters depends somewhat on the period used and the dataset. Comparing the most recent decade 1995–2004 with the previous decade 1985–1994, the CRED data shows the number of people affected increased 1.5 times, economic damage increased 1.8 times and total deaths increased 2.0 times. The latter figure is heavily affected by the 26 December 2004 tsunami tragedy. Prior to that date, the trend in death rates since the 1950s was downward, as a result of improving early warning systems, better preparedness and response, including systematic food aid systems. Together these now avoid the massive famines and flood losses that earlier prevailed.

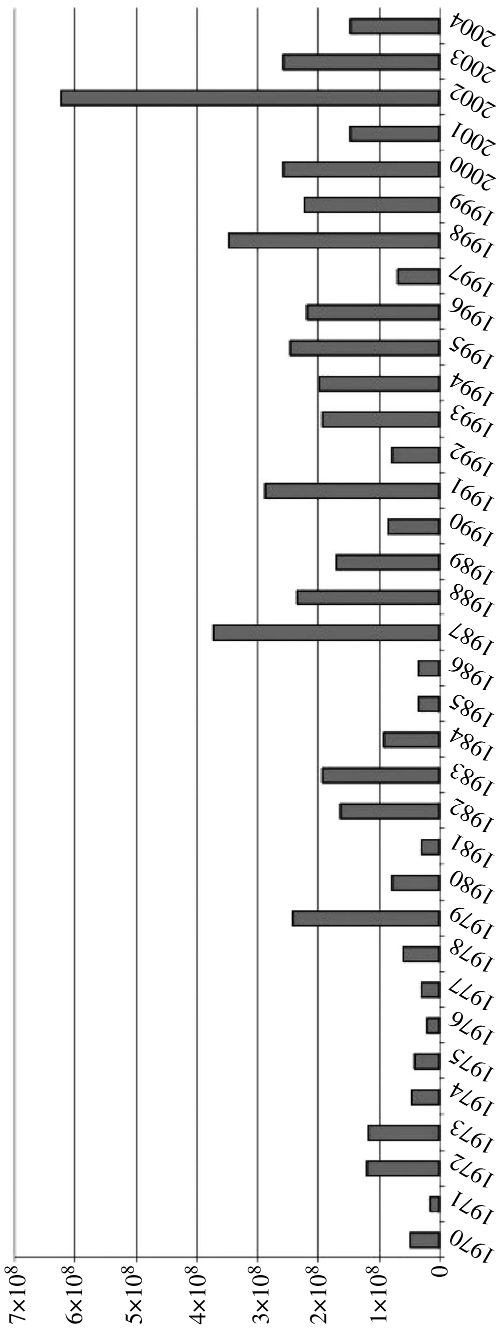
2. Early warning systems and their elements

The expression 'early warning' is used in many fields 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.

In the present setting we are concerned with geophysical hazards—storms, floods, droughts, landslides, volcanic eruptions, tsunamis, etc—and related hazards that have a geophysical component, such as wild-land fire, locust plagues and famines. In the current UN-ISDR terminology, early warning is defined as 'the provision of timely and effective information, through identified institutions, that allows individuals exposed to a hazard to take action to avoid or reduce their risk and prepare for effective response' (ISDR 2004).

The concerns of early warning researchers and practitioners therefore span the natural and social sciences and theoretical and practical matters (Zschau & Küppers 2002; EWC II 2004). To be effective and complete, an early warning system needs to comprise four interacting elements (ISDR-PPEW 2005*a*), as shown in figure 2, namely: (i) risk knowledge, (ii) monitoring and warning service, (iii) dissemination and communication and (iv) response capability. While this set of four elements appears to have a logical sequence, in fact each element has direct two-way linkages and interactions with each of the other elements.

The second element, the monitoring and warning service, is the most well-recognized part of the early warning system, but experience has shown that technically high-quality predictions by themselves are insufficient to achieve the desired reduction in losses and impacts. The human factor in early warning systems is very significant (Twigg 2002). Failures in early warning systems typically occur in the communication and preparedness elements. This was true of Hurricane Katrina which affected New Orleans in late August 2005, though in this case there was the additional failure in respect to risk knowledge, namely



source: 'EM-DAT: The OFDA/CRED international disaster database / International Strategy for Disaster Reduction (UN-ISDR)'

Figure 1. Number of people affected by natural disasters, 1970–2004.

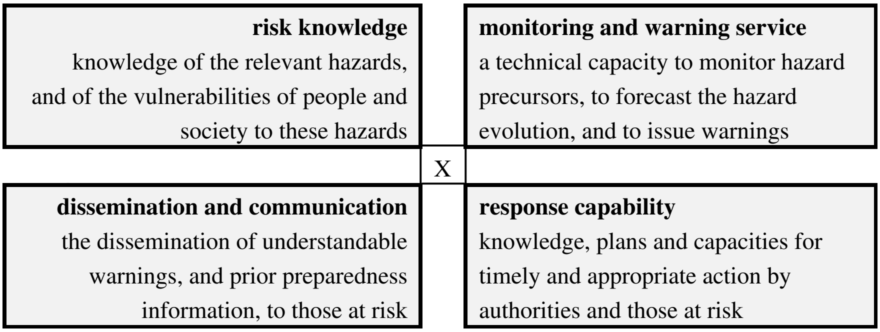


Figure 2. The four elements of systematic people-centred early warning systems.

a lack of full public and political appreciation of the core vulnerability of the inadequate levees and the consequences of their structural failure or overtopping by storm surges. In the case of the December 2004 Indian Ocean tsunami, there were major failures in all four elements.

It should be noted that in order to sustain the four elements over the long run, it is necessary to have strong political commitment and durable institutional capacities, which in turn depend on public awareness and an appreciation of the benefits of effective warning systems. Public awareness and support is often high immediately after a major disaster event—such moments can be capitalized on to strengthen and secure the sustainability of early warning systems.

3. A broader view of natural risk

If disasters arise from the concatenation of multiple factors, natural and social, then in principle at least, an early warning system should address all of the factors relevant to the particular risk. From this perspective it is desirable to monitor and provide early warning and foresight not only on the short-term precipitating hazards and geophysical conditions but also on the relevant longer-term factors such as declining environmental state, risk-raising development practices and projects, risk-altering policy changes, the status of social communications and capacities, trends in food markets, settlement trends and migration, conflict and health status. This involves a wide range of time frames, as illustrated in table 1, and diverse methodologies for monitoring and forecasting.

Extending this line of thinking, one can argue that the citizen and the public risk manager is not so concerned with the specifics of particular hazards, but rather the package of risks faced and how to mitigate and prepare for them. This implies that an approach that addresses all relevant hazards in an integrated fashion, and not as separate unconnected systems, is more appropriate to the management of natural risks. Such a ‘multi-hazard’ or ‘all-hazard’ approach should provide synergies and cost-efficiencies, e.g. in data gathering and processing and in public preparedness efforts, and should assist in sustaining warning capabilities for the more infrequent hazards, such as tsunamis.

It is important, however, not to gloss over the very specific characteristics of the different hazards. For example, tsunamis and storm surges both cause coastal inundation but the detection and monitoring methods, lead-time, duration of the

Table 1. Illustration of factors of relevance to early warning systems and their time frames in seconds (S), minutes (M), days (D), weeks (W), months (M), years (Y) and decades (D).

factor	time frame						
	S	M	D	W	M	Y	D
seismicity, tsunami	X	X	X				
weather, oceans, floods		X	X	X	X		
soils, reservoirs, snow pack, El Niño				X	X	X	
people exposed, conflict, migration			X	X	X	X	
crop production, prices, reserves, food aid				X	X	X	
environmental management and state					X	X	X
industry, urban, infrastructure design					X	X	X
land use planning, climate change						X	X

hazard and response actions are very different. A multi-hazard approach should not be allowed to force generalities or centralized control upon warning systems, but must be tailored to the needs of each hazard and built upon the specific technical capabilities required and the available institutional capacities. The need is for a coordinated 'system of systems'. Much remains to be elaborated in the practical implementation of these ideas.

4. The linear paradigm of model-based early warning systems

The most common current view of early warning systems comprises a 'warning chain', a linear set of connections from observations through warning generation and transmittal to users. In the meteorological community the term 'end-to-end' warning system is often used. The end-to-end concept aims to make forecasts and warnings more relevant and useable to end-users, and has evolved partly in response to the commercialization imperative in many national meteorological services, as well as through efforts to make better practical use of the probabilistic and weakly predictive seasonal forecasts of the El Niño phenomenon. It emphasizes the necessity to have all the links in the early warning chain in place and systematically connected.

At the heart of all early warning systems is some sort of model that describes the relevant features of the hazard phenomenon and its impacts, particularly their time evolution. The model provides the means to make projections of what might happen in the future—and therefore what actions might be desirable in response. Models may be as elaborate as the physics-based global numerical weather prediction models, or as straightforward as 'common knowledge' mental models (e.g. that the noisy approaching tsunami wave will arrive in a few minutes). They may be slowly evolving, as in a drought model where the loss of soil moisture may occur over months, or very rapid, such as in an earthquake where the differential speed of electromagnetic signals relative to seismic waves can be used to automatically shut down a distant sensitive system a few seconds before damaging stresses occur.

Models also underlie the other parts of the warning system, such as the likely impacts of a hazard, the way warnings are communicated and acted on, and the dynamics of evacuation processes, but these vulnerability and response process models are generally much less developed than the geophysical process models.

All models are driven by a specification of an initial state, which must be obtained by observations (or from the output of an upstream observation-driven model). Observation systems can be expensive to install and operate and are often rather inadequate, especially in poorer countries. The initial state is, therefore, always imperfectly known, owing to imperfect spatial representation, instrument error and absence of data on some relevant factors. These uncertainties of the initial state propagate through the models, and together with errors in the model physics and representations thereof and random noise factors, result in uncertainty in the model estimates of future conditions. Warnings are, therefore, inherently probabilistic, even if based on sound physics and presented in a categorical format. Of note are forecasts of seasonal climate anomalies, which are strongly affected by system noise and uncertainty, and can only be represented in probability terms, and where it must be left to the end-user to judge the possible impact consequences of the projected possible climate outcomes.

A very different example to illustrate these issues is that of tsunami early warning systems, as shown in table 2. Currently, tsunami warnings mostly are based on simple statistical relationships with precursor seismic observations, but these latter observations do not allow accurate prediction of the oceanic response, and so the false warning rates are high and the probability characteristics are poorly known. Usually, the warnings are provided only in categorical forms that usually require immediate response action. However, developments in ocean observation systems and in ocean wave propagation and coastal inundation models are in place to improve this situation in the near future (Titov *et al.* 2005).

5. Shortcomings of the linear paradigm

Scientists and technologists are typically the core stakeholders in early warning systems, as they are the custodians of the geophysical and technical knowledge base upon which the warning system relies, and they are generally very motivated to use that knowledge for the good of society. As a result, early warning systems tend to be largely conceived as hazard-focused, linear, top-down, expert driven systems, with little or no engagement of end-users or their representatives. It can be noted, however, that people generally are not interested in early warning systems until some personally threatening event arises, and so most of the time are happy to leave the matter to the experts.

While the prevailing end-to-end linear paradigm is an advance on previous techno-centric concepts it nevertheless retains a number of shortcomings, as follows:

(i) the focus still tends to remain on the hazard, with less emphasis on the vulnerabilities, risks and response capacities,
(ii) the different hazards are typically dealt with by separate independent technical institutions, with few synergies or mutual benefits being sought,
(iii) the dominance of the expert can lead to difficulties in user appreciation of such things as the meaning of a warning, warning uncertainty, the nature of false alarms and the necessary responses to different types of warnings,
(iv) the role of research and knowledge from outside the core area of expertise is often not acknowledged,

Table 2. Example of linear model characteristics and constraints: tsunami early warning systems.

steps along the chain	main characteristic	factors involved	needs and challenges
assessment	baseline risks	time and space characteristics of tsunami-genic sources and vulnerabilities thereto	uncertainty and inadequate data, such as on submarine geology, coastal bathymetry and social vulnerability
monitoring	initial state	seismicity, sea level, visual observations	ocean observations needed; tsunameters expensive to establish and maintain
system model(s)	time-evolving	seismic or other forcing, ocean wave generation and propagation, bathymetry and coastal topography	wave propagation models for far-field events if ocean-state data are available; statistical models based on seismic data for near-field events
predictions	probabilistic	need time-space estimates of wave train structure, run-up, inland penetration, turbulence; intrinsic uncertainty and probabilistic nature of estimates	very rapid assimilation of data; high 'false' alarm rate for seismicity-based warnings; little time to review and revise warnings; experience limited by the infrequency of events
impact	complexity	human settlements have high spatial and behavioural complexity	inundation models require extensive data and evaluation; impacts depend on response
response	complexity	multiple warning channels; human behaviour depends on knowledge, belief, experience, preparedness, practice, emotion, etc	preparedness strategies; control of warning channels; discounting of low frequency risks; high cost of false alarms; need for very fast response

(v) there is little engagement or empowerment of those at risk in the design and operation of the warning system, and hence a tendency by users to lack any sense of ownership in the system and to mistrust the experts and authorities,

(vi) there are few systematic mechanisms to improve the system through the incorporation of the knowledge, experience and feedback from users and those at risk, and

(vii) weak public engagement and recognition tends to lead to weak political and budgetary support for the warning system.

The Hurricane Katrina disaster is a case in point where the meteorological warnings of wind speed, storm surge and rainfall were accurate and frequently communicated many hours in advance but the public and official engagement and responses to the warnings were inadequate. Similar experiences elsewhere have shown that to be effective, early warning systems must be both technically systematic and people-centred (EWC II 2004).

The ‘people-centred’ characteristic requires many systematic approaches and diverse activities spanning the four elements of early warning systems described above, such as: identifying target populations, especially the vulnerable and disadvantaged and interacting with them to determine needs and capacities; conducting town meetings and involving communities in exploring and mapping their risks and planning their responses; fostering the development by communities of monitoring and warning systems for local risks; generating public information tailored to target groups and making innovative use of the media and education systems; establishing people-focused benchmarks and performance standards for technical warning services; developing formal mechanisms for public representatives to monitor and oversee warning system design; using surveys to measure public awareness and satisfaction; creating monuments, publications, annual events and other anchors of public memory and learning; providing training on social factors for technical experts, authorities and communicators who operate the warning system; conducting research on factors that enhance or impede human understanding of and response to warnings; and providing exercises and simulations to enable people to experience and practice warning interpretation and responses.

It is important to recognize that these diverse activities cannot be undertaken or directed by any one organization, but require the coordinated participation of many different types of organizations, bound by a consensus of commitment to the ‘people-centred’ concept, and to the idea of an integrated system that is measured by its performance—namely protecting those at risk. National platforms for disaster reduction, stakeholder roundtables or inter-departmental committees should be empowered or established to organize the required coordination. The core technical agencies can play a key role by demanding the establishment of such mechanisms and supporting them with specialized technical information.

6. An integrated systems model for early warning systems

Early warning systems have evolved in line with the development and application of scientific knowledge. Four developmental stages can be distinguished:

(i) pre-science early warning systems. Warnings, if any, may be based on unrelated factors such as meteor occurrence, cloud shapes, plant flowering or fruiting performance, etc., but also may be based on indigenous observations of relevant factors such as the state of the oceans or visibility of the stars,

(ii) *ad hoc* science-based early warning systems. These are systems such as are often established on the initiative of scientists or community groups concerned with particular hazards, such as near-Earth space objects, a nearby volcano or a flood-prone river,

(iii) systematic end-to-end early warning systems. The best known and most developed are those of national meteorological services, for weather-related hazards. Typically these systems operate under a country-wide mandate and involve the organized, linear and largely uni-directional delivery by experts of warning products to users, and

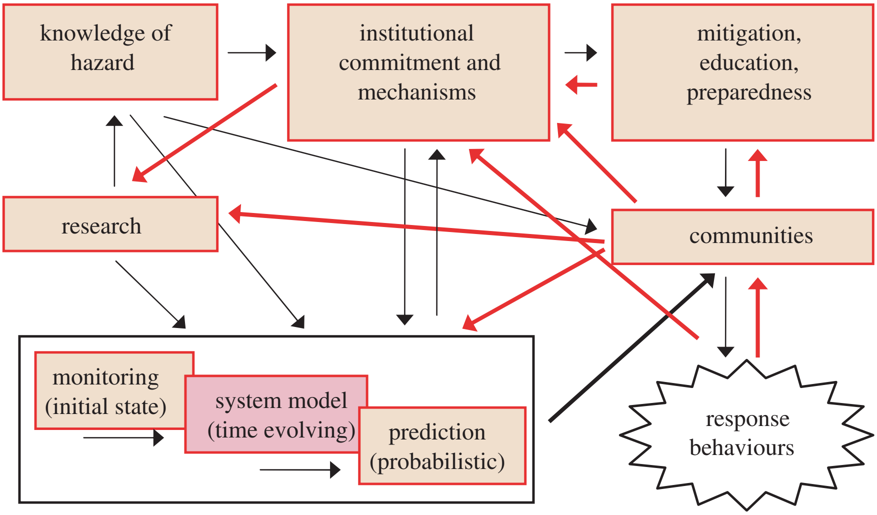


Figure 3. Integrated systems model of early warning system. Linear technical warning service in box at bottom. Feedback paths indicated in red.

(iv) integrated early warning systems. This concept, as proposed here and illustrated in figure 3, emphasizes the following characteristics: the linkages and interactions among all the elements necessary to effective early warning and response, the role of the human elements of the system and the management of risks rather than just warning of hazards.

The integrated model proposed in figure 3 includes the core warning system elements, but in addition contains two new key features. The first is the inclusion of actors that often are not recognized as part of the warning system, most notably the political-administrative supporting entities, the district and community actors and the research community. The second feature is the explicit inclusion of multiple linkages and feedback paths, particularly from affected populations through their organizations to the political and technical actors. The model could be elaborated further for the particular circumstances of countries, e.g. to better specify the district-level and community-level elements or the collaborative roles of different discipline-based technical institutions (e.g. such as seismological, oceanographic and meteorological organizations in a tsunami early warning system).

Figure 3 is largely conceived as a nationally based system, but it is worth noting that many warning systems depend on regional and international cooperation to secure the exchange of necessary data and warnings. This is not a simple matter to arrange, however, as sovereign states can view their data as having strategic or commercial value, and for these reasons can deny or limit its exchange. In the field of meteorology, many years of discussion under the auspices of the World Meteorological Organization (WMO), a specialized technical agency of the United Nations, have led to formal agreements on the types of data that are routinely exchanged (WMO 1995). Much remains to be done to achieve similar levels of agreement in other hazard fields, e.g. in respect to rainfall and river flow data required for flood warnings in shared river basins and seismic data for tsunami warnings.

Underlying the integrated model is the important foundational assumption that we are dealing with a *system*, defined here as a set of elements and associated linkages designed to achieve a particular result—namely the reduction of risk for target populations and assets through early warning. The system is judged on its effectiveness at delivering the desired result, and can only be effective if the elements and the linkages are well-understood, well-designed and well-operated.

7. Systems-oriented research needs for early warning

Early warning systems require a broad multidisciplinary knowledge base, building on the substantial existing discipline-based research in the geophysical, environmental and social science fields. There is a need for more systemic, cross-cutting and applied research, including on the following topics:

(i) development and use of geospatial data models, risk maps and scenarios,
(ii) cost-effective observations systems,
(iii) data generation and assimilation (e.g. bathymetry for tsunami models),
(iv) improvement of core prediction system models and prediction tools,
(v) warning decision system tools for disaster managers,
(vi) management under warning uncertainty,
(vii) evaluation and comparison of warning communication methods,
(viii) models of human response behaviour including evacuations,
(ix) visualization of impacts and response options for community preparedness,
(x) operationalization of the 'all-hazards' approach,
(xi) role of early warning as an adaptation to climate change,
(xii) warning system performance, indicators, benchmarks, and
(xiii) economic assessments of warning system effectiveness.

The last two topics are of critical importance. If an early warning system is to be justified on its benefits, we need to define and measure not only the benefits but also the contribution made by each part of the system. We must also develop a systems culture that sets and achieves well-defined performance objectives and standards for each system.

8. Recent moves to develop better early warning systems

The December 2004 tsunami shone an intense spotlight on questions of early warning systems and preparedness, leading most notably to the call by United Nations Secretary General Kofi Annan in January 2005 for a global warning system for all hazards with no country left out. This was to be followed later in the year by his request to the International Strategy for Disaster Reduction (ISDR) secretariat to coordinate a global survey of early warning systems, with a view to identifying gaps and opportunities, as a basis for developing such global capacities (UN 2005*a*).

Meanwhile, negotiations by states over 2004 culminated in a major international agreement on disaster risk reduction at the World Conference on Disaster Reduction in Kobe, Japan, 18–22 January 2005, namely the *Hyogo*

Framework for Action 2005–2015: building the resilience of nations and communities to disasters (UN 2005*b*). The topic of risk and early warning is one of its five priority areas for action. Leading UN agencies announced at the conference the launch of an International Early Warning Programme (IEWP), as a vehicle to stimulate and coordinate cooperative initiatives to advance early warning methodology and to build early warning capacities (ISDR-PPEW 2005*b*). Shortly afterwards, Germany offered to host a third International Conference on Early Warning (EWC III) under UN auspices (see www.ewc3.org).

Rapid progress has been made on developing a tsunami warning system for the Indian Ocean, with strong support by the countries affected and by the international donor community, including through a multi-partner, multi-donor US $11 million project coordinated by the ISDR secretariat (ISDR-PPEW 2005*c*). This project has underwritten the important work of UNESCO's Intergovernmental Oceanographic Commission (IOC—see http://ioc3.unesco.org/indotsunami/) to upgrade regional seismic and oceanic observation systems, to assess national technical needs and to establish intergovernmental coordination mechanisms. It has also supported WMO efforts toward upgrading meteorological telecommunications networks to handle high-speed tsunami information transfers, as well as projects by United Nations organizations and Asian regional disaster organizations to improve public awareness and disaster preparedness. The project seeks to link and integrate these various initiatives into a strategy to build long-term disaster risk reduction and risk management networks and policies. Separately, the IOC is building the necessary global institutional framework to support tsunami early warning systems in other at-risk regions such as the Mediterranean, Caribbean and Central America.

In early 2005, the British Government established a Natural Hazard Working Group under the guidance of the government chief scientist to advise on the mechanisms that could be established for the detection and early warning of global physical natural hazards, particularly those hazards that could have high global or regional impact, and including international mechanisms needed to enable the international science community to advise governments (UK-DTI 2005).

The Working Group recommended the establishment of an International Science Panel for Natural Hazard Assessment, within the UN disaster management framework, to enable the scientific community to provide authoritative information on potential natural hazards likely to have high global or regional impact, by addressing gaps in knowledge and advising on potential future threats and on how science and technology can be used to mitigate threats and reduce vulnerability. The Working Group also noted that the well-established WMO international system operated by national meteorological services for weather data gathering and warning provision provided a potential basis for strengthening other less-developed hazard warning systems.

The Working Group's recommendations subsequently were taken up in part by the 2005 meeting of the G8 ministers, who noted that 'early warning systems for global geophysical events should be based on high quality and appropriate scientific advice that can be translated into effective action by policy makers and those most at risk at a local level' (G8 2005). While not explicitly referring to the British proposal for a new panel, the G8 stated 'We will support closer co-ordination on natural hazard assessment to enable the scientific community to advise on potential natural hazards likely to have high global or regional impact … '. The ISDR secretariat is consulting with interested parties on options for following up on these ideas.

9. Institutional frameworks

The task of putting science to work in policy and practice can only be achieved through sound institutional mechanisms—at national, regional and international levels. The major failures of early warning systems over recent times have been failures largely of institutions rather than science. Institutions are required to capture and sustain political commitment, to capitalize on and apply existing scientific knowledge, to assess risks and manage investments in systems, to globalize and systematize early warning systems, and to guide and resource underpinning scientific research.

Early warning systems are a well-recognized element of the ISDR and its predecessor the International Decade for Natural Disaster Reduction (IDNDR). The ISDR mechanism was initiated by the UN General Assembly (UN 2000) as a vehicle for shared agenda setting and action on disasters by governments, UN agencies, regional organizations and civil society organizations (ISDR 2005*b*). These organizations have primary responsibility for developing and supporting operational early warning systems. The ISDR system is supported by a secretariat that provides advocacy, policy development, information and supports countries through outreach units in the Americas, Africa and Asia. The ISDR system advocates for disaster reduction and encompasses a wide range of networks in governments, academia and non-governmental organizations (NGOs). It has fostered considerable activity on early warning issues, including international conferences on early warning, a working group on early warning, the establishment of the ISDR Platform for the Promotion of Early Warning (PPEW), and the development of the IEWP.

The landmark World Conference on Disaster Reduction was initiated and organized through ISDR mechanisms, and, as noted above, it was at this conference that governments agreed on the Hyogo Framework. The ISDR system is currently being re-organized and strengthened in order to build the wider and more systematic engagement of governments and organizations necessary to implement the Hyogo Framework over the decade.

The UN global survey of early warning systems will be an important step toward setting out gaps and needs in respect to early warning systems globally. It is clear that any globally comprehensive warning capacity will not be a centrally managed system, but will build on and strengthen existing institutional arrangements, particularly the operational mandates of WMO, UNESCO, the Food and Agriculture Organization (FAO), the UN Environment Programme (UNEP), the member bodies of the International Council of Scientific Unions (ICSU), and the Group on Earth Observations (GEO—see www.geosec.org), and on the organizational contexts of the ISDR and the Hyogo Framework. The embryonic IEWP provides a vehicle to coordinate and focus energy on systemic issues and capacity building in early warning systems development.

10. Conclusions

Awareness and interest in disasters and early warning systems is high and the time is ripe for bold action to implement the globally comprehensive, systematic and people-centred early warning systems for all hazards and all countries that UN Secretary General Kofi Annan called for in January 2004. There is a strong technical and institutional basis for progress, but there are also some glaring gaps and shortcomings that must be addressed. A new broad 'systems' agenda is required, and more needs to be done to strengthen the scientific and institutional mechanisms involved, and to ensure proper inputs from both the natural sciences and the social sciences. The Hyogo Framework and the ISDR are critically important frameworks for implementing better early warning systems. And we must always keep focused on the ultimate goal—the reduction of disasters.

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ISDR 2005*b* See General Assembly resolution *A/RES/59/231 International Strategy for Disaster Reduction*, distributed on 22 February 2005, and *Implementation of the International Strategy for Disaster Reduction* (report of the Secretary General, General Assembly document A/60/180). These documents and related material are available at the web site http://www.unisdr.org/eng/about_isdr/bd-lwr-2004-eng.htm. International Strategy for Disaster Reduction secretariat, Geneva.

ISDR-PPEW 2005*a* Many of the points presented in this paper have been discussed and illustrated in the early warning web pages of the ISDR. The 4-element view of effective people-centred early warning systems is discussed at http://www.unisdr.org/ppew/whats-ew/basics-ew.htm and in ISDR-PPEW (2005b). ISDR Platform for the Promotion of Early Warning (PPEW), Bonn.

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Discussion

J. Page (*University of Sheffield, UK*). The ISDR secretariat ran a web dialogue on monitoring progress on the Hyogo Framework for Action, which had 550 participants ranging from the World Bank to small farmers. The results were very interesting and can be seen at the ISDR website. One issue in disasters that needs more attention is that of animals. For example, many people are very resistant to being evacuated without their pets, since they fear the pets will not survive if left behind.

R. Basher. The dialogue results are accessible at http://www.unisdr.org/HFdialogue/. The topics covered included: understanding how to measure progress in disaster risk reduction; implementation and application of indicators; and procedures for reviewing national progress. The point about the importance of pets was made very clear during the New Orleans evacuations. Equally, the animals of poor farmers may be their most critical assets and the prime basis of their livelihoods.

J. Woo (*BHRC, University College London, UK*). Measurements of disaster losses in economic terms tend to underestimate the real impact on poorer countries. Are there fairer ways to estimate losses?

R. Basher. In principle, economic losses can be scaled in local purchasing power parity terms to reflect the real impacts. However, this still may not reflect the seriousness of the losses of livelihoods, environmental goods and non-monetary activities.

J. Woo. The recent hurricanes in the Gulf of Mexico showed that early warning and evacuation are effective tools in the United States, but in some nearby developing countries, local authorities had no resources to deal with their disasters. How can their needs be raised in the priorities of donors, the UN and other organizations?

R. Basher. Governments have the primary responsibility for setting priorities, in their negotiations with donors and in their own budgeting processes. Cuba is an example where high priority is given to early warning and preparedness, and the death rates from hurricanes are relatively low there. Resources are often available after disasters strike—but an urgent need is to get governments, donors and development banks to recognize the importance of disaster reduction and invest in it as an ongoing long-term priority.

M. L. Davies (*Department of Earth Sciences, University College London, UK*). Poverty is a factor in vulnerability, in both developing and developed worlds, as shown by Hurricane Katrina and other events, forcing hard choices on the poor between basic needs and responding to early warning systems. What role does poverty reduction have in a disaster reduction strategy?

R. Basher. Disasters and poverty are strongly linked—each worsening the other. A primary goal of the Hyogo Framework is the mainstreaming of disaster reduction into development strategies and programmes, to reduce disasters and protect the gains of development. Equally, real poverty reduction will release resources for more effective steps to reduce vulnerability and disasters.

C. E. Synolakis (*Technical University of Crete, Greece*). Emergency responses by donors sometimes seem insultingly inadequate—how can they be better expedited and coordinated?

R. Basher. The UN Office for the Coordination of Humanitarian Affairs (UN/OCHA) is progressively developing standard coordination mechanisms, but each event is different and requires extremely urgent action. In the case of the Indian Ocean tsunami, the needs were massive, but so was the donor response and the coordination by the UN and among donors and NGOs was generally quite good. The real problem is for the smaller and slowly emerging disasters—the ones that do not get media attention and generous funds.

A. F. Farnsworth (*University of Bristol, UK*). Would it be wise to create an independent organization, with expert advisory committees, for instance through the UN, to handle post-disaster reconstruction, in order to reduce mis-management and corruption with the large aid flows that are present?

R. Basher. A major challenge after any disaster is to manage the shift from urgent short-term relief operations to sustained recovery and reconstruction programmes. The goal should be to strengthen national capabilities to manage such activities, not only immediately after disasters but in the long run, rather than impose control from outside. The UN and donors see the recovery and reconstruction stage as an opportunity to support improvements in governance and project management, as well as in disaster resilience such as through the implementation of codes for construction and better environmental management.

S. Steacey (*University of Ulster, UK*). Should an international agency such as the UN organize a geophysical instrument pool that could be made available when a large earthquake occurs, as earthquakes are known to cluster?

R. Basher. I think there is potential for systematic approaches like this where the scientific evidence justifies them. Actually, volcanic experts and UNESCO have been trying to develop an international scheme like this for the swift deployment of monitoring equipment to volcanoes that are showing signs of possible eruption. But it is also important to ensure that countries at risk are able to maintain a basic level of capacity themselves.