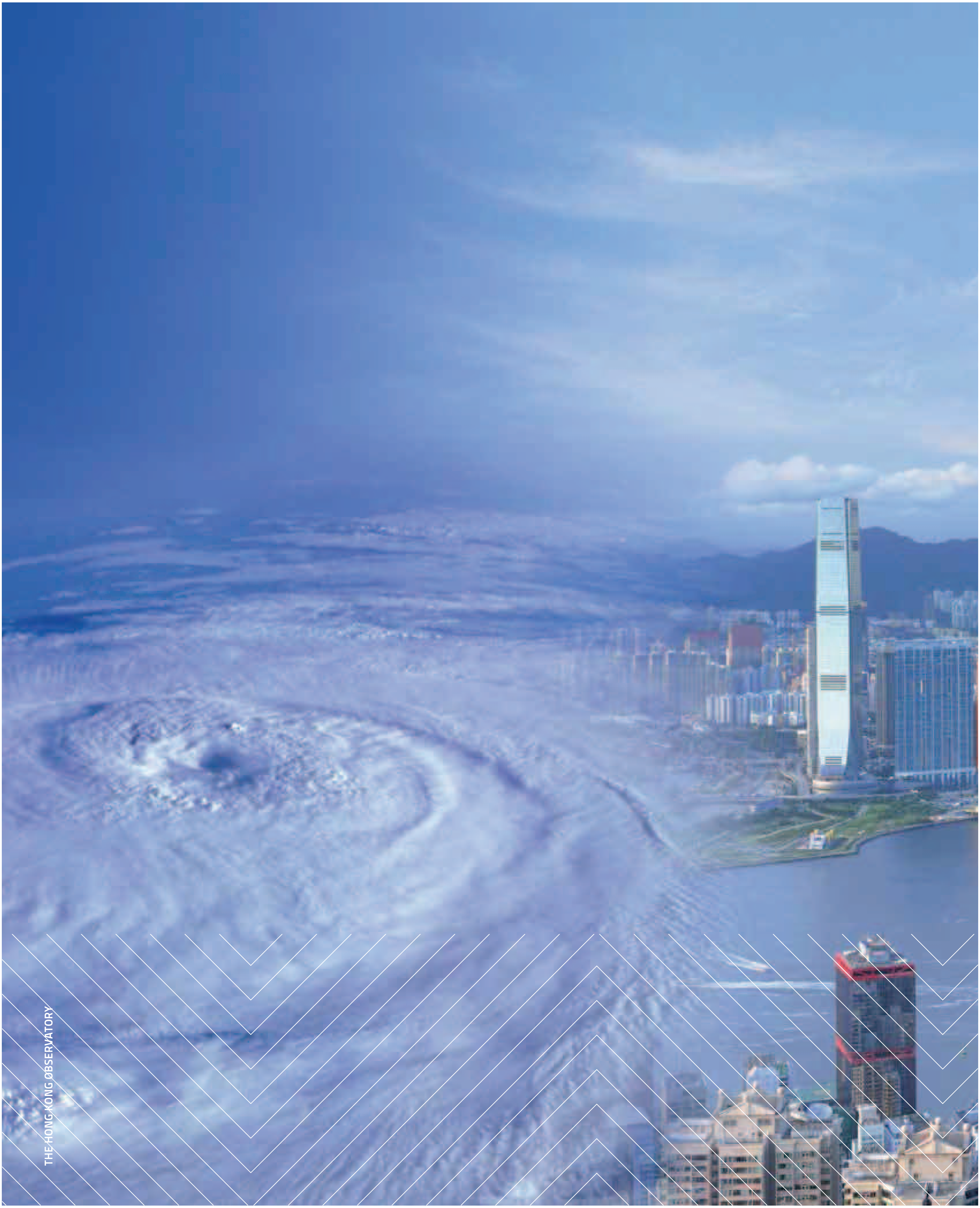

THE HONG KONG OBSERVATORY

3

THE VALUE OF EARLY WARNING

CHAPTER 3 THE VALUE OF EARLY WARNING

"I acted as soon as I heard the warnings.
That was the day before the cyclone was supposed to make landfall,
but I went anyway. I did not want to risk anything."

Kamala from Odisha, India, after cyclone Phailin in 2013.[1]

A key component of disaster risk reduction is an effective early warning system. Around Asia and the Pacific such systems save thousands of lives and many millions of dollars. An effective warning system combines science and technology with practical local approaches and is fully integrated into broader national and regional strategies for building resilience and reducing disaster risks.

Early warning systems build resilience to disasters and thus mitigate their impact. This is clearly recognized in the Sendai Framework for Disaster Risk Reduction 2015-2030, whose seventh global target is:

> "(g) Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to people by 2030."

Member States and their partners are thus committed to making early warning systems more people-centred, and also to improving access to risk information for end users. In disaster risk management, this will mean combining scientific information with practical approaches.

Each national government is responsible for its own early warning systems. But many hazards cut across national boundaries and affect multiple countries simultaneously – those that share coastlines, for example, or mountain ranges or rivers. There are therefore many opportunities for international and regional cooperation. As a result, in Asia and the Pacific, regional warning mechanisms have been set up, especially for tsunamis and tropical cyclones, with linkages to global networks, and there is a general trend towards strengthened regional and South-South cooperation.

At both national and regional levels, well-functioning, people-centred early warning systems save lives and livelihoods.[2] There is evidence of this from across the region.

- *Bangladesh* – The Cyclone Preparedness Programme has strengthened early warning at the local level, in particular through a network of over 50,000 community volunteers, and done so within a coherent, overall framework for disaster risk reduction. Combined with the construction of shelters and other structural measures this has made a major difference (Box III-1).
- *India* – In October 2013 the country was struck by cyclone Phailin, the second-strongest storm

BOX III-1

Improved early warning and preparedness reduces cyclone impact in Bangladesh

Over the past 40 years, the Government of Bangladesh and its partners have made great strides in reducing the human and economic impact of tropical cyclones. As part of the overall national strategy on disaster risk reduction, there has been a strong focus on strengthening the early warning system down to the local level. One of the key measures has been the Cyclone Preparedness Programme (CPP), which was introduced in 1972 as a joint programme of the Government of Bangladesh and the Bangladesh Red Crescent Society.

The CPP supports a local early warning system for the coastal population. Through a network of over local 50,000 volunteers, the CPP ensures rapid dissemination of official Bangladesh Meteorological Department cyclone warning signals to the communities. Once the community has been warned, the project also assists in sheltering, rescuing and providing immediate medical attention. As such, the CPP is a good example of a large-scale 'last-mile' project in early warning, which achieves results through community mobilization.

The CPP is one of several complementary measures that have contributed to the reduction in the number of deaths from cyclones in Bangladesh. Other key measures include the construction of embankments along the coastline, the construction of cyclone shelters and the re-fitting of public infrastructure. There have also been important improvements in hazard monitoring and a very active use of mobile technology for early warning dissemination.

Cyclone	Year	Strength (Saffir–Simpson scale)	Estimated death toll
Bhola	1970	Category 3	300,000
BOB 01	1991	Category 5	138,866
Sidr	2007	Category 5	4,234

Source: EM-DAT (accessed May 2015).

ever to make landfall in India. Nevertheless, timely and accurate warnings, combined with preemptive evacuations of over 550,000 people, helped minimize the casualties. Similarly in 2014 the arrival of cyclone Hudhud triggered large-scale evacuations that brought thousands of people to safety.

- *Myanmar* – Following the 2008 cyclone Nargis, which killed an estimated 138,000 people, the Government adopted a more comprehensive approach to disaster risk management. The benefits were evident in 2010 when Myanmar was struck by a storm of comparable strength – cyclone Giri. In the days prior to Giri making landfall, the Government worked with the Red Cross to pre-position relief items and evacuate over 50,000 people at risk. The Government also asked the United Nations and its humanitarian partners to remain on standby. This helped keep the number of casualties to a minimum.[3]
- *Nepal* – In 2014 two adjacent river basins, Karnali and Babai, experienced their worst floods in living memory. Across Bardiya district, which comprises both Karnali and Babai, over 100 lives were lost, about 3,000 homes were completely destroyed and over 11,500 more were partially damaged, displacing 81,000 people.[4] In Babai the forecasting station was washed away, so

people were unaware of the severity of the imminent floods. In Karnali, however, the early warning system worked, vulnerable people were alerted and brought to safety and no casualties were recorded.

- *Vanuatu* – In March 2015, cyclone Pam, one of the strongest storms ever to hit the Pacific, caused massive devastation, affecting 188,000 people out of a total population of 272,000.[5] Yet the number of fatalities was limited to 11.[6] This was due to an effective early warning system built on traditional knowledge and effective communications technology, combined with disaster preparedness at the local level.[7] Updates and warnings were sent by radio and SMS, enabling residents to trace the path of the cyclone on maps printed in every telephone book. Encouraged by the Government and relief groups, many people sought shelter in robust buildings such as schools and churches, while others hid in caves or in traditional, low and windowless 'cyclone houses'.[8]

Despite progress in a number of countries, there are still many gaps in early warning chains. Filling these will require substantial additional investment, particularly at the local level to cover the 'last mile' – though it could just as well be called the 'first mile', given the importance of reaching the most vulnerable people who are usually at the forefront of any disaster.

A powerful reminder of this was the impact of typhoon Haiyan ('Yolanda') in the Philippines in 2013. National authorities had accurately forecast this typhoon, and the accompanying seven-metre high storm surge, several days in advance.[9] Nevertheless at least 6,300 people were killed, mostly by the storm surge. Subsequent research pointed to shortcomings at the 'last mile', including gaps in risk awareness, preparedness and communication. As a consequence many people did not evacuate, or moved to unsafe places.[10]

In the light of this experience, when typhoon Hagupit ('Ruby') was about to strike in December 2014 the authorities in the Philippines and their early warning partners made great efforts to raise awareness and drastically increased the scale of preemptive evacuations. As a result there were far fewer casualties (Table III-1).[11] In parallel, the Government also modified its Tropical Cyclone Warning System to generate simpler and more impact-based forecasts, thus making the warning information more accessible to end users.[12]

EARLY WARNING – BASIC CONCEPTS

Early warning has four main elements: risk knowledge, monitoring and warning, dissemination and communication, and response capability.[13] An early warning system with all these elements is referred to as an 'end-to-end' system (Table III-2).

TABLE III-1

Evacuations and casualties in the Philippines

Year	Name (international/local)	Strength at landfall	Pre-emptive evacuations	Casualties
2012	Bopha/Pablo	Category 5	41,608	1,901
2013	Haiyan/Yolanda	Category 5	125,604	6,354
2014	Hagupit/Ruby	Category 3	716,639	18

Source: Government of the Philippines, National Disaster Risk Reduction and Management Council.

Developing an effective early warning system can be difficult and time consuming – requiring careful coordination and an efficient division of labour between multiple actors at regional, national and local levels. For each hazard, there should be one entity authorized to issue official warnings. Given the need for inter-agency coordination, the early warning system requires standard operating procedures (SOPs) that spell out the main tasks, roles and responsibilities in the event of an emergency.[14] These SOPs need to be tested and revised on a regular basis.

A key requirement is clear and unambiguous information. Unreliable or conflicting messages from official and non-official sources can allow rumours and disinformation to spread. The flow of information needs to be coordinated and shared among multiple actors – with a high degree of redundancy in the dissemination channels, since people are most likely to act on warnings corroborated from multiple sources (Box III-2). Fortunately, science and technology are now providing more of the necessary information management tools and these will continue

TABLE III-2

The four elements of an end-to-end early warning system

	Risk knowledge	Monitoring and warning	Dissemination and communication	Response capability
Main activity	Systematically collect data and undertake risk assessments	Develop hazard monitoring and early warning services	Communicate risk information and early warnings	Build national and community response capabilities
Key questions	Are the hazards and vulnerabilities well known? What are the patterns and trends? Are risk maps and data widely available?	Are the right parameters being monitored? Is there a sound scientific basis for making forecasts? Can accurate and timely warnings be generated?	Do warnings reach all those at risk? Are the risks and the warnings well understood? Is the warning information clear and useable?	Are response plans up to date and tested? Are local capacities and knowledge made use of? Are people prepared and ready to react to warnings?

Source: Adapted from UNISDR: Basics of Early Warning. Available from http://www.unisdr.org/2006/ppew/whats-ew/basics-ew.htm (accessed 19 May 2015).

BOX III-2

Why do people respond - or not - to warnings?

Research supported by ESCAP has shown that people are likely to act on warning information when they:

- Know what specific actions can be taken to reduce their risks;
- Are convinced that these actions will be effective;
- Believe in their own ability to carry out the tasks;
- Have validation from multiple sources;
- Believe other people are also doing it.

to improve (Figure III-1). In Asia and the Pacific, regional trends suggest that such new technologies can significantly strengthen early warning systems but must be combined with people-centred approaches.

The ultimate test of an early warning system is whether it provides timely and actionable information to all of the most vulnerable people – including children, pregnant and lactating women, older persons, the sick and people with disabilities. For persons with disabilities, information should be provided in accessible formats. If such vulnerable groups are not adequately informed and supported, the system as a whole must be judged to have failed.

An early warning system that covers multiple hazards should be sufficiently flexible to allow for the appropriate timeframes for each type of hazard. Rapid onset disasters such as near-field tsunamis and flash floods only allow between 15 minutes and a couple of hours from detection to impact, so the warning system should be able to respond to imminent danger. Other hazards, such as cyclones and seasonal floods, may be detected days or even weeks in advance – allowing people to protect assets and livelihoods (Figure III-2). With sufficient warning, businesses can move productive assets to safe ground, and households can shutter windows and reinforce rooftops. Given these varying needs, the warning authorities need to carefully judge how to release information – achieving the optimum balance between timeliness and accuracy.

FIGURE III-1

Disaster forecasting – the current and likely future state of science

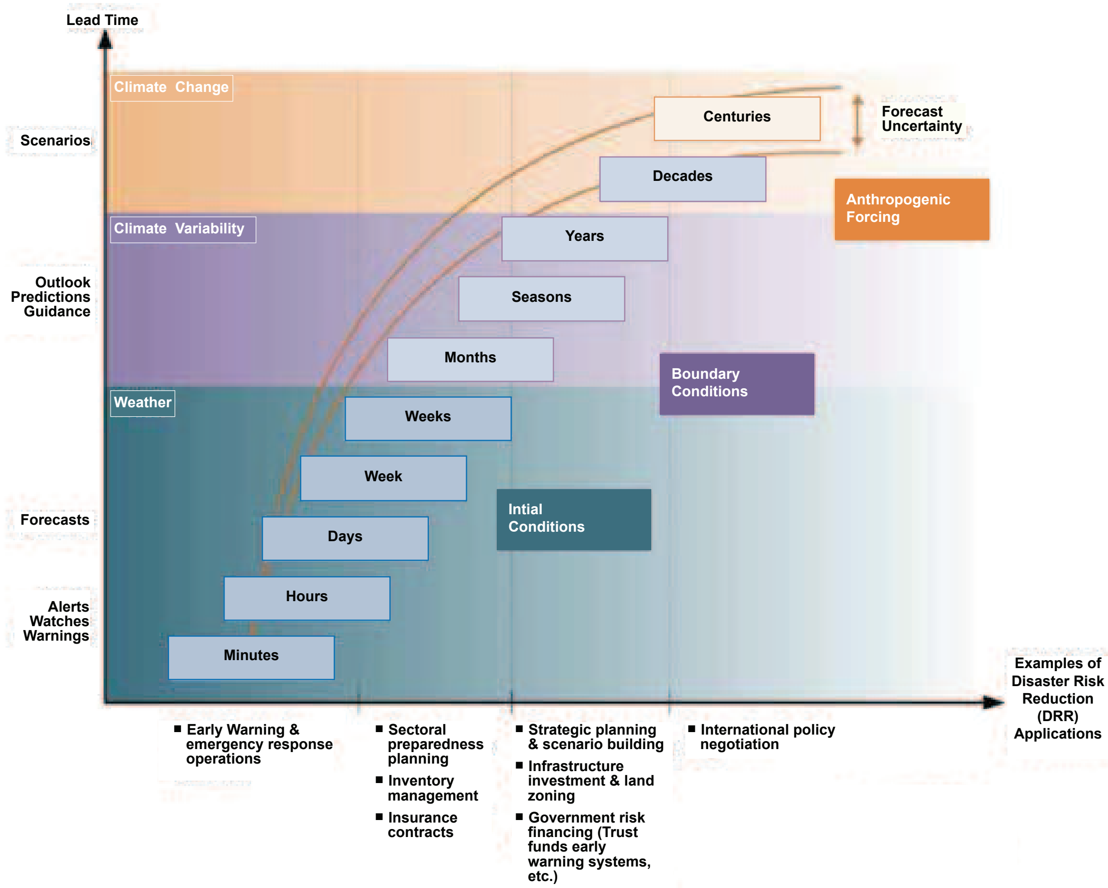
	Ability to produce reliable forecasts					
	Now (2014-2015)			2040		
	Space	Magnitude	Time	Space	Magnitude	Time
Geophysical hazards						
Earthquakes	2	1	1	3	2	1
Volcanoes	3	2	2	5	3	3
Landslides	2	2	1	3	3	2
Tsunamis	2	2	1	3	3	2
Hydrometeorological hazards	6 days ahead					
Storms	3	3	4	5	5	5
Floods	3	3	4	5	5	5
Droughts	5	5	5	5	5	5
Hydrometeorological hazards	6 months ahead					
Storms	2	2	2	3	3	3
Floods	2	2	2	4	4	4
Droughts	2	2	2	4	4	4

Source: Foresight Reducing Risks of Future Disasters: Priorities for Decision Makers (2012) Final Project Report. The Government Office for Science, London. Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/286476/12-1289-reducing-risks-of-future-disasters-report.pdf

Notes: Numbers indicate the ability to produce reliable forecasts on a scale from 1 (low) to 5 (high).

FIGURE III-2

Lead times and applications of early warning information



Source: Adapted from a figure in the World Meteorological Organization Strategic Plan 2012-2015.

STATUS OF EARLY WARNING SYSTEMS IN ASIA AND THE PACIFIC

A number of Asia-Pacific countries have developed early warning systems over several decades. But the status of early warning for the region as a whole was transformed following the 2004 Indian Ocean tsunami which affected 14 countries in Asia and Africa, and led to over 230,000 deaths. With no tsunami early warning system in place at the time, most of the victims received no warning at all.

The 2004 tsunami was a watershed moment. It had a profound impact on the development of the Hyogo Framework of Action (HFA) only weeks later. And it led to major changes in policies and budgets – stimulating extensive operational and technical work and triggering greater investment in prevention and mitigation. This progress was assessed in the 2012 *Asia-Pacific Disaster Report* (APDR).[15] The report found there had been more frequent disasters such as typhoons, floods and landslides and greater damage to property and livelihoods.

Devastation in Aceh, Indonesia, following the 2004 Indian Ocean tsunami.

Yet in some subregions the death toll was decreasing – as a consequence of better disaster risk management, including investments in early warning systems and preparedness. However, the report also identified continuing weaknesses in a number of countries with limited capacities and resources.

Since then there has been further progress in the Asia-Pacific region. The technology for assessing risks and detecting approaching threats has reached a high degree of sophistication. But again there are disparities: some countries have made great advances, but many others with fewer resources are lagging behind, and often struggle to maintain their current early warning systems. The main obstacles to early warning saving more lives are usually related to gaps in (1) ensuring fast and reliable dissemination of warnings to all concerned, and (2) building the knowledge and capacity of communities to act appropriately. Of the four main components of early warning, the more advanced in Asia and the Pacific are risk knowledge, and monitoring and warning. But many countries still have gaps in communication and response capacity.

For all Asia-Pacific countries, a common weakness is that early warning is seen primarily as a science initiative. It can thus remain isolated from policy and decision-making in other areas, even in disaster management. As a result, there is often limited contact between forecasters and disaster managers, and various sectors of the economy make limited use of the existing warning and risk information.

REGIONAL COOPERATION

Many hazards and disasters in Asia and the Pacific are cross-border. Asia-Pacific countries have therefore developed regional cooperation mechanisms, notably for tsunamis and tropical cyclones. Indeed overall there is a general trend towards strengthened regional and South-South cooperation as well as building international frameworks.

A regional early warning system can be considered a 'public good' – in that its use by one country does not prevent other countries benefitting from it. Indeed the more countries that use the same system the better, because this will make it more valuable and sustainable for all members. On their own most countries would be unable to afford a comprehensive tsunami early warning system, for example, but they can achieve more if they share the costs with other countries and relevant regional and international organizations. They can also share expertise – in assessing risks, developing sustainable monitoring and warning services, improving dissemination and building capabilities for response.[16]

The Indian Ocean Tsunami Warning and Mitigation System

In the aftermath of the Indian Ocean tsunami, a major milestone of regional cooperation was the establishment of the Indian Ocean Tsunami Warning and Mitigation System (IOTWS) which became operational in 2011. In the IOTWS, Australia, India and Indonesia are responsible for issuing tsunami bulletins to member States. There are also region-wide communication tests twice a year, and full-scale regional exercises every two to three years. Along with the development of the IOTWS, 24 countries around the Indian Ocean have established national tsunami warning centres.

There have also been extensive investments in tsunami observation systems and in information sharing through regional and global networks. As a result, between 2004 and 2014, the number of Indian Ocean broadband seismometers detecting tsunamigenic[17] earthquakes and sharing near real-time data grew from 13 to over 140 (Table III-3).[18] Over the same period, the number of deep ocean tsunameters sharing data in near real-time and available for tsunami warning purposes increased from zero to nine while the number of real-time coastal sea level gauges grew from four to over 100. Taken together, these new resources networked through the IOTWS represent a major improvement in regional preparedness (Figure III-3). A study for ESCAP estimated that on average, over the next century the IOTWS will save at least 1,000 lives per year.[19]

The IOTWS was modelled on, and initially supported by, the Pacific Tsunami Warning and Mitigation System. Established in 1968, this system has remained a "gold standard" in early warning, and today can issue tsunami warnings in only seven minutes.[20] Since 2011, the service providers of the IOTWS have also reached a high degree of sophistication, and normally issue the first tsunami bulletins within 10-15 minutes of a tsunamigenic earthquake.

Regional cyclone warning mechanisms

The Asia-Pacific region also has intergovernmental platforms for addressing tropical cyclones (known as typhoons if they originate from the West Pacific). One is the ESCAP/WMO Typhoon Committee (TC) which covers storms emerging from the Western Pacific. The other is the WMO/ESCAP Panel on Tropical Cyclones (PTC) which covers the Bay of Bengal and the Arabian Sea. Since 2005, both have expanded and strengthened their activities, bringing about closer regional cooperation in early warning. They have also helped integrate the fields of meteorology, hydrology and disaster risk reduction – building capacities and developing joint strategies across countries and professional fields. The TC and the PTC undertake original research and pilot projects to further improve the understanding of tropical cyclones and related hazards.

TABLE III-3

Development of IOTWS networks, 2004-2014

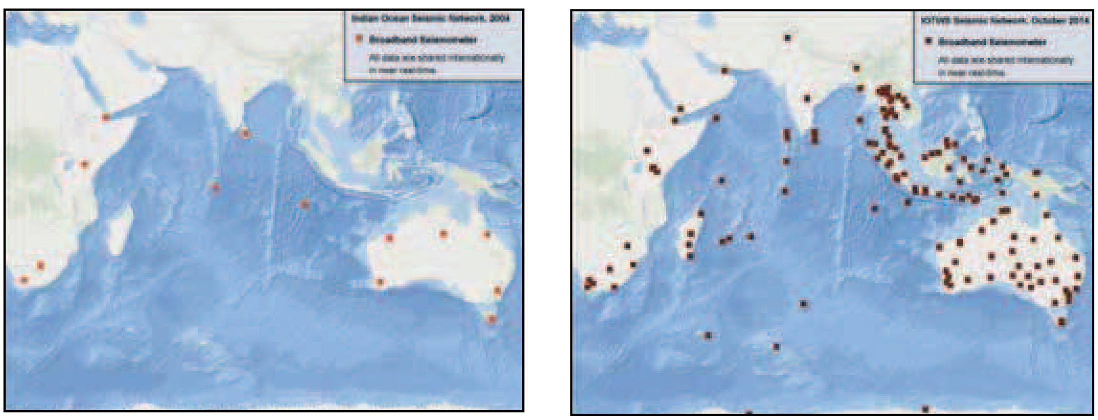
	2004	2014
Broadband seismometers sharing data in near real- time	13	>140
Coastal sea level gauges sharing data in real-time and available for tsunami warning purposes	4	>100
Deep ocean tsunameters sharing data in near real- time and available for warning purposes	0	9

Source: UNESCO, 2014.

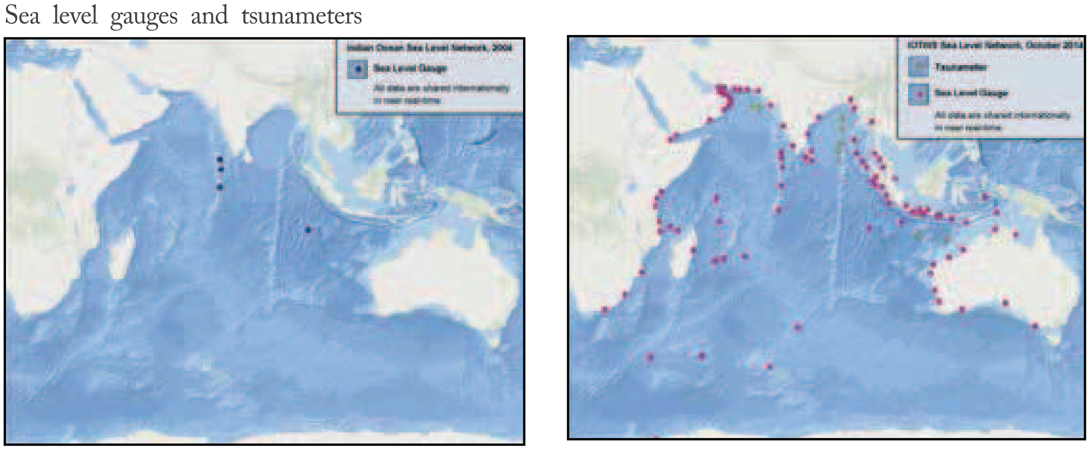
FIGURE III-3

Evolution of the Indian Ocean Regional Tsunami Observation System 2004-2014

Broadband seismometers



Sea level gauges and tsunameters



These maps illustrate the improvements between 2004 to 2014 in the core seismic network and the core coastal sea-level station and deep ocean tsunameter networks. Developed as part of the IOTWS, these networks share data regionally and globally in near real time.

Source: UNESCO, 2014.

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

In February 2015, the TC and the PTC held a joint session hosted by ESCAP during which they agreed to establish a mechanism for long-term cooperation – covering such issues as periodic joint sessions, technical projects, information sharing, research and analysis, and training activities.

Regional Specialized Metrological Centres

The activities of the TC and the PTC are backed up by the regional specialized meteorological centres in New Delhi and Tokyo. These centres operate within the framework of the WMO's World Weather Watch Programme and support countries with analysis, forecasting and training especially those with limited domestic capacity.

Regional Integrated Multi-Hazard Early Warning System for Africa and Asia

In 2009, with support from ESCAP, governments established the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES). This is an intergovernmental institution focusing on the generation and application of early warning information and supporting capacity building. By 2015, RIMES had grown to include 13 member States and 19 collaborating countries.

Gaps in regional cooperation

Despite progress in regional early warning systems, especially for tsunami and tropical cyclones, and the availability of technology, there are significant gaps for other hazards. Consequently, countries in Asia and the Pacific are calling for better regional early warning systems for hazards such as transboundary river-basin floods (e.g. in South Asia and South-East Asia), landslides, flash floods and glacial lake outburst floods.

There is a particular need for strengthened regional cooperation in early warning for transboundary river basin floods stemming from the Hindu Kush Himalayan region. A total of 1.3 billion people in 15 countries depend on this natural 'water tower', which feeds water into nine large river basins. At the same time, the area is prone to floods.

Given the transboundary nature of the river basin flood hazard, no country can ensure effective early warning on its own; the key to greater disaster resilience is regional cooperation. Such cooperation could involve sharing data and knowledge, including innovations such as nested modelling solutions that couple climate scenarios, river-basin hydrology and flood forecasting. Cooperation can also take the form of dialogues and institutional partnerships based on an integrated flood management approach. There have already been a number of initiatives including those from WMO, PTC and the International Centre for Integrated Mountain Development. Since river basin flood hazards are frequently transnational, these efforts need to be re-energized and consolidated into a regional warning mechanism.

The region also needs to make greater efforts on warning systems for landslides and flash floods. For this purpose there have already been a number of pilots that can be scaled up and replicated. In the Philippines, for example, with support from Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), a landslide early warning system was successfully set up 2012 in the municipality of Saint Bernard in the province of Southern Leyte. This was one of the first of its kind in the Philippines, and has been integrated with existing warning systems.

Also in the Philippines, there is an innovative flash floods warning system in the city of Cagayan de Oro in Mindanao. This was set up with support from the Republic of Korea's National Disaster Management Institute following the devastation caused by typhoon Washi in 2011. Effective community-based flood early warning systems have also been established successfully in Nepal, by the Government and a wide range of partners participating in the Nepal Risk Reduction Consortium. These initiatives offer important advances that could be shared and further scaled up through regional cooperation.

DEVELOPMENTS IN FORECASTING

At the Third United Nations World Conference on Disaster Risk Reduction in March 2015, participants highlighted the need for impact-based forecasts and warnings, accompanied by specific recommendations for precautionary action.[21] End users too are increasingly seeking downscaled, customized forecasts to guide local preparedness and mitigation.

For this purpose, Asia and the Pacific can take advantage of its strength as a hub for science, innovation and good practice. This creates opportunities for using space technology, remote sensing and geographical information systems for assessing and monitoring impending hazards. Initiatives in the Asia-Pacific region include:

Climate model-based seasonal hydrologic forecasting

The region has been adopting global scientific innovations such as climate model-based seasonal hydrologic forecasting. Initially developed in the United Kingdom, this model couples climate scenarios, river basin hydrology and flood forecasting.[22] The resulting analysis is particularly useful for hydrologic forecasting and thus also for flood early warnings.

In Bangladesh, for example, the Government partnered with RIMES to apply this innovation and was able to increase the lead time for flood forecasting from three to ten days. They combined meteorology, hydrology and flood forecasting and developed a probabilistic system based on climate modelling and water discharge in the Ganges River and Brahmaputra rivers. The forecasts are shared with decision makers at national and district levels through fax and e-mail, and with pilot communities through SMS and flag networks. This has vastly improved the ability of authorities and communities to take early action to protect lives and livelihoods. An evaluation of the project found that, in 2014 alone, the average household saved $472, with even higher savings recorded for households living from fishing, agriculture and livestock.[23] This global-level innovation thus has the potential for replication elsewhere in Bangladesh and in the Asia-Pacific region as a whole.

Strengthening national services

In 2011 RIMES and WMO, with financial support from ESCAP, started a joint effort to strengthen the national meteorological and hydrological service (NMHS) in five high-risk countries – Bangladesh, India, Myanmar, the Maldives and Sri Lanka – and help them develop user-friendly forecasts. For each monsoon season there are biannual forums for forecast generators and users of the forecasts. In advance of each monsoon forum, RIMES and WMO work with the NMHS to develop the seasonal forecast and related products, and to train users, such as line ministries, local governments and their partners. At the forums themselves, the users discuss the corresponding preparedness and mitigation measures.

There are also many other initiatives underway to build the capacity of national forecasters, under the respective umbrellas of the TC, PTC and RIMES. In particular, the regional specialized metrological centres in New Delhi and Tokyo, working in the framework of the WMO, are training national forecasters. At their joint session in 2015, TC and PTC members recommended the further scaling up of such training.

Severe Weather Forecasting Demonstration Project

In the Pacific, a group of countries led by New Zealand has shown the value of the WMO-led Severe Weather Forecasting Demonstration Project. The project uses a 'cascading forecasting process' to provide guidance from global and regional weather models to participating countries such as Vanuatu and the Solomon Islands. In this way, national forecasters do not need to invest in expensive computing power. Instead, the system ensures that large-scale numerical predictions are created cost-effectively by a few national meteorological and hydrological services, and then shared with other countries.[24]

NATIONAL INITIATIVES

Beyond the progress at the regional level highlighted above, improvements are also apparent at the national level. Trends include:

- *Increasing national investments.* Since 2004, several countries have made major investments in national early warning systems. These include setting up state-of-the-art warning centres that are helping make the Asia-Pacific region a global hub of excellence in this field.
- *Promoting community-based disaster risk management.* In line with the approaches promoted by the HFA and the Sendai Framework, a number of countries and partners in the region have embraced the concept of community-based disaster risk management (CBDRM),[25] and implemented it in vulnerable communities, especially in coastal areas. CBDRM is a participatory process that leads to a locally appropriate and locally 'owned' strategy for disaster preparedness and risk reduction, which has been implemented successfully in countries such as India, Nepal, the Philippines and Viet Nam.
- *Addressing specific hazards.* Several countries are also making progress in addressing their unique warning requirements. In Mongolia, for example, the National Agency for Meteorology and Environmental Monitoring has worked with partners such as Mercy

Tsunami route evacuation sign, Sri Lanka

Corps and RIMES to strengthen early warning systems for weather-related hazards following the *dzud*[26] in 2010, in which 8.4 million head of livestock died.[27] With the goal of reducing the future impact of *dzud* and other weather-related hazards, RIMES provides daily weather information for herder communities in three pilot sites in Arkhangai province. The forecast and the interpretation are passed on to the communities via a local meteorological office. Local NGOs assist the communities in assessing the potential impact of severe weather events on livelihood systems and designing mitigation and coping strategies.

MULTI-HAZARD SYSTEMS

Each hazard has its own specific warning requirements and lead times. But where possible, early warnings for individual hazards should be integrated into a multi-hazard system. This brings benefits in terms of economies of scale, sustainability and efficiency. And since a multi-hazard system will be activated more regularly it is likely to be better maintained and more readily available for hazards such as tsunamis that occur infrequently. Such integrated systems may also help the public better understand the range of risks they face and the need to prepare and to respond to warnings.

In line with the vision of the Sendai Framework, a number of cities and countries have moved to multi-hazard systems.

- *Australia* – The multi-hazard system, which is operated by the Bureau of Meteorology, covers severe storms, tropical cyclones, hazardous winds, heat, fires, flooding, tsunamis, and marine and aviation hazards. Driven by the experiences of the 2004 Indian Ocean tsunami and the 2011 Queensland floods, warning operations have now been standardized.
- *Shanghai, China* – An effective multi-hazard early warning system provides alerts on tropical cyclones, storms surges, and extreme temperatures, as well as on floods, diseases, physical damage and other impacts.[28]
- *India* – The Government has integrated the early warning systems for tsunamis and storm surges, as a step towards bringing together warning information for a wider range of hazards.

One of the problems in developing multi-hazard systems is that responsibilities can be distributed across different departments and ministries. For example, many Asia-Pacific countries have already set up warning systems that are common for most hydrometeorological hazards. However, it can be difficult to combine these systems with those for geophysical hazards which are often managed by other ministries. One exception is in Myanmar, where responsibilities for both types of hazards rest in the Department for Meteorology and Hydrology, thus opening up opportunities for developing a truly integrated warning system in the future. Other examples are Indonesia and Malaysia.

With financial support from ESCAP, the TC and the PTC have developed a manual for multi-hazard SOPs. It is based on research from 13 countries and outlines ways of integrating the procedures for multiple hazards, improving operations and achieving synergies by combining systems. The manual is expected to be rolled out in 2016, by the TC, the PTC and their member States. A number of countries have also taken up new tools and standards such as the Common Alerting Protocol (Box III-3).

BOX III-3

Common Alerting Protocol

In their efforts to establish multi-hazard early warning systems, countries in Asia and the Pacific are increasingly deploying global standards and innovative technologies. One such standard is the Common Alerting Protocol (CAP). This is being implemented in a number of countries, including China, India, Japan and Thailand and, with support from ESCAP, is being introduced in the Maldives and the Philippines.

The CAP is a digital format for emergency alerts covering any hazard. It allows for a consistent alert message to be disseminated simultaneously over many different communications systems, such as TV, radio, the internet and SMS.

With the CAP, a single alert can trigger a wide variety of public warning systems, increasing the likelihood that the intended recipients are alerted by one or more communication channels. The CAP also allows warning authorities to target alerts to a geographically defined area. As such, it can significantly improve the dissemination and consistency of alerts.

Source: WMO.

FINANCING

Greater political commitment to disaster risk reduction has not been matched by corresponding financial investments. Donor resources for disaster prevention and preparedness remain uneven and have not increased substantially since 2003.[29] Over the last decade in Asia and the Pacific less than 1 per cent of total development assistance, and only around 10 per cent of humanitarian assistance, was spent on disaster preparedness and prevention.[30] Generally, donor funding for disaster risk reduction also remains heavily concentrated on a few countries.

Economic benefits of early warning

Often, the costs of early warning systems are outweighed by the economic benefits especially for hydrometeorological hazards such as floods. According to World Bank research, investments in hydrometeorological warning services in developing countries could have a benefit-cost ratio of between four and 36, with substantial benefits for weather-sensitive sectors such as agriculture and energy.[31] Much of the investment required is in people – specifically the technical staff of NMHSs, in order to make forecasts more accurate and user-friendly and to increase warning lead times.

This is confirmed by research by RIMES which suggests considerable economic benefits from investments in local and national warning systems for high-frequency, low-impact hazards, such as storms and floods (Table III-4). However, for low-frequency, high-impact hazards, such as tsunamis in the Indian Ocean, it would be more economical to take a regional or a collective approach.[32]

In Bangladesh, for example, RIMES found that for every $1 invested in increasing the accuracy and lead-times for cyclones warning, there would be a return of $41 in benefits.[33] This study assumed a major cyclone every five years but economic benefits would be considerable even over a longer return period. As stated above, an

TABLE III-4

Cost effectiveness of early warning

Country	Hazard	Benefit-cost ratio
Bangladesh	Cyclones	40.9
Sri Lanka	Floods	0.7
Bangladesh	Floods	447.1
Thailand	Floods	1.8
Viet Nam	Hydro-meteorological	10.4

Source: Subbiah, Bildan and Narasimhan, 2008.

initiative in the same country to increase the lead time for flood forecasting up to ten days has also shown promising economic benefits.

For the Indian Ocean region as a whole the greatest potential economic benefits from forecasting would be for cyclone, floods and volcanic eruptions. This is because, except for flash floods, these hazards can be predicted fairly accurately – making it possible to evacuate people and reduce damage to property and livelihoods.[34] The benefits can be lower from tsunamis which, although they can be very destructive occur less frequently.

These benefits will only be realized, however, if the investments are well directed.[35] A World Bank report cautions against over-reliance on expensive technologies with high operating and maintenance costs. Instead, the report suggests addressing practical needs – such as estimating and calibrating models, carrying out hazard analysis, digitizing past data and improving data from ground observations.

Innovative funding models

Given the resource constraints, the best way to maximize the impact of finance, especially donor funds, is through pooled funding. Multiple partners can coordinate their investments and thus reduce the risk of duplication. One example, established after the 2004 Indian Ocean tsunami, is the ESCAP Multi-donor Trust Fund for Tsunami, Disaster and Climate Preparedness (Box III-4), which applies a regional approach focused on South-South cooperation. An independent evaluation found that the fund had helped significantly strengthen early warning systems, especially by helping establish the IOTWS and RIMES, and also by providing dedicated support to high-risk, low-capacity countries.[36]

An example of a large-scale pooled fund is the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR). By the end of 2013, GFDRR's global portfolio consisted of 226 grants worth $156 million.[37] This included 45 grants worth $34.8 million in East Asia and the Pacific, and 30 grants financed with $13.6 million in commitments in South Asia. Among the valuable early warning activities supported at the country level were participatory risk mapping in Indonesia, integrated flood risk management in the Philippines, and community resilience in Viet Nam.

BOX III-4

ESCAP Multi-donor Trust Fund for Tsunami, Disaster and Climate Preparedness

The Trust Fund was established in 2005 following the devastation wrought by the Indian Ocean tsunami. Its original mission was to support tsunami early warning systems in Indian Ocean and South-East Asian countries. In 2010, following an independent review, the member States and ESCAP expanded the thematic scope of the Trust Fund to include overall disaster and climate preparedness, while retaining a focus on end-to-end early warning for coastal hazards. In 2015, the geographic scope was expanded to include small island developing States in the Pacific.

The Trust Fund supports the strengthening of early warning for coastal hazards such as tsunamis, typhoons and storm surges, while applying a regional approach. It contributes to the narrowing of capacity gaps through regional and South-South cooperation, sharing of resources and the development of an integrated regional warning system comprising a network of collaborative centres.

The strategy of the Trust Fund has three main pillars:

I. Regional intergovernmental mechanisms;
II. Specific country needs; and,
III. Civil society innovations and business sector initiatives.

As of July 2015, the Trust Fund had approved 26 projects with a combined budget of approximately $13.7 million, directly benefitting 19 countries. In particular, the Trust Fund has made important contributions to the establishment of a regional warning system for tsunamis and the provision of cost-effective warning products and services especially to low-capacity countries.

Another innovative pooled funding model that promotes coordination and synergies among multiple actors is the Global Initiative on Disaster Risk Management. This is coordinated by GIZ with financial support from the Federal Government of Germany. The initiative brings together a wide range of stakeholders from Germany, Asia and the Pacific and other regions – providing a forum for collaboration in disaster risk management between donors and implementing partners. One of the three main focus areas is early warning.

Sustainability

A major concern for investment in early warning systems is sustainability. Governments have many competing priorities and, over time, may come to question the value of relatively expensive systems, especially for infrequent hazards such as tsunamis. For this reason it is important to build multi-hazard systems whose value can be demonstrated more regularly. Early warning systems for geophysical and hydrometeorological hazards, for example, have many components that can be shared – both for technology and human resources (Figure III-4). Integration can not only reduce costs but improve performance.

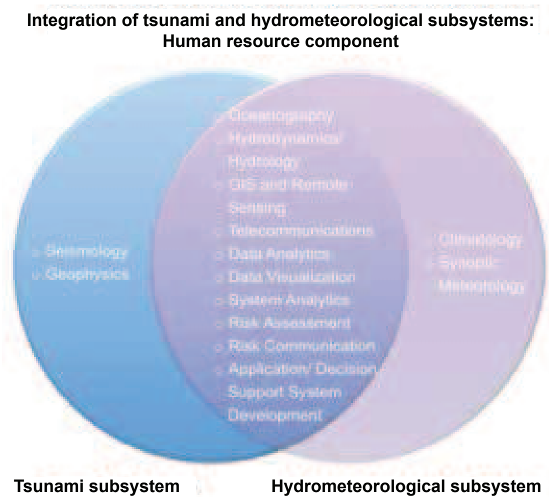
Sustainability is a priority for the IOTWS.[38] The initial investment was $300 million, mostly borne by the governments of Australia, India and Indonesia and their partners. As of 2014, the total annual cost to operate and maintain the IOTWS was approximately $90 million.[39] To make the IOTWS more sustainable the members are taking a multi-hazard approach and have recommended that governments enshrine their financial commitment in legal frameworks and long-term policies.

FIGURE III-4

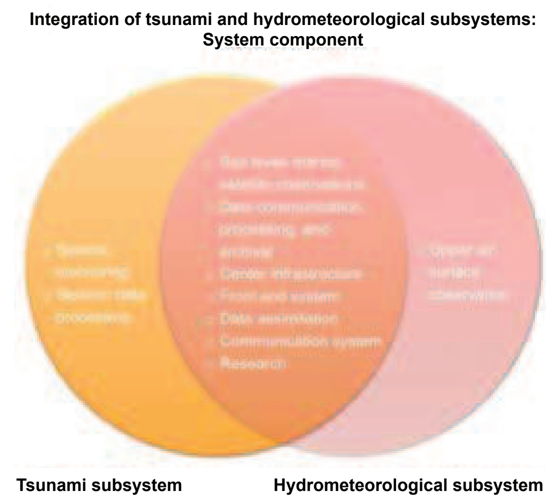
Potential integration of tsunami and hydrometeorological warning systems

Integrating tsunami and hydrometeorological early warning systems into one multi-hazard system brings potential synergies and economies of scale, both in the human resource and the system components.

Human resources



Systems



Source: A.R. Subbiah, Lolita Bildan and Ramraj Narasimhan, 2008. "Background Paper on Assessment of the Economics of Early Warning Systems for Disaster Risk Reduction." Paper submitted to the World Bank Group Global Facility for Disaster Reduction and Recovery (GFDRR).

To further strengthen sustainability, it is important to avoid that early warning is seen as a science project that is taking place in isolation from society as a whole. Instead, whenever possible, early warning information should be made relevant to supporting livelihoods in multiple sectors of the economy, as seen in the example above regarding the monsoon forums. In this way, the early warning system can become an enabler for sustainable development, with clear economic benefits. Going forward, linking the early warning system to the needs of end users in various economic sectors can thus help make the case for sustainable funding for early warning.

In India, a good example is the information provided to small-scale fishermen by the National Centre for Ocean Information Services. These weather forecasts and fishing zone advisories enable fishermen to reduce their exposure to hazards, as well as cut their fuel consumption, as they spend less time searching for fish. Targeted weather and ocean forecast services have also provided benefits for other economic activities such as desalination and ornamental fishing.[40]

UNMET NEEDS IN INDIAN OCEAN AND SOUTH-EAST ASIAN COUNTRIES

New research by ESCAP highlights the unmet needs in early warning across Indian Ocean and South-East Asian countries.[41] Although it focuses on coastal hazards, the findings, outlined below, illustrate a state of affairs common across the Asia-Pacific region with respect to the four elements of early warning.

Risk knowledge

There are significant gaps for both the generation and dissemination of risk information (Box III-5). For generation, the priority should be to improve data gathering on hazards, exposure and vulnerability, and to develop hazard and risk maps at smaller scales that can guide local efforts at risk reduction and preparedness. There is also a lack of regional-level multi-hazard risk maps including for transboundary hazards. The production of such maps should not however be seen as one-off efforts but rather as continual processes to understand the dynamic nature of hazards and vulnerabilities. For this purpose and to ensure local ownership it is vital to involve local communities in gathering data.

For knowledge dissemination, the key task is to develop user-friendly ways of communicating, especially to local disaster managers, other government officials and the population. It is thus essential to bridge the gaps between scientists and disaster managers.

Monitoring and warning services

Many Asia-Pacific countries have successfully applied new advances in science and technology to enhance observation networks. But a number of least developed countries have limited capacity to take advantage of these advances (Box III-6). Such countries can benefit greatly from regional cooperation – which can offer them better access to information and expertise. Communities too can make a valuable contribution – for example by complementing technological data with traditional risk indicators such as changes in animal behaviour or vegetation.

For issuing warnings it is important to balance the accuracy and timeliness of the information, and frequently update SOPs at various levels. Even the most technologically advanced countries can struggle with this.

Another problem is that vital parts of early warning systems, such as weather stations, may themselves be damaged during disasters. In 2013

BOX III-5

Main unmet needs in risk knowledge

Knowledge generation

- Improving international exchange on assessment methodologies and harmonization.
- Producing more hazard and risk maps down to scales of 1:5,000/1:10,000 when possible.
- Improving data gathering on hazards, exposure and vulnerability using scientific methods as well as indigenous knowledge and community-based methods (e.g. crowdsourcing).
- Reviewing coastal inundation, storm surge and tsunami hazard maps (including more detailed bathymetry) and considering developing multi-hazard maps for “big ocean waves”, which could include both tsunami and storm surge.
- Including climate change related information in risk assessments (priority on precipitation, sea level rise and severe winds), in addition to disaster information parameters.

Knowledge dissemination

- Assessing the risk information needs of local disaster managers and developing more user-friendly ways of presenting data to this target group.
- Communicating the inherent uncertainties in risk information to the end users.
- Improving the sharing of good practice examples of educational materials related to early warning.

BOX III-6

Main unmet needs in monitoring and warning services

- Balancing the accuracy and the timeliness of alerts in order to avoid many false alarms.
- Incorporating information from citizens for warning purposes.
- Improving rain forecasting to enhance the reliability of the forecasting of fresh water coastal floods.
- Further developing and expanding the coverage of the direct observations of wave heights of storm surges, tsunamis and swells (e.g. using coastal radar, pressure-type sensors, satellite-based altimeters, observation of cyclone by airplanes).
- Improving indirect methods of tsunami observation using more specific earthquake data (e.g. focal mechanisms) with GPS data and faster computers.
- Regularly updating international/regional SOPs that are in place for status communication and information on hazardous events (probably every five years and after significant events).
- Formulating national SOPs in countries where these are missing, and implementing existing SOPs more diligently in many countries.

typhoon Haiyan partially or completely destroyed 12 weather stations in the Philippines – at an estimated replacement cost of $1.63 million.[42] Post-disaster needs assessments and recovery plans should thus incorporate reconstruction needs for damaged early warning systems.

Communication and dissemination

Warning information and alerts should be formulated such that the end user understands them and knows how to respond. In some cases, the message may have to be very direct, such as "Evacuate now to save your life". In others, the message may be subtler and contain less urgency. Either way, a common pitfall is that the warning information becomes too technical and complicated.

In many countries, there are also gaps in communications channels and networks (Box III-7). As a result, vulnerable and remote populations may not receive warnings. This may be a matter of geography as for small island developing States. In other cases the barriers may be social – in countries, for example, that have large and diverse populations, with a variety of languages.

An important way of reaching many people quickly is through the broadcast media. These should be incorporated into warning chains – both to take advantage of their reach and to ensure that they do not spread inaccurate or exaggerated information. In two projects supported by the ESCAP Trust Fund for Tsunami, Disaster and Climate Preparedness, the Asia-Pacific Broadcasting Union has developed guidelines and other warning tools for broadcasters. However, in order to be effective in an emergency the broadcast media need a formal role in the warning chain – established through SOPs.

A related issue is the contribution of social media – which can disseminate accurate warnings but may spread false alarms, rumours and misinformation. Rather than let misinformation pass unchallenged, the authorities are usually better off monitoring the social media and themselves using these platforms to reach the public with the correct information.

BOX III-7

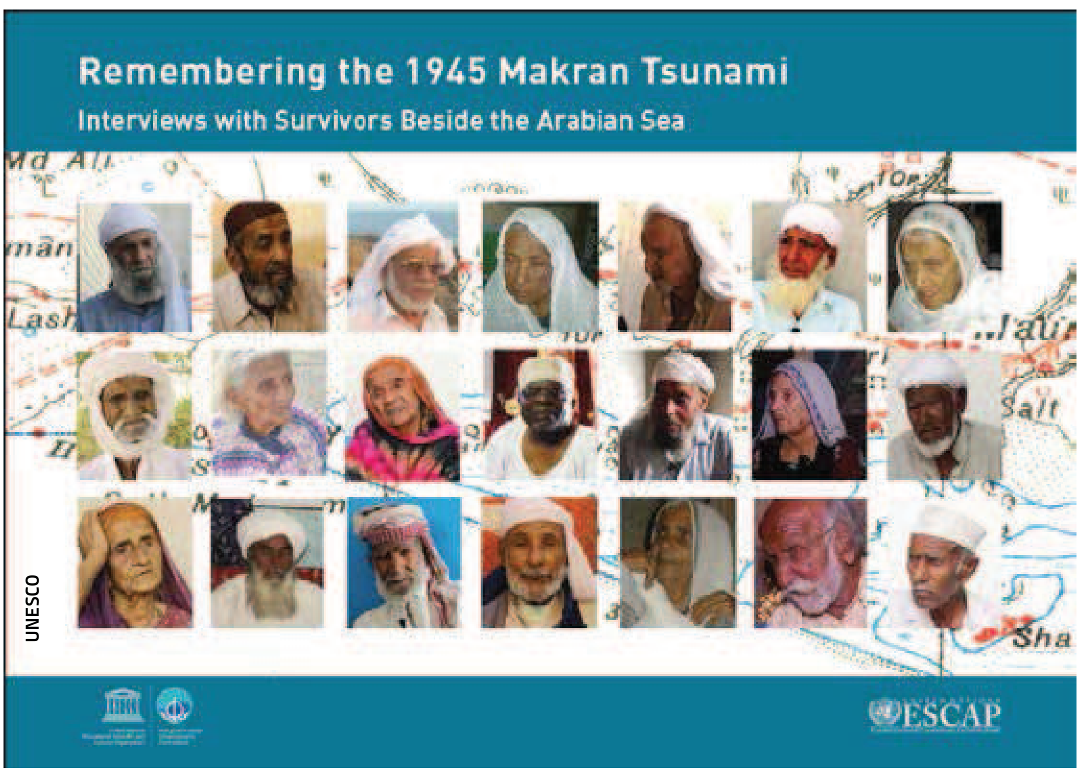
Main unmet needs in communication and dissemination

- Reviewing and adjusting warning messages, alert levels and educational materials if they are found to be too complicated or the language is not well adjusted to the target population.
- Investing additional effort in reaching populations at the 'last mile'. Technical means of spreading alerts are available but have to be used in a more widespread manner.
- Integrating the broadcast media, including TV and radio, more thoroughly into the early warning chain and discouraging unauthorized warnings. Short and frequent updates from warning authorities during emergencies are recommended.

Having reliable information corroborated through diverse channels can prevent panic and false alarms that can undermine public confidence, breed mistrust, dilute the impact of official alerts and reduce the credibility of future warnings. In 2007, in Aceh, Indonesia a local tsunami siren went off by mistake causing mass panic and injury as residents fled. Anger led residents to later disable the tsunami warning system, causing unnecessary vulnerabilities and long-term risk.[43]

Response capability

Warnings are only useful if they reach the last mile and people are capable of acting on them. There thus needs to be constant attention to



Cover page of educational booklet on the 1945 Makran tsunami, produced by UNESCO with financial support from the ESCAP Multi-Donor Trust Fund for Tsunami, Disaster and Climate Preparedness.

the linkages between the warning system and the communities at risk (Box III-8). Risk maps and contingency plans, for example, require continuous updating to match changes in population and land use patterns. Proper signage and evacuation centres need to be maintained. These activities should be accompanied by sustained education and outreach to maintain risk awareness among local communities and government officials.

Regional warning mechanisms also need to be tested down to the local level (Box III-9). Currently, local exercises and drills tend to be ad-hoc and not linked to the revision of SOPs, leading to missed opportunities for learning and for system improvement.

Cross-cutting issues

Beyond the unmet needs within the four elements of early warning, there are a number of cross-cutting issues (Box III-10). Most of the gaps here – such as improving communication among key actors, participation of local communities and performance assessments – relate to good governance. Countries generally have national legislation on specific mandates for early warning

BOX III-8

Main unmet needs in response capability

- Identifying evacuation routes and evacuation centres with proper signs.
- Conducting frequent drills at the community level and simulation exercises for disaster managers (e.g. once a year).
- Ensuring that disaster managers pay attention to the type of expected hazard and the evacuation routes and places that are appropriate for the respective hazard.
- Designing and constructing evacuation centres to withstand common hazards (e.g. severe winds or ground shaking).

BOX III-9

Testing warning systems, end to end

A broader challenge in Asia and the Pacific is to ensure that regional systems are tested end to end. The IOTWS, for example undergoes communications tests every six months and large-scale exercises every two to three years. In general, recent tests and exercises have been successful and shown that the regional system performs well but have not been linked effectively with local-level drills and exercises. At the 2014 region-wide exercise (IOWave14) only three out of 24 participating countries (India, the Seychelles and Timor-Leste) conducted public evacuation drills. As a result, the ability of the regional warning system to trigger local life-saving action was not fully tested. The 10th Session of the Intergovernmental Coordination Group for the IOTWS in 2015 recommended future region-wide exercises to make such public evacuation drills a priority.

Source: IOC-UNESCO, 2015. Exercise Report, IOWave 14.

BOX III-10

Main unmet needs regarding cross-cutting issues

- Ensuring adequate in-country information sharing and coordination.
- Improving the communication between technicians/scientists and other groups using the risk information (e.g. communities, businesses, politicians).
- Integrating various early warning systems to establish multi-hazard systems, as many systems currently only deal with one hazard type.
- Improving the participation of local communities in early warning.
- Addressing the warning needs of people with disabilities and older persons, e.g. by identifying those receptive impaired who live alone and need special arrangements to alert them and assist them in preparations. Gender issues as well as the special needs of other vulnerable groups such as pregnant women and older persons also need to be taken into account.
- Given growing international migration and tourism, integrating non-permanent residents into the early warning system. International standards proving common alert levels and colour codes in a multi-hazard approach could help facilitate this.
- Exploring mechanisms on how to improve the sustainability of early warning systems.
- Improving cost-benefit analysis of early warning, especially for political decision makers and private companies.
- Developing and testing different approaches for assessing the performance of early warning systems (e.g. with success indicators).

roles and responsibilities. But it is important also to build the political will and institutional commitment to ensure the necessary resources and coordination.

To meet the needs of the most vulnerable people, early warning systems must reflect gender considerations and provide for the needs of especially vulnerable groups such as those with disabilities, pregnant women and older persons, who are likely to require extra assistance in the case of an emergency. ESCAP has supported the development of guidelines on early warning for people with disabilities.[44]

FUTURE PRIORITIES

For the global target of the Sendai Framework to be reached by 2030, early warning systems and services must be considered public goods that should be widely available and adequately financed by public investment.[45] Such investments have high returns for society as a whole – building resilience, minimizing loss of life and preparing for an accelerated recovery.

Recommendations:

1. Integrate the concept of 'early warning as a public good' into national planning, policy and decision-making.
2. Strive to make early warning systems multi-hazard and people-centred, keeping in mind the response requirements at the local level ('the last mile').
3. Ensure that forecasters are mindful of the specific needs of the end users of different types of warning information, and tailor products and services accordingly.
4. Seek effective communication channels with the people at risk, including by integrating the broadcast media into the early warning chain.

5. Link SOP development/revision with operational tests, including local evacuation drills.
6. Strengthen regional cooperation in early warning, going beyond coastal hazards to include hazards such as transboundary river basins floods.
7. Concentrate external assistance on low-capacity, high-risk countries.

Early warning systems are essential for reducing disaster risks and building greater resilience. But they should be part of coherent framework for disaster risk reduction and have clear institutional arrangements.

ENDNOTES

1 IFRC, 2013.

2 World Bank, 2010b.

3 UNDP, 2010a.

4 Zurich Insurance Group, 2014.

5 OCHA, 2015c.

6 Vanuatu, 2015b.

7 Australian Red Cross, 2015.

8 Coates and Feast, 2015.

9 A 'storm surge" is a rising of the sea as a result of atmospheric pressure changes and wind associated with a storm.

10 GIZ, 2014.

11 The Guardian, 2015.

12 WMO, 2015b.

13 UNISDR, 2006.

14 ESCAP/WMO Typhoon Committee and WMO/ESCAP Panel on Tropical Cyclones, 2015.

15 ESCAP and UNISDR, 2012.

16 ESCAP, 2010.

17 Tsunamigenic refers to those earthquakes, common along major subduction zone plate boundaries, which can generate tsunamis.

18 UNESCO, 2014.

19 Teisberg, 2011.

20 Weinstein, 2014.

21 United Nations News Centre, 2015.

22 Xing, Wood and Ma, 2015.

23 Deltares, 2014.

24 National Meteorological and Hydrological Services

25 ADPC, 2006.

26 *Dzud* is a Mongolian term for a severe winter in which a large number of livestock die, primarily from starvation or directly from the cold.

27 Eldev-Ochir Erdenebat, National Agency for Meteorology and Environment Monitoring of Mongolia, "Early warning system: Status and Priorities", presentation given at the 6th RIMES Council Meeting, Bangkok, Thailand, 29 May 2014.

28 Golnaraghi, 2012.

29 Kellett and Caravani, 2013.

30 See Chapter 1 of this publication.

31 Hallegatte, 2012.

32 Subbiah, Bildan and Narasimhan, 2008.

33 Ibid.

34 Teisberg and Weiher, 2009.

35 World Bank, 2010b.

36 Aysan, 2011.

37 Available from https://www.gfdrr.org/our-portfolio

38 Jaksa, Kumar and Wandono, 2014.

39 Ibid.

40 India, 2012.

41 ESCAP, 2015g.

42 Report from ESCAP/WMO Typhoon Committee Post-Haiyan Expert Mission to the Philippines, April 2014.

43 Pearson, 2012.

44 ADPC, GAATES and ABU, 2014.

45 United Nations, 2015.