From Commitments to Action:

Advancements in Developing an Indian Ocean Tsunami Warning and Mitigation System

Intergovernmental Oceanographic Commission of UNESCO

United Nations
Educational, Scientific and
Cultural Organization

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The Intergovernmental Oceanographic Commission (IOC) of UNESCO promotes international cooperation and coordinates programmes in research, services and capacity building, in order to learn more about the nature and resources of the ocean and coastal areas and to apply that knowledge for the improvement of management, sustainable development, the protection of the marine environment, and the decision-making processes of its Member States.

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IOC Brochure 2006-1

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Promoting a new culture of tsunami awareness

On 26 December 2004 we were confronted with an unprecedented catastrophe: the most deadly tsunami recorded in history. Humanity, perhaps for the first time following the disaster in horror via satellite television, reacted with an equally unprecedented outpouring of solidarity, goodwill and material aid.

The strength of the earthquake that gave rise to this killer tsunami was also exceptional, the most powerful ever recorded since 1964. The associated rupture of the earth's crust at the bottom of the sea extended for over 1,200 kilometres. Science had never before recorded such a strong movement with the new, modern instrumentation developed during the sixties. This was a stark reminder that the entire surface of the planet, composed of tectonic plates, constantly moves in response to huge geotectonic forces. This continuous natural process exposes certain regions of the globe to enhanced seismic hazards, as all inhabitants of the Pacific rim, the so-called 'ring of fire', know from experience.

Taking a wider, long-term view

Disasters like floods, fires, volcanic eruptions, earthquakes, hurricanes, storm-surges and tsunamis are part of Nature. We also face human-made, technological disasters. The losses from natural disasters have increased dramatically in the past decades, not because disasters are increasing in frequency, but because human population and the vulnerability to disasters have increased. Often it is the accumulation of many individual decisions, like the settlement in a coastal megacity, for example, that compounds the natural hazard, adding to the vulnerability of populations and increasing the total risk.

Catastrophic tsunamis are infrequent, travel at the speed of a jetliner over deep water and affect countries far away from their origin. Very often in each locality the return time of large destructive tsunamis can be measured in decades, even centuries. With the passing of several human generations, society loses the knowledge, the collective memory fades away and awareness disappears. In the long run, the ultimate challenge is therefore to put in place and constantly nurture a culture that can counteract this inexorable fact of life.

A lasting way to support the Indian Ocean region's recovery

Today we have the awareness and the political will to act. During the past year, we have built upon a series of international intergovernmental meetings to generate the necessary agreement and spirit of cooperation to establish a single Tsunami Warning and Mitigation System in the Indian Ocean. After several high level meetings, this consensus was obtained in March in Paris during the First Coordination Meeting through the adoption of the basic principles for cooperation among nations and the main architecture of the system.

The Paris meeting went even further and immediately established an Interim Tsunami Advisory Information Service to broadcast seismic tsunami-relevant information to the countries of the Indian Ocean from the Intergovernmental Oceanographic Commission of UNESCO-sponsored

‘Today we have the awareness and the political will to act’

Photo courtesy IISD/Earth Negotiations Bulletin

Dr Patricio A. Bernal

Pacific centres of Hawaii and Tokyo. This system started on 1 April 2005, a day when fourteen Indian Ocean nations had already established their official Tsunami Information Focal Points with the ability to receive and disseminate the information twenty-four hours a day, seven days a week. In fact these information centres were the first bricks of the twenty-eight National Tsunami Warning Centres that are needed for the full operation of the system.

This was just the start of a long process. This brochure will guide you through our advances so far in implementing a complete end-to-end Tsunami Warning and Mitigation System in the Indian Ocean. The success and efficiency of such a system will always depend in the end on the good governance of each country and on long-term support from national authorities. National centres must move away from their present minimal configuration to develop their own national detection networks, their own risk-assessment and preparedness procedures, and their own national educational or awareness plans.

A united effort

We are very proud that this challenge has been approached in a truly cooperative inter-agency style. The Intergovernmental Oceanographic Commission of UNESCO has established close collaboration and valued partnerships with the World Meteorological Organization, the International Strategy for Disaster Reduction, the International Federation of Red Cross and Red Crescent Societies, the United Nations Development Programme, the United Nations Office for the Coordination of Humanitarian Affairs, and sixteen UN agencies and programmes through the UN-OCEAN network. These partnerships have extended to the United States Agency for International Development and many other national agencies, donors and international NGOs and organizations.

The coordination efforts that we are leading with our partners and the public sector on behalf of the UN system are designed to protect lives, property, livelihoods, and the long-term stability and development of our society. May we never again have to witness a disaster of the magnitude of the December 2004 Indian Ocean tsunami.

Dr Patricio A. Bernal
Assistant Director-General, UNESCO
Executive Secretary, IOC

The Asian Tsunami: One Year Later

By Sir Arthur C. Clarke
Award winning author, inventor and visionary
Resident of Colombo, Sri Lanka

The Asian Tsunami of December 2004 left an unprecedented trail of destruction in my adopted country Sri Lanka and around much of the Indian Ocean. When they arrived with little or no warning, the mega-waves were ruthless and indiscriminate. They swept away fishermen and tourists, pilgrims and prisoners, soldiers and rebels.

The Tsunami's death toll could have been drastically reduced if the warning - already known to scientists - was disseminated quickly and effectively to millions of coastal dwellers along the Indian Ocean rim. It is appalling that, in spite of our sophisticated technology, the systems needed to warn people were simply not in place that fateful day.

The best tribute we can pay to all who perished or suffered in this disaster is to heed its powerful lessons. We need to address the long-term issues of better disaster preparedness, functional early warning systems and realistic arrangements to cope with not just tsunamis, but a multitude of other hazards. It is imperative that we improve our monitoring and early warning systems, but we must also put in place a fail-proof plan to sound the alarm as and when necessary. Technology can certainly be part of that solution, but in the end, it depends critically on sound management and nations working together.

Nature has spoken loud and clear, and we ignore her at our peril. Let us make sure we are better prepared next time.

Developing end-to-end tsunami early warning systems in the Indian Ocean and other regions at risk

IOC's mission

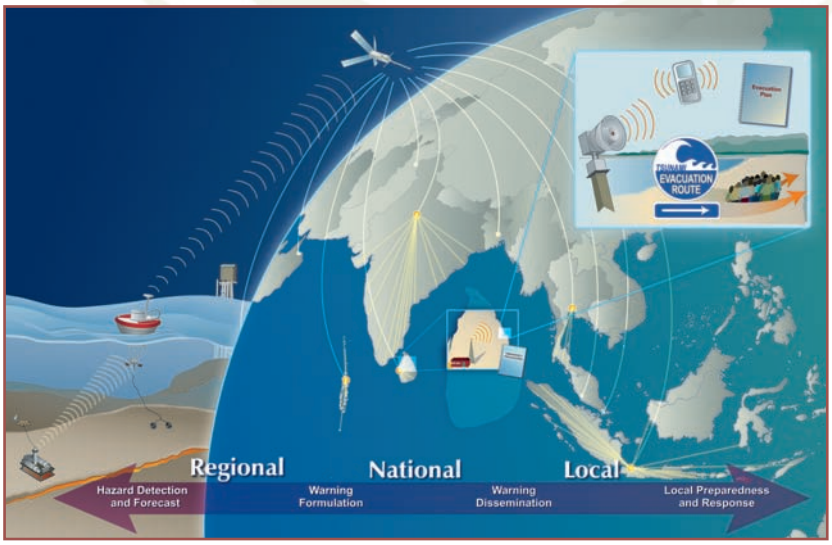
The Intergovernmental Oceanographic Commission (IOC) of UNESCO, established in 1960, acts as the United Nations' focal point for ocean sciences and ocean services. We work to establish international cooperation so that major ocean science programmes operating over vast, often global, areas can take place.

Through the combined resources and abilities of our 133 Member States, we are able to coordinate large-scale initiatives in order to address regional, national and global problems and ensure that equitable access to information and operational oceanographic services are freely available to all.

IOC's role in the Indian Ocean Tsunami Warning and Mitigation System

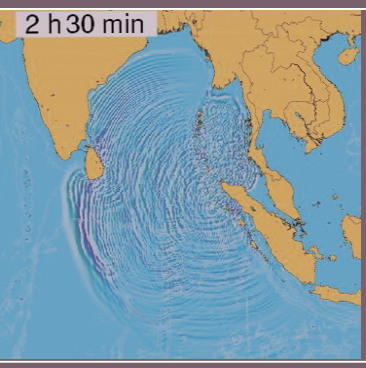
Working together with WMO, UN-ISDR and other key partners at the international, regional, and national levels, the IOC of UNESCO is contributing the expertise acquired during the past forty years running the Pacific Tsunami Warning System (ICG/ITSU). This international ocean service supported by the International Tsunami Information Centre (IOC/ITIC) has - until now - been the only tsunami warning system anywhere in the world. It is one of the most successful, long-term international cooperative programmes ever undertaken by the IOC, serving twenty-six Member States in the Pacific region.

Through the concerted action of the Member States of the IOC of UNESCO, this experience is currently being fast-tracked to help the Indian Ocean countries to benefit from an interim tsunami advisory system and to undertake the building of a full-fledged Tsunami Warning and Mitigation System, with an initial operational date forecast for July 2006.



Courtesy of USAID and the U.S. Indian Ocean Tsunami Warning System Program

If an earthquake occurs, the Indian Ocean Tsunami Warning and Mitigation System will confirm if a tsunami wave has been generated and send out warnings to the authorities and to the exposed population.



Courtesy of NOAA

No warning

The lack of an operational warning system in the Indian Ocean meant a tragedy of unprecedented proportion.

At 0100 GMT on 26 December 2004 a 9.3 magnitude earthquake occurred on the sea floor near Aceh, northern Indonesia, generating a powerful wave resulting in the strongest tsunami the world has known in over forty years. The wave spread in all directions. Towards the east, the tsunami surged ashore without warning just north of Phuket, Thailand, where the waves hit the beaches at up to 10.5 metres (34 ft) high and speeds of up to 8 metres a second (29 kms/hr). Towards the west, it continued on, still without warning, taking close to two hours to reach Colombo, Sri Lanka and then the east coast of India. Almost eight hours after the tsunami had hit Asia, the fishing communities of Somalia and Kenya still had no idea that the wave was coming. With a warning system in the Indian Ocean, it would have been possible to warn, evacuate and save countless lives.

When the wave receded

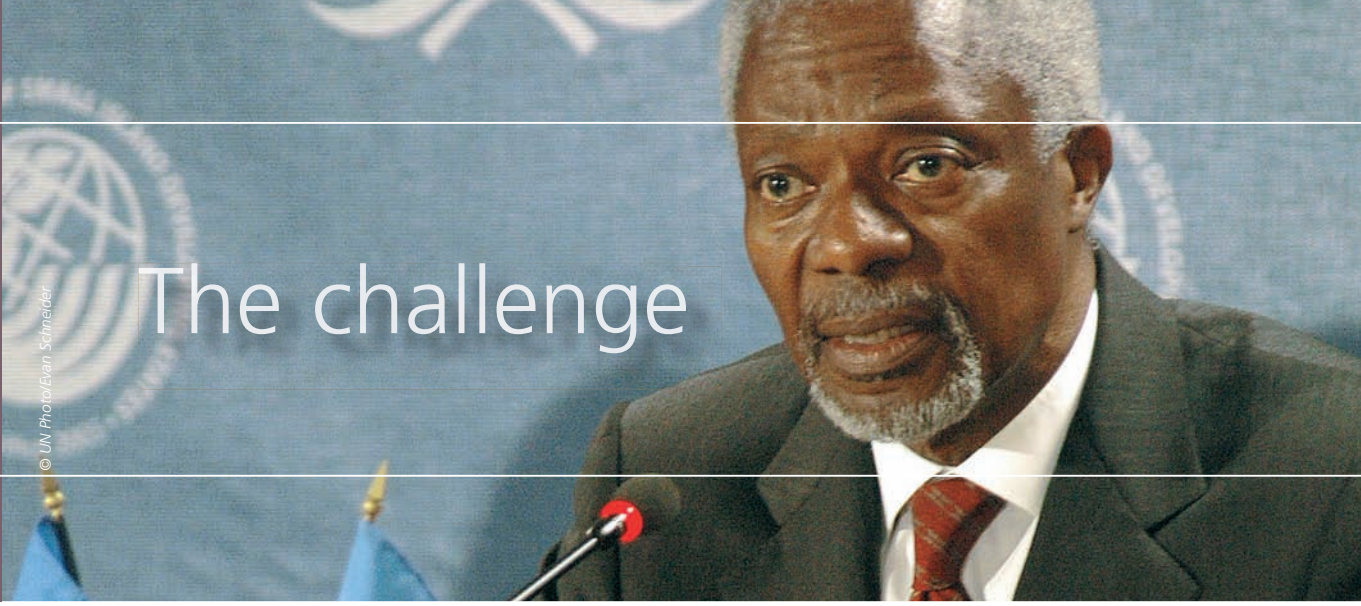
The Indian Ocean tsunami is estimated to have killed over 240,000 people and severely affected more than 158 million more. Half a million people were injured, one million displaced and at least five million more needed urgent assistance.

Today, millions of people in the region are still struggling to regain their livelihoods and re-establish their homes. The Asian Development Bank estimates that the five countries hit by the tsunami -- Indonesia, India, Sri Lanka, the Maldives and Thailand -- suffered nearly $8 billion in overall damage and losses. Indonesia experienced the most significant loss with damages totaling $4.5 billion to $5 billion, followed by India at $1.5 billion. Sri Lanka's losses totaled $900 million, while the Maldives suffered approximately $300 million in losses.

The need for a tsunami early warning system

There is little doubt that thousands of lives could have been saved if an alert system, similar to that operating in the Pacific since 1965, had been in place in the Indian Ocean region. The population in Banda Aceh would most likely have had to depend on its own awareness and emergency preparedness to protect itself. However, the coast of the rest of Indonesia, Thailand, Malaysia, Sri Lanka, India, the Maldives, Seychelles, Australia, Somalia, Kenya, and in fact all the rest of the Indian Ocean Basin would have been fully protected had there been a properly issued warning.

Most large destructive tsunamis are generated by big earthquakes. However, given our current state of knowledge, the date, time and place where an earthquake will occur cannot be forecast. The causal link between earthquakes and tsunamis is weak, and at best unidirectional. Although most distant (or teletsunamis) are caused by earthquakes, only a small proportion of earthquakes generate destructive teletsunamis. Tsunami warning depends strictly on an early detection of a tsunami perturbation in the ocean itself. It does not and cannot depend on seismological information alone.



The challenge

UN Secretary-General Kofi Annan

Getting the warning out

An effective early warning system must be able to detect and locate with sufficient precision the place and depth of an earthquake, confirm if a tsunami wave has been generated (as only a very small proportion of earthquakes generate tsunamis), and send out a warning to the authorities and to the exposed population in the right manner. Such a system requires an infrastructure so that those who are notified must then immediately know exactly what to do, where to go and how fast they need to go there when alerted.

The system is not just science and 'hard technology' associated with the detection and communication of the warning. The system is as much 'soft' technology associated with the organization and management of tsunami risk. This involves the setting up and running of national services, the training of the human resources required and the implementation of complex emergency preparedness and awareness plans at national and local levels.

Designing a system to cope with different types of tsunamis

The actual danger posed by tsunamis is specific to a given region. Local tsunamis (less than 100 Km) or regional tsunamis (less than 1,000 kms) can be generated by small earthquakes, a landslide or lava flow. Distant tsunamis (or teletsunamis) on the other hand, like the one off the coast of Sumatra on 26 December 2004, can travel thousands of kilometres over the deep ocean before hitting the coastline.

Depending on the location of the source in respect to the coast, a tsunami can strike the shore within minutes, leaving very limited time for issuing an alert. In such a case, the affected population must depend almost exclusively on its own knowledge, awareness and preparedness and on effective communication networks if a warning becomes available. Distant tsunamis, however, allow more time to react, warning centres can notify national authorities and evacuations can be safely carried out.

The challenge is therefore to put in place a warning system that can protect local populations at very short or no notice, as well as populations far away from the origin where a proper warning and confirmation of a tsunami can be effectively issued.

© UNESCO/Evan Schneider

'We cannot stop natural calamities, but we can and must better equip individuals and communities to withstand them.'

UN Secretary-General Kofi Annan

Coordinating international partners and global scientific efforts

No single country can adequately protect itself from tsunamis without an international network composed of hundreds of observation stations. In order to build a truly regional system, countries need to pool their efforts, commit their assets and institutions, and assume responsibility for their maintenance and upgrade. Working together, nations can contribute national resources through their concerted action under the Intergovernmental Oceanographic Commission of UNESCO coordination process, especially in terms of data sharing.

IOC of UNESCO's strategy for system design and management

The architecture of the system consists of the simultaneous operation of two distinct components:

1) Internationally coordinated detection networks of instruments and
2) A network of twenty-eight National Tsunami Centres.

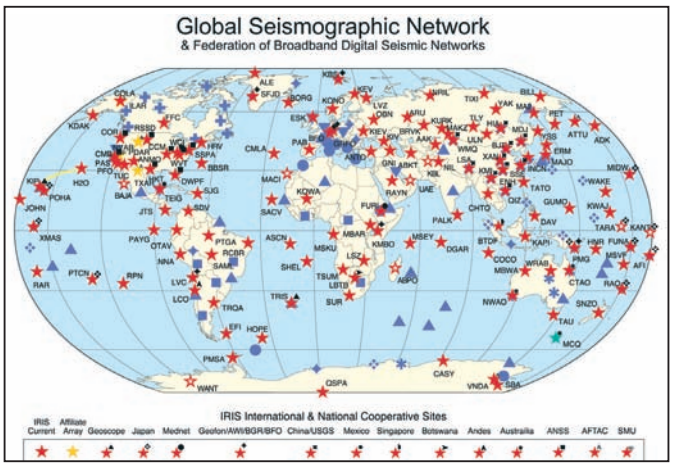
IOC of UNESCO will coordinate at the intergovernmental level both the detection networks and the national efforts, and each country will be responsible for its own national Tsunami Warning Centre, capable of receiving and disseminating warnings to national authorities and ultimately the population. National Tsunami Warning Centres are the development of emergency preparedness and awareness plans, including hazard and risk assessment of their coastal regions and populations.

IOC of UNESCO is assisting nineteen countries that have requested it to carry out needs assessments in respect to material and capacity building requirements, and in relation to public awareness and risk reduction needs. Recommendations have been delivered directly to, and discussed with, national authorities and will be used to guide technical plans and support national and regional strategies.

The Indian Ocean tsunami warning and mitigation system

What exactly is 'the system'?

A reliable system is essentially composed of an internationally run detection/alert system linked to nationally run warning and disaster management organizations.



The Global Seismographic Network (GSN) consists of more than 125 GSN stations located around the world with near-uniform spacing.
Map courtesy of the Global Seismographic Network (GSN), a cooperative scientific facility operated jointly by the Incorporated Research Institutions for Seismology (IRIS), the United States Geological Survey (USGS), and the National Science Foundation (NSF).

The detection system is built on state-of-the-art technology combining three elements: an improved seismographic network; a real-time sea-level observing network covering all of the Indian Ocean basin; and the deployment of deep-sea pressure sensors capable of detecting the tsunami signal close to its origin or as it travels over the deep ocean.

Most importantly, as Laura Kong, Director of the IOC of UNESCO International Tsunami Information Centre in Hawaii, explains, 'the system is not just seismic data and water levels but making sure that a warning gets out to government agencies and that those agencies already have a tsunami response plan'. Awareness campaigns that train the public to respond to warnings in homes, schools, hospitals and businesses in vulnerable regions are the vital final key to making the system effective.

Building a system that will last

Tsunamis are relatively rare and future generations must be protected against the eventuality that the next event may occur decades or even centuries from now. The most cost effective and efficient way to provide data for ocean hazard warnings is therefore to integrate the system within a long-term ocean observing strategy that includes other natural hazard warning systems, such as El Niño, seasonal forecasts of climate, hurricanes, storm surges and large-scale ocean circulation changes.

In this way, data that will be eventually used for tsunami warnings will also be used regularly for other purposes and be of potential interest to an enormous array of users and stakeholders. It is these other users who will ensure the system is maintained operationally over the long term. This is precisely the strategy the IOC of UNESCO has been following to put in place the Global Ocean Observing System (GOOS), the climate module of which constitutes the ocean component of the Global Climate Observing System (GCOS).

‘If another tsunami happened today in the region, people will be safer and will have a better chance to save their lives.’

Salvano Briceño, Director of the International Strategy for Disaster Reduction (ISDR)

Who is involved in the system?

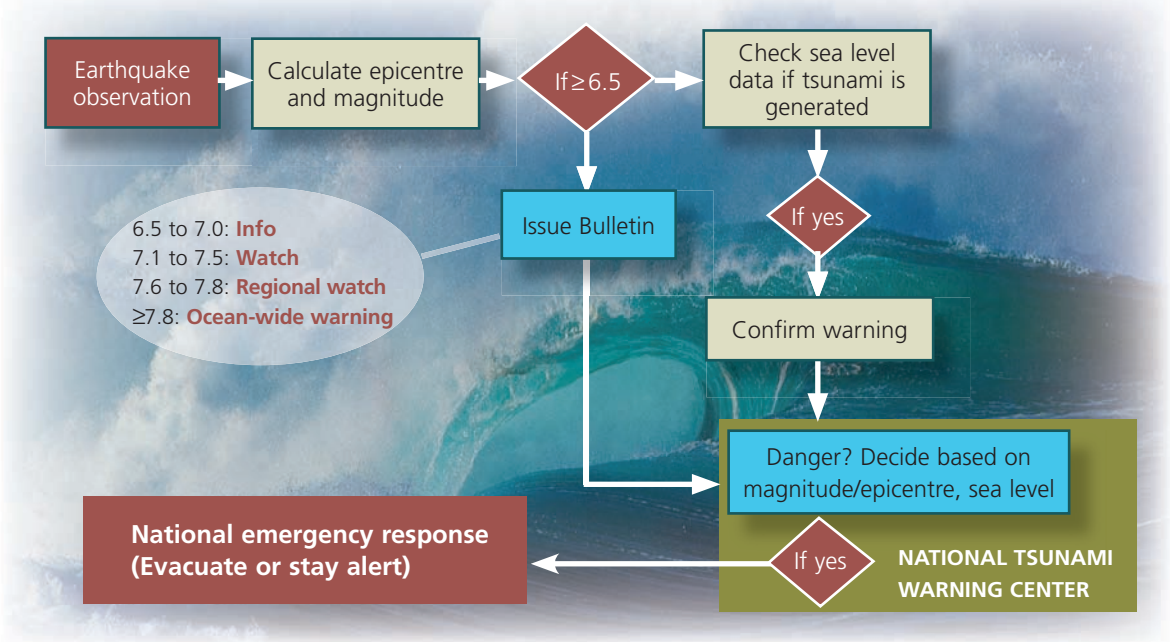
Developed in close collaboration between the Intergovernmental Oceanographic Commission of UNESCO, the World Meteorological Organization (WMO) and the UN International Strategy for Disaster Reduction (ISDR), the Indian Ocean Tsunami Warning and Mitigation System’s assets are owned and operated by the Member States hosting or otherwise taking responsibility for them.

The IOC of UNESCO is using its intergovernmental mechanisms and its technical networks to mobilize national and regional agreement and action to design and build the core elements of the system. We provide the governance structure through the Intergovernmental Coordination Group (ICG) to commit resources, constantly evaluate the status of the system and assess how it satisfies needs.

The ICG was created last June in Paris, France as a subsidiary body of the IOC Assembly. It is chaired by Dr P.S. Goel, Secretary of the Department of Ocean Development of India, seconded by S.C. Seeballuck, Secretary of Home Affairs of Mauritius, and Jan Sopaheluwakan, Deputy Chairman for Earth Sciences at the Indonesian Institute of Sciences.

The networks of instruments, operated by national agencies from Member States, are coordinated by IOC of UNESCO under the principles of international cooperation and the free, open and unrestricted exchange of data and information.

Interim Tsunami Advisory Information Service.
The upgrade of the regional sea level network for tsunami monitoring will enable the Centres to issue Tsunami Warning messages in the future.



Tsunami Hazard Assessment

Nations must first of all be able to identify vulnerable areas and populations and the level of risk in order to develop a national response plan to warn against both local and distant tsunamis and prepare appropriate action to reduce the impact of hazards.

Historical data from earlier tsunamis may help quantify these risks. Numerical models can provide estimates of areas that will be flooded in the event of a local or distant tsunami in order to form the basis for creating evacuation maps and procedures.

IOC of UNESCO's action plan, in partnership with other UN agencies and organizations, strengthens national capacities by providing products for risk assessment and training for disaster risk management of tsunamis and other related coastal hazards, such as typhoons. National hazard assessments identify training needs and facilitate the transfer of knowledge and expertise for the development of basic emergency preparedness tools, such as precise inundation maps of vulnerable coastal areas.

To date, twenty-six Indian Ocean countries have enhanced their knowledge and capacity to identify requirements for national tsunami warning and mitigation systems through participation in two study tours to Japan and Hawaii organized by UN/ISDR and the IOC of UNESCO. Fifty high level administrators, responsible for tsunami warning activities in Indian Ocean rim countries, attended these tours in order to observe existing Pacific Ocean tsunami early warning systems. The knowledge they have gained is already being used to organize national tsunami early warning centres and provide disaster response information products, such as evacuation plans, inundation maps and educational materials needed by the public and decision-makers.

© Digitalglobe

Satellite images of Banda Aceh, Indonesia, before the tsunami (left) and the extent of flooding following the disaster (right).

2 Tsunami Detection and Warning

On 28 March 2005 an 8.7 magnitude earthquake near Nias, Indonesia caused widespread panic. It was feared that another tsunami, similar to that of 26 December 2004, would be generated but the ocean remained calm. In fact, very few such strong, shallow earthquakes actually produce tsunamis.

Until now, tsunami detection has largely relied on the Global Seismic Network, a research network of seismographs that detects the location and depth of earthquakes. This network was not designed for an optimal detection of earthquakes that can originate tsunamis. Significant improvements to this network have been agreed among participating nations. Nevertheless, in order to reduce the number of false alarms and increase public confidence, effective tsunami warnings cannot be based on seismic information alone.

The detection component of the Indian Ocean Tsunami Warning and Mitigation System is comprised of three networks of instruments in addition to the seismographic network, including a sea level network and the deployment of deep sea pressure sensors, which continuously transmit data in real-time to warning centres.

The Global Ocean Observing System (GOOS)

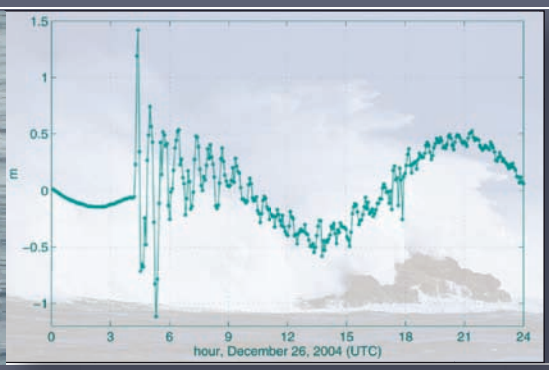
GOOS is one of the main operational observing systems overseen by the IOC of UNESCO. GOOS includes observations using many types of instruments and platforms constantly reporting in real-time and delayed mode on the state of the ocean and is active in the coordination of a number of observation networks in the Indian Ocean. GOOS is implemented by national and regional partners, and benefits from the technical guidance of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM).

Deep-ocean Assessment and Reporting of Tsunamis (DART)

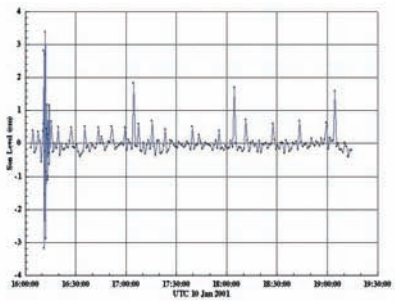
Although some significant technological progress has been attained, effective warning for populations located very close to the source of a distant tsunami (or teletsunami) is at the limit of science and technology. DART buoys are critical to improve the rapid detection and forecast of tsunami as they can be deployed offshore near tsunamigenic areas. Each DART system includes a seafloor bottom pressure-recording (BPR) instrument that can detect small sea level changes and send data to a companion surface buoy with satellite transmitters for real-time communications. In case of a seismic event the observations are used in numerical models to find the direction of propagation and determine when a tsunami would make landfall. There are plans in progress by seven Indian Ocean nations for the deployment of deep-ocean tsunami detection instruments covering both the Sumatra and Makran sources, off Indonesia and Pakistan respectively.

Courtesy of GFZ Potsdam

Tsunami detection buoy



Sea level as observed at Male (Maldives) on 26 December 2004 showing the arrival of the first wave generated by the Indian Ocean tsunami. *Courtesy of Mark Merrifield, University of Hawaii Sea Level Center.*



The 10 January 2001 M6.9 Alaskan earthquake was an excellent example of the value of DART data to quickly confirm potentially destructive tsunamis and reduce false alarms. The earthquake occurred at 07:03 local time about 70 miles southwest of Kodiak, Alaska, and an information bulletin was issued at 07:08 by the warning centre. At 07:11, a DART system at 51 deg N and 157 deg W picked up the earthquake waves that induced an apparent sea level change of approximately six centimeters and triggered the buoy to start transmitting 1-minute data. By 07:13 these data were plotted on the website, and showed no tsunami present.

The Global Sea Level Observing System (GLOSS)

Established in the mid-1980s by the IOC of UNESCO, and now part of GOOS, the global network of tide gauges under GLOSS represents a critical part of the Indian Ocean Tsunami Warning and Mitigation System. These sea level stations can detect the presence or absence of a tsunami generated wave after a strong earthquake by measuring sea level changes. Resulting data can also be used for operational storm surge monitoring and modelling, production of flood maps and monitoring of long-term sea level change.

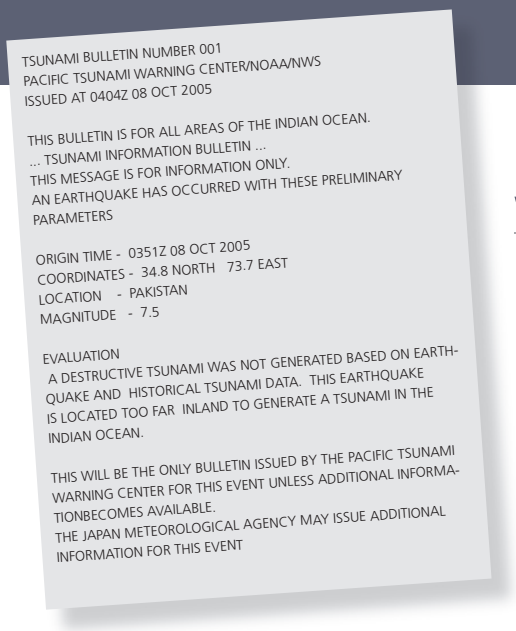
The IOC of UNESCO is currently coordinating the upgrade of the GLOSS network of tide gauges in the Indian Ocean to enable them to measure and broadcast continuously. By mid-2006 twenty-three stations will be continuously transmitting data in real-time.

An immediate enhancement of existing sea level networks has already begun. Instruments are being upgraded to make them real-time compliant. The map on the left shows which organization will fund the real-time sea level station upgrades. Under the Indonesian-German bilateral agreement an estimated additional ten gauges will be installed.

The map on the right shows the estimated timeline for the Indian Ocean installations. Five installations are planned under the Indonesian-German agreement in 2006.
Maps courtesy of Mark Merrifield and Bernie Kilonsky, University of Hawaii Sea Level Center

‘Such systems must incorporate more than technology … They should represent a new way of thinking that ensures environmental stability factors, based on local wisdom and knowledge, are built into disaster plans.’

UNEP Executive Director Klaus Toepfer



TSUNAMI BULLETIN NUMBER 001
PACIFIC TSUNAMI WARNING CENTER/NOAA/NWS
ISSUED AT 0404Z 08 OCT 2005

THIS BULLETIN IS FOR ALL AREAS OF THE INDIAN OCEAN.
... TSUNAMI INFORMATION BULLETIN ...
THIS MESSAGE IS FOR INFORMATION ONLY.
AN EARTHQUAKE HAS OCCURRED WITH THESE PRELIMINARY PARAMETERS

ORIGIN TIME - 0351Z 08 OCT 2005
COORDINATES - 34.8 NORTH 73.7 EAST
LOCATION - PAKISTAN
MAGNITUDE - 7.5

EVALUATION
A DESTRUCTIVE TSUNAMI WAS NOT GENERATED BASED ON EARTHQUAKE AND HISTORICAL TSUNAMI DATA. THIS EARTHQUAKE IS LOCATED TOO FAR INLAND TO GENERATE A TSUNAMI IN THE INDIAN OCEAN.

THIS WILL BE THE ONLY BULLETIN ISSUED BY THE PACIFIC TSUNAMI WARNING CENTER FOR THIS EVENT UNLESS ADDITIONAL INFORMATIONBECOMES AVAILABLE.
THE JAPAN METEOROLOGICAL AGENCY MAY ISSUE ADDITIONAL INFORMATION FOR THIS EVENT

Warning Centres

In order to benefit from international tsunami warning data, every country’s government must designate a National Agency, with operational capabilities 24/7 to act as its National Tsunami Warning Centre. Designated Warning Centres, receiving all the information from the detection networks are then responsible for issuing information bulletins with predicted tsunami travel and arrival times at selected coastal communities to alert all participating centres. National centres take responsibility to issue domestic warnings in the territory under their jurisdiction.

At the present time, twenty-six countries in the region have established official Tsunami Focal Points to receive interim advisory information based only on seismological information from the operational centres serving the Pacific in Hawaii and Tokyo.

These countries are: Australia, Bangladesh, Comoros, East Timor, France, India, Indonesia, the Islamic Republic of Iran, Kenya, Madagascar, Malaysia, the Maldives, Mauritius, Mozambique, Myanmar, Oman, Pakistan, Seychelles, Singapore, South Africa, Sri Lanka, Tanzania, Thailand, the United Arab Emirates, the United Kingdom and Yemen.

Communications

Tsunami warning systems have unique and extensive communications requirements. Meeting these needs requires a variety of communication methods through satellites, fiber optic networks, and cellular telephone technologies.

The WMO’s Global Telecommunications System (GTS) is being used as the backbone for the distribution of Tsunami Warning System bulletins to countries on the Indian Ocean rim region, including the Interim Tsunami Advisory Information service, and will have the added long-term advantage of providing the basis for an all-hazards information exchange system for the future.

3 Tsunami Awareness and Emergency Preparedness

Ten years ago on 17 January 1995, the city of Kobe, Japan was struck by a major earthquake that, in just twenty seconds, killed 6,433 people and injured 40,000 more. At that time, according to Satoru Nishikawa, Director for Disaster Preparedness of Japan's Cabinet Office, people were not knowledgeable about earthquakes: 'Now they know. We have learnt a great deal since 1995 and we have since invested a lot in education and preparedness measures to improve our resilience to disasters.'

Making sure the warning is heard

The third essential component of the Indian Ocean Tsunami Warning and Mitigation System is an effective education and preparedness programme. Although technology is essential for information analysis and delivery, the success of any warning system lies in its ability to reach people and in people knowing what they need to do.

National and local officials in threatened nations must be prepared to develop appropriate emergency planning and be able to respond to warnings within minutes, and communicate them to local populations via sirens, mass media, specialized radio systems, and other notification technologies.

'It has to be done in the language that is familiar to those people in the communities and it has to take into account the cultures, the religion, a number of different very local issues,' says Laura Kong, Director of the IOC of UNESCO's International Tsunami Information Centre in Hawaii.

Working towards community preparedness

Developing this kind of infrastructure to ensure that people along the coasts receive rapid warnings and know what to do in response is a community based effort, Laura Kong explains, 'so ultimately what we hope is that this is the type of programme that will build or empower communities to be ready for the next tsunami.'

With this objective in mind, public awareness and safety brochures, flyers, mass media information products, school curricula, etc. have been custom designed, translated into local languages, and distributed to a wide range of audiences, including the general public and children. Regional workshops involving UN agencies, national institutes, broadcasting agencies and NGOs are being held so that weather warning experts and participants can share experiences and draw up plans to implement public awareness campaigns.

Mobilizing for the Indian Ocean

© UN Photo/Rick Bajornas

During the past year, the Intergovernmental Oceanographic Commission of UNESCO has been simultaneously engaged in two objectives: obtaining political and technical consensus, and building the regional Indian Ocean Tsunami Warning and Mitigation System.

We are achieving both these objectives through an intensive series of high profile, international intergovernmental meetings that have resulted in the unprecedented commitment and unified action of our Member States.

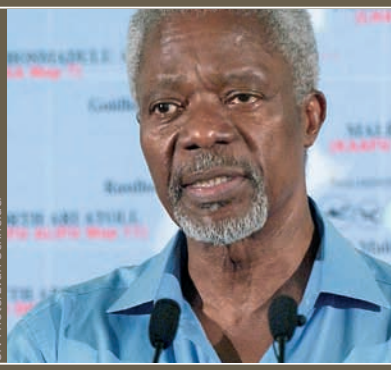
The declarations, principles and agreements produced by nations during these meetings have been instrumental in laying the foundation for developing the technical specifications and establishing the regional intergovernmental framework for an Indian Ocean tsunami early warning system.

As a direct outcome, an interim warning system has now been rapidly implemented in the region and swift progress is being made towards establishing an initial operational system, forecast for July 2006.

Immediate actions taken
28 December 2004: Cooperation with UN-ISDR to draft a joint Project for the UN Flash Appeal; IOC of UNESCO assumes responsibility for the Core System Elements.
31 December 2004: Opening of an IOC of UNESCO electronic mail service to the general public. This service automatically receives all official Tsunami Warning Information Bulletins issued by the Pacific Tsunami Warning Center, the Japan Meteorological Agency and the West Coast/Alaska Tsunami Warning Center. (The list includes about 3,000 institutional and individual subscribers at the present time.)
6 January 2005: Contacts with the CTBTO to explore access to its instrumental networks.

‘Should disaster strike again, and it will in some part of the world, we must be able to say that we did everything humanly possible to build resilient societies.’

UN Secretary-General Kofi Annan



UN Photo/Evan Schneider

Progress achieved in building the system January – December 2005
March, Paris; April, Mauritius: Political and technical consensus achieved on the system’s key elements and technical requirements.
1 March 2005: Opening of a SMS text message service broadcasting all tsunami information messages issued by the Pacific Tsunami Warning Center to government officials and designated authorities through IOC of UNESCO’s collaboration with RANET Project.
Ocean observing systems (IOC of UNESCO) and data communications (WMO/GTS) being upgraded and connected throughout the region.
Data from the CTBTO seismographic network experimentally tested, demonstrating significant improvement in reducing time-lags and increased precision in the determination of epi- and hypocentres.
25 July 2005: Opening of a real-time earthquake broadcasting display and alerting tool to government and other official agencies through IOC of UNESCO’s collaboration with the U.S. Geological Survey.
Data of existing observational systems now freely available throughout the region through GTS.
11 November 2005: Twenty-three real-time sea level stations being established in countries of the Indian Ocean, completing the upgrading of the GLOSS sea level network in the region; seven are already in operation. Provision of a sea level data decoder and display tool for satellite-transmitted sea level data to tsunami warning centres for tsunami monitoring.
National capacity assessed in participating Member States. Sixteen national reports available. Synthesis report published. Three missions pending.
14 December 2005: Capacity building, training and educational programmes started. Provision of custom tsunami awareness materials for the general public and children that can be adapted according to the needs of local populations and cultures.
Mechanism for regional policy setting and coordination instituted, IOC Resolution XXIII-12, Intergovernmental Coordination Group, July 2005.
Twenty-six operational National Tsunami Focal Points presently receiving tsunami-relevant information and warnings from Tokyo and Honolulu within the framework of the interim system.
Resources mobilized to implement an initial Indian Ocean Tsunami Warning and Mitigation System by July 2006.

A year of international cooperation and political will

6 Jan 2005

Nations unite for action

Special ASEAN Leaders' Meeting on Aftermath of Earthquake and Tsunami - Jakarta, Indonesia, attended by national leaders and technical experts.

Resulted in: The Declaration on Action to Strengthen Emergency Relief, Rehabilitation, Reconstruction and Prevention in the Aftermath of Earthquake and Tsunami Disaster.

Commitments	Action
To 'Establish a regional early warning system' and 'Promote public education and awareness as well as community participation in disaster prevention and mitigation through *inter alia* a community based disaster preparedness and early response'.	UN Secretary-General Kofi Annan launches a US$977 million flash appeal for emergency aid, the largest ever for a natural disaster. US$18 million of this appeal is targeted at the development of early warning systems and other risk reduction measures.

10-14 Jan 2005

The international community in unanimous agreement

International Meeting for the 10-year Review of the Barbados Programme of Action - Port Luis, Mauritius attended by more than 2,000 delegates from at least 110 countries.

Resulted in: The Mauritius Declaration and Strategy for the further implementation of the Barbados Programme of Action for the Sustainable Development of Small Island Developing States.

Commitments	Action
Agreement for 'the proposed establishment of a regional natural disaster early warning system for the Indian Ocean and the South-east Asia region, and enhanced international cooperation and partnerships to build and manage effective regional early warning systems, public education and awareness, and disaster management'.	Governments specifically back calls for an Indian Ocean extended early-warning system. Donors pledge support. The UN Secretary-General calls for the creation of a global multi-hazard warning system.

‘The risk of tsunami is real ... I therefore urge all governments participating in this initiative ... to really commit themselves.’

Koïchiro Matsuura, Director-General of UNESCO

© UNESCO/Michel Ravassard

Blueprint to strengthen the capacity of disaster-prone countries

18 Jan 2005

The World Conference on Disaster Reduction - Kobe, Japan attended by over 4,000 participants from more than 150 countries.

Resulted in: The Hyogo Declaration and Hyogo Framework for Action 2005–2015.

Commitments	Action
A Common Statement of the ‘Special Session on the Indian Ocean Disaster: Risk Reduction for a Safer Future’ was adopted, recognizing ‘the need to use the experience of the existing Pacific Ocean tsunami early warning systems, making use of the existing coordination mechanisms of the IOC and other relevant international and regional organizations’.	Delegates pledge their support to create a regional tsunami early warning system in the Indian Ocean. Countries across the globe commit national resources and technical assistance in establishing the system.
IOC of UNESCO is invited to lead efforts in establishing the early warning system, not only in the Indian Ocean but extended to all oceans across the globe and including all forms of natural and human-made disasters, including climate change.	Within the framework of the Tsunami Flash Appeal (6 January 2005), the IOC Secretariat requests US$3.5 million for the core system implementation. (The request was approved by UN-ISDR and activities started in March 2005.)

Implementing an interim early warning system

29 Jan 2005

The Ministerial Meeting on Regional Cooperation on Tsunami Early Warning Arrangements - Phuket, Thailand attended by ministers, special envoys, UN agencies and other organizations.

Resulted in: The Phuket Ministerial Declaration on Regional Cooperation on Tsunami Early Warning Arrangements.

Commitments	Action
Delegates agreed ‘to cooperate towards the establishment of interim early warning arrangements and strengthening and upgrading of national systems, while moving towards a coordinated regional system’.	IOC of UNESCO starts plans to establish an interim system by September 2005 and a long-term fully-fledged system with a target completion date of mid-2006.
Delegates agreed ‘to take immediate and practical steps to enhance early warning capabilities in the Indian Ocean and South East Asia’.	UNESCO works with the Asian Disaster Preparedness Centre in Thailand and the Asian Disaster Reduction Centre in Japan to fast-track the linguistic and cultural adaptation of awareness materials developed for the Pacific Region including public brochures, teaching materials and other tools.

The Second International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean (From left to right): Dr Patricio A. Bernal, Executive Secretary, IOC; Hon. Paul Raymond Bérenger, Prime Minister of Mauritius; Hon. R.A. Bhagwan, Minister of Environment & National Development Unit; Mr Salvano Briceño, Director, UN/ISDR.

16 Feb 2005

Long-term plans – a global warning system

The Third Earth Observation Summit - Brussels, Belgium, attended by more than 50 representatives of the world's governments.

Participants issued a communiqué supporting 'the coordinating activities of the UNESCO Intergovernmental Oceanographic Commission and related national and regional initiatives to realize effective tsunami warning systems in the Indian Ocean and other regions of the world, as an integral part of a multi-hazard approach supported by the Global Earth Observing System of Systems (GEOSS)'.

3-8 Mar 2005

An interim tsunami warning system takes shape

International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean within a Global Framework - Paris, France attended by governmental experts and organizations from 45 countries. Experts discussed technical information with Indian Ocean Member States and drafted a framework proposal for international, regional and national level involvement in the tsunami warning system.

Resulted in: The Communiqué of the International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean within a Global Framework.

Commitments	Action
All nations agreed to participate in a single process coordinated by the IOC of UNESCO to harmonize all international efforts being made.	Recommends establishing the Intergovernmental Coordination Group (ICG/IOTWS), with IOC of UNESCO as Secretariat to govern the system.
It was agreed to start an interim tsunami advisory information service effective 1 April 2005. The interim system would be based on a coordinated network of National Tsunami Centres and each Member State would be responsible for issuing warnings within its respective boundaries based on the free exchange of necessary data among countries.	As of 1 December 2005, there are 26 (out of 28) national tsunami information centers, established as an interim step, capable of receiving and distributing tsunami advisories 24/7, relying exclusively on seismic data from earthquake-monitoring stations in Tokyo (Japan Meteorological Agency) and Hawaii (Pacific Tsunami Warning Center).

(Continued, facing page)

'At a time when the international community has already committed itself to upholding minimum standards of development, we cannot replace poverty with poverty, and leave people as vulnerable to tragedy as they were before. We must do better, and by working together, we will.'

Former U.S. President and the UN Secretary General's Special Envoy for Tsunami Recovery, Bill Clinton

© WFP/Barry Came

Commitments	Action
It was further agreed to install and/or upgrade sea level gauges in affected countries to cover immediate sea level observation gaps in the Indian Ocean. Through a joint project with the UN-ISDR the installation of 6 new sea level gauges in India, Indonesia, Malaysia, Myanmar, Sri Lanka and Thailand, and the upgrading of 15 others placed throughout the Indian Ocean basin was planned, along with the installation of deep ocean bottom pressure sensors.	By mid 2006 there will be 23 stations continuously transmitting data in real-time as part of the GLOSS network in the Indian Ocean. (See station maps on page 13.) After eight months of designing, testing and surveying, the first GPS early warning deep ocean bottom pressure sensors were deployed by Germany and Indonesia off the coast of Sumatra in November 2005.
A timeline for implementation was determined.	The initial tsunami warning system will be operational by July 2006, composed of an improved seismographic network (25 new stations) and a real-time sea level network (23 new stations), plus three Deep-ocean Assessment and Reporting of Tsunamis (DART) sensors (one deployed by Malaysia and two by Germany).

13 Apr 2005

Special Envoy for Tsunami Recovery

The UN Secretary-General appoints former U.S. President Bill Clinton as Special Envoy for Tsunami Recovery 'to mobilize support for regional efforts to establish a mechanism for disaster prevention and mitigation, making sure, in particular, that the proposed regional early warning system for the Indian Ocean countries and South-East Asia is established'.

14-16 Apr 2005

The way forward

Second International Coordination Meeting for the Development of a Tsunami Warning and Mitigation System for the Indian Ocean - Grand Baie, Mauritius, attended by high level government officials and donors to discuss funding and to agree on implementation requirements and national strategic plans.

Resulted in: The Mauritius Declaration on the Second International Coordination Meeting for the Development of an Indian Ocean Tsunami Warning and Mitigation System.

Commitments	Action
Participants invited 'the countries of the Indian Ocean to complete by July 2005, where necessary with the support of IOC-UNESCO, an assessment of their requirements and capacity needs for an effective and durable national tsunami warning and mitigation system, to be followed by the development of appropriate national strategic plans'.	IOC of UNESCO and partner agencies undertake 16 national assessment missions between May and August 2005 to interested countries to determine available resources and inform stakeholders on the strategic requirements needed for establishing the system.

(Continued, next page)

Jakarta, Indonesia, October 2005: the tsunami early warning buoy hand-over celebration event. *© BGR 2005*

Commitments	Action
The UN's World Meteorological Organization (WMO) Global Telecommunications System (GTS) was recommended as a backbone system for sending bulletins for contact points.	Indian-rim countries requiring upgrading of their equipment and GTS links identified; WMO plans expert missions to them.
Commitments of participating countries and partners by calling 'for the formal creation of the Indian Ocean tsunami warning system and the Intergovernmental Coordination Group by a resolution at the Assembly of the IOC of UNESCO'.	Donors pledge additional financial support, amounting to approximately US$5 million and indicate their continuing support and willingness to provide more financial aid as plans for the system became more clearly defined.

21-30 Jun 2005

A historic date – the Indian Ocean tsunami warning and mitigation system formally comes into existence

The Twenty-third Session of the Intergovernmental Oceanographic Commission Assembly – Paris, France. The Assembly supported the leading role accorded to the IOC of UNESCO by the international community in the development of the tsunami warning system and called on all relevant UN agencies, other organizations (including non-governmental) and donor agencies to actively collaborate with the IOC of UNESCO.

Resulted in: Resolution XXIII-12.

Commitments	Action
With unanimous approval from the Assembly, the Indian Ocean Tsunami Warning System was formally established, along with the Intergovernmental Coordination Group (ICG) to govern it under Resolution XXIII-12.	The ICG moves to completion of the first phase of its work: the technical design of the system, concentrating on the observational networks to be deployed in the Indian Ocean.
Resolutions were also adopted establishing similar bodies for the Caribbean and adjacent regions as well as the North-East Atlantic, the Mediterranean and connected seas. The Assembly further recommended that the IOC of UNESCO 'conduct an urgent study of the needs for such systems in all oceans and seas'.	Plans are drawn up for the establishment of a global framework for tsunami and other ocean related hazard early warning systems, linked to the establishment of a permanent ocean observing system (GOOS) that the IOC of UNESCO has been pursuing for the past ten years.

'Following the Indian Ocean disaster we had the most immediate and effective response ever from the humanitarian community to a major disaster'

Jan Egeland, United Nations Under-Secretary-General for Humanitarian Affairs

Exchanging knowledge and technology

3-6 Aug 2005

First Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) - Perth, Australia.

Commitments	Action
Evaluations by experts of the technical and scientific requirements of the warning system, as well as the national capacity of Indian Ocean countries to deal with tsunamis (based on assessments carried out by IOC of UNESCO experts) leading to an initial plan for an integrated regional warning system.	The ICG endorses a plan of action to start work in building the system by establishing four technical working groups, given the task of studying the optimal deployment of these instrumental networks. Inundation maps are being developed for a large number of countries, and detection instruments are being updated to provide the real-time information crucial to ensure accurate data.

Moving towards completion

14-16 Dec 2005

Second Meeting of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) - Hyderabad, India. The ICG will review the development of a comprehensive capacity building master plan to guide the system's first phase towards completion in June 2006. This plan will include a definition of the system's core elements, including the basic seismographic network and identification of bandwidth needs for quake waveform transmission, as well as national plans forming the hazard assessment and emergency preparedness pillars of the system.

G. Mark Lane Photography

The National Disaster Warning Centre of Thailand officially opened on 30 May 2005. The Centre has the capability to receive and analyze real-time multi-hazard observational data, and to issue warnings through various means, including a number of warning towers in risk areas, real-time media channels and via SMS to over 20 million mobile phones in Thailand.

Keeping an eye on our Planet

© Jayne Doucette, WHOI

Expanding tsunami warning system coverage to protect regions at risk worldwide.

Continuing expansion

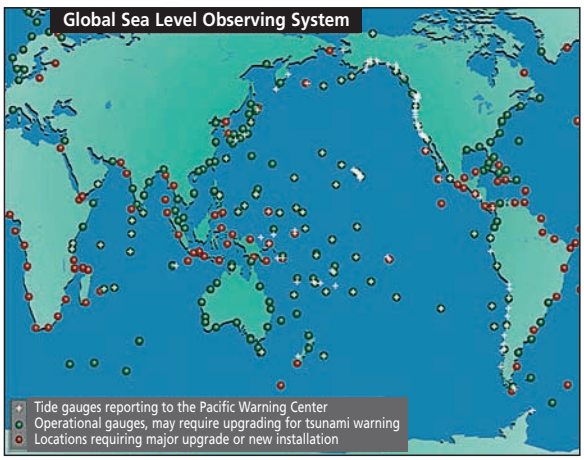
By the year 2025 the UN estimates that three-quarters of the world's population will be living in coastal areas. The expanded tsunami network that the Intergovernmental Oceanographic Commission of UNESCO is coordinating is just the first step in building a global tsunami warning system designed to monitor oceans and seas everywhere.

During the past year, the IOC of UNESCO has been drawing up plans to extend tsunami warning to other regions:

- The Intergovernmental Coordination Group for the North-Eastern Atlantic, the Mediterranean and Connected Seas met in Rome, Italy, in November 2005 and agreed to have an initial operational system in place by December 2007.
- Following a workshop in Mexico City in June 2005, the Caribbean and Adjacent Regions system was established in July and its Intergovernmental Coordination Group is scheduled to meet in January 2006 in Bridgetown, Barbados.
- The Alaska and Hawaii Tsunami Warning Centers, operated by the U.S. National Oceanic and Atmospheric Administration (NOAA) as part of the IOC's International Tsunami Warning System in the Pacific, have already expanded services to provide tsunami alert information to the U.S. Atlantic Coast, the Gulf of Mexico, Puerto Rico, the U.S. Virgin Islands and Eastern Canada. By April 2006, NOAA will have three new sea level stations operational in the Caribbean and the U.S. Geological Survey (USGS) will deploy nine new seismic stations in the Caribbean, all providing data to Tsunami Warning Centers as part of the Global Seismographic Network.

A global comprehensive warning system

The IOC of UNESCO's global framework aims to develop these regional warning systems towards the completion of the Global Ocean Observing System (GOOS). As such, GOOS is expected to be a key first piece in the Global Earth Observation System of Systems (GEOSS), a worldwide effort to build a comprehensive, sustained and integrated Earth observation system within the next ten years, in close cooperation with UN-sponsored observing systems. GEOSS is led by the Group on Earth Observations (GEO), a partnership involving sixty countries, the European Commission, and forty-three international organizations.



© Nature. *Alverson, K. (2005). Watching over the World's Oceans.* Nature *434, 19-20.*

The integration of a global comprehensive warning system not only includes all countries at risk, but also considers all of the hazards (tsunamis, storms, floods) faced together and is crucial to future poverty reduction, environmental and sustainable development strategies.

Nature at its worst; humanity at its best

Courtesy of GFZ Potsdam

The international community responded to the Indian Ocean tsunami with an unprecedented outpouring of goodwill and aid. Governments, the United Nations, international organizations, civil society groups and individuals mobilized to rush relief and emergency resources to tsunami-affected countries. Over US$2 billion alone was pledged by private sources, representing a quarter of all the funding received. Approximately US$1 billion was received from the United States, with hundreds of millions from individuals.

UN Flash Appeal

A provision for the establishment of an early warning system for the Indian Ocean region was included within the UN-launched Flash Appeal, 6 January 2005. Contributions totaling US$11 million were received shortly thereafter. The IOC of UNESCO made a complementary request to the Flash Appeal Mid Term Review for US$12 million to fast-track the warning system implementation, which was positively received.

Countries contributing to these projects are: Australia, Belgium, the European Commission, Finland, France, Germany, Ireland, Israel, Italy, Japan, Norway, Sweden, and the USA. In addition, seven countries in the Indian Ocean have committed large national contributions to build parts of the system as a contribution towards the whole system. These nations are Australia, India, Indonesia, Iran, Malaysia, Pakistan and Thailand.

The Flash Appeal projects will support many organizations as part of an overall needs-based approach - not only the IOC of UNESCO, but also the World Meteorological Organization (WMO), the International Strategy for Disaster Reduction (ISDR), the UN University-Institute for Environment and Human Security (UNU-EHS), the UN Environment Programme (UNEP), the UN Development Programme (UNDP), the UN Economic and Social Commission for Asia and the Pacific (UNESCAP), and others.

© BGR 2005

Indonesia's tsunami early warning system is being implemented through cooperation with China, France, Germany and Japan. The German government, working in coordination with the IOC of UNESCO, is currently implementing a pledge made for 45 million euros to install tsunami warning instruments off the Indonesian coast, and to upgrade Indonesian networks of instruments. The automatic Indonesian-German seismic system installed last June is now operational and the first seafloor equipment and two buoys were installed in Indonesian waters in early November 2005. In addition to the technical components of the system, which involves 47 seismic and 80 tide gauges, public awareness and preparedness activities will also be undertaken.

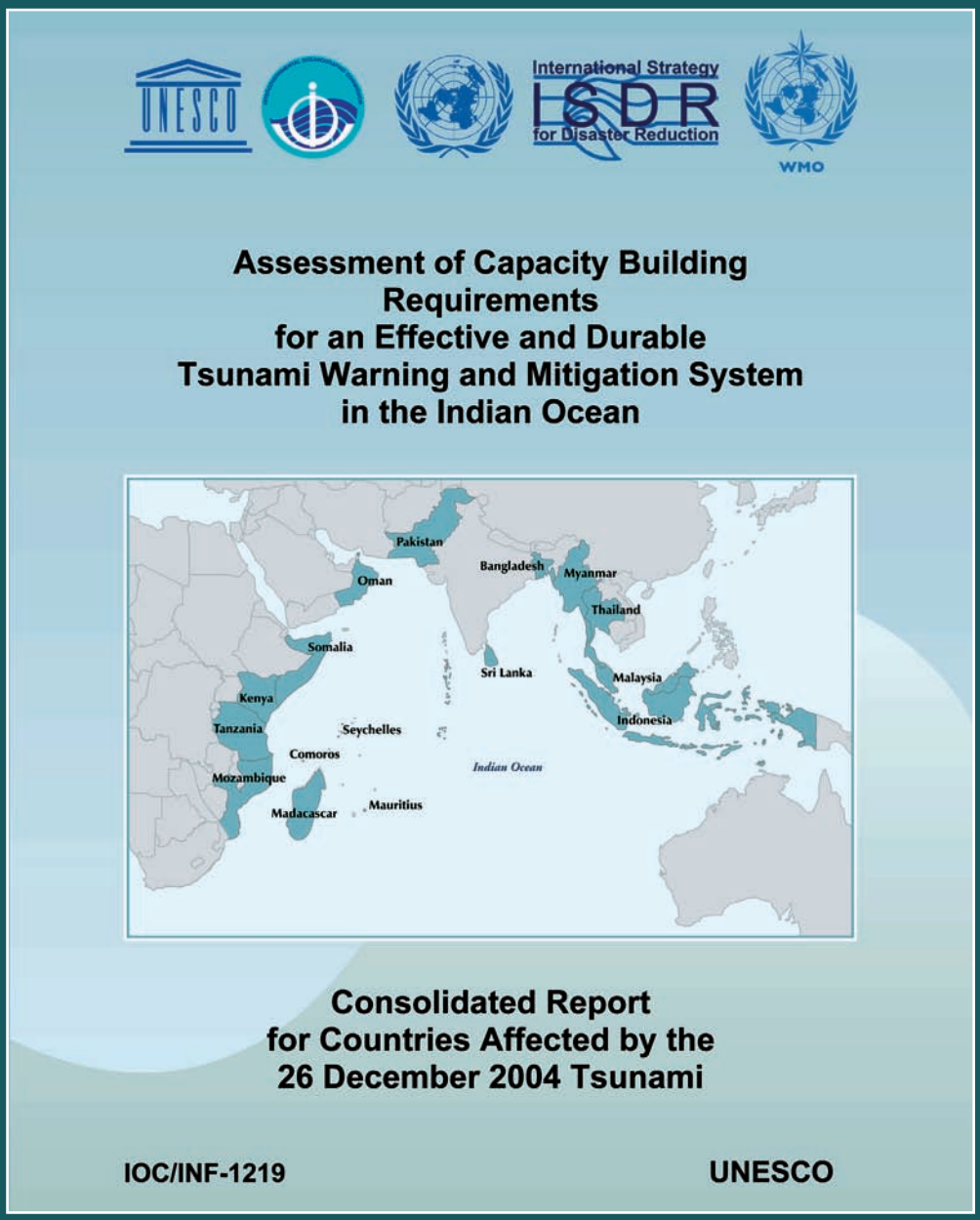
Acronyms

ABU	Asia-Pacific Broadcasting Union
ADPC	Asian Disaster Preparedness Center
ADRC	Asian Disaster Reduction Center
ASEAN	Association of Southeast Asian Nations
CTBTO	Preparatory Commission for the Comprehensive Nuclear Test-Ban-Treaty Organization
DART	Deep-ocean Assessment and Reporting of Tsunamis
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEOSS	Global Earth Observing System of Systems
GFZ	GeoForschungsZentrum Potsdam
GLOSS	Global Sea Level Observing System
GMT	Greenwich Mean Time
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GTS	Global Telecommunications System
ICG	Intergovernmental Coordination Group
ICTs	Information and Communications Technologies
IFRC	International Federation of Red Cross and Red Crescent Societies
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOTWS	Indian Ocean Tsunami Warning and Mitigation System
ISDR	United Nations International Strategy for Disaster Reduction
ITIC	International Tsunami Information Center
ITSU	Tsunami Warning System in the Pacific
JCOMM	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
NOAA	National Oceanic and Atmospheric Administration (USA)
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
PTWC	Pacific Tsunami Warning Center
RANET	Radio and Internet for the Communication of Hydro-Meteorological and Climate Related Information
SMS	Short Message Service
UNDP	United Nations Development Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN-OCEAN	Interagency coordination mechanism on ocean and coastal issues within the United Nations system
UNU-EHS	United Nations University-Institute for Environment and Human Security
UNV	United Nations Volunteers programme
USAID	United States Agency for International Development
USGS	United States Geological Survey
WHOI	Woods Hole Oceanographic Institution
WMO	World Meteorological Organization

Between May and September 2005, international experts conducted national assessments of sixteen countries in the Indian Ocean. These national assessment missions provided an opportunity to define the components and implementation actions of tsunami early warning and mitigation systems and to identify related capacity building opportunities. This Report provides a summary of the types of guidance documents and capacity building activities that will help to catalyse national actions.

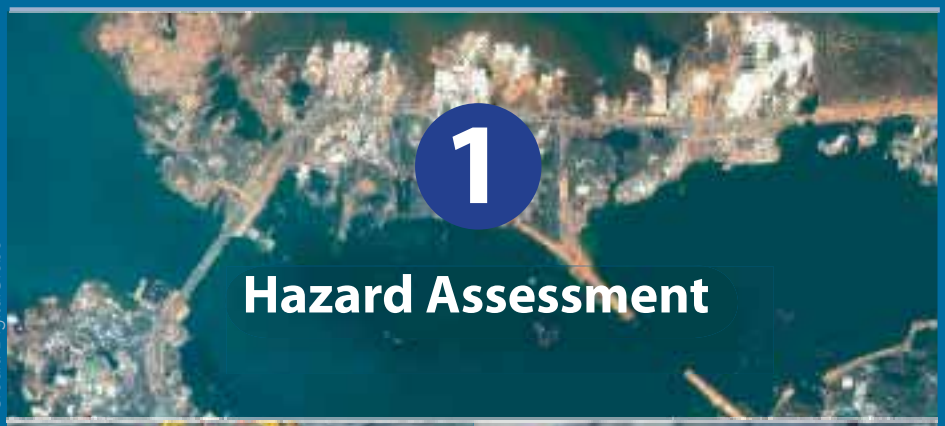
Published by the Intergovernmental Oceanographic Commission of UNESCO.

Now available

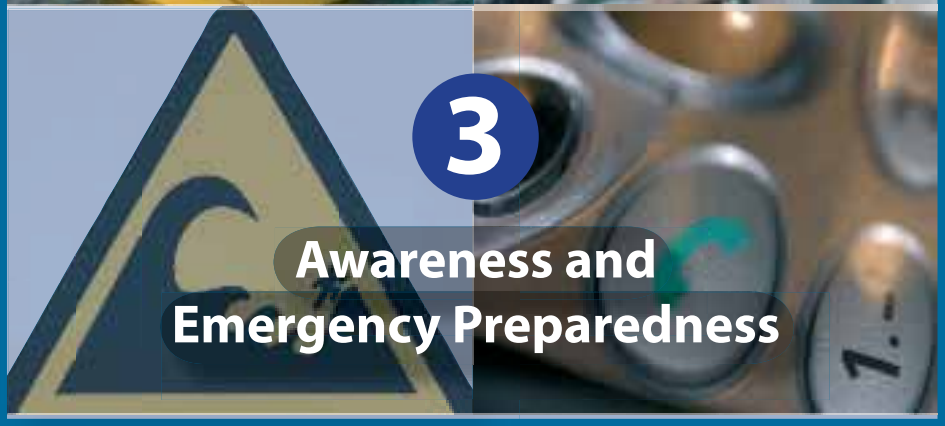


The Consolidated Report for Countries Affected by the 26 December 2004 Tsunami includes a CD-ROM containing the sixteen national assessment reports, which are also available online at:
http://ioc3.unesco.org/indotsunami/nationalassessments.htm

The Indian Ocean Tsunami Warning and Mitigation System (IOTWS)



Credit: DigitalGlobe



The Intergovernmental Oceanographic Commission of UNESCO, in close collaboration with partner agencies, has promoted a consensus among nations that is mobilizing action to design and build the core elements of this system.