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The UNESCO-IOC framework – establishing an international early warning infrastructure in the Indian Ocean region

J. Lauterjung[1], P. Koltermann[2], U. Wolf[2], and J. Sopaheluwakan[3]

[1]Deutsches GeoForschungsZentrum GFZ, Telegrafenberg, 14473 Potsdam, Germany
[2]UNESCO IOC – Tsunami Unit, 1 Rue Mollis, 75732 Paris Cedex, France
[3]Lembaga Ilmu Pengetahuan Indonesia – LIPI (The Indonesian Institute of Sciences), Jl. Gatot Subroto 10, Jakarta 12710, Indonesia

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Abstract. The Sumatra-Andaman earthquake with a magnitude of 9.3, and the subsequent destructive tsunami which caused more than 225 000 fatalities in the region of the Indian Ocean, happened on 26 December 2004. Less than one month later, the United Nations (UN) World Conference on Disaster Reduction took place in Kobe, Japan to commemorate the 1995 Kobe earthquake. The importance of preparedness and awareness on regional, national and community levels with respect to natural disasters was discussed during this meeting, and resulted in the approval of the Hyogo Declaration on Disaster Reduction. Based on this declaration the UN mandated the Intergovernmental Oceanographic Commission (IOC) of UNESCO (United Nations Education, Science and Cultural Organization), taking note of its over 40 years of successful coordination of the Pacific Tsunami Warning System (PTWC), to take on the international coordination of national early-warning efforts for the Indian Ocean and to guide the process of setting up a Regional Tsunami Early Warning System for the Indian Ocean.

1 Introduction

More than 225 000 people lost their lives on 26 December 2004, due to the Sumatra-Andaman Earthquake with a magnitude of 9.3 and the ensuing destructive ocean-wide tsunami. In January 2005 the UN World Conference on Disaster Reduction took place in Kobe, Japan. The Hyogo Declaration on Disaster Reduction is since then the basis for the establishment of Tsunami Early Warning Systems all around the world (UN_1, 2005). During this conference a dedicated resolution was also passed to mandate the Intergovernmental Oceanographic Commission of UNESCO (IOC) to take responsibility for the international coordination of the national efforts in the Indian Ocean regions in order to guide the process of setting up a Regional Tsunami Early Warning System for the Indian Ocean (UN_2, 2005; UN_3, 2005).

2 The UNESCO framework

UNESCO IOC started its activities with a series of regional conferences in Paris in March 2005 and a few weeks later in Mauritius which resulted in the formation of the Intergovernmental Coordination Group (ICG) for the establishment of an Indian Ocean Tsunami Early Warning and Mitigation System (ICG-IOTWS). This ICG-IOTWS started regular work (see Table 1) with its first meeting in Perth in August 2005.

Members of the ICG-IOTWS are all Indian Ocean Rim counties. Ex-officio members are UN organizations, i.e. WMO (World Meteorological Organization), UNDP (United Nations Development Programme), OCHA ((UN) Office for the Coordination of Humanitarian Affairs), donor countries and other invited organizations. The ICG has an organizational structure and is managed by a secretariat based in Perth, Australia.

Already during the preparatory phase several Working Groups had been formed to tackle the major challenges and requirements for a Regional Tsunami Early Warning System. Finally six Working Groups were established which are lead by IOTWS member countries and meet 1–2 times a year to discuss the respective development and to formulate decision proposals for ICG-IOTWS assembly resolutions.

Correspondence to: J. Lauterjung
(lau@gfz-potsdam.de)

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Table 1. List of IOC IOTWS ICG meetings, places and dates.

Meeting	Place	Date
IOC Kick-Off	Paris, France	3–8 March 2005
IOC (preparatory)	Mauritius	14–16 April 2005
ICG I	Perth, Australia	3–5 August 2005
ICG II	Hyderabad, India	14–16 December 2005
ICG III	Bali, Indonesia	31 July–2 August 2006
ICG IV	Mombasa, Kenya	28 February–2 March 2007
ICG V	Kuala Lumpur, Malaysia	8–10 April 2008
ICG VI	Hyderabad, India	7–9 April 2009
ICG VII	Banda Aceh, Indonesia	14–16 April 2010

The following Working Groups were established in 2005 and 2006:

- Working Group 1: seismic measurements, data collection and exchange.
- Working Group 2: sea level data collection and exchange, including deep-ocean tsunami detection instruments.
- Working Group 3: risk assessment.
- Working Group 4: modelling, forecasting and scenario development.
- Working Group 5: establishment of a system of interoperable advisory and warning.
- Working Group 6: mitigation, preparedness and response.

2.1 Major results of working group activities

The main activities have been in the field of monitoring instrumentation (seismic, tide gauges), tsunami modelling, risk assessment and interoperability.

2.1.1 Monitoring instrumentation

As the monitoring instrumentation around the Indian Ocean before the tsunami of 2004 was very sparse and not sufficient for a basin-wide monitoring the key task of Working Groups 1 and 2 was the definition of a core network of seismic stations and tide gauges around the Indian Ocean. Figure 1 depicts the result of discussions in Working Group 1 for the distribution of seismic stations which is considered as minimum for tsunami early warning.

A similar discussion was held in Working Group 2 for sea level measurements and the distribution of tide gauges (Fig. 2). All tide gauge data are delivered to the sea level data facility of UNESCO IOC (IOC, http://www.ioc-sealevelmonitoring.org). Within these Working Groups numerous training courses on seismology, sea level monitoring and technical implementation of instrumentation have been performed for the Indian Ocean countries.

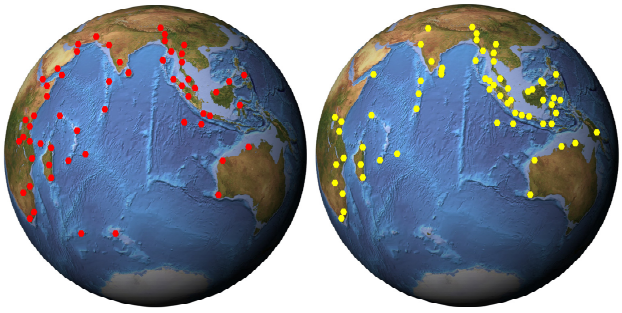

Fig. 1. Recommendation of Working Group 1 for the establishment of an Indian Ocean wide seismic network. Left: plan developed in 2005. Right: status of the network in 2010.

2.1.2 Tsunami modelling and forecasting

Main focus of the modelling Working Group is the establishment and introduction of a so-called community based model which can be used by all Indian Ocean countries for their individual modelling demands. The other focus of the group is the validation of the different available modelling systems in order to achieve comparable tsunami forecast results for a given tsunami source. This is especially important if tsunami early warning information (arrival time, wave height) based on calculated scenarios is distributed among the Indian Ocean countries from different warning centres. The work is still ongoing. Also in this context a number of training courses and workshops on model comparisons have been conducted.

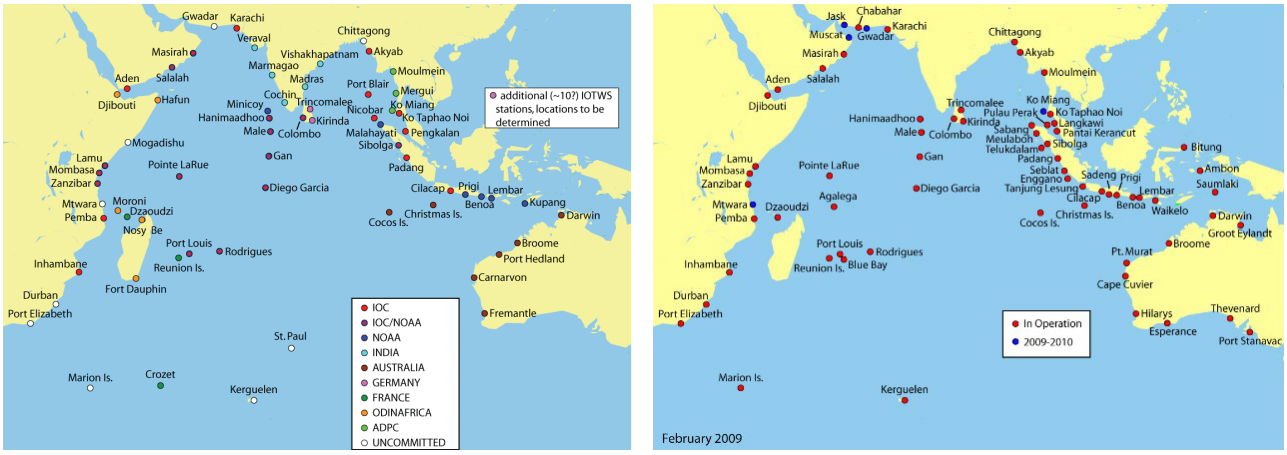

Fig. 2. Recommendation of Working Group 2 for the establishment of an Indian Ocean wide tide gauge network. Left: plan developed min 2005. Right: status of the network in 2009 (the blue marked tide gauges for 2009–2010 are in operation now).

2.1.3 Risk assessment, preparedness and response

Risk assessment and the preparation of risk maps as well as vulnerability maps is of ultimate importance for the early warning process, not only for the case of an urgent warning but also for questions of disaster prevention and preparation i.e. the issue of evacuation, public awareness and infrastructure planning processes. Working Groups 3 and 6 concentrated on the definition of basic rules and the determination of best practice strategies for risk assessment.

Another focus of these Working Groups is the definition of different types of watch and warning messages to be exchanged between the warning centres and national focal points in the case of a tsunami threat. Terms of reference for the necessary content of these messages and the type of advice to be conveyed by warning messages have been discussed and agreed. This work was essential for the concept of the Regional Tsunami Watch Providers (RTWPs, see below).

2.1.4 Interoperability

It was clear from the beginning of ICG-IOTWS activities that all Indian Ocean countries wanted to operate their own national warning centres and did not want to rely on the information of one or more dedicated warning centres for the Indian Ocean. Therefore, the concept of Regional Tsunami Watch Providers (RTWP) was conceived. The basic idea is that some of the national warning centres which have certain capabilities (monitoring infrastructure, modeling capabilities) commit themselves to serve as a basin wide information provider to secure that warning information is distributed to all Indian Ocean countries, especially those who do not operate their own monitoring infrastructures. In close cooperation with the risk assessment group, Working Group 5 has specified requirements for warning and information products (service levels) to be delivered by the RTWP. Three service levels have been defined (UNESCO_1, 2008), as follows:

Service Level 1 is the service level provided for event analysis and provision of a series of advisories from initial assessment through to confirmation that the tsunami threat is over. RTWPs will shadow the service by sharing products among other RTWPs, but not issuing "public" products. Elements of this service include:

- Reliable twenty-four hour a day, seven day a week center operations.
- Analysis of earthquake location, magnitude, and other seismic parameters to determine potential tsunami threat.
- Initial analysis of travel times to designated coastal forecast points.
- Analysis of sea level data from tsunameters and coastal sea level stations to determine whether or not a tsunami was generated and if so, significance of the event (e.g., local, regional, basin wide) and tsunami wave amplitude where possible.
- A series of advisories and updates as new data are available and analyzed.
- Coordination with other centers (e.g. among PTWC (Pacific Tsunami Warning Centre) and JMA (Japanese Meteorological Agency), with relevant NTWCs) to inform/verify analyses and share information.

Service Level 2 is a more robust service level that includes all of the elements of Service Level 1 but adds modeling and forecast elements so that Watches and Advisories include:

- Estimated wave height(s) (EWH) for offshore forecast points.
- Estimated time(s) of arrival (ETA) for offshore forecast points.
- Other tsunami characteristics (eg duration, wave period, time of max amplitude) where available.
- Potential threat zones.
- Confidence levels as applicable and appropriate.
- Advanced warning and notification products such as graphical forecasts.

National tsunami warning centres will need to utilize watch information to formulate tsunami threat information for their communities (under bilateral arrangements with RTWPs if required).

Service Level 3 links the Service Level 2 services and products with local risk and hazard assessment and inundation models through NTWCs to provide coastal inundation forecasts for communities at risk.

Until now Australia, India and Indonesia have officially indicated their willingness to take over the role of a RTWP for the Indian Ocean as all three countries have invested in the set-up and operation of a comprehensive early warning infrastructure and have largely contributed to the RTWP implementation process.

Major papers outlining the results of the Working Group activities in detail include the IOTWS Implementation Plan (UNESCO_3, 2010), the IOTWS Implementation Plan for Regional Tsunami Watch Providers (UNESCO_1, 2008) and a document describing the results of the first Indian Ocean wide communication and alerting experiment IOWave09 (UNESCO_2, 2009).

Reflecting the progress made in the establishment of the IOTWS and in preparation for the future sustained governance of the system the 7th Session of the ICG-IOTWS in Banda Aceh, Indonesia, 14–16 April 2010, dissolved the 6 already existing Working Groups and established 3 new Working Groups:

- Working Group 1: tsunami risk assessment and reduction.
- Working Group 2: tsunami detection, warning and dissemination.
- Working Group 3: tsunami awareness and response.

This modification corresponds with the structure of the Working Groups in all other tsunami warning systems facilitating the co-operation and exchange of experiences and knowledge to provide a global cover at equal standards.

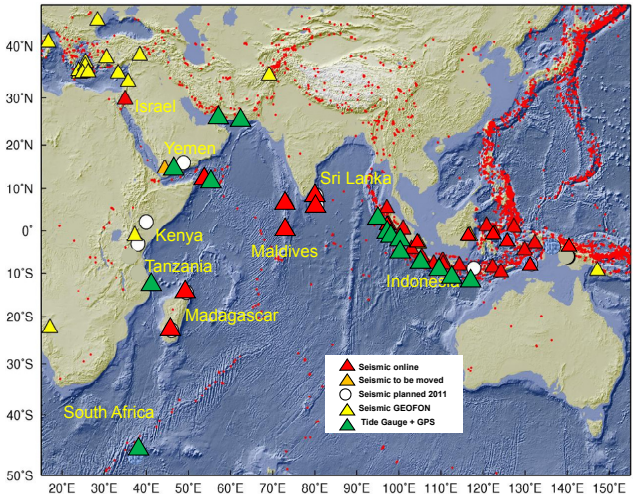

Fig. 3. GITEWS instrument installations around the Indian Ocean. (Red and yellow triangles: seismic stations, green triangles: tide gauge stations including GPS).

2.2 The role of international scientific communities

One of the overall aims of the international coordination efforts has been the interoperability between national warning systems to guarantee for data and information exchange. Already during the very first meetings it was agreed to follow the standards for data exchange and station design of the large scientific communities, i.e., one the one hand, the International Federation of Digital Seismograph Networks (FDSN, http://www.fdsn.org/) for the seismic networks and on the other hand the Global Sea Level Observing System (GLOSS, http://www.gloss-sealevel.org/) dealing with the installation of coastal tide gauges.

2.3 The role of GITEWS

Just a few days after the 2004 tsunami a group of German scientists started to develop a concept for a tsunami early warning system for the Indian Ocean region. Negotiations with different countries were started by the German government, ending with a positive reaction by Indonesia. By 14 March 2005 a Joint Declaration for the installation of a tsunami early warning system between Indonesia and Germany was signed, and the GITEWS project (German Indonesian Tsunami Early Warning System) was started (Rudloff et al., 2009).

Since 2005 the GITEWS project has been an integral part of the internationally coordinated activities for the establishment of an Indian Ocean Tsunami Early Warning System under the leadership of UNESCO/IOC. This involvement of GITEWS in the ICG-IOTWS process has been extremely fruitful and an absolute necessary undertaking as the early warning system in Indonesia plays a crucial role for tsunami

early warning in the Indian Ocean. Due to the geotectonic situation most of the tsunamigenic earthquakes threatening the Indian Ocean are generated along the Sunda Arc, an active continental margin running along the coastline of Indonesia (Lauterjung et al., 2010). The early warning system in Indonesia is able to deliver very first and fast indications and data with respect to a tsunami and, therefore, contributes to an ocean wide communication and information network for regional tsunami warning.

Although GITEWS participates in the ICG-IOTWS processes as an observer only, scientists have been actively involved in the Working Group activities. In this context GITEWS took over the task of the installation of seismic stations outside Indonesia (Sri Lanka, Maldives, Madagascar, Yemen, Kenia) including a satellite communication network. The result of this work is shown in Fig. 3. In addition most of the countries around the Indian Ocean are using SeisComp 3 (http://www.seiscomp3.org/), the seismic communication and processing software developed during the course of the GITEWS project (Hanka et al., 2010). Along with the installation of this software package an introduction and training for the users of SeisComp3 was already provided. This software is now a quasi-standard for seismic processing. Furthermore all data of seismic stations around the Indian Ocean are stored and are available online in the GEOFON archive at GFZ in Potsdam (GEOFON, http://www.gfz-potsdam.de/geofon).

GITEWS also set up a number of tide gauges, partly with the support of UNESCO IOC (Fig. 3) and training of the respective operators in data evaluation and station maintenance was also provided.

GITEWS was also strongly involved in general training and education activities. For more than 25 years the GFZ in Potsdam has been offering annual international training courses for Seismology, Seismic Data Analysis, Hazard Assessment and Risk Mitigation under the auspices of UNESCO (Letz and Bormann, 2002). These training courses were extended after the 2004 tsunami by a module Tsunami Early Warning. The last training course took place in early 2010 in Citeko/Indonesia using the new training facility of BMKG (Badan Meteorologi, Klimatologi dan Geofisika – Indonesias Agengy for Meteorology, Cliamatology and Geophysics)/Indonesia. This training course was attended by 30 participants from 19 Indian Ocean Countries.

2.4 Major achievements of ICG-IOTWS

The work of the ICG resulted in several achievements:

1. Interim Tsunami Watch Provider

   Already during the first stage of the international effort to set up an Indian Ocean wide Tsunami Early Warning System it was agreed between the member countries in early 2005 that the Pacific Tsunami Warning Centre (PTWC) and the Japanese Meteorological Agency (JMA) should serve as Interim Tsunami Watch Provider and deliver tsunami information based on results of global seismic networks to the Tsunami Warning Focal Points (TWFP). The responsibility to disseminate Tsunami information on a national scale is under the aegis of the respective member country (see next bullet: Tsunami Warning Focal Points).

2. Nomination and identification of Tsunami Warning Focal Points.

   As a first reaction to the deficient distribution of information during and after the 2004 tsunami each Indian Ocean country nominated an organization whose duty it then became to operate a 24/7 office for the reception of tsunami alerts produced by the PTWC and/or JMA and to disseminate warning products within the countries.

3. Working Groups

   The ICG-IOTWS established specific Working Groups to identify the needs of the different components of early-warning systems, to identify the needs of the community for joint activities, to organize the definition of requirements for a basin wide early warning system and to define the specifications and terms of reference of an Indian Ocean Regional Tsunami Watch Provider (RTWP).

4. Risk Assessment

   During the years 2005 and 2006 a number of Tsunami Hazard and Risk assessment studies in the Indian Ocean rim countries were conducted by international scientific groups under the auspices of UNESCO IOC. In many countries these studies resulted in national strategies for disaster reduction and preparedness forming the basis for further steps and activities in the field of early warning.

2.5 First ideas for a Global Tsunami Warning System

Within the framework of UNESCO IOC four Intergovernmental Coordination Groups have been organized (Fig. 4):

- the ICG/PTWS covering the Pacific and incorporating the existing PTWC and JMA;
- the ICG/CARIBE concentrating on the Caribbean Sea and;
- the ICG/NEAMTWS (North-east Atlantic, Mediterranean and Connecting Seas);
- the ICG/IOTWS covering the Indian Ocean.

The implementation strategy of tsunami early warning processes in these ICGs is almost comparable to the ICG-IOTWS as described above. Based on the successful work in the existing ICGs, IOC implemented a Working Group

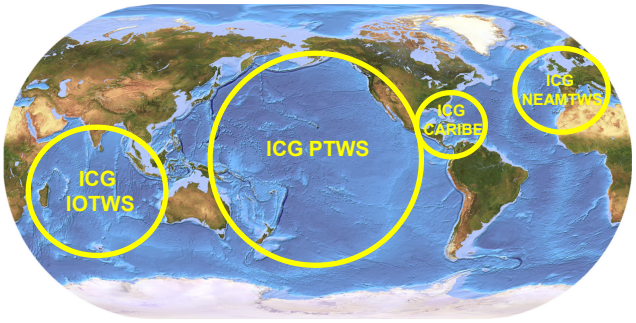

Fig. 4. The four Intergovernmental Coordination Groups (ICG) under the UNESCO framework.

Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG). This Working Group is developing terms of reference for a global early warning structure not only for tsunamis but expanding the existing infrastructures to other sea related hazards, and in cooperation with organizations such as GEO (Group of Earth Observation) and GEOSS (Global Earth Observing System of Systems) to implement a global multi-hazard approach. A global system will be based on the existing RTWPs, or similar entities, within the four ICGs and, therefore, the main focus of this Working Group is the harmonization and standardization of procedures, data exchange and products within this framework. Details can be found on the UNESCO website (http://ioc-unesco.org/index.php?option=com_oe\&task=viewEventDocs\&eventID=653).

3 Conclusion and outlook

Triggered by the disastrous tsunami in the Indian Ocean on 26 December 2004 UNESCO took over the task of coordinating tsunami early warning activities around the Indian Ocean immediately in early 2005. This coordination effort turned out to be very useful and the strategy to tackle the complete warning chain from hazard monitoring over simulation and modeling to preparedness and response in dedicated Working Groups including respective experts was highly effective. After five years of work the implementation of effective early warning structures in the Indian Ocean basin is almost completed. The Indian Ocean Tsunami Warning System IOTWS will be fully operational at the end of 2011. By that time the Interim Watch Providers PTWC and JMA will be discharged from the obligation to provide the appropriate cover which has been their responsibility since January 2005. It must also be stated that not only organizational structures and technical solutions have been triggered by this process but also a remarkable network of expertise and cooperation among the countries and many scientific institutions has been initiated through this process. The international coordination under the leadership of UNESCO/IOC was and is therefore an indispensable framework for the establishment and future operation of such systems dedicated for the management of transnational threats such as tsunamis.

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