Intergovernmental Oceanographic Commission
Reports of Governing and Major Subsidiary Bodies

Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS)

First Session

Perth, Western Australia
3–5 August 2005

UNESCO

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Abstract

The first Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System was held in Perth, Australia, from 3–5 August 2005. The Session was attended by 60 participants from 14 countries in the Indian Ocean, 4 other IOC Member States, 7 organizations, and 23 observers. The objectives of the meeting were to:

- gain an understanding of the technology deployment plans of the Indian Ocean countries;
- discuss related systems including sea level networks, seismic, data and information management, communications and warning centres; and
- establish an intersessional process for continuation of this work and to reach agreement on the preferred way forward.

To achieve these objectives four technical sessions were held, and reports accepted, on the topics of:

- Seismic measurement, data collection and exchange;
- Sea level data collection and exchange, including deep-sea tsunami detection instruments;
- Tsunami hazard identification and characterisation, including modelling, prediction and scenario development; and
- The establishment of a system of interoperable operational centres.

To achieve the objective of “an intersessional process”, it was agreed that Working Groups would be established on each of these topics, each with Terms of Reference and action items to be addressed before the second session of ICG/IOTWS in Hyderabad, 13–15 December 2005.

(SC-2005/WS/57)

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1. WELCOME AND OPENING OF SESSION

1 Dr Patricio Bernal, Assistant Director-General of UNESCO and Executive Secretary, Intergovernmental Oceanographic Commission (IOC), opened the first session of the IOC Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) at 09:00 hours on Wednesday 3 August in the Conference Room of the Sheraton Hotel, Perth, Western Australia. In doing so, he welcomed in particular Dr Judy Edwards, Minister of Science, Government of Western Australia, Dr Geoff Love, Director of Meteorology, Australia, and Dr Rob Gates, Department of the Premier and Cabinet, Office of Science and Innovation, Western Australia, and expressed his appreciation to the Governments of Australia and of Western Australia for hosting the meeting, and for providing such excellent facilities and support. Dr Bernal noted that the mechanism for coordinating and providing oversight to an Indian Ocean Tsunami Warning and Mitigation System (IOTWS) was now firmly established, in the form of the Intergovernmental Coordination Group (ICG), and that it was now the job of the ICG, beginning with the present meeting, to move forward quickly in developing the technical plan for the IOTWS and with its implementation.

2 Dr Bernal then presented a message from the Director-General of UNESCO, Mr Koichiro Matsuura. Mr Matsuura firstly thanked the Government of Australia for hosting the first ICG session, and also for contributing actively to the development of the IOTWS. He then summarized events since the tragic tsunami event of 26 December 2004, and noted that the present meeting was expected to substantially enhance progress towards the planning of the tsunami detection networks, the identification of national needs, and the coordination of assistance to meet these needs. Mr Matsuura stressed that the future IOTWS would depend on the coordinated efforts of all Indian Ocean countries for the success of the monitoring and detection system, and at the same time with each country implementing its own national centre, in particular for the receipt of tsunami monitoring information and advisories and for the dissemination of warnings at the national level. He then emphasized the important role being played by UNESCO, and in particular the IOC, in assisting countries in the Indian Ocean region to enhance the sea level monitoring system, and to develop national capacities to prepare risk assessment plans, to provide adequate national tsunami warning facilities, and to conduct and maintain essential public awareness and preparedness campaigns. Mr Matsuura then thanked the many governments, both within and outside the Indian Ocean region, which had contributed vast resources, enabling UNESCO and its IOC to undertake the important task of establishing the IOTWS. In particular, he reiterated his thanks and gratitude to the Government of Australia for hosting the present meeting and for its support for the establishment of the IOTWS, including for the Secretariat of the ICG, which will be based in Perth in the UNESCO/IOC Regional Programme Office. Mr Matsuura concluded by wishing participants a fruitful meeting and a successful achievement of the common goal of a fully operational IOTWS. The full text of Mr Matsuura's address is given in Annex III.

3 Dr Judy Edwards, Minister of Science, Government of Western Australia, welcomed participants in the meeting to Perth and to Western Australia, and recognized in particular the presence of Dr Bernal and Dr Love. She noted the leading role being played by the IOC in the planning and implementation of the IOTWS, and thanked the Commission for selecting Perth to be the location for the Secretariat for the ICG/IOTWS, as a part of the existing IOC Perth Regional Programme Office, supported jointly by IOC and the Governments of Australia and Western Australia. Dr Edwards underlined the importance which Western Australia placed on the successful implementation of the IOTWS, with its very long and potentially vulnerable coastline facing the Indian Ocean, and she indicated the willingness of her State to contribute to the development and operation of the system. She noted the importance of the present meeting, in beginning the detailed IOTWS planning process, and in assessing needs and requirements of

Indian Ocean countries to be able to adequately detect and warn of future tsunami events. Dr Edwards concluded by wishing participants a successful meeting, and offered the ongoing support of the Government of Western Australia to the IOC Perth Regional Programme Office.

4 Dr Geoff Love, Director of Meteorology, Australia, welcomed participants in the meeting to Australia, and expressed the hope that their stay would be enjoyable and useful. He noted that the ICG had an urgent mission, to ensure the future prompt delivery to all countries in the Indian Ocean region of an optimal and sustainable tsunami warning system. To this end, the present meeting should be concerned with the major issues of the sharing of data and information, with the maintenance of infrastructure including communications, with capacity building and with public education. Dr Love recognized that the ICG needed to learn from the existing tsunami warning system in the Pacific, and in particular from the experience and existing facilities and operations of Japan and the USA. At the same time, he noted that the IOTWS was likely to be different to the system in the Pacific, because of the different composition of countries and concerns in the Indian Ocean region, and that eventually the IOTWS might, in turn, provide a model for other parts of the world. Dr Love concluded by wishing participants a productive meeting.

5 Dr Rob Gates, Department of the Premier and Cabinet, Office of Science and Innovation, Government of Western Australia, also welcomed participants to Western Australia. He noted that Western Australia was very much a part of the Indian Ocean, and underlined the important responsibilities and expertise which existed in Perth and in the State as a whole to support and contribute to a successful IOTWS.

6 The representative of the Secretary-General of WMO, Dr Dieter Schiessl, expressed the appreciation of WMO at being able to participate in the present meeting. He underlined the existing important work and experience of WMO in the general field of early warning systems for natural hazards, and related public education and awareness, and stressed the willingness of his Organization to fully cooperate with IOC and the ICG in the development and maintenance of the IOTWS, as well as similar systems in other parts of the world. Support which could be provided by WMO and National Meteorological and Hydrological Services (NMHS) included expertise in early warning systems as noted above, the enhancement of the GTS to support IOTWS communications, links to satellite agencies, and input to public awareness and outreach work. Dr Schiessl concluded by wishing participants a successful meeting.

7 The representative of the Director, ISDR secretariat, Mr Yuichi Ono, expressed the full support of the ISDR for the present meeting and for the ICG. He noted the work of his Organization to date in supporting the development of tsunami warning systems, including funding the convening of coordination meetings, study tours, and country assessments, and stressed the need to maintain a balanced approach to the development of warning systems and to the whole area of natural disaster preparedness and mitigation. He concluded by wishing participants a successful meeting.

8 The list of participants in the meeting is given in Annex VIII.

2. ORGANIZATION OF THE SESSION

2.1 ADOPTION OF THE AGENDA

9 **The ICG adopted** its agenda for the session, which is given in Annex I. **It agreed** that the order in which agenda items might be dealt with could be modified as required.

2.2 ELECTION OF MEETING CHAIR

10 **The ICG elected** Dr Harsh Gupta (India) as its chair for the duration of its first session. **It was agreed** that the election of the future chair for the ICG, together with other officers, would be considered under agenda item 2.4.

2.3 THE CREATION OF THE ICG

11 The Executive Secretary provided a status report on the activities to date in the development of an IOTWS. Details are given in Annex IV. He also provided background on the establishment of the ICG and outlined its expected role. He noted, in particular, the detailed guidance contained in IOC Resolution XXIII-12 (Paris, June 2005), which established the ICG/IOTWS and provided its terms of reference, as well as the documents adopted at the Paris and Mauritius workshops leading up to this establishment. Dr Bernal noted that the ICG was intended to provide oversight and technical guidance to the Indian Ocean Tsunami Warning and Mitigation System (IOTWS), and ensure the integrity of the system servicing all the nations of the Indian Ocean region, and operating through their concerted action. It was also to provide effective coordination amongst countries, technical and operational planning, and adequate resources, sharing of data and information, promotion of research, implementation of capacity building and other objectives, as stated in the ICG's terms of reference.

12 Dr Bernal noted that the plan for the IOTWS would involve three streams —detection and warning; assessment of risk; and preparedness. These must be integrated in the overall system and fully accountable. He concluded by recalling that the IOC was now providing significant Secretariat support, both in Perth directly for the ICG and at headquarters in Paris, for tsunami warning system development and implementation in general, and that the ICG would eventually need to cooperate and coordinate closely with similar bodies involved with tsunami warning systems in other ocean basins.

2.4 DISCUSSION OF PROCEDURES FOR APPOINTMENT/ELECTION OF OFFICIALS OF THE ICG/IOTWS

13 The Executive Secretary outlined procedures for the appointment of ICG officers, which would be those contained in the IOC Rules of Procedure relating to the election of officers of the IOC Governing Bodies. **The ICG agreed** that it would require strong leadership in the coming years, as well as strong support from Member States, and that it should proceed with the election of its officers on the basis of these procedures. **It further agreed** that it would require a chair and two vice-chairs, to ensure a good geographical balance of officers covering the whole Indian Ocean Region, and that initially these officers would be elected on a country basis. **The ICG stressed**, however, that the individuals selected by these countries to fill the positions should be made known to, and accepted by, the ICG, at the earliest possible opportunity. Finally, **the ICG agreed** that its officers should be elected for initial terms of two years, with the possibility of renewal for a further two-year term each.

14 On this basis **the ICG elected** by consensus, as its officers, to act in this capacity from the end of the present meeting:

Chair: India
Vice-chairs: Indonesia and Mauritius.

15 Finally under this agenda item, **the ICG stressed** the importance of all Indian Ocean Member States designating both their representatives to the ICG, and also their national focal

points for receipt of tsunami information and advisories, noting that these should be experts and/or agencies directly involved nationally in the tsunami warning process.

3. BACKGROUND AND REPORTS

3.1 NATIONAL REPORTS FROM MEMBER STATES AND ORGANIZATIONS PROVIDING CAPACITY TO THE IOTWS

16 **The ICG noted with appreciation** reports from Member States contributing, or planning to contribute, major system components and technology to the IOTWS, on their commitments and progress to date in establishing their national systems. Such reports were received from Australia, India, Indonesia and Malaysia. These reports included, in particular, national plans for observing instrumentation, communications equipment and systems, data systems, and national and local warning centres. The full national reports are given in Annex V. The ICG was further informed of work being undertaken by WMO, in support of the development and implementation of tsunami warning systems in general and of the IOTWS in particular. This report is given in Annex VI.

17 **The ICG expressed its considerable appreciation** to these countries and to WMO for the significant work undertaken to date, and for the major contributions which they were making already to the IOTWS. **It agreed** that these contributions, and others, would form the basis for the detailed discussions in the working groups under agenda items 4 and 5.

3.2 REPORT FROM ITSU: PROGRESS ON PACIFIC TSUNAMI WARNING CENTRE (PTWC) INCLUDING CHILE, SW PACIFIC AND CARIBBEAN AND MEDITERRANEAN WARNING SYSTEMS

18 The meeting recalled that an update on the development of tsunami warning systems in other regions, including likely enhancements within ITSU, had been provided in the overview presentation of the Executive Secretary under agenda item 2.3, and recorded in Annex IV.

3.3 INTERIM REPORT ON IOC ASSESSMENT PROCESS

19 Mr Peter Pissierssens, IOC Secretariat, noted that the national assessment project being undertaken in the Indian Ocean region by the IOC Secretariat, in association and with the support of various national agencies as well as other Intergovernmental and Non-governmental Organizations, was expected to be completed by the end of August 2005.

20 **The ICG noted** that a consolidated report on these assessments would be available by October 2005, for input to the ongoing work of the technical working groups, and for further detailed consideration by ICG/IOTWS-II in December 2005.

3.4 GLOBAL MULTI-HAZARDS AND GLOBAL COORDINATION

21 Dr Gary Meyers, representative of the Indian Ocean Panel for Climate, co-sponsored by Indian Ocean GOOS (IOGOOS) and CLIVAR, presented an overview of the Indian Ocean climate observing plan, which in particular identified existing or potential overlaps and gaps among the different systems as well as synergies with the IOTWS. A summary of the presentation is given in Annex VII. Dr K. Radhakrishnan, chair of IOGOOS, also made a brief presentation on the work being undertaken within IOGOOS.

4. DEVELOPMENT OF IOTWS

22 **The ICG recalled** that the IOTWS will be a coordinated network of national systems and capacities, and will be a part of a global network of early warning systems for all ocean-related hazards. Within the IOTWS, each Member State will have the responsibility to issue warnings within their respective territories. Recognizing the unique tectonic plate structure of the Indian Ocean, with primarily two tsunamigenic sources that could affect the coastlines of the Indian Ocean, the ICG agreed that the overall IOTWS would include, in particular:

- contributions by Australia, India, Indonesia, Malaysia and Thailand to detect, analyse and provide timely warning if tsunami generated along the Indonesian seismic zone and its extensions;
- contributions by India, Iran and Pakistan to cover the Makran source;
- efforts by all countries of the Indian Ocean region to enhance their abilities to receive tsunami advisory information and warnings and issue appropriate warnings within their respective territories on a twenty-four-hours/seven-days-a-week basis.

23 **The ICG recognized** that the objectives of the current session of the ICG were to: identify the present state of progress in developing each component of the detection system; prepare an accurate depiction of the observing networks with coordinates of existing or planned instruments, including details of communication links (observing instruments to centre, centre to centre); develop of standards for data representation and dissemination, and documentation of the methods used for processing such data; document the methods for tsunami detection and of the hazard represented by tsunami, including through modelling, forecasting and scenario development; and document progress toward establishing a single, coordinated regional warning system for the entire Indian Ocean basin through the establishment of national inter-operable centres, including the modalities of operation, methods and standards for development and issuance of warnings, and requirements in terms of coordination and operating within a multi-hazard approach. To further the process to achieve these objectives, **the ICG agreed** on the establishment of technical sessional working groups, to develop technical plans for the IOTWS based on national and international contributions, as follows:

SWG 1: Seismic measurements, data collection, and exchange.

SWG 2: Sea level data collection and exchange, including deep-ocean tsunami detection instruments.

SWG 3: Tsunami hazard identification and characterisation, including modelling, prediction and scenario development.

SWG 4: The establishment of a system of interoperable operational centres.

24 It was agreed that SWG 1 and SWG 3 would work in parallel, followed by SWG 2 and SWG 4, again in parallel. **The ICG recognized** that it was important that this work be developed within the context of the results from the 3–8 March meeting in Paris and, in particular, the discussion of “Development of the Design Plan, Work Plan and Timetable”. In view of the fact that the IOC Assessment process was still underway, **it was further agreed** that detailed discussion of capacity-building activities would be the focus of the second meeting of the ICG/IOTWS.

25 **The ICG considered** that it was important that the working groups should develop a description of the initial (interim) IOTWS and, in the case of interoperable networks and

systems, identify a process and way forward for agreeing arrangements for sharing and exchange of information and warnings, consistent with the principles set down in the Terms of Reference for the ICG/IOTWS, the Paris Communiqué and the Mauritius Declaration.

5. WORKING GROUP MEETINGS

26 The full reports of the sessional working groups established under agenda item 4 are given in Annex II. **The ICG approved** the reports and recommendations of the working groups.

27 **The ICG recognized** that, although considerable progress had been achieved by the working groups during the current session, much still remain to be done in fully defining the necessary technical specifications of the IOTWS. It therefore agreed that the work should continue during the coming intersessional period, with support as required from the ICG Secretariat, with a view to presenting more detailed reports to ICG/IOTWS-II. Terms of reference and membership of the intersessional working groups are also given in Annex II. **The ICG welcomed** the offer of Japan to participate in and support the work of all the intersessional working groups. **The ICG requested** the chairs of the working groups to immediately initiate actions as specified in the terms of reference through email correspondence with working group members (with copy to the ICG Secretariat).

6. SECRETARIAT AND OTHER GOVERNANCE ARRANGEMENTS

28 The Executive Secretary reviewed the provision of Secretariat support for the ICG, to be provided through the IOC Perth Regional Programme Office as formally agreed at the 23rd IOC Assembly (Paris, June 2005). He explained in particular the arrangements established with the Government of Australia for providing for this Secretariat and related support to the ICG, noting that this support amounted to AUD 400,000 per year, with the current, signed agreement covering the period 1 July 2005 to 30 June 2009. This support would be used, *inter alia*, to fund a new, regular IOC Professional Officer staff post in the existing IOC Perth office, to hire one local support staff, and to provide other essential Secretariat support to the work of the ICG. The Executive Secretary further noted that the enhancements being undertaken to the IOC Secretariat in Paris to support tsunami warning systems globally would also be available to support the work of the ICG as necessary. **The ICG expressed its appreciation** to the Government of Australia for this generous support, and to the IOC Secretariat for its considerable work to date, and ongoing support, for the development and maintenance of an IOTWS. It noted the potential substantial benefits to the IOTWS, to the work of the ICG, and as a capacity-building exercise, through the possible secondment of staff from Indian Ocean Member States to work in the ICG Secretariat office in Perth, and **urged** Member States to support these secondments where possible.

29 India proposed using the Indian Ocean GOOS (IOGOOS) as a framework for regional aspects of IOTWS, as well as the IOGOOS Secretariat at INCOIS as the secretariat for ICG/IOTWS. India noted that IOGOOS is recognized as an organization fully supported by the region for developing GOOS, and had been recognized in a number of fora as a framework for moving towards comprehensive ocean measurement and forecasting in the Indian Ocean, as well as for providing support to the development of an IOTWS. In this context, India recommended that the IOGOOS Secretariat located in India at INCOIS, Hyderabad, could provide necessary secretarial support for ICG/IOTWS.

30 **The ICG recalled** the potential benefits to be gained from enhanced coordination and cooperation between the IOTWS and IOGOOS, as addressed under agenda item 3.4. It further noted that all the GOOS Regional Alliances could eventually provide an important contribution to multi-hazard warning systems. **The ICG recognized** the work being undertaken by the IOGOOS Secretariat in coordinating the development of IOGOOS. **The ICG noted** that the IOC Secretariat, working through its IOC Perth Regional Programme Office with regard to the ICG/IOTWS, would coordinate, as appropriate, with the secretariats of all the GOOS Regional Alliances, including the IOGOOS Secretariat in Hyderabad, in further developing synergies between these Regional Alliances and the ICGs for the different tsunami warning systems, in areas of mutual interest such as observing system maintenance and multi-hazard warning systems.

7. PROGRAMME AND BUDGET FOR 2005–2006

31 The Executive Secretary outlined the funds available for supporting the ICG during 2005–2006, including those provided by Australia, as well as funds available through the IOC Regular Budget. **The ICG noted** the ongoing requirement of support from participating Member States to sustain the activity, development, implementation and ongoing maintenance of the IOTWS, and **urged** all Member States to provide such additional support where possible. **It further noted** that a more complete budget statement relating to the work of the ICG would be considered at ICG/IOTWS-II.

32 In order to assist the Secretariat to support the needs of IOTWS, the IOC will establish a trust fund on training and a trust fund to facilitate the participation of regional countries in meetings of the ICG. The ICG, supported by its Secretariat, will develop a priority of training needs for the IOTWS, and this will be included on the agenda for the second ICG/IOTWS.

33 The IOC Secretariat will coordinate with donors in the lead up to ICG/IOTWS-II.

8. NEXT MEETING

8.1 CONFIRMATION OF DATE AND PLACE OF NEXT MEETING

34 **The ICG accepted** the kind offer of India to host the second session of the Group in Hyderabad, India, in the first half of December 2005. **It recalled** that a workshop was also planned to take place in conjunction with this session. **It therefore agreed** that the workshop would take place on 12 and 13 December 2005, with the second session of the ICG/IOTWS to be held from 14 to 16 December 2005.

8.2 CONFIRMATION OF TARGET DATE FOR ICG/IOTWS-III

35 **The ICG welcomed** the kind offer of Indonesia to host ICG/IOTWS-III in Bali, Indonesia, in late June or July 2006.

9. OTHER BUSINESS

36 No other issues were raised during the session.

10. ADOPTION OF THE SUMMARY REPORT AND RECOMMENDATIONS

37 **The ICG reviewed and adopted** the summary report and recommendations of its deliberations.

11. CLOSE OF MEETING

38 In closing the meeting, the chairman, Dr Harsh Gupta, expressed his appreciation to all participants for their input and enthusiasm, which had contributed to the success of the meeting and to the substantial progress that had already been made towards the establishment of the IOTWS. He then wished the working groups a productive intersessional period, and looked forward to welcoming all participants to the second session in Hyderabad in December 2005.

39 On behalf of all participants, Mr S.N Sok Appadu (Mauritius) offered particular thanks to the chair for his tireless work towards the establishment of the IOTWS in general, and for his very efficient and effective conduct of the present meeting in particular, which had greatly facilitated the work of the ICG. Mr Sok Appadu also expressed his sincere appreciation to the Government of Australia, and in particular the Bureau of Meteorology and the local secretariat, for hosting the meeting and for the very efficient and friendly way in which they had undertaken the management of participant support and other coordination and local support arrangements, especially at such short notice, which had not only contributed to the success of the meeting, but also made the stay of participants in Perth very agreeable one.

40 Speaking on behalf of the Australian delegation, Mr Robert Owen-Jones also offered his appreciation to the chair for his highly effective and stimulating conduct of the meeting, which had contributed substantially to its success. He then thanked IOC/UNESCO, and in particular the Executive Secretary, Dr Patricio Bernal and his staff, for their substantial support for the establishment of the IOTWS, for their support to Australia in hosting this first session of the ICG, and also for having chosen to work through the IOC Perth Regional Programme Office to provide the necessary ongoing Secretariat support for the ICG/IOTWS.

41 The Executive Secretary, Dr Patricio Bernal, expressed his appreciation, on behalf of the Director-General of UNESCO, Mr Koichiro Matsuura, as well of the IOC specifically, to the Government of Australia, for its ongoing very generous support for the IOC Perth Regional Programme Office, and in particular for the new funding support provided, to allow for the expansion of the Office to provide the Secretariat support required by the ICG/IOTWS. He also thanked the Australian Bureau of Meteorology for hosting and supporting the present meeting so effectively, and particularly thanked the local secretariat staff, including the Bureau's Regional Director for Western Australia, Mr Gary Foley and his staff, Ms Val Jemmeson and Ms Susie Wilhelm, for their tireless efforts in support of the meeting and of the participants. Dr Bernal concluded by also thanking the chair, Dr Harsh Gupta, both for his very able conduct of the present meeting, and for his many years of active engagement with and support of IOC and its programmes in general.

42 The first session of the ICG/IOTWS closed at 15:45 hours on Friday 5 August 2005.

ANNEX I

AGENDA

1. WELCOME AND OPENING OF SESSION

2. ORGANIZATION OF THE SESSION

2.1 ADOPTION OF AGENDA

2.2 ELECTION OF MEETING CHAIR

2.3 THE CREATION OF THE ICG

2.4 DISCUSSION OF PROCEDURES FOR APPOINTMENT/ELECTION OF OFFICIALS OF THE ICG/IOTWS (IOC RULES OF PROCEDURE)

3. BACKGROUND AND REPORTS

3.1 NATIONAL REPORTS FROM MEMBER STATES AND ORGANIZATIONS PROVIDING CAPACITY TO THE IOTWS

3.2 REPORT FROM ITSU: PROGRESS ON PACIFIC TSUNAMI WARNING CENTER (PTWC) INCLUDING CHILE, SW PACIFIC, CARIBBEAN AND MEDITERRANEAN WARNING SYSTEMS.

3.3 INTERIM REPORT ON IOC ASSESSMENT PROCESS

3.4 GLOBAL MULTI-HAZARDS AND GLOBAL COORDINATION

4. DEVELOPMENT OF IOTWS

5. WORKING GROUP MEETINGS

6. SECRETARIAT AND OTHER GOVERNANCE ARRANGEMENTS

7. PROGRAMME AND BUDGET FOR 2005-2006

8. NEXT MEETING

8.1 CONFIRMATION OF DATE AND PLACE OF NEXT MEETING

8.2 CONFIRMATION OF TARGET DATE FOR ICG/IOTWS III

9. OTHER BUSINESS

10. ADOPTION OF THE SUMMARY REPORT AND RECOMMENDATIONS

11. CLOSE OF MEETING

ANNEX II

SESSIONAL WORKING GROUP REPORTS

Working Group 1: Seismic measurements, data collection, and exchange

Summary of findings and recommendations

The working group found that a number of national initiatives are well advanced in their planning and implementation to upgrade existing and install new seismograph stations. The level of data interchange planned is extensive, and a number of data interchanges are already underway. Their success is encouraging in terms of the likelihood of success of more comprehensive data interchanges.

The working group recommends that an intersessional working group be formed to oversight a number of initiatives. Draft terms of reference are appended for consideration.

The working group resolved to build a database, in the form of a fully attributed GIS layer, of all stations, recording the locations, instrumentation, status (new or planned), data logging and communications systems, and other relevant information. Australia agreed to build the database using information to be provided by other nations, with assistance from the intersessional working group. The IOC Secretariat office in Perth would be asked to assist through providing introductions to the countries of the Indian Ocean.

The database would be used by the intersessional working group to identify gaps in data, capability and knowledge, and to make recommendations on mitigation strategies to IOC/IOTWS-II in Hyderabad in December 2005.

The working group recommends that countries bordering earthquake prone zones where large earthquakes can generate tsunamis consider installing strong motion sensors such as accelerometers (as well as broad band seismographs), because they have greater dynamic range.

The working group recognised that considerable network interoperability exists already, and urges nations that are adding additional capability to introduce systems that are able to link with existing systems, and share data in recognised data formats, preferably dataless SEED for station parameters or MiniSEED for time series data.

The working group recommends that, wherever possible, VSAT be used for data exchanges between national centres because of its speed and apparent reliability.

The working group also recommends that the intersessional working group should design and conduct two experiments to be carried out before ICG/IOTWS-II in Hyderabad (i) to test peak loads and resulting data latencies on the data communications system, particularly internet-based systems, and (ii) to identify the extent of non-uniformity in earthquake magnitude estimation. The latter experiment is in anticipation of earthquake magnitude being used as a primary parameter in any decision process that might lead to further steps towards issuing an alert, and the confusion that might result if some centres proceed while others do not. The intersessional working group should bring the results of these experiments to ICG/IOTWS-II, together with recommendations for mitigating any adverse effects on the communications system of peak data loads, and of any variability in earthquake magnitude estimation.

The working group strongly recommends to the IOC that sustainability of seismograph networks be an agenda item for ICG/IOTWS-II in Hyderabad.

Setting the scene

The Executive Secretary of the IOC set the framework for the working group, suggesting that unlike the Pacific Ocean, where the geotectonic structure is such that each country was equally at risk from both tsunamis generated by earthquakes that happened locally, and from transoceanic tsunamis, countries of the Indian Ocean were exposed to only locally generated or transoceanic tsunamis. This in turn has led to a range of national technical responses. It is likely that the eastern half of Indian Ocean and the Makran zone in the north will become the "sending side", and the western half will be the "receiving side" of transoceanic tsunamis. It is the responsibility of each nation to decide its own role in this scenario. Each country must also determine what communication platforms they wish to put in place to deal with access to the raw data generated by seismograph networks, and to determine their capability to send and receive, and to distribute internally alerts and issue warnings.

Working group approach

The working group was presented with a number of questions that were designed to focus and direct its discussions. The report addresses the questions, but because some of the findings of the working group relate to both of the first two questions, they are reported together.

A. TECHNOLOGY

- *What types of seismometers are being maintained/planned by IO member states that are relevant to the IO Tsunami Warning System? Where are they located? Are they already installed? If not, when will they be, and are they long-term?*
- *What are the capabilities (limitations, advantages/disadvantages) of these seismometers? Are there aspects that will limit their utility for the IOTWS?*

B. NETWORK SUFFICIENCY

- *Are there sufficient seismic stations available continuously and in real-time in the IO region to locate and estimate earthquake magnitude? [must define sufficient; will flow from A]*
- *If not, what are the gaps in station density and/or in instrument quality? What is the importance of each seismic station within the IOTWS network relative to the known seismic threat, e.g. would the station be classified as (a) essential [must be maintained at all times; if missing poses considerable extra risk], (b) important [should be maintained and provides a unique contributions], (c) important, but only locally (that is, not essential for the IOTWS but considered important locally), or (d) optional [performs a useful purpose but does not represent a site of significant risk in terms of seismic coverage].*

The working group recognised that a number of initiatives are currently underway around the Indian Ocean Basin to upgrade existing and install new networks, but that representatives from all nations were not present at this meeting to report their activities. Nor were representatives from each of the global networks, although one member of the working group was able to represent the views of the Federation of Global Seismic Networks. The working group also recognized the important contributions of the PTWC and JMA in providing interim tsunami advisories for the Indian Ocean. The system makes use of the Global Seismic Network and CTBTO stations to locate and size earthquakes and to issue tsunami information to designated national tsunami focal points within 10-20 minutes of the earthquake occurrence. It was therefore difficult to identify whether any gaps exist in the seismograph networks. Therefore, before the next ICG/IOTWS meeting in Hyderabad in December 2005, we need to identify any gaps. The working group recognised that the results of the IOC's capacity assessments of countries in the region would be an important element of this work, and that the results would be available prior to the Hyderabad meeting.

Germany indicated that it may be in a position to help fill any gaps that are identified in the networks. It may be possible to locate stations near the borders of neighbouring countries to achieve efficiency.

The meeting resolved that, to help identify gaps, we need to build a database of the existing and proposed seismic stations around the Indian Ocean. This should also be used to determine what data would be collected and whether it would be available for sharing.

DECISION OF THE WORKING GROUP: **The working group accepted** Australia's offer to build the database of seismograph stations and make it available to all Indian Ocean countries who want it (shape file, table and hard copy map). The database would be in the form of a GIS layer of stations, fully attributed with, among others:

- Station identifier (name or number)
- Focal point for a country
- Latitude, longitude, elevation
- Whether the station is existing or planned, and if planned, when would it be likely to be installed? If operational, date of commencement
- Whether the instrumentation is short period, broadband, and includes an accelerometer; what instruments are installed/proposed?
- Whether the seismometer(s) is in a borehole or vault
- Are the data communicated in real time, and to which hub?
- Is there access to the hub from other national and regional systems, and if so, by what communications system?
- Basic data specifications including number of channels, sampling rate, dynamic range, whether there is a data compression system used, and if so using what system?
- The data formats used
- Whether the station contributes to a national (eg. Indonesian), regional (eg., ASEAN) or basin-wide/global system

The database should include the stations in the region from the global and regional networks, e.g., GSN, Geoscope, CTBTO, Geofon and JISNET networks. **The working party resolved** to ask the IOC Secretariat in Perth to help facilitate the responses to a survey to collect the data because not all nations were present.

The working group recognised that several software systems are currently in use throughout the region, and **noted** that data are currently being exchanged readily among several of them, either using the software directly or with free add-ins provided by the software vendors to allow interoperability. **The working group recommends** that any nation which is considering installing new software, give special consideration to whether their new software provides compatibility with existing systems.

With respect to the optimum design of seismograph networks, **the working group recognised** that unlike the Pacific Ocean, the likely sources of earthquake-related tsunamis are in the eastern Indian Ocean, near the trench extending south and east from Sumatra, and in the Makran zone of the north-west Indian Ocean. For countries bordering the Indian Ocean, therefore, two general tsunami source scenarios exist, and these are directing the design of national systems:

1. Vulnerable areas that lie within 30-minute travel time of a tsunami, e.g., Sumatra, Java and the islands of southern Indonesia; western Thailand, Malaysia, Andaman Islands, Makran zone, Sri Lanka, small islands of the western Indian Ocean, need a dense network, as is the case of Japan. Earthquake location and magnitude need to be determined within 2-3 minutes of the earthquake. Strong motion sensors such as accelerometers that are unlikely to saturate are important, and the working group recommended that countries in this situation consider installing them. The software used for locating the event should be efficient and fast, and therefore presumably automated, in order not to use time that would otherwise be available for evacuations. The seismological community should continue to monitor and participate in the development of new methodologies and techniques for recording and locating events and determining their magnitudes, particularly for great earthquakes. Nevertheless communities may have to be warned based only on the knowledge that a very large event has happened, and in the absence of sea level data that would corroborate that tsunami is on the way.

2. Vulnerable areas > 30 minutes (Sri Lanka, East African countries, Australia) have more time to analyse the seismic data, and to try to observe the tsunami on a sea level gauge before issuing an alert or warning.

The working group was strongly of the opinion that the sharing of full waveform data in real time was critical in both scenarios. For the case of local tsunamis, where the national or regional centres might be at risk from the earthquake or tsunami, other centres would be in a position to provide backup. For trans-oceanic tsunamis, data from all sources are critical to the tsunami modelling and forecasting process. Data sharing also contributes to the overall redundancy of the IOTWS, and helps mitigate data losses caused by a range of reasons.

In practical terms, the seismograph networks appear to be resolving into three categories:

- National networks that in some cases are very dense, reflecting the setting of the country, e.g. Indonesian network,
- Regional networks made up of subsets of adjoining national networks, designed through bi- or multi-lateral arrangements e.g. the multi-national ASEAN network accesses a subset of three Indonesian stations, and
- Basin —wide coverage that is yet to be fully resolved, but is likely to include subsets of both global (e.g. IRIS) and regional networks (e.g. ASEAN).

C. DATA FORMATS, STANDARDS, AND DISSEMINATION

- *What are field station data collection characteristics —sample interval and digitizer and data logger, instrument response / calibration, transmission methods, data formats, archiving systems, etc.*
- *how are seismic data to be made available by and to IO member states (nationally within their own country, or internationally to all interested parties)? Transmission methods include dedicated lines, VSAT, Internet LISS, and others. What data formats are to be used for collection and transmission?*
- *are data that will be made available to be waveforms (which would not be possible through the GTS), or parametric (seismic arrival times or hypocenters/magnitudes (which could be transmitted through the GTS)*
- *is there an issue of interoperability between the different existing or planned seismic stations*

Detailed specifications of the field collection characteristics are not as important as the equipment and data specifications and the availability of data from network hubs. This information will be collected into the database to be built as discussed above. Existing national systems are demonstrating a high degree of interoperability in trials done to date under bi-lateral arrangements, and through the interim arrangements for the IOTWS provided by JMA and PTWC. Data sharing is being undertaken by a variety of means, including the Internet and VSAT.

The working group discussed briefly whether the Global Telecommunications System (GTS) of the WMO would be able to handle seismic data transmission. Although the GTS would be able to pass parametric data, it would be unable in its current configuration to handle waveform data, which can amount to 50-100Mbytes per day for a typical broadband station with adjacent accelerometer. **The working group noted** that VSAT transmission is fast, dedicated and apparently more reliable and **recommends** it as the preferred medium for transmitting data between national centres.

The working group discussed conducting a test of the transmission network for seismic data to determine any weaknesses that might arise when full data sharing is underway and the communication system evolves to peak load. This was **recommended** by all delegates when the working party gave its initial report during the subsequent plenary session.

The CTBTO has currently agreed to release their data for trial use to UNESCO identified tsunami warning centres. JMA has received and used CTBTO data already. The PTWC will be receiving CTBTO data through the US National Earthquake Information Center. **The working group noted** that every country can apply to CTBTO to establish a national data centre to access the data, and for the software to read and interpret the data.

Similarly, all countries present in the working group agreed to share their seismic data, although some countries may be able to share only subsets of their national station coverage. Most data are currently shared in dataless SEED format for station parameters and miniSEED format for time series data. Software exists to convert other common data formats, e.g., that used by the CTBTO and other open source data formats, although the need to convert data formats may impede fast, real time interpretation of data. Countries are therefore **encouraged** to limit their data to SEED or miniSEED formats.

There was a preference for the sharing of real-time full waveform time series data, although countries were also **urged** to consider sharing parametric data as well.

D. PROCESSING AND OPERATIONAL ANALYSIS OF DATA IN REAL TIME

- *How are earthquakes to be located (through 1-station such as TREMORS system, regional seismic network, other)? How are magnitudes determined (e.g., Richter, Moment based on what phases and seismogram time window, other)? What softwares are used and briefly, how do they work (what data are used)? How fast are results available?*
- *How are seismic data used for tsunamigenic evaluation? How does one assess whether a tsunami has been generated? What are the seismic criteria used to decide what level of tsunami messages is issued?*

All national centres are using or plan to use commercial or freeware software packages that provide comprehensive data communications handling, event location and magnitude estimation. The various forms of magnitude estimation were discussed. The existing warning centres, including the interim IOTWS involving JMA and PTWC use earthquake magnitude as a primary parameter in the decision process used to determine whether to take further steps that would lead to the issue of alerts and warnings. Similar procedures are likely to be implemented in new warning centres in the Indian Ocean. **The working group was concerned** that a lack of uniformity of magnitude estimations is likely to arise from the various national centres, and this might trigger alerts from some centres but not from others. The delegates during the subsequent plenary session **asked for this to be considered** out of session before the ICG/IOTWS II meeting in Hyderabad.

E. SUSTAINABILITY

This issue was **added** to the agenda by **the working group**.

The issue of sustainability of the seismograph networks throughout the Indian Ocean region was **recognised** by the working group as an important one to be considered both regionally by the IOC and at national levels. The working group did not have time to discuss this issue further. Nor did it have a complete picture of the full extent of national systems and their current upgrades, or of the form of individual national funding sources and international donor contributions beyond the initial setting up and upgrading of some national systems that are currently underway.

The working group therefore recommends to the IOC that sustainability of seismograph networks be an agenda item for ICG/IOTWS-II in Hyderabad.

DRAFT TERMS OF REFERENCE
FOR THE INTERSESSIONAL WORKING GROUP

Preamble: Membership of the working group will be sought from IOC countries of the Indian Ocean. Because of the technical nature of the tasks to be performed, participation from countries that are establishing national centres is especially important. The Chairman and rapporteurs of Working Group 1 will work to establish the intersessional working group. Specialized global network operators and earthquake monitoring centres such as the PTWC, JMA, USGS NEIC, FDSN, GFZ/Geofon and IRIS are invited to participate.

Objectives:

1. The working group should ensure that all earthquakes of magnitude 6 or greater can be reliably located and sized in a timely manner.

2. The working group should review and make recommendations regarding upgrading and enhancements to the network, communications, processing and analysis to further reduce the time required for earthquake source characterization to meet a local warning response of 5-10 minutes.

1. The working group will elect its own convenor, and determine the rules by which it will operate.
2. The working group will provide support to Australia in collating data from countries bordering the Indian Ocean in order to build a database containing information on seismic station deployment. The working group will make recommendations to ICG/IOTWS on gaps in the seismic networks, and mitigating strategies to fill the gaps.
3. The working group will design an experiment to test the effects of peak loads on data communication systems, particularly data latency on internet-based systems. The working group will report its findings to ICG/IOTWS-II and make recommendations on how to mitigate any adverse effects of peak loads.
4. The working group will design an experiment to test the variability of earthquake magnitude estimates generated during the standard operating procedures that would be enacted at a number of centres at the time of a large earthquake, and report its findings to IOC/IOTWS. It will make recommendations on ways to mitigate the effects of any variability on the decision support systems used to move forward to issuing an alert.

The working group will make recommendations to ICG/IOWTS on how it should evolve into a long-term community of practice for sharing ideas and expertise amongst its members, and with other warning systems.

Working group 2: sea level data collection and exchange, including deep-ocean tsunami detection instruments.

Sea level data collection and exchange

A. TECHNOLOGY

1. What are the locations of sea level gauges being maintained in the Indian Ocean relevant to the IOTWS?

There are a number of sea-level gauges run by Indian Ocean states. In addition networks of GLOSS gauges also exist in the IO. The following diagram indicates commitments to upgrade the sea level stations to real-time status suitable for the IOTWS (Note: Port Blair is an Indian station).

2. Who operates and maintains them?

IOC	Indonesia
NOAA	Malaysia
India	Sri Lanka
Australia	U.K.
Germany	Mauritius
France	Maldives
Ocean Data and Information Network	Oman
Africa	Tanzania
ADPC	Seychelles
Thailand	

3. When were they installed, or will be?

The timetable of the installations will be dependant on individual IO member states and the IOC. IOC funded sea-level gauges will begin to be installed in the Q3 2005.

4. What types of sea-level gauges are they?

There are a number of technologies currently available. Recommended standards for the selection of sea-level gauges exist such as that for GLOSS.

Guidelines are as follows;

Hardware considerations

- Independent power/communications
- Fault-tolerant redundant sensors
- Local logging & readout of data
- Warning center event trigger
- Surveying benchmarks

Sampling & messages

- 1-minute sampling, redundant data
- 15-minute transmission cycle
- Immediate retransmission via GTS
- Automated levelling information

5. What are the characteristics of the data available from the gauges (sampling rates, accuracy, etc.?

- 4 GLOSS sites with 15-minute real-time data transmissions.
- 11 GLOSS sites with hourly real-time data transmissions.

6. Do the sites serve multiple purposes or are they dedicated to the IOTWS?
[This should capture those needed for impacts.] Since the requirements for each are different, will the stations be used for climate monitoring or tsunami monitoring or both?

It was recognised that there may be a need to examine various user requirements for sea level gauges in the IOTWS sea level network. A multi hazard approach to the sea level network in the IOTWS should be examined.

B. NETWORK SUFFICIENCY

1. What are the broad characteristics of a sufficient network of sea level gauges in the IO for the IOTWS? Are there sufficient real-time sea level stations in the IO region by this measure?

The broad characteristics of a sufficient network of sea level gauges in the IO for IOTWS are such that the presence of a tsunami wave can be proven or disproved within a predefined time frame and that the sea level gauges sufficiently cover areas where tsunamigenic earthquakes may occur.

2. Identify (a) critical gaps that must be addressed, (b) critical gaps that require alternative approaches, (c) significant gaps that could be addressed given resources,

This group recommended that a working group be formed to identify critical gaps that must be addressed based on the information obtained from the IOC National Assessment on the Sea Level network and the projected location of the deep ocean tsunami detection buoys.

3. What is the importance of each site defined relative to the tsunami source threat or the sea level station response (some sites may not be good because they amplify the wave)? Would they be classified as (a) essential [must be maintained at all times; if missing poses considerable extra risk], (b) important [should be maintained and provides a unique contributions], (c) important, but only locally (that is, not essential for the IOTWS but considered important locally), or (d) optional [performs a useful purpose but does not represent a site of significant risk in terms of sea level coverage].

It was **identified** that in order to achieve desired warning times sea level gauges must be employed in optimum positions and quantity around possible sources of tsunamigenic events to prove or disprove the presence of a tsunami wave.

2. If there are not sufficient stations, then will the planned actions by IO member states respond to the need ?

The group recommended that the intersessional working group for sea level measurement should examine the current and future requirements for the IOTWS.

C. DATA DISSEMINATION

1. How are sea level data made available by and to IO member states (nationally within their own country, or internationally to all interested parties)?

Sea level data can be made available to IO member states via the internet or GTS. This group recommends that the WMO OPAG-ISS Expert Team on GTS-WIS Operations and Implementations (ET-OI) to investigate the possibilities of switching existing bulletins transmitted via the GTS to IO member states.

2. How are data transmitted (sampling frequency, transmission frequency, transmission formats)?

Currently sea level stations throughout IO are transmitting in varying temporal resolutions, such as 1-minute, 6-minute, etc. and different transmission cycle 15-minute, hourly, etc. Currently there is no standard WMO code form for seal level data. **This group recommended** that the WMO CBS OPAG-ISS Expert Team on Data Representation and Codes (ET-DRC) investigate an appropriate format for sea level data. **This group will also provide** the ET-DRC with data requirements for sea level data.

3. Are or will data be disseminated through the GTS?

Currently some sea level data are transmitted on the GTS using some inconsistent bulletins headers because there is no standard bulletin headers (TTAAii). **This group recommended** that the WMO CBS OPAG ISS Expert Team GTS-WIS ET-OI investigate the dissemination of sea level data through the GTS using a consistent header.

4. Are there any technical issues, such as bandwidth or satellite coverage, related to disseminating the data through the GTS?

   The technical issues of bandwidth and satellite coverage require an intersession group to investigate and report to the next ICG meeting.

4. Is there an issue of interoperability between the different existing or planned sea level stations?

   Issue with the interoperability between the existing sea level stations, such as the lack of metadata, do exist and there is a requirement to investigate this issue in regards to the current and future sea level stations. **The group recommended** that an intersessional group be formed to investigate these issues such as the development of metadata for sea level sites. For the terms of reference refer to Appendix 1.

D SUSTAINABILITY

The working group recognized the importance of the sustainability of the system. However, due to the limited time available, **the working group recommended** that this be addressed at ICG/IOTWS-II.

Deep-ocean tsunami detection instruments

A. TECHNOLOGY

1. Who are the countries or companies which have proven technologies? How are they similar or different

   Germany has the deep ocean technology and expects the first two deployments in October 2005. The USA has the proven DART buoy technology and there are a number of systems located in the Pacific. The USA also mentioned that the DART II located off Hawaii will be used a reference site for deep ocean intercomparisons. The Paris meeting recommended that the standards for DART systems be implemented. India indicated that they currently produce deep ocean data buoys in India.

2. What are the components of a deep-ocean tsunami detection system that will be used by different countries? What are field station data collection characteristics —sample interval and digitizer and data logger, instrument response / calibration, transmission methods, data formats, archiving systems, etc. What types of sensors will be used and what is their sensitivity for detecting waves in the deep ocean?

Indicative DART buoy measurement requirements for tsunami forecasting are:

- Measurement type —tsunami amplitude over time for input into forecast models
- Measurement accuracy —0.5 cm
- Measurement sample rate —1 min or less

- Measurement processing —within 2 min
- Measurement availability —within 5 minutes to assimilate into forecast models

3. What are the plans for deployment of deep-ocean tsunami detection instruments? Location? Timing? What are the plans for maintenance?

There are various plans by IO member states for the deployment of deep-ocean tsunami detection instruments. It was **recommended** that a DART operators group be formed to investigate various issues relating to a IOTWS deep-ocean tsunami detection instruments network. Refer to Appendix 2 for the terms of reference. There were discussions on two approaches on deep-ocean tsunami detection design. The first to nominate 30min/1 hour deep-ocean tsunami detection instrument location from tsunamigenic source and the second was based on IO member states desired warning times. Subsequent studies could be based on energy generated from tsunamigenic event and based on the critical impacts to IO coasts.

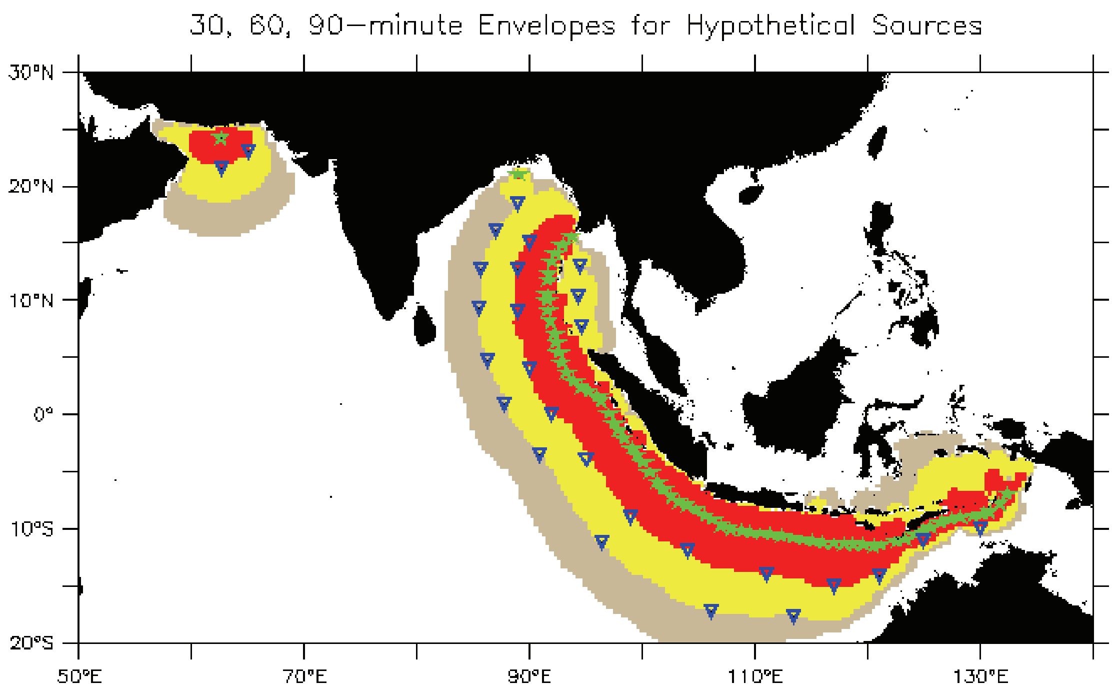
It was **recognized** that numerous difficulties exist with the ongoing maintenance of deep-ocean tsunami detection system, such as the logistics of servicing.

4. What are the advantages of this type of data over coastal sea level gauges?

Deep-ocean tsunami data provides critical input into tsunami forecasts models allowing the adjustment, which can verify the presence of large tsunamis as well as provide the ability to cancel warnings of small tsunamis. Deep-ocean tsunami detection instruments provide much needed coverage in areas that can not be covered by standard sea level instruments.

5. Where are the gaps in proposed coverage of the network?

An estimated 20 DART buoys are required in the IO to fully cover IOTWS requirements to provide 1-hour warning time for IO States. It should be further investigated by the intersessional working group on deep ocean tsunami detection instruments.



6. Are there issues related to technology transfer?

The USA has freely made available the technical plans for the DART buoy on the web.

This group recommended that an intersession working group be formed consisting of IO state members and countries/groups already operating deep ocean bottom pressure gauges (DART type) wishing to participate in planning of the technology transfer. Refer to Appendix 2.

B. NETWORK

1. Describe in general terms the deep-ocean tsunami detection network needed for the IO? What criteria (detection time, estimated coastal wave impact height, or other) should be used to evaluate where instruments are best located to be able to provide warnings or cancellations of warnings in a timely manner to the region?

The deep-ocean tsunami detection network needed for the IO is based on theIO Member States desired warning times, the need to cover gaps in the sea level network and the need to interpret seismic, tide gauge and ocean bottom pressure data for tsunami detection and forecasts in the potential tsunamigenic areas in the Indian Ocean.

2. What are the current plans for provision of deep-ocean tsunami detection instruments in the IO?

The DART buoy operators group will discuss and develop the plans and provisions for deep-ocean tsunami detection instruments in the IO. Measures need to be undertaken to safe guard against vandalism the deep-ocean tsunami detection network (see appendix 2).

C. DATA DISSEMINATION AND ANALYSIS FOR TSUNAMI WARNING OPERATIONS

1. How are deep-ocean tsunami data made available by and to IO member states (nationally within their own country, or internationally to all interested parties)?

The deep-ocean tsunami data for the Indian Ocean are currently not acquired.

2. How are deep-ocean tsunami data triggered and transmitted (sampling start and end, sampling frequency, transmission frequency, data format)?

DART II deep-ocean tsunami data is transmitted via satellite to targeted warning centres. The normal transmission mode is hourly reporting of 15-minute data to confirm readiness. The automated mode is triggered by seismic or tsunami wave and is also available on demand.

3. Are or will deep-ocean tsunami data be disseminated through the GTS?

It was recommended that the WMO OPAG ISS Expert Team GTS-WIS ET-OI investigate the dissemination of deep-ocean tsunami data as well as sea level data through the GTS using a consistent header.

4. Are there any technical issues related to disseminating the data through the GTS or other means?

   As with sea level data there are no standard WMO codes for deep-ocean tsunami data. **This group also recommended** that the WMO OPAG-ISS Expert Team on Data Representation and Codes (ET-DRC) investigate an appropriate format for deep-ocean tsunami data as well as sea level data.

5. What numerical modelling is required for analysing deep-ocean tsunami data [see also SWG 3]?

   The deep-ocean tsunami data is currently treated as a sea level data which is used in tsunami forecasting. Additional R&D work is required to utilise the full potential of deep-ocean tsunami data.

6. Is there an issue of interoperability between the different existing or planned deep-ocean tsunami detection instruments?

   As with the issue of interoperability between the existing sea level stations and there is a requirement to investigate this issue in regards to the current and future deep-ocean tsunami detection instruments. **The group recommended** that an intersessional group be formed to investigate these issues. For the terms of reference refer to Appendix 1.

Appendix 1

DRAFT TERMS OF REFERENCE OF THE INTERSESSIONAL GROUP FOR SEA LEVEL MEASUREMENT

There is important work that needs to be progressed intersessional in collaboration with GLOSS and WMO.

To form an intersessional working group to :

i. Liaise with CBS/WMO and relevant Expert Teams to develop a more effective data representation and code form for Real Time exchange of Sea Level data and to conduct test of latency (timeliness) of GTS transmissions.
ii. Liaise with the IOC National Assembly to identify additional sites for implementation and/or enhancement.
iii. Coordinate plans for Sea Level for Sea Level observing sensitivity tests to understand the optimal, effective IOTWS Sea Level network.
iv. Develop guidance on mandatory metadata including detail of local bathymetry.

Suggested membership:

Convenor: Dr Bernie Kilonsky (USA/GLOSS)
Indonesia, Iran, Australia, Sri Lanka, Tanzania, others to be identified.

Appendix 2

INTERSESSIONAL WORKING GROUP ON THE ESTABLISHMENT OF AN INTERNATIONAL DART PARTNERSHIP

Buoys for the deep ocean assessment and reporting of tsunami (DART) are highly sophisticated instrumentation packages used to detect the passage of tsunami in deep ocean waters.

In the aftermath of the Indian Ocean tsunami of 26 December 2004 a number of countries have announced national plans to operate DART kind of buoys or increase the number of DART buoys that they operate. Over the next few years the numbers of DART buoys deployed globally are expected to increase from today's total of less than ten to eighty or more. DART buoys are critical to the rapid detection and forecast of tsunami.

The Intergovernmental Coordination Group of the Indian Ocean Tsunami Warning System (ICG/IOTWS) hereby agrees at its First Meeting held in Perth on 5 August 2005 to form a working group to explore the feasibility of forging an International DART Partnership to promote common efficiencies in the development of DART technology and the operation of DART buoys.

It is proposed that the partnership will be under the auspices of UNESCO's Intergovernmental Oceanographic Commission (IOC) and will utilize where appropriate the *IOC Criteria and Guidelines on the Transfer of Marine Technology* (IOC/INF-1203). DART buoys are likely to be located both in international and territorial waters. It is anticipated that each partner will bring significant and ongoing value to the proposed Partnership.

Potential areas for international cooperation with regard to DART buoys include:

- the setting of common DART standards,
- the establishment of an international DART research and development program, including joint activities,
- maximizing the sharing of DART technology among partners to facilitate the production of DART buoys worldwide,
- cooperation on the testing and calibration of DART buoys,
- maximizing opportunities for coordination and cooperation among partners with regards to the siting, deployment, operation, maintenance and support of DART buoys.

Membership of the International DART Partnership will focus on those countries that operate or plan to operate DART buoys globally. The objective is to facilitate practical cooperation on a critical technology for tsunami warning. Members of the intersessional working group are Australia (chair), Germany, Indonesia, India, Malaysia, Thailand and the United States of America.

The intersessional working group will draft terms of reference for the proposed International DART Partnership for agreement at the Second Meeting of the ICG/IOTWS, to be held at Hyderabad in December 2005.

Working group 3: Tsunami hazard detection and characterisation, including modelling prediction and scenario development.

The delivery of reliable tsunami warnings and the assessment of tsunami hazard and risk are dependent on the methods, models, and data that can be developed and made available to Indian Ocean states for use in mitigating tsunami impacts and risk. This working group conducted a brief overview of the issues and developed a series of recommendations to accelerate the implementation and coordination of tsunami modelling and risk information and products to Indian Ocean countries.

1. Observations

The Working Group opened with a discussion on the types of observations used to detect and verify tsunamis. It was noted that these are all needed in real-time.

The obvious importance of seismic data was firstly acknowledged. Short period and long period (broadband) seismic observations are necessary, as the estimation of earthquake magnitude can be crucially dependent on long period measurements. It was noted that GPS data can be used to verify earthquake displacements.

For the verification of the existence of tsunamis, sea-level observations are required from both deep water (DART buoys) and from tide gauges in shallow water.

2. Methods

There was discussion on the methods used to estimate the impact of tsunami waves. There are several methods available to transform deep-water information into wave height at the coast which are available in the public domain. The inundation and run-up of waves must be treated separately and several models are being used and/or are under development.

It was noted that impact estimates can also be made after the event through post-tsunami surveys and inundation mapping and that these are also useful for the validation of numerical models.

Physical models are important for the estimation of smaller scale impacts and validation of numerical models.

3. Models

The Group agreed that the modelling aspect can be broken down into three major components: Deep-water models, coastal models and risk assessment. Discussion focussed on the specific inputs and output parameters that are important for each type of model.

a) Deep-water models (up to 200 m depth)

Deep-water models typically consist of a linear propagation model, which takes a surface disturbance as its forcing function. In the operational environment, these can be enhanced via data assimilation, where the data to be assimilated can be updated using sea-level and seismic observations.

b) Coastal (fine scale) models

Coastal models are used to estimate inundation. It was noted that detailed information on coastal structure is required for estimates of the impact.

The development of "geo-databases", including GIS data requires significant resources.

Some current limitations of coastal models were noted:

- It is not feasible to model every part of the coastline
- Detailed bathymetric data is needed to improve the accuracy of these models
- In current state-of-the-art inundation models, coastal elements (e.g. buildings) do not interact with the wave.
- Model verification is required but often is limited due to lack of data.

c) Risk assessment

Risk assessment models should include social and economic vulnerability modelling in order to obtain estimates of the total risk. It was noted that these should include population and infrastructure information for input to comprehensive vulnerability analysis. It was also noted that risk assessment models are needed for long-term planning activities.

The report of the IOC Paris meeting noted that hazard and risk modelling development should have the following elements:

- Develop maps of extreme / maximum run-up and impact;
- Develop maps of probabilities of different run-ups and impacts;
- Focus initially on earthquake and volcanic sources in the subduction zones in the east Indian Ocean;
- Focus initially on identifying regions of higher hazard (headlands, bays, etc.), which can be done without detailed bathymetric or topographic data; and
- Develop over time to capture impact as well as uncertainty and variability in hazard and risk to communities.

4. Model applications

The Group spent some time discussing the uses and applications of the above types of models.

- Operational forecasting
- Educational tools and public awareness – particularly graphic simulations
- Mitigation
  - Land-use planning
  - Physical intervention —e.g. green belts
  - Risk assessment and management
  - Hazard risk maps and other data layer maps, including built environment, and population distributions
  - Inundation maps —inundation and run-up, including calculations such as predicted currents

- Evacuation maps, which include safe areas and shelters, how to get there, and where to go, based on scientific products.

5. Model Inputs/Outputs

Bathymetry

The importance of accurate bathymetry for both deepwater propagation models and the coastal models was emphasised. It was noted that the hydrographic community may need to alter the priorities and/or parameters they use to collect bathymetric data —in particular, data collected for navigational charts may not provide the information that is required by the tsunami modelling community. Further guidance may be required.

It was suggested that an estimated minimum spatial resolution required for operational forecasts of inundation is 50 m.

Limitations to existing bathymetric datasets are:

- Gaps in datasets
- Mismatches between topographic and bathymetric datasets
- May need updates of coastal information after major events

Tsunami source information

The required forcing function for deepwater models is spatial distribution of sea-floor or surface displacement. The potential locations of major earthquakes are well known, but probabilities of occurrence and details of likely earthquake ruptures require additional research. Volcanic and submarine landslide sources have generally not been characterised. Meteor/asteroid sources were noted but not discussed.

Sea-level data

Sea level data is needed for updating of model/data assimilation, either from DART buoys or tide gauges

Coastal information

- Coastal topography and bathymetry are required at coast but generally have not been integrated into seamless databases
- Tidal information required for inundation
- Exposure data (population, demographics, infrastructure, buildings) is required for risk

Output parameters

- The importance of spatial and temporal information was stressed, i.e., wave height as a function of both location and time
- Current velocities are important for inundation/impact.
- Worst-case scenarios in addition to probability distributions and ranges
- Wave run-up

6. <u>Needs of National Agencies</u>

A possible model for the Indian Ocean system is for a central repository or library of tsunami scenarios, which are pre-run from the tsunami source to near-shore using deep-ocean methodology and internationally available bathymetric grids. These scenarios should be in the public domain and available to all, including the software. Each nation would provide its own bathymetry to bring information into shoreline. Near-shore modelling requires more detailed bathymetry that may only be available to national institutions.

There are likely to be several models available from academic community —there is a need to provide protocol for operational model requirements. Forecast models need to be well documented, maintained and supported. Ongoing developments need to be incorporated and distributed to users. R&D is required to continually improve the models. There should be a method by which feedback from users can be passed to the R&D community.

<u>The group noted</u> that there will be a training workshop on TIME (a widely used tsunami propagation model) in the Philippines from 17 to19 November 2005.

SUMMARY AND RECOMMENDATIONS

The problem of tsunami modelling can be broken into three separate components.

1) Propagation of the wave in the deep ocean

2) Coastal inundation and

3) Assessment of risk and vulnerability

The Working Group recommended the following actions:

Recommend to seismic research groups around the world to advise on credible seismic scenarios that need to be captured for numerical tsunami modelling e.g., location, magnitude, rupture, orientation, dip, and probability of occurrence.

Some nations will develop hazard scenarios. **Recommend** that they be made freely available. These need to be well documented.

The development and application of models needs an agreed framework for testing and evaluation of models, particularly those used in operations. This would involve a Model Intercomparison Project for the Indian Ocean**.** To this end, **a workshop should be convened**. Establish an organizing committee with one person from each of the following countries: Australia, India, Indonesia, Iran, Kenya, Malaysia, Thailand, South Africa, Sri Lanka and USA. The convenor will be Prof. Chari Pattiarachi.

- Obtain details on models that are currently used or in development
- Provide benchmark tests —historical databases are useful (e.g. U. Hawaii)
- Agree to documentation (inputs, outputs etc.) Possible starting points are: WMO document, GODAE template
- Establish a web-page under IOC secretariat
- Hold a one or two-day workshop prior to ICG/IOTWS-II, with draft of documentation.

- Include coastal inundation models

Establish requirements for bathymetry. Communicate requirements and urgency of these requirements to the International Hydrographic Organization. This is also necessary on a national basis.

Establish Intersessional Working Group to address issue of assessing hazard, vulnerability and risk. The working group would facilitate the access to models, and develop a programme of training and capacity building. Terms of reference for this working group are attached.

Risk Assessment Working Group

The development of a tsunami early warning system for the Indian Ocean needs to be put into a risk management framework that can be applied at global, regional, national and local levels. The goal is to reduce tsunami risk and vulnerability to Indian Ocean nations.

A Working Group will be formed under the auspices of the ICG/IOTWS with the following terms of reference:

- Facilitate the development of consensus models and decision support tools for tsunami hazard and risk assessment for IO nations
- Facilitate access to and development of databases including exposure, tsunami hazard and vulnerability data
- Liaise with other committees and organizations or professional groups that are developing models and data
- Facilitate capacity building and knowledge transfer in the form of workshops, training programs and case studies for risk assessment in all IO countries
- Liaise with risk and emergency managers to facilitate the development of models and products that are of maximum practical use to decision makers.
- Develop guidelines for tsunami risk assessment as part of a multi-hazard risk management framework.
- Encourage and inform the process of developing cost-effective and practical mitigation measures

The products from risk assessment activities include:

1. Hazard maps showing areas of high potential for tsunami inundation
2. Inundation maps (inundation and run-up) for maximum credible tsunami scenarios for areas of high vulnerability or risk
3. Risk maps capturing the potential aggregated impact of all tsunami sources on the built environment, population and local and regional economy.
4. Evacuation maps, which include safe areas and shelters, how to get there, and where to go, based on scientific products.

These products will be important for:

- Identification of high-risk areas for further study or mitigation efforts

- Land-use planning
- Strengthening of lifelines and other public structures
- Building code revision
- Structural interventions (e.g., tsunami breakwaters, sea walls and secure water supply
- Non-structural interventions (e.g., protection, rehabilitation, conservation and improvement of coastal ecosystems)
- Construction of protective coastal structures and elevated shelters
- Risk transfer or sharing options (e.g., insurance disaster relief policies)
- Development of evacuation routes and disaster response plans

Some high priority items were identified at the Paris IOC meeting:

- The use of available data and models;
- Regional hazard/vulnerability assessment in order to identify areas of highest risk;
- Development of credible "worst" case scenarios for planning purposes;
- Evaluation of most probable sources of tsunamis;
- Consideration of mechanisms other than earthquakes, such as in the western Indian Ocean;
- Capture lessons learned from the 26 Dec 2004 tsunami;
- Establishment of a distributed, uniform and consistent database for hazard, vulnerability and impact modeling and assessment; and
- Establishment of guidelines for data collection (including post disaster).

Proposed membership:

John Schneider, Australia
SSL Hettiarachchi, Sri Lanka
Akiko Nakamura, ADRC
SR Subbia, ADPC, Thailand
Hiroshi Tajihi, Japan
Yuichi Ono, UN/ISDR, Bonn, Germany
Andrzej Kijko, CGS, South Africa
Zainal Arifin, LIPI, Indonesia
Pariuhutan Manurung, Bakosurtanal
Dr B. R. Subramanian, India
(Mauritius)
Dr Mehl, Germany
(Iran)
David McKinnie, USA

Working Group 4 : The establishment of a system of interoperable operational centres

1. INTRODUCTION

1.1 This sessional Working Group was given the following tasks (Terms of Reference):

(i) To progress the establishment of a coordinated regional warning system for the entire Indian Ocean basin, through the establishment of a network of National interoperable Warning Centres.

(ii) To advise on the modalities of operation, methods and standards for development and issuance of warnings, and requirements in terms of coordination and operating within a multi-hazard approach.

2. CONSTRAINTS AND EXTENSIONS OF TOR

2.1 The WG addressed the tasks against a background of three other WGs that addressed the issues of seismic and sea level data collection, sharing, tsunami detection and hazard identification which included open ocean modelling, inundation modelling and risk assessment modelling. These latter capabilities would be developed by some IO nations and would be developed within the constraints of the recommendations of SWG3.

2.2 During the consideration of the TOR (i) and (ii) it was agreed by the WG that an additional TOR needed to be included in the discussions: that will link the National Warning distribution of a Centre to the emergency organisations, the media, and finally the public at risk.

3. AN INTERIM SYSTEM AS CAPABILITIES DEVELOP

3.1 The Working Group recognised that it needed to develop a description of the initial (interim) IOTWS and, in the case of interoperable warning networks, identify a process and way forward for agreed arrangements for sharing and exchange of information and warnings, consistent with the principles set down in the Terms of Reference for the ICG/IOTWS and the Paris Communiqué in particular. The WG took into account the results of the IOC Workshop Report No 196, Paris, 3–8 March 2005.

3.2 In that Report it was agreed that a **National Tsunami Warning Centre was: A Centre operated by a Member State with responsibility for and capabilities to generate tsunami warnings for that Member State.** The Centre may also act as the Operational Contact Point for warnings generated by other Tsunami Warning Centres.

This interim system will be dependent on:

- The results of the current IOC/WMO Assessments, particularly for those Member States that do not have significant national capability.
- The need to focus on the development of a system and identify those parts that will provide the primary capability.
- Consideration of emergency communication and information awareness issues. These need to be linked to the warning centres. Technology and technology transfer and sustainability were dealt with by the other working groups.

3.3 The WG discussed the original concept that the IOTWS should be a network of networks, with each National Tsunami Warning Centre (NTWC) having a differential capacity to contribute to the overall system. The aim is to determine the details of how each country will contribute, and if each country is capable of operating within this environment.

3.4 In order to allow consideration of NTWC capabilities, the WG considered Mr Yamamoto's (JMA) criteria for the type of warning centre (A, B and C) depending on the criteria of: analysis of seismic data and evaluation of tsunamigenic potential; receipt of tsunami information from others; issuance of warning; monitoring of sea level. In this method of categorisation, only the PTWC and JMA centres have current capability for the highest level (type A). However, there are several other NTWC that are working rapidly toward this capability, and other centres that would not need to reach this or the "type B" centre. The WG agreed that only two categories should be considered, with obviously some minor variations in capability within these categories. As discussed below, these will be essentially "major" centres with the capability to receive all appropriate seismic and sea level data, ability to operate standardised models and the capability to distribute "advisory" information on tsunami information to other NTWC and all other NTWCs, which must be able to receive these advisories and act on them 24/7 by providing their nation's warnings.

3.5 'A' level centres will have standard open ocean models, undertake intercomparison of models, and have agreed advisory format and dissemination. This allows consistency of the message —a sub-network of regional Major Centres (A Centres) that would pass on advisories on to all 27 NTWC in the Indian Ocean.

3.6 This is a conceptual approach that can be adapted to a geographical setting: the essential characteristics (capability, functionality)

(i) National Tsunami Warning Centre (NTWC) —operations 24/7, clear, precise, unambiguous operational procedures— so that the warning message is based on an advisory which is unambiguous, and hence "interpretation" responsibility is not placed on its operational staff,

(ii) Regional Tsunami Advisory Centres (RTAC) responsible for real time issuance of tsunami advisories to NTWCs.

3.7 Consideration was given to advisories from several RTACs being provided to all NTWCs. However, it was agreed that this would be unmanageable for many NTWCs. After discussion, it was felt that a maximum of two RTACs should confer on the issuance of an advisory to an individual NTWC, or to make available to several. Examples for this type of real time operational conferral include IEA (nuclear accidents) and Tropical Cyclone regional centres.

3.8 To the best of its knowledge the WG members considered all countries in IO (except those in unforseen circumstances such as wars) operate a 24/7 NTWC capable of national response, currently based on JMA/PTWC advisory information. Some Member States also utilise their own capability, or plan to do so in the near future, to detect tsunami events.

4. A PERMANENT IOTWS: OPERATIONAL CAPABILITY

4.1 As discussed above, the current interim IOTWS operates on the advisories prepared by the JMA and PTWC. Essentially, these "A" Centres are acting as default, or interim, Regional

Tsunami Advisory Centres (RTACs). They (PTWC and JMA) must be provided with a timetable for transition to a self sufficient IOTWS.

4.2 IOC Assembly Resolution XXIII-12 recognised the plans and intentions of several Member States to develop their national capability to detect, analyse and issue timely warnings of tsunamis generated in particular seismic zones. The WG considered that these Member States would be appropriate to provide advisories to other countries in the IO, once their capability had been fully developed. These national centres that could form the basis of "advisory" nodes for the overall network of 27 NTWCs.

Planned Regional Tsunami Advisory Centres (RTACs) for the Indian:

Australia
India
Indonesia
Iran
Malaysia
Pakistan
Thailand

4.3 As discussed earlier, the arrangements need to be in place for ideally two RTACs to confer in rapid real time to agree on the content and issuance of an advisory to the Member States NTWCs affected by tsunami's generated in the zones of their concern (or that they are responsibly for monitoring).

4.4 Currently some of these RTACs already have established communication links. Communication links between centres will reflect the focus of countries on the separate source regions (Makran or Sunda). An additional effective approach considered by the WG was for a number of "secondary" distribution hubs to be identified (e.g. La Reunion and Nairobi for Africa), while retaining the inbuilt redundancy of the network of networks. This secondary level of redundancy needs to be explored further. It must be emphasised that RTACs will issue advisories, not warnings, for use by national warning authorities (NTWCs).

4.5 A major issue to be addressed is the protocol to be adopted to coordinate the multiple advisories, to avoid confusion in the receiving nations, eg pairing of centres as used by IAEA. The format and content of advisories from all major centres should be standardised. The communications medium to be used to distribute advisories is the GTS.

5. CONCLUSION: TOWARDS ICG/IOTWS-II

5.1 **The WG considered** that the details for the IOTWS model described above would need further delineation of detailed arrangements and should be addressed by an intersessional working group to report to ICG/IOTWS-II in December 2005.

5.2 The TOR should be those given in paragraph 1.1, (i) and (ii), together with two additional TOR (iii) and (iv):

(i) To progress the establishment of a coordinated regional warning system for the entire Indian Ocean basin, through the establishment of a network of National inter-operable Warning Centres.

(ii) To advise on the modalities of operation, methods and standards for development and issuance of warnings, and requirements in terms of coordination and operating within a multi-hazard approach.

(iii) In consultation with the IOC Secretariat, examine the IOC/WMO Assessment process results still underway, and develop guidelines for the distribution of tsunami warnings by the National Tsunami Warning Centres to emergency centres in their country, the media and the public. These should be based on the national assessments. These Guidelines will be included in the IOTWS master plan being developed by the IOC tsunami technical unit.

(iv) Provide further detailed elaboration of the role of NTWCs, including responsibility for advisories, and on the modalities and responsibilities of RTACs.

ANNEX III

OPENING ADDRESS

by Mr Koïchiro Matsuura
Director-General of the United Nations Educational, Scientific and Cultural Organization (UNESCO)[1]

3 August 2005

Excellencies,
Distinguished Participants,
Ladies and Gentlemen,

It gives me great pleasure to send this message to the first meeting of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) here in Perth, Australia. I would like first to acknowledge and sincerely thank the Government of Australia for its generosity, not only in hosting this meeting, but also in contributing actively to the development of the IOTWS.

The last seven months have been active ones. Building upon the impetus created by the 26 December 2004 tsunami and the resulting impact upon public awareness, we have made remarkable progress to reach the point where we are today. We now have an interim tsunami warning system in place that has proven its worth. National needs assessments that will be used to advance the technical plans for both national and regional systems are progressing steadily, giving excellent results and promoting a high level of national coordination. Inundation maps are being developed for a large number of countries, and detection instruments are being updated so they can provide the real-time information that is crucial to ensure accurate data. In short, though it is not yet at its optimum level, we have gone a long way in building the System.

This meeting in Perth will move us further ahead. As you know, a robust, comprehensive approach for mitigating the tsunami risk is based on three mutually dependant components: (1) the assessment of the tsunami hazard; (2) an operational detection and warning system; and (3) the planning and adoption of emergency preparedness measures. Putting these components in place has been our challenge here in the Indian Ocean. One of the tasks of this first session of the ICG will be to attempt to complete the planning of the detection networks, by defining the common minimum requirements and contributions of the different participating countries. It will also have to review plans for assessing and quantifying national needs and to decide how best to coordinate international assistance to satisfy the identified needs.

The reality of the vast Indian Ocean rim is diverse and each country still has to define the best strategy for facing the challenge of active participation in the IOTWS, while respecting the three component requirements for the System that I mentioned earlier. The international community has expressed strong support for the efforts of the countries of the region and has proven its readiness to assist. In this regard, I would like to acknowledge the contributions that several nations of the Indian Ocean are making to the System, as well as their efforts in establishing national communication infrastructures, an essential component in delivering alerts and warnings to the people at risk.

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[1] delivered on behalf of the Director-General by Mr Patricio Bernal, Assistant Director-General, Intergovernmental Oceanographic Commission (IOC)

I would like to insist, however, that no nation can single-handedly provide effective warning for a natural phenomenon like a tsunami. For the detection and warning of tsunamis, especially distant ones like the one that struck last December, an international detection system based on international cooperation is required. This international detection system depends on fully integrated oceanographic networks deployed over the affected basin, as well as seismographic networks deployed over the affected territories. These networks need to be able to broadcast in real-time the data they collect.

Of course, we expect each nation to establish and develop its own national centre, which at the minimum will be able to receive data and information, deliver both to the relevant persons, and advise national emergency authorities on the measures required to warn the people at risk. I am happy to report that progress has been made in this regard. In fact, it was with great satisfaction that I was able to report to the Secretary-General of the United Nations, Mr Kofi Annan, that as a result of an initiative that your countries adopted in the Paris Coordination Meeting last March, we have, today, 25 operational national tsunami focal points receiving tsunami-relevant information and warnings from Tokyo and Honolulu within the framework of the interim system. You should know that we are conducting tests and drills to verify the communication links and, as time passes, the networks are becoming more and more effective.

Our success so far should, however, not allow us to become complacent. The national centres must try to move away from their present minimal configuration to develop their own national detection networks, their own risk-assessment and preparedness plans, and their own national educational or awareness plans.

Regarding detection, by expanding seismographic and sea-level networks, and equipping these instruments with ancillary systems that can help in local decision-making, we can accomplish much. For example, in the project that the IOC is implementing, the main goal is to enlarge the network of real-time sea-level detection instruments. All countries in the Indian Ocean basin have some sea-level measuring device operating in their ports and bays. In the majority of cases, these are not real-time instruments. The new instruments, which use solar power to make the signals autonomous from the local power source - which is usually the first thing that is lost in an emergency - will require closer supervision and maintenance. IOC expects to help with the maintenance of the new instruments for three years, and also to help train local operators in their use, once they are in place.

UNESCO has a very rich experience in building scientific capabilities in the developing world. There is no stronger message for authorities than that pertaining to early detection of tsunami, where science capabilities are developed to underpin directly an important application that has large societal implications. Building and participating in the Tsunami Warning System is a huge opportunity for developing nations to break through in the development of capacities in geosciences and oceanography, and UNESCO and others are ready to assist in this process. I recognize that these are long processes and that the immediate needs have the absolute first priority, but the durability of the system in the long run requires that we develop such an initiative in parallel.

Regarding the development of risk assessment plans, these are by necessity activities that national authorities and institutions need to conduct. However, here too there is a significant need for the transfer of know-how and technology. Precise inundation maps of coastal cities and other sensitive coastal areas are a basic tool of emergency preparedness. The technology and know-how to build them, according to our experience, can easily be transferred to each nation.

I cannot repeat often enough that the ultimate resource that is essential to the success of any warning system is individual knowledge. Populations have to know what they need to do when confronted with the emergency. Knowledge implies education, one of the main pillars of UNESCO's action. Awareness-raising tools and experiences can be shared with great benefit. As you are no doubt aware, we have already started to work with specialized groups, such as the Asian Federation of Broadcasters and the Asian Disaster Reduction Centre, to transfer our accumulated experience from the Pacific region to the Indian Ocean region. Now it is up to you, the ICG, to take full cognizance of all these activities and fully integrate them into your planning for the IOTWS.

Ladies and Gentlemen,

We are very satisfied to see that many of your countries are actively building capabilities and securing the resources to make a strong contribution to the international effort. The Indian Ocean is vast and will require several strong national systems that can take the lead at the sub-regional level, and take on a significant part of the burden of operating the system in its initial phases, while other countries are still in the process of building their capacities. I look to these strong nations to ensure that no one is left behind.

Finally, I would like to thank the many governments, both within and outside the Indian Ocean region, which have contributed vast resources, enabling UNESCO and its IOC to undertake the important task of establishing the IOTWS. In this regard, allow me to extend particular thanks to the Governments of Belgium, Finland, France, Germany, Ireland, Italy, Japan, Norway, Sweden, the USA and the European Union. I would also like to reiterate my thanks and gratitude to the Government of Australia, which is so kindly hosting this meeting, and is providing tremendous support for the establishment of the IOTWS, including for the Secretariat of its ICG, which will be based here in Perth, in the UNESCO/IOC Regional Programme Office.

It only remains for me to wish you a fruitful meeting. I am sure you will make great progress in reaching our common goal.

Thank you.

ANNEX IV

IOTWS Status Report
3 August 2005

26 December 2004

- Over 200,000 people died
- Nations of the region act: Jakarta, Kobe, Phuket
- IOC invited to lead efforts to establish EWS
- IOC and Partners ready to assist
- UN/OCHA Project submitted and funded
- March 2005: project started

ISDR proposal to UN/OCHA

- The 11 M$ project has five components, including
  - core system implementation,
  - integrated risk knowledge,
  - public awareness and education,
  - community level approaches
  - project coordination

- IOC: core system implementation: 3.5 M$

Core system implementation

- Governance
  - 2 intergovernmental coordination meetings
- Capacity building
  - Expert advisory missions
  - Startup training programme
- Core system observational network
  - Operation of interim tsunami advisory information system
  - Establishment operational sea-level network

ISDR and WMO

- ISDR/IOC: Study Tours (Tokyo and Hawaii)

- ISDR/WMO: GTS missions

- WMO: reinforcement of GTS to carry sea level data

Progress March-June 2005

- 3–8 March: 1st coordination meeting Paris (IOC Workshop Report 196)
  - Communiqué
- 14–16 April: 2nd coordination meeting Mauritius (IOC Workshop Report 198)
  - Declaration
- March/April: identification interim focal points (25 incl East Timor)

- April: start interim tsunami advisory information system (PTWC/JMA)
- June: start national assessment missions

Paris meeting outcome

- Recommends to establish Intergovenmental Coordination Group (ICG/IOTWS) with IOC as Secretariat
- System= coordinated network of national systems
- Warnings= responsibility of countries
- Need to establish National Tsunami Warning centres
- Need to share data
- Established interim tsunami advisory information service (JMA and PWC)

Mauritius meeting outcome

- Mauritius declaration
  - Re-affirms commitment of nations
  - Nations fully informed of, and agree with work plan
  - Invites countries to assess requirements and capacity building needs by July 2005, followed by development of national strategic plans
- Donors pledge support
  - –Finland, Belgium, Norway, Germany, Italy,…

National assessments

- Purpose
  - to inform national stakeholders on the requirements (organizational, infrastructural and human resources) for the establishment and operation of a tsunami warning and mitigation system;
  - to assess the available resources;
  - to promote the establishment of national coordination committees involving widest possible group of stakeholders
  - to identify capacity building needs
  - Partnership IOC, WMO, ISDR, IFRC, ADRC

Countries that requested mission

Towards Capacity Building Strategy

- The 18 national assessment reports will be formally submitted to each visited country
- The 18 national assessment reports will be consolidated in one document
- The document will identify similar requirements for CB at the regional and sub-regional level
- December meeting will design and adopt CB plan

Milestone: 23rd Assembly IOC (June 2005)

- Established Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning System (ICG/IOTWS) (Resolution XXIII-12)
- Secretariat to be hosted by Australia in Perth
- Two Sessions in 2005: August and December

June-December 2005 timeline

Missions SL network
Missions Report
ICG/IOTWS-I ICG/IOTWS-II
Study Tours

Tokyo & Hawaii Study Tours

- for high level administrators that are responsible for tsunami warning activities in Indian Ocean rim countries to acquire, through the comparison of different types of systems in Hawaii and Japan, the necessary judgment and methods of assessment to identify the components of the national tsunami warning and mitigation system that need to be built or strengthened
- Example Hawaii: 20 countries, 50 participants

Hawaii study tour

Sea level network expansion/upgrade

PROVISIONAL TIMETABLE

- Deadline for submission of bids 28 July 2005
- Selection of contractor 15 August 2005
- Establishment of contract 15 September 2005
- Installation/upgrades of Indian 1 October 2005

Ocean gauges to begin

- Start of maintenance phase 1 September 2006
- End of UNESCO/IOC supported maintenance phase 31 August 2011

Station planning

New Real-Time Installations

ANDAMAN IS.	INDIA	92°46' E	11°41' N
NICOBAR	INDIA	93°50' E	7°00' N
SIBOLGA*	INDONESIA	98°47' E	1°44' N
PRIGI*	INDONESIA	111°43' E	8°17' S
AKYAB	MYANMAR	92°54' E	20°09' N
PENGKALAN/TLDM/LUMUT	MALAYSIA	100°11'E	4°14' N
KO TAPHAO NOI	THAILAND	98°26' E	7°50' N

Upgrades for Existing Real-Time Stations

GAN	MALDIVES	73°10’ E	0°42’S
HANIMAADHOO	MALDIVES	73 °10’ E	6°46’ N
MALE	MALDIVES	73°30’ E	4°10’ N
RODRIGUES	MAURITIUS	63°25’ E	19°41’ S
SALALAH	OMAN	54°0’ E	17°00’ N
MARIRAH	OMAN	58°52’ E	20°41’ N
ZANZIBAR	TANZANIA	39°11’ E	6°09’S
COLOMBO	SRI LANKA	79°51’ E	6°57’N
LAMU	KENYA	40°54’ E	2°16’ S
DIEGO-GARCIA IS.	U.K.	72°30’ E	7°00’ S
PT. LA RUE	SEYCHELLES	55°32’ E	4°40 S

ICG/IOTWS-I: Perth 3–5 August

Objectives

- Have a clear overview and understanding of the IOTWS technology deployment plans of the Indian Ocean countries and to record this information in the meeting report as an initial plan for an integrated regional warning system. The meeting will discuss possible overlap, complementarity and technical compatibility.
- To discuss related systems including seismic, communications, warning centres, sea level networks and data and information management, to establish an intersessional process for continuation of this work and to reach agreement on the preferred way forward.
- Discuss and plan the future operation of the ICG to ensure support of the process establishing the IOTWS including near-term activities, resources and objectives.

ANNEX V

NATIONAL REPORTS

AUSTRALIA

Introduction

The Australian Government has approved funding for the establishment of an Australian Tsunami Warning System (ATWS). The ATWS will: (i) provide a comprehensive tsunami warning system for Australia; (ii) support international efforts to establish an Indian Ocean tsunami warning system (IOTWS); and (iii) contribute to the facilitation of tsunami warnings for the South West Pacific.

Australia will work in close cooperation with our key regional partners to deliver the IOTWS. The ATWS will deliver significant benefits to the Indian Ocean region. This will be achieved by:

- Facilitating international collaboration through:
  - Participating in the development of an international framework for implementation of the Indian Ocean Tsunami Warning System, and
  - Establishing Secretariat support at the IOC's Regional Programme Office in Perth for the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS).
- Contributing seismic and sea level observations in the SE Indian Ocean.
- Facilitating exchange of data in the region and the establishment of protocols for exchange of alerts and warnings.
- Provision of warnings from the ATWS into the IOTWS in accordance with protocols established by the ICG/IOTWS.
- Sharing of relevant knowledge and technology, including, as appropriate, shared and coordinated logistical support.
- Supporting regional and national efforts to build community capacity and raise community tsunami hazard awareness.

Australian Tsunami Warning System

The Australian Government has determined that the development and implementation of an ATWS will be delivered by the following agencies: Bureau of Meteorology, Geoscience Australia, and Emergency Management Australia:

- Bureau of Meteorology operates the National Tidal Centre (NTC) and has national responsibility for tide and sea level related services, including operation of the Australian Baseline and SW Pacific sea level networks. The Bureau of Meteorology Research Centre is responsible for developing the Bureau's ocean forecast system, including tsunamis. The Bureau has a network of State and Territory offices, which use well-established communications systems to issue severe hazard warnings to State and Territory emergency management organisations, including tsunami alerts generated by its National

Meteorological and Oceanographic Centre (NMOC). The Bureau is responsible for promulgating any public advices and warnings, including those relevant to tsunami events. The Bureau maintains the Australian connection to the Global Telecommunication System (GTS) of the WMO, which will be used by the IOTWS to share data and warnings.

- Geoscience Australia currently operates the national network of seismic monitoring stations to provide alerts for emergency organisations and to support research. It also has expertise in developing risk models for assessing the impact of sudden onset natural hazards.
- EMA is a registered training organisation and is therefore well placed to develop nationally consistent training programs and has considerable experience in facilitating community awareness and preparedness programs.

Central to the ATWS will be the joint Bureau/GA national Tsunami Operations and Analysis Centre, which will provide a 24/7 monitoring and warning capability. Using its enhanced seismic network, GA will identify a potentially tsunamigenic earthquake. The Bureau, in conjunction with GA, will then verify the existence of a tsunami from the enhanced sea level gauge network. Using these data as a constraint on and, as appropriate, to initialise tsunami wave propagation and inundation models, the Centre will produce a forecast for the timing and magnitude of a tsunami striking the Australian coast. The Bureau will then issue initial warnings to emergency services organisations through its State and Territory warning networks, followed immediately by full public warnings through the media and other avenues, such as the Internet. EMA would notify relevant State and Territory emergency management organisations to facilitate and coordinate disaster management, underpinned by a targeted public awareness program. As more data became available GA and the Bureau would update the forecasts.

Contributions to IOTWS

Australia will contribute capacity to the Indian Ocean Tsunami Warning and Mitigation System (IOTWS) in a number of areas. Details of these are given briefly below.

Observing System

Seismic monitoring

Geoscience Australia currently operates a network of seismograph stations throughout the continent for the purpose of monitoring earthquakes onshore in Australia. The current network will be upgraded to include more multi-component broadband stations with greater dynamic range, and a number of new stations will be added. The data from the upgraded network coupled with data from other national warning systems and global seismograph networks will allow large, potentially tsunamigenic earthquakes throughout the Indian and southwest Pacific Oceans to be monitored. It will therefore be able to contribute seismological input to tsunami warnings for regions beyond Australia's coastline. In order to facilitate this, Geoscience Australia will establish a 24/7 operations centre at it Canberra headquarters. It will be linked with the Melbourne operations centre of the Australian Bureau of Meteorology.

The table below provides a general description of the categories of seismograph installations and upgrades. No details are given for a number of seismograph stations in the region for which funding has been provided for installation or upgrade. The detailed layout of the broader regional network is still subject to technical design, overcoming logistic issues, and the results of negotiations with the relevant countries and international organisations.

Table 1. List of seismographic stations to be installed or upgraded

Station Name	Activity	Station Name	Activity
Manton Dam	Upgrade	Charters Towers	Upgrade
Nanutarra	New	Macquarie Island	Upgrade
Fitzroy Crossing	Upgrade	Casey	Upgrade
Buckleboo	Upgrade	Cocos Island	Upgrade
Christmas Island	New	Port Moresby	Upgrade
Lord Howe Island	New	Diego Garcia	Upgrade
Norfolk Island	New	Canberra	Upgrade
Narrogin	Upgrade	New Amsterdam	Upgrade
Marble Bar	Upgrade	Dili	New
Hobart	Upgrade	Rabaul	New
		Wewak	New

Note: Plus 14 other stations to be installed or upgraded throughout the region not listed above or shown in Figure 1

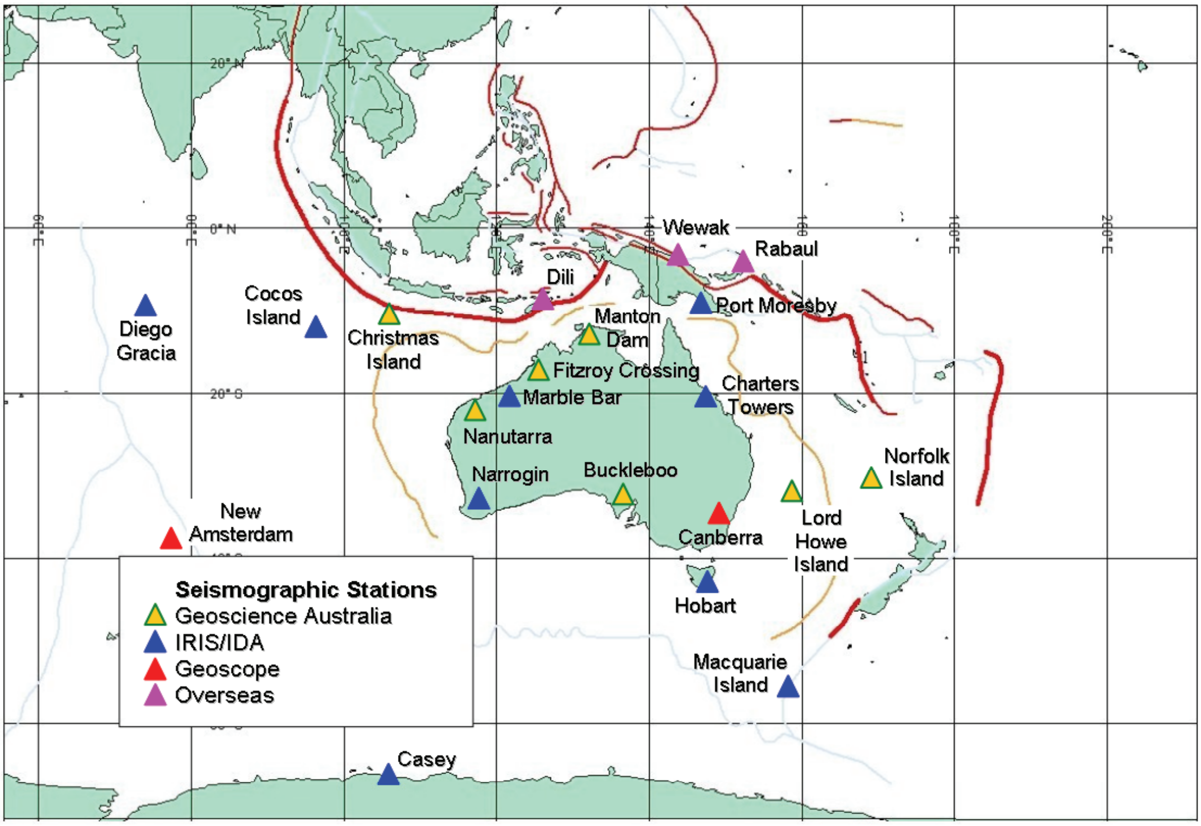


Figure 1. *Seismometer stations for detection of tsunamis off the west coast of Australia and contributing to an IOTWS (regional stations are subject to full technical design, overcoming logistic issues, and negotiations with the countries involved).*

Sea level monitoring

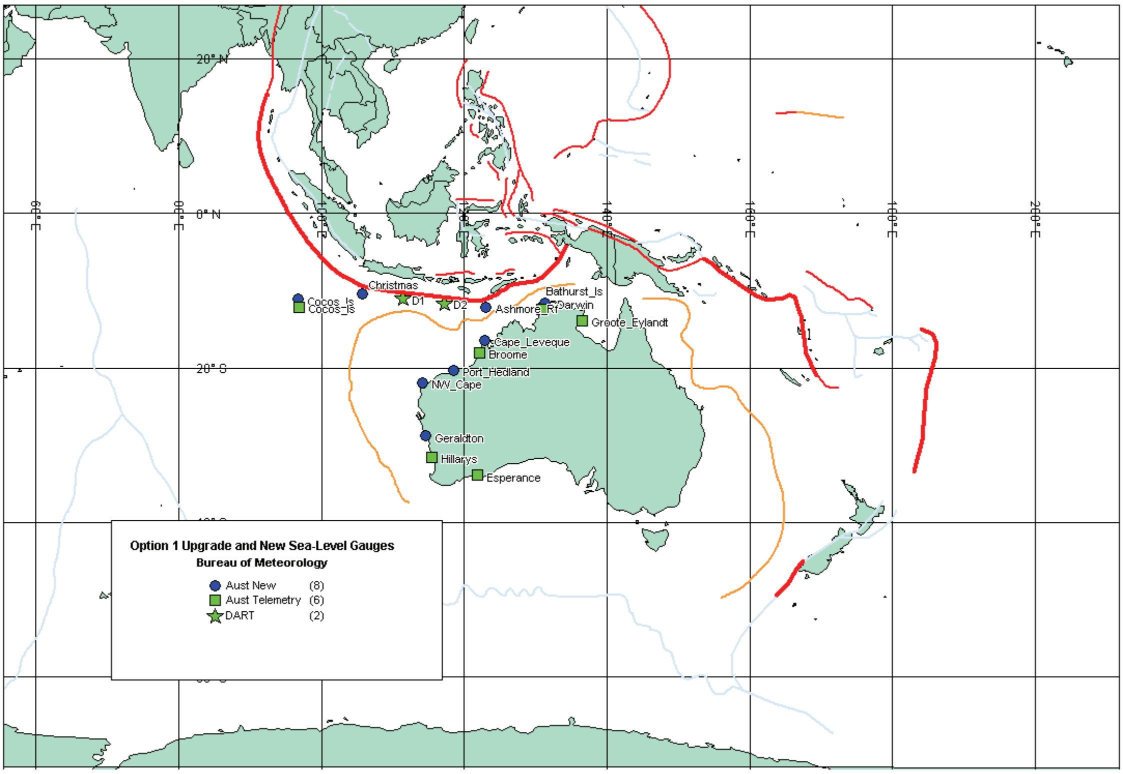
The Indian Ocean component of the ATWS plans to incorporate sea-level gauges on Cocos and Christmas Islands and Ashmore Reef and two DART buoys in the adjacent deep ocean (see Figure 1), subject to a rigorous scientific design and user requirements analysis being undertaken. Data from Cocos and Christmas Islands and Ashmore Reef are critical in any tsunami warning system for the Indian Ocean and so will provide Australia with the opportunity to contribute vital data to the IOTWS. The information will help better characterise the basin wide propagation of any tsunamis. The DART buoys will provide clear indication of the deep-ocean size of any tsunami and so will provide critical real-time calibration information on the potential impact of any tsunami for Australia and for the IOTWS. A further 5 new gauges with real-time active telemetry equipment reporting via satellite, are planned to be installed along the north west coast of Australia at key 'first strike' locations. An upgrade of telemetry communication equipment to 6 existing Australian sea level stations will provide supplementary monitoring capability. Table 1 lists the instruments planned to be installed or upgraded for the Indian Ocean component.

Table 2. *List of instruments planned to be installed or upgraded for the Indian Ocean*

Location	Instrument	Capital investment type
Broome	Existing NTC gauge	Install telemetry
Cocos Island	Existing NTC gauge	Install telemetry
Darwin	Existing NTC gauge	Install telemetry
Esperance	Existing NTC gauge	Install telemetry
Groote Eylandt	Existing NTC gauge	Install telemetry
Hillarys	Existing NTC gauge	Install telemetry
Exmouth – Cape Leveque	Sea level gauge	New gauge with telemetry
Port Hedland	Sea level gauge	New gauge with telemetry
North West Cape	Sea level gauge	New gauge with telemetry
Geraldton	Sea level gauge	New gauge with telemetry
Bathurst Island	Sea level gauge	New gauge with telemetry
Christmas Island	Sea level gauge	New gauge with telemetry - solar
Cocos Island	Sea level gauge	New gauge with telemetry - solar
Ashmore Reef	Sea level gauge	New gauge with telemetry - solar
Indian Ocean	2 x Moored DART buoy	New buoys with telemetry

Given its strategic importance, a back-up sea level gauge will be located on Cocos Island as a matter of priority. The new gauge will be placed on an outer reef facing the open ocean and the tectonic plate boundary to the north and northeast. This provides a level of redundancy in the event of a tsunami incident and possible washing away of this gauge. Cocos Island is considered a key global monitoring station and a very important contribution to the IOTWS.

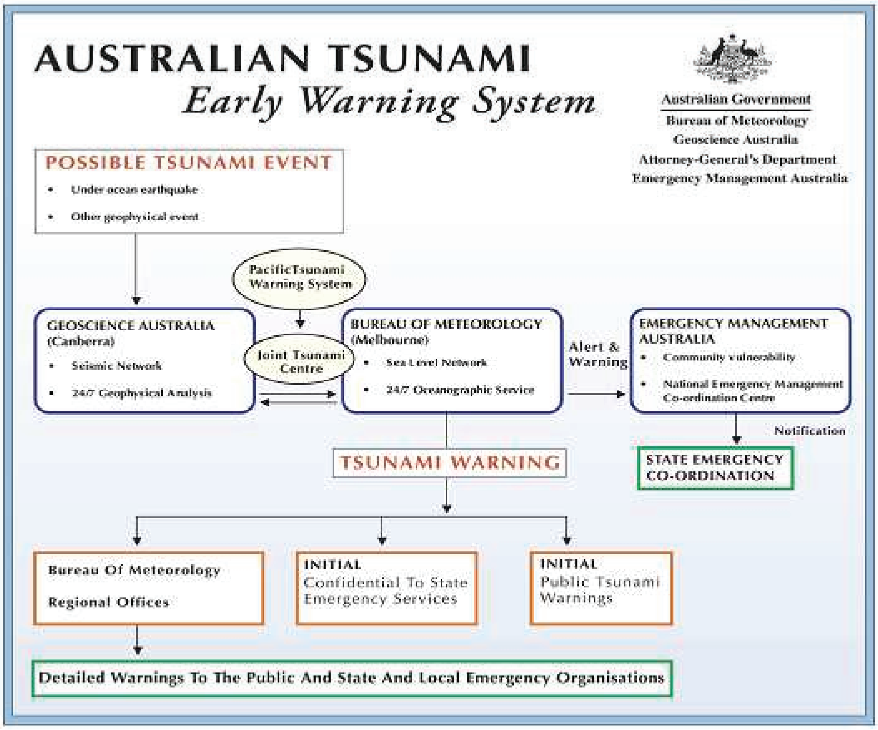
Figure 2. *(next page). Sea level gauges for detection of tsunamis off the west coast of Australia and contributing to an IOTWS. Major Sources of Tsunamis in the Australian Region are shown as red fault lines. The 90-minute isochrons for tsunamis reaching the Australian coast from both the Indian and Pacific Oceans are shown in orange.*



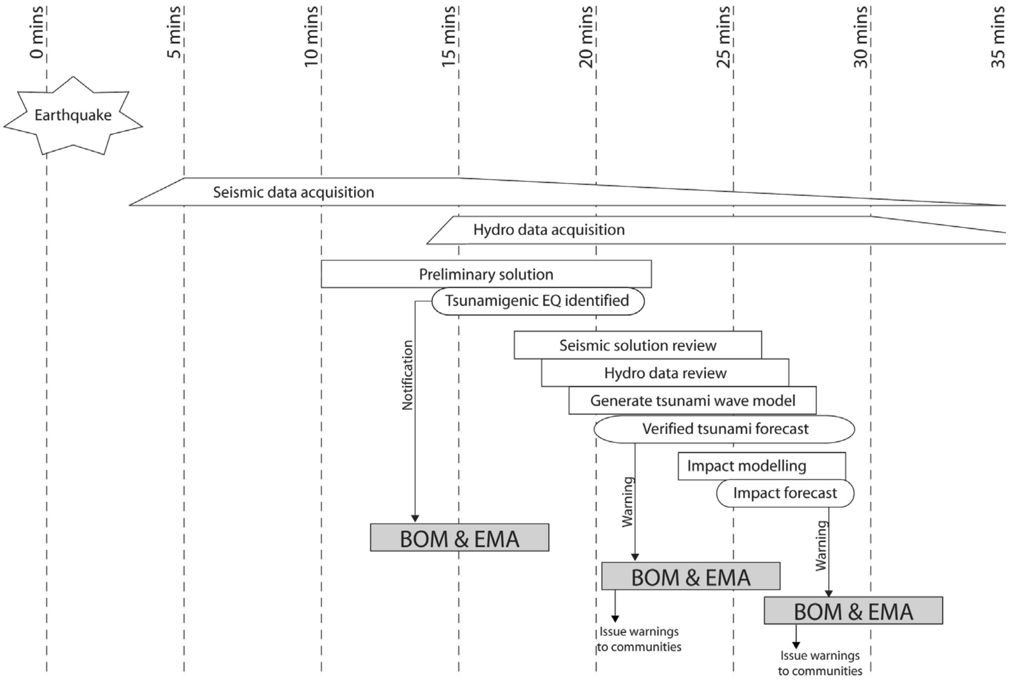
Operational Tsunami Warning Service

The ATWS includes the establishment of a national networked Tsunami Operations and Analysis CentreThe Centre will provide around-the-clock monitoring and analysis capability. The Bureau of Meteorology's component of the Centre will be co-located with its National Meteorological and Oceanographic Operations Centre (NMOC) in Melbourne, leveraging off its existing 24/7 support arrangements. To ensure complete redundancy and fail-safe operations, the Operations and Analysis centre in Melbourne will be mirrored in the Geoscience Australia operations centre in Canberra.

All of Geoscience Australia's activities will be concentrated at its Canberra headquarters. The activities will include research and development into the use of seismological data for characterising earthquakes as tsunamigenic, as well as full network support and operational monitoring. Within the Bureau of Meteorology, overall program and service support activities will be split between the Bureau's Head Office and the National Tidal Centre (NTC). These activities include providing national and international planning and coordination, undertaking research and development to support service requirements, overseeing the operational monitoring and analysis activities of the tsunami warning centre, and managing the operational performance of the sea level gauge network, including installation, calibration and maintenance activities.



The Timeline below shows functional activities for the identification of a tsunami and issuance of a warning.



Development of tsunami impact risk assessment

The instrumentation and technical and scientific support for the ATWS will provide input to the development of Australian tsunami risk models and a national risk assessment capability. This development will rely heavily on complementary model development and expertise, which exists already, for natural hazard risk assessment, particularly in earthquake, flood, and storm surge, and the acquisition and processing of exposure and hazard data. Although these data will not be sufficient to assess tsunami risk in detail for all coastal areas, they will provide the basis for a national assessment. The existing data and modelling capability in Geoscience Australia and the Bureau of Meteorology will be supplemented by that of other organisations (e.g. State, Local, private sector), in order to adequately assess risk in specific areas of higher risk.

**Community awareness and preparedness,
warning dissemination and education and training programs.**

Increased community awareness of the risk posed by tsunamis is essential if the public is to engage in appropriate protective behaviours and know how to act in the event of a tsunami alert. Because tsunamis are infrequent events, long-term awareness programmes aimed at reducing complacency, together with strengthened emergency management training and exercise regimes will be required. The potential for tsunami inundation in Australia is greatest in exposed high density coastal settlements, isolated indigenous communities and areas that attract high levels of tourism, especially international tourists. At risk are, the lives of large numbers of people and Australia's economically significant tourist industry. Likewise large numbers of people who live, work, or holiday in other tsunami prone countries in the Region are also at risk. Australia's population is characteristically mobile and our tourism industry is promoted and viewed overseas from a national perspective. Australia has a national vocational education and training system which is internationally recognised. The proposed approach to education and training is therefore based on national industry agreed competency standards in areas such as risk management, emergency planning, evacuation and exercise management. The education program will underpin a national communication and public education strategy for tsunami risk and is therefore consistent with promoting a national perspective.

Tsunami awareness and effective disaster management planning must be integrated into relevant industry sectors, especially all elements of the tourism and hospitality industry. Existing relationships with the national Industry Skills Council covering hospitality will facilitate this approach. Experience in a range of contexts has demonstrated that effective engagement of private industry is more likely when senior management has an appreciation of the risk to their industry. To ensure effective and efficient use of resources this Project will require risk assessments to be undertaken to identify the communities at risk. Successful education programs and capacity building will depend on effective risk communication with all stakeholders including peak bodies and senior executives. Relationships established through EMA's involvement in the development of the Australian/New Zealand standard for risk management provide credibility, expertise and leadership in the field of risk management. Communication strategies, industry workshops and training in new risk awareness programmes will need to be developed and delivered, both through competency based training and through private industry organisations. Further, the development of capability to manage tsunami risk to Australian indigenous communities will require culturally sensitive consultation to develop appropriate strategies. It should be recognised that these strategies may take longer to implement in a sustainable way because of the need to reflect traditional values and customs.

To maximise the potential of the tsunami warning system to reduce loss of life and damage to Australia's economically strong tourist industry, it is proposed that EMA work with Australian, state and local government agencies and private industry, to develop a comprehensive education and training program to support and promote a national tsunami awareness and preparedness programme that addresses both public and institutional preparedness. The development of a national plan and an exercising regime will support effective implementation of the tsunami warning system. The EMA National Emergency Management Co-ordination Centre will require some augmentation to existing communication equipment.

INDIA

The Indian delegation reported the status of the project undertaken in India for developing a dual-use Early Warning System for mitigation Tsunami and Storm Surges in the Indian Ocean region. Department of Ocean Development (DOD) is the nodal department within the Government of India for the Project The major participants in the Project are institutions under DOD [Indian National Centre for Ocean Information Services (INCOIS), National Institute of Ocean Technology (NIOT), Project Directorate of Integrated Coastal and Marine Area Management (ICMAM)], Department of Science and Technology [India Meteorology Department (IMD), Survey of India (SOI)], Department of Space (Indian Space Research Organisation (ISRO) and National Remote Sensing Agency (NRSA)] and Council of Scientific and Industrial Research [National Institute of Oceanography (NIO) and National Geophysical Research Institute (NGRI)]. Significant progress has been achieved over the last few months in the Project. The key elements of the warning system are slated to be put in place by March 2006 and the entire national Early Warning System is targeted to be made operational by September 2007 after necessary testing and simulations. Also, it was also informed that this Project has been has been identified by the Government of India as a thrust area in its basic agenda for 2005

The objectives of the Project are (a) to realize an operational National Early Warning System for Tsunami and Storm Surges within the next 2½ years, (b) to set up the National Early Warning Centre in Hyderabad located at DOD's Indian National Centre for Ocean Information Services (INCOIS) for operation on a 24x7 basis and (c) to institute a mechanism to sustain the System to generate and issue 'warning' and 'watch' advisories, as the responsible national agency. The Project covers (i) setting up a dedicated Tsunami Warning Centre (including Storm Surge) in India for operation on 24x7 basis and for generation of timely advisories, (ii) interconnecting a network of land-based Seismic Stations for earthquake detection and estimation of focal parameters in the two known tsunamigenic zones (viz. Java-Sumatra-Andaman-Myanmar belt and the North Arabian Sea) that would affect the Indian Ocean region and communicating the same to Early Warning Centre in near-real time, (iii) detection of Tsunami generation through a network of 10-12 bottom pressure recorders around these two tsunamigenic zones, (iv) enhancement of the real-time observational network for upper ocean parameters and surface met-ocean parameters, especially in the areas of cyclogenesis and coastal sea, for improving forecast of Storm Surges (v) monitoring the progress of Tsunami and Storm Surges through a network of 50 real time tide gauges, (vii) generating and updating a high resolution data base on bathymetry, coastal topography, coastal land use, coastal vulnerability as well as historic data base on Tsunami and Storm Surge to prepare and update Storm Surge/Tsunami hazard maps for costal areas within 1-3 km in general and for 10-25 km at selected areas near coastal water bodies, and (viii) capacity building, training and education of all stake holders on utilization of the maps, warning and watch advisories. It is also envisaged to take full advantage of the existing/committed In-situ Ocean Observing Systems (e.g. Data Buoys, ARGO profiling floats) of DOD as well as the Earth Observing Satellites (IRS Series, Cartosat and Oceansat Series) and Communication Satellites (INSAT Series).

A detailed statement of work packages is given below:

a) Interconnecting a network of Land-based Seismic Stations for Earthquake detection and estimation of focal parameters in Tsunamigenic Zones and communicating to the Tsunami Early Warning Centre in near-real time.

   It is planned to upgrade, wherever necessary and interconnect through V-Sat, the existing Seismic Stations including those at Port Blair, Chennai, Visakhapatnam, Shillong, Delhi, Pune, Bhuj, Kolkata, Kodaikanal, Hyderabad, Cuddapah, Dharward and Kozhikode for near-real time determination of earthquake parameters in Tsunamigenic zones. This network will be connected with the Tsunami Warning Centre through V-SAT. Once an Earthquake of magnitude 7 and above on the Richter scale occurs in the two known Tsunamigenic zones, that shall be communicated in real time to the Tsunami Warning Centre.

b) Setting up a network of Deep Ocean Assessment and Reporting Systems for detection of Tsunami

Typical locations proposed for Deep Ocean Bottom Pressure Recorders with Surface Buoy system for covering the two known Tsunamigenic Zones of Indian Ocean are given in Figure .1, along with the network of Seismic stations.

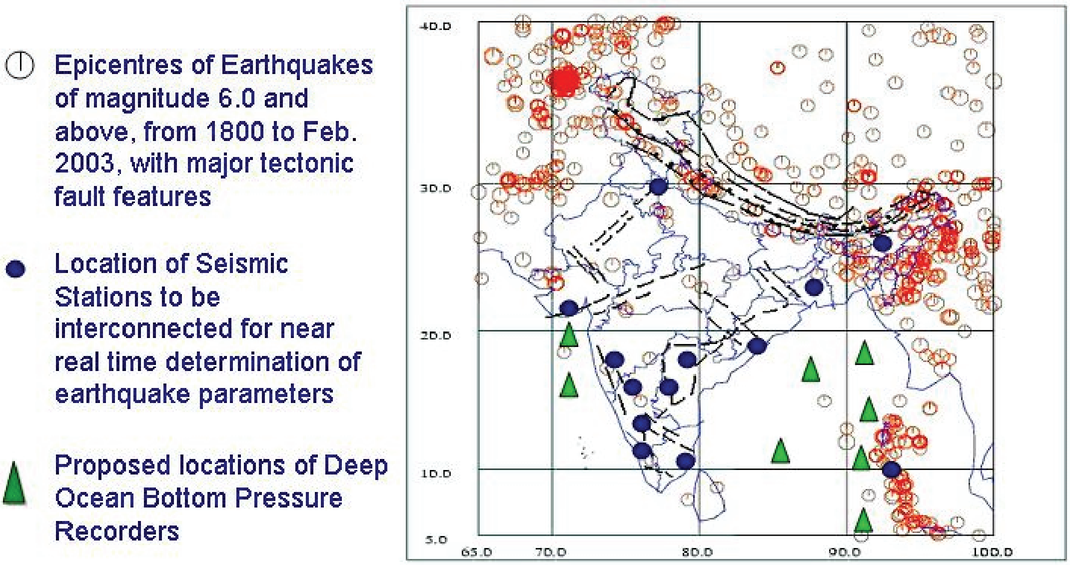


Figure 1. *Typical locations of Deep Ocean Bottom Pressure Recorders*

c) Setting up a network of Automatic Tide Gauges for Real time Sea level Monitoring

About 45-50 real-time Tide gauges at selected locations along the Indian Coast, islands as well as a few of the Off-shore platforms connected to the Early Warning Centre through INSAT Satellite System.

d) Enhancement of Upper Ocean and Surface Met-Ocean Observing System

There is an ongoing programme for ocean observing systems encompassing Moored Data Buoys, Drifting Buoys, ARGO Profiling Floats, Current Meter moorings and Expendable Bathythermographs. It is planned to establish a network of in-situ observing platforms including automatic weather stations.

e) Modelling (Tsunami, Storm Surge)

Ocean modelling efforts in the country, promoted under the INDOMOD Project of DOD as well as several efforts of Academia have resulted in developing capability in Storm surge modelling using freeware as well as indigenous adaptation of the models. While it is planned to make best use of existing operational modelling packages that are used elsewhere, efforts are being mounted for development of appropriate models for prediction of Tsunami generation and propagation with a view to improve the reliability of warnings. Basic research will be pursued to extract information related to source dynamics, rupture velocity, direction and displacement through a suite of modeling and wave form inversion techniques.

f) Generation of High Resolution Bathymetry for the Indian Coast

Coastal Bathymetry is the prime determinant of the height of the Tsunami Wave or storm surge as it approaches the coast. High resolution coastal bathymetry is thus the key input for various tsunami and storm surge prediction models. The available NHO charts would be supplemented by data from the ongoing Swath Bathymetric Mapping.

g) Coastal Vulnerability Modelling and Seawater Inundation Mapping for the Indian Coast

It is planned to prepare Coastal Vulnerability maps indicating the areas likely to be affected due to flooding and rending damage. Information from remote sensing and field investigation will be integrated in GIS for modelling and mapping of inundation of seawater for determination of setback lines, planning coastal defences etc. Necessary expertise and resources are available in the country to undertake coastal vulnerability modelling as well as inundation mapping.

h) Setting up Early Warning Centre with Developing Decision Support System

The Early Warning Centre will be set up at the Indian National Centre for Ocean Information Services (INCOIS), an institute under the Department of Ocean Development that has been notified by the Government of India as the organization responsible for triggering tsunami warning in the country. The Centre operating on a 24x7 basis, will have facilities for receiving in real time data from the observational systems, computational infrastructure, operational models and the necessary decision support systems to facilitate quick decision-making, and dissemination, following a standard operating protocol.

i) Capacity Building, Training and Education

Technical training of project personnel will be taken up to equip them with necessary skills to implement all the work packages of the project efficiently. Periodic workshops will be organized for the user community to familiarize them with the use of tsunami and storm surge advisories as well as inundation maps. Easily understandable publicity material on earthquake, tsunami and storm surges will be generated in vernacular languages to be distributed to the general public.

INDONESIA

Acknowledgement

This report is made as an ongoing effort of the Indonesian National Commission IOC-UNESCO to contribute to the development of National Tsunami Warning System as an integral part of the regional Indian and Pacific Oceans Tsunami Warning System as part of the Global Tsunami Warning System. Numerous institutions, scientists and individuals have contributed their ideas and share their opinions, to which The Indonesian National IOC-UNESCO Commission would like to thank for their utmost contribution. The IOC-UNESCO would like to apologize for institutions or individuals for any possible misrepresentations in developing this report.

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- Naval Hydrographic Services (DISHIDROS)
- Department of Transportation (DEPHUB)
- Department of Communication and Information (KOMINFO)
- Department of Foreign Affairs (DEPLU)
- National Coordinating Agency for Disaster Response and Displaced Population (BAKORNAS PBP)
- Indonesian National Committee for UNESCO (KNI UNESCO)

Introduction

WAKE UP CALL FROM ACEH

Had there been a tsunami warning center in Indonesia and the Indian Ocean region, the tragic damage and loss would have not been that huge. World leaders have responded quickly to this and pledged in January 6, 2005 to set up an Indian Ocean early warning system which could save lives in the event of a repeat of Asia's devastating tsunami. The one-day emergency summit is an attempt to co-ordinate the massive aid effort for tsunami-hit countries, with more than 20 leaders from donor and affected countries and international organisations attending. The declaration, signed by delegates from nations and groups attending the Jakarta conference, pledges to set up a warning system similar to that in the Pacific Ocean to ensure that coastal residents have time to flee to higher ground in the event of a fresh earthquake. Asia could be hit by a second wave of deaths, this time from preventable causes, United Nations Secretary-General Kofi Annan told an emergency summit on January 6, 2005 in Jakarta. Annan said: "We will never know the exact magnitude of how many men, women and children have perished in the 11 days since the tsunami, the real figure is likely to exceed 150 000." He said: "We do know at least half-a-million were injured, that nearly two million need food aid and that many more need water sanitation and health care".

The President of Republic of Indonesia, Susilo Bambang Yudhoyono, had called for an unprecedented response to the Asian Tsunami in his opening address to a one-day emergency summit in Jakarta. He said: "What the victims went through beggars the imagination. This tragedy has been a humbling experience, it proves no nation can survive alone." He called on all of the countries present at the meeting to meet the combined cost of the catastrophe. "Our response to this unprecedented catastrophe must be equally unprecedented so that we immediately put an end to the human suffering and misery that came later."

The provinces of Aceh and North Sumatra bore the brunt of the earthquake and subsequent tsunami that hit on 26 December. The quake shattered buildings and roads before tidal waves swept up to 6 kilometers inland in parts of northwestern Aceh. The Government estimated a death toll in Indonesia of at least 120,054, with 132,000 missing. Aceh, which already has a fairly large number of internally displaced persons, will add to the existing number of displaced persons with a figure of about 500,000, or 11% of the province population. Total damage from the tsunami is estimated at $4.5 billion - almost equal to the entire GDP of Aceh - according to a preliminary damage assessment prepared by the Indonesian Government, World Bank, ADB, and other development partners. Aceh's total population is just over 4 million, of which 470,000 is coastal. Poverty had been increasing over the past few years, reaching almost 30% in 2003 while the national poverty incidence declined to 17.4%. Aceh fell from being the 5th richest province in 1999 to 3rd poorest in 2002, after Papua and Maluku.

THE INTERNATIONAL RESPONSE

Following the Jakarta Tsunami Summit, along with the immense response of the international community, the United Nations took the lead in the establishment of the Indian Ocean Tsunami Warning system within the framework of the multihazards system. Tens of international meetings and technical workshops have been conducted round the world to review and plan for future robust disaster management system worldwide. Indonesia has been actively participated in those meetings and workshops, including technical visits to the established and comprehensive Tsunami Warning Systems in Japan and Hawaii, USA. The Intergovernmental Oceanographic Commission (IOC) of the UNESCO has taken the leadership in realizing the mandate given to the UN by organizing two times International Workshops in Paris (March, 2005) and Mauritius (April 2005), leading the resolution on the establishment of the Indian Ocean Tsunami Warning System, recently passed in its 23rd Assembly in Paris in June 21–30, 2005.

THE STANDING THREAT

No place on earth has such most active deformation and earth crustal movements as the Indonesian Archipelago. The beauty of this "emerald in the tropics" is threatened by hundreds of earthquakes occurring daily and the ensuing tsunamis, as most of the earthquake epicenters are under the seas and oceans. During the last decade or so, Indonesia has suffered one destructive tsunami for every two years. Due to the close distance (10 – 200 km) between the tsunamigenic source and the coastal plain, there is practically very short lead time needed by the wave to arrive to the closest shore (5 – 40 minutes). Such a high risk of being inundated by the local tsunamis would require a very effective and reliable National Early Warning System which will be followed by a quick response of evacuation and humanitarian aid. An early warning system which is able to produce warning within the order less than 5 minutes is therefore highly recommended.

The island of Sumatra, being part of the eastern most Indian Ocean, has been repeatedly inundated by severe tsunamis. The destructive ones are the 1833, 1883, 1935 and 1967 tsunamis which hit the western coastal cities in Sumatra as well as the areas around the Sunda Strait (by the 1883 Krakatau Eruption). The 1833 tsunamis had been generated by earthquake of 9 SR, producing a tsunami of similar magnitude to the recent Trans Indian Ocean 2004 Sumatran tsunami. Despite the lively geoscientific debate on the near future giant seismic shock and the ensuing tsunami, geoscientists agreed that the future danger will still be along the same sources that generated the mentioned historical events.

END-TO-END WARNING SYSTEM AND DISASTER REDUCTION STRATEGY IN INDONESIA

End-to-end warning system must be comprehensive, durable and sustainable. It comprises three major components: (1) the warning guidance through the establishment of a national and regional **warning** system against local and regional tsunamis; (2) hazard assessment by **assessing** the national tsunami risks; and (3) mitigation through the promotion of community **preparedness** against tsunami hazard. The three components will need a close collaboration between warning center operators, tsunami and geoscientists.

An end-to-end tsunami warning system will cover three interrelated elements: (1) network of national, regional and international networks of seismic and oceanographic real time and on-line monitoring and detection stations; (2) national warning system; and (3) public awareness and public preparedness. Given the facts that Indonesian tsunamis are of local origin, in comparison to the ones —for example in India, Sri Lanka or East Africa— which are of distant origin, then public preparedness plays a major role and as important as the development of the warning system itself.

THE INDONESIAN TSUNAMI WARNING SYSTEM AND ITS DUAL RESPONSIBILITIES WITHIN THE FRAMEWORK OF THE INDIAN AND PACIFIC OCEANS AND GLOBAL TSUNAMI WARNING SYSTEMS

The Indonesian National Tsunami Warning System will be part of the future networked national, regional and global multidisaster warning centers. It will empower and in line with the existing national, regional and global disaster management centers dealing with the earthquake generated, terrestrial, marine and fluvial, atmospheric and climatic as well as other technological and man made disasters. The establishment of the end-to-end National Tsunami Warning System has dual purposes, i.e. to develop national and regional and global capacity which will embrace three strategic objectives:

1. To assess national tsunami risk by developing assessment in hazard prone coastal areas in the country, covering all those tsunamigenic zones which generate local and distant tsunamis.

2. To promote preparedness and risk reduction against tsunami hazard through mitigation and development of multimodal public awareness system and campaigns.

3. To establish national and regional warning system on 24/7 basis for local and distant tsunamis.

Following a series of international meetings, notably organized by the IOC–UNESCO, Indonesia and other countries in the Indian Ocean rim have expressed their commitment to protect their people within their territory and in other countries. The establishment of the Indian Ocean Tsunami Warning System, which will complement the existing Pacific Ocean Tsunami Warning System, will be followed by systems in the Mediterranean and Carribean Seas. These reflect the worldwide commitment to the establishment of the global tsunami warning system, to which the Indonesian system be part of the whole network of networks.

Indonesian Contribution to IOTWS

The Indonesian Government has committed to allocate appropriate funding for the establishment of the comprehensive end-to-end tsunami warning system as part of the national all hazards system and the global initiative of the tsunami warning system. In the short term, the commitment will include the improvement and upgrading of the existing seismic and sea level networks, along with initial stages of public awareness and preparedness. In the longer term, this will facilitate the completion of the observation networks, risk assessment and public preparedness and the necessary capacity building.

To facilitate better the implementation of the end-to-end tsunami warning system within the perspective of the all hazards warning system, the government has appointed:

- The Ministry of Research and Technology as the focal point of Capacity Building;
- The Meteorology and Geophysics Agency as the focal point of Indian Ocean Tsunami Warning System, along with its function as the national tsunami warning authority;
- Indonesian Institute of Sciences as the focal point of Public education and preparedness;
- Department of Communication and Information as the focal point of the ICT component;
- National Coordinating Agency for Disaster Management as the focal point of the rescue and emergency relief.

Typical Architectures of Indonesian Tsunami Warning System

The general geotectonic setting of the Indonesian archipelago determines the basic configuration of the architecture of the observation, monitoring and detection system as part of the total INA TWS. The observation, monitoring and detection system consists of the seismic network component, the sea level component, the communication network component, and the processing and analysis component. All these components are configured in what are termed as the Sumatra-type setting and the Java-type setting, respectively (Figs. 1A and 1B). These typical setting are basically addresses the fundamental difference due to the presence of the uplifted and emerged forearc islands (in the Sumatra type as represented by the row of the islands of Simeulue, Nias, Mentawai and Enggano), or the absence of such islands (as in the Java type). These islands can be regarded as the “natural —permanent buoys”, whereby tide gages network can be installed on them and be complemented by the buoys (Fig. 1A). In the Java type, installment of buoy is a necessary element.

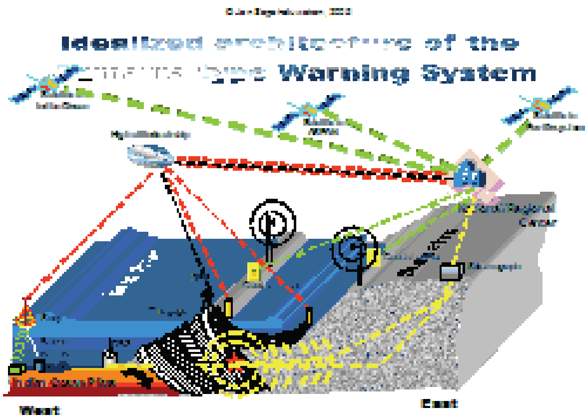


Fig. 1A

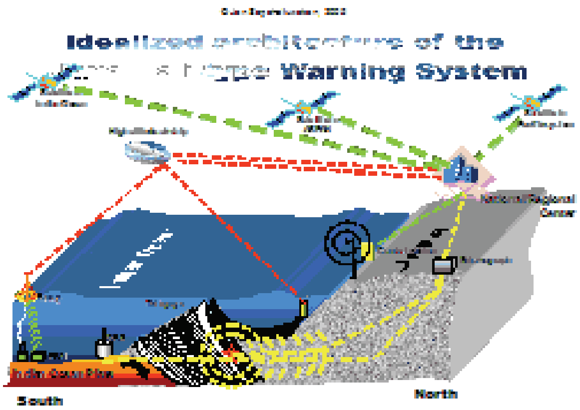


Fig. 1B

THE SEISMIC NETWORK COMPONENT

There are currently five regional tsunami warning centers in the country that will observe, monitor and report the occurrence earthquakes, to which all the broadband, analogue and digital stations are linked to the centers in Medan, Ciputat, Makassar, Kupang and Jayapura. The present 5 regional centers (Fig. 2) will be upgraded and rearrangement of the regionalization will be carried out within the near future. There will be 10 regional centers (Fig. 3), in which all the contributed stations from Agency of Meteorology and Geophysics, Germany, Japan, China, CTBTO, Volcanological Survey of Indonesia, Gajah Mada University, and the Provincial Government of Nabire (Papua) are networked and integrated to the National Earthquake and Tsunami Warning Center located in Jakarta and operated by the Agency of Meteorology and Geophysics.

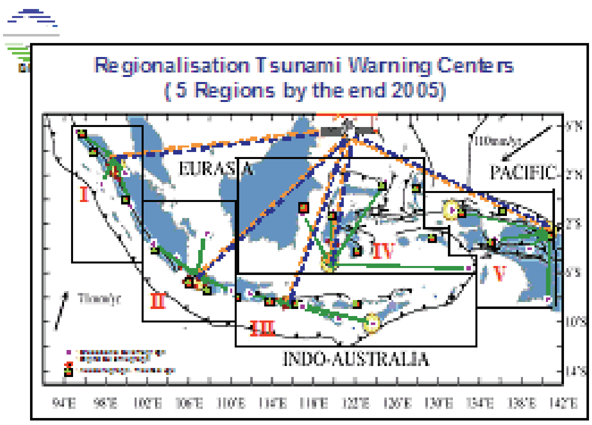


Fig. 2

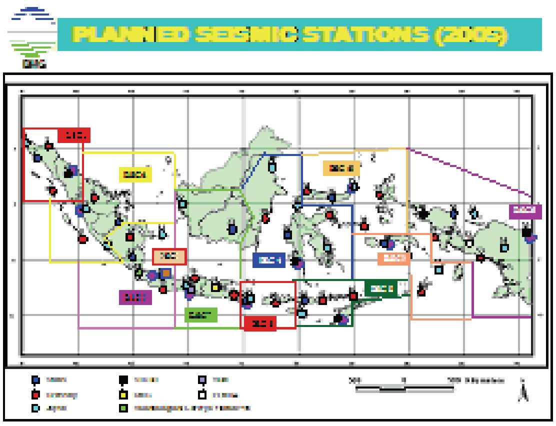


Fig. 3

By July 2005, there are 9 online broadband stations already installed, consisting of those contributed by Japan (Banda Aceh, Padang Panjang, Jambi and Kepahiang), Germany (Nias) and CTBTO (Makassar, Kupang and Jayapura). Some effort are in progress, which include the onlining and integration, software conversion and communication link. These stations will be part of the 55 broadband stations dedicated to the nationa, regional and global networked to be installed in Indonesia (Fig. 3). The complete list of these stations and their corresponding coordinates, mode of communication, instruments, facilities and the bedrock type are tabulated in the following pages. These 55 stations will eventually form part of the national wide 160 seismograph stations that constitute the 10 regions and 1 national network. This will also form the backbone the ASEAN Earthquake and Tsunami Information Center attached to the Agency of Meteorology and Geophysics.

Within the light of data and information exchange with the ASEAN member countries, significant progress have been made which among others include the designation of seismic stations for real time data exchange, the protocol involved, template and format of information exchange and the server and communication configuration needed. An encouraging dry-run tsunami dry-run test has been conducted on July 29, 2005 at 03:00 UTC (Fig. 4). Some countries in this test can even receive the message in 2 minutes time range. If every installment plan and the supporting communication link and the analysis and processing routes needed are available in due time, this may lead to the shortening of the time needed to issue the warning as stipulated in Fig. 5.

DRY-RUN TSUNAMI WARNING BMG INDONESIA
29 JULI 2005 03:00 UTC

SMS
SEND TO

SING	MALAY	BRUNEI	PHILIP	THAI	VIETNAM	LAOS	KAMBOJA	MYANMAR
V	V	V	V	V	V	V	X	X

RECEIVE

SING	MALAY	BRUNEI	PHILIP	THAI	VIETNAM	LAOS	KAMBOJA	MYANMAR
V	V	X	X	X	X	X	X	X

FAX
SEND TO

SING	MALAY	BRUNEI	PHILIP	THAI	VIETNAM	LAOS	KAMBOJA	MYANMAR
V	V	V	V	V	V	V	X	X

RECEIVE

SING	MALAY	BRUNEI	PHILIP	THAI	VIETNAM	LAOS	KAMBOJA	MYANMAR
V	X	X	X	X	X	X	X	X

EMAIL
SEND TO

SING	MALAY	BRUNEI	PHILIP	THAI	VIETNAM	LAOS	KAMBOJA	MYANMAR
V	V	V	V	V	V	V	X	X

RECEIVE

SING	MALAY	BRUNEI	PHILIP	THAI	VIETNAM	LAOS	KAMBOJA	MYANMAR
V	V	V	V	V	V	X	X	X

Fig. 4

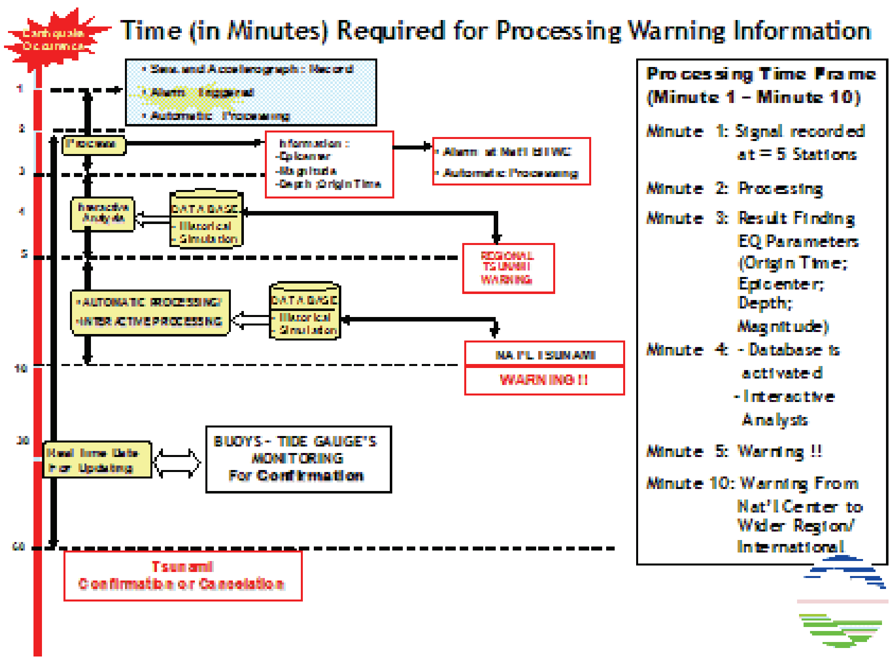


Fig. 5

PLANNED SEISMIC STATIONS

No	Station	Code	lat.	lon.	Elev.	Communication				Instruments			Facilities		Bedrock	Remarks
						SSB	Vhf	Vsat	Telp	BB	Accel	OHP	S.Vault	Elect.		
	MEDAN (REG. 1)															
1	Banda Aceh	BSI	5.4950	95.2930		v		v	v	JISNET					Limestone	JAPAN
2	Meulaboh		4.1200	96.1310		v									Alluvium	CHINA
3	Lhokseumawe		5.1900	97.1400											Sandstone	GERMANY
4	Prapat	PSI	2.6950	98.9240		v			v	IMS		v			Andesite Volcanic	CTBT
5	Gunung Sitoli	GSI	1.2750	97.5950		v	v				v		v		Limestone	GERMANY
	PADANG (REG. 6)															
6	Pekanbaru		0.5510	101.4400		v									Alluvium	GERMANY
7	Padang Panjang	PPI	-0.4580	100.3970		v		v	v	JISNET					Andesite	JAPAN
8	Mentawai		-3.0720	100.3560											Sandstone	GERMANY
9	Kepahyang	KSI	-3.6338	102.5923		v			v	JISNET					Andesitic Basalt	JAPAN
10	Jambi		-1.5880	103.6080		v		v		JISNET					Sandstone	CHINA
	CIPUTAT (REG. 2)															
11	Tanjungpandan	TPI	-2.7460	107.6180		v		v		JISNET					Granite	JAPAN
12	Palembang		-2.9840	104.7600		v		v	v						Sandstone	GERMANY
13	Kotabumi	KLI	-4.8638	104.8567		v	v		v	JISNET					Volcanic Rock	CHINA
14	Krakatau	KRT	-6.1580	105.4370		v	v		v	v	v		v	v	Volcanic Rock	INA Volc. Surv
15	Pameungpeuk		-7.6333	107.7000											Andesite Basalt	GERMANY
16	Lembang	LEM	-6.5958	107.6175		v		v	v	IMS					Andesite Basalt	CTBT
	YOGYAKARTA (REG. 7)															
17	Banjar Negara		-7.3167	109.7083		v									Limestone	JAPAN
18	Yogyakarta	YGI	-7.7830	110.3160						JISNET			v		Limestone	UGM/Germany
19	Semarang		-6.6700	110.4850		v		v	v						Sedimentary	GERMANY
20	Banyuwangi		-8.2167	114.3330											Volcanic breccia	GERMANY
21	Tretes	TRT	-7.4200	112.4600		v			v						Volcanic breccia	BMG
22	Pontianak		-0.0210	109.3270		v			v	JISNET					Sedimentary	JAPAN

PLANNED SEISMIC STATIONS

No	Station	Code	lat.	lon.	Elev.	Communication				Instruments			Facilities		Bedrock	Remarks
						SSB	Vhf	Vsat	Telp	BB	Accel	OHP	S.Vault	Elect.		
23	Palangkaraya		- 2.2120	113.9250		v		v	v	JISNET					Sedimentary	CHINA
	DENPASAR (REG. 3)															
24	Denpasar	DNP	- 8.6771	115.2101									v		Volc. breccia	CHINA
25	Kahang-Kahang	KHK	- 8.4490	115.6200											Conglomerate	JAPAN
26	Plampang		- 8.8100	117.8080											Volc. breccia	GERMANY
	MAKASSAR (REG. 4)															
27	Tarakan		3.2740	117.6150		v			v	JISNET					Sedimentary	JAPAN
28	Balikpapan	BKB	- 1.2500	116.9155		v		v	v	JISNET					Sedimentary	GERMANY
29	Kappang	KAPI	- 5.0144	119.7513		v	v		v	IMS					Volc. breccia	CTBT
30	Mamuju		- 2.7450	118.9340											Sedimentary	CHINA
31	Kendari	KDI	- 3.9570	122.6190		v				JISNET					Sedimentary	JAPAN
32	Luwuk		- 0.9390	122.7930		v									Limestone	GERMANY
33	Palu	PCI	- 0.1905	119.8367		v			v	JISNET					Basaltic Rock	JAPAN
	MANADO (REG.10)															
34	Tolitoli		1.1220	120.7940						JISNET					Sedimentary	GERMANY
35	Manado	MNI	1.4770	124.8860		v			v	JISNET					Volc. breccia	JAPAN
36	Gorontalo		0.5650	123.0660		v			v						Sedimentary	CHINA
37	Ternate	TNT	0.8490	127.2400									v		Volc. breccia	GERMANY
38	Sanana		- 2.0167	125.9667											Metam. Rock	GERMANY
	AMBON (REG.9)															
39	Ambon	AAI	- 3.6410	128.1460		v			v		v		v		Andesite-Breccia	CHINA
40	Saumlaki	SLKI	- 7.8340	131.2990		v			v		v		v		Coral Limestone	GERMANY
41	Tual	TLE	- 5.7590	132.7230		v			v		v		v		Coral Limestone	JAPAN
42	Bandaneira		- 4.5290	129.8980											Andesite Basalt	GERMANY
	KUPANG (REG.8)															
43	Kupang	KUG	######	123.5900		v			v	IMS					Sandstones	CTBTO
44	Ruteng		- 8.6190	120.4740		v			v						Volc. breccia	CHINA

PLANNED SEISMIC STATIONS

No	Station	Code	lat.	lon.	Elev.	Communication				Instruments			Facilities		Bedrock	Remarks
						SSB	Vhf	Vsat	Telp	BB	Accel	OHP	S.Vault	Elect.		
45	Waingapu	WSI	-9.6770	120.2927					v				v		Coral Limestone	JAPAN
46	Alor		-8.2600	124.9490		v									Andesite	GERMANY
47	Maumere		-9.8620	124.2760											Sedimentary	GERMANY
	JAYAPURA (REG.5)															
48	Sorong	SWI	-0.8850	131.3280		v			v	IMS					Sedimentary	CTBT
49	Fakfak		-2.8850	132.3480		v			v						Pelagic Limestone	GERMANY
50	Manokwari		-0.8530	134.0840		v									Coral Limestone	CHINA
51	Biak		-0.9780	135.9500											Coral Limestone	JAPAN
52	Nabire		-3.3600	135.4840											Alkali Basalt	LOCAL GOVT
53	Timika		-4.7560	136.5580											Alluvium	GERMANY
54	Wamena	WAMI	-3.8847	138.7114											Alluvium	JAPAN
55	Jayapura	JAY	-2.5077	140.7018					v	IMS					Limestone	CTBT

THE TIDE GAGE COMPONENT

Sea level monitoring stations are operated by the National Coordinating Agency for Survey and Mapping (BAKOSURTANAL). They recorded the wave form at a number of ports along the coastal islands facing the Indian Ocean. The stations are part of national permanent sea level monitoring network consisting of 60 stations located in the main ports of Indonesian Archipelago. The sea level stations are, however, not part of a tsunami-warning network.

The first real time sea level station, located in Sibolga North Sumatra (Fig. 7), has been operating since 22 April 2005 with data transmission via Global Telecommunication System (GTS) operated under the World Meteorological Organization (WMO). The real time data can now be accessed by the Agency of Meteorology and Geophysics.

Upgrading and addition of tide gage stations are presented in Fig. 6. The existing 25 digital stations and a number of 60 additional proposed stations should be capable of supporting the early warning. However, upgrade in data communication and power supply of the existing stations are still necessary. The majority of stations require modification for faster sampling rates (1-2 minutes) and near real-time transmission of data (hourly or more frequent) via satellite.

Requirements for tide gauge network should consist of instruments and technical specification as follows:

- Float gauge digital recording with one-minute data sampling rate allowing real time monitoring that can cover extreme change of sea level with time duration relatively short.
- Pressure gauge digital recording one-minute data sampling rate with high capability in detecting quick change of pressure caused by tsunami.
- Radar gauge tidal recording with 10 second data sampling rate enabling monitoring the sea level with higher time resolution recording
- VSAT (satellite communication) with 1.2 kbps data transmission rate and 5 KHz bandwidth.
- Main Hub and redundancy for VSAT for 150 clients and main server and redundancy for data center.

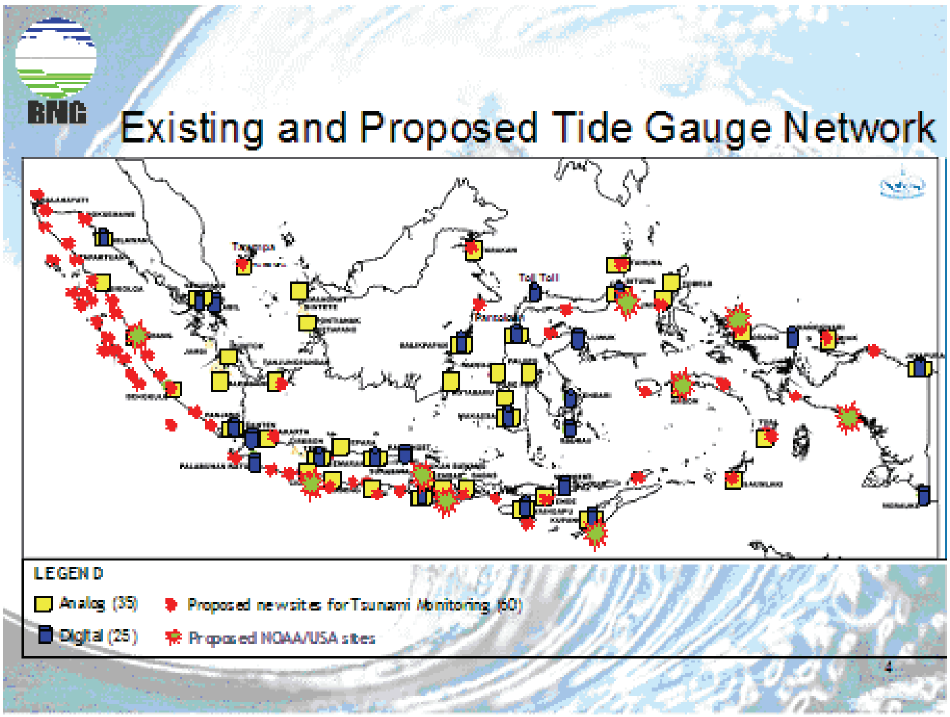


Fig. 6. Existing and proposed tide gage stations in Indonesia.

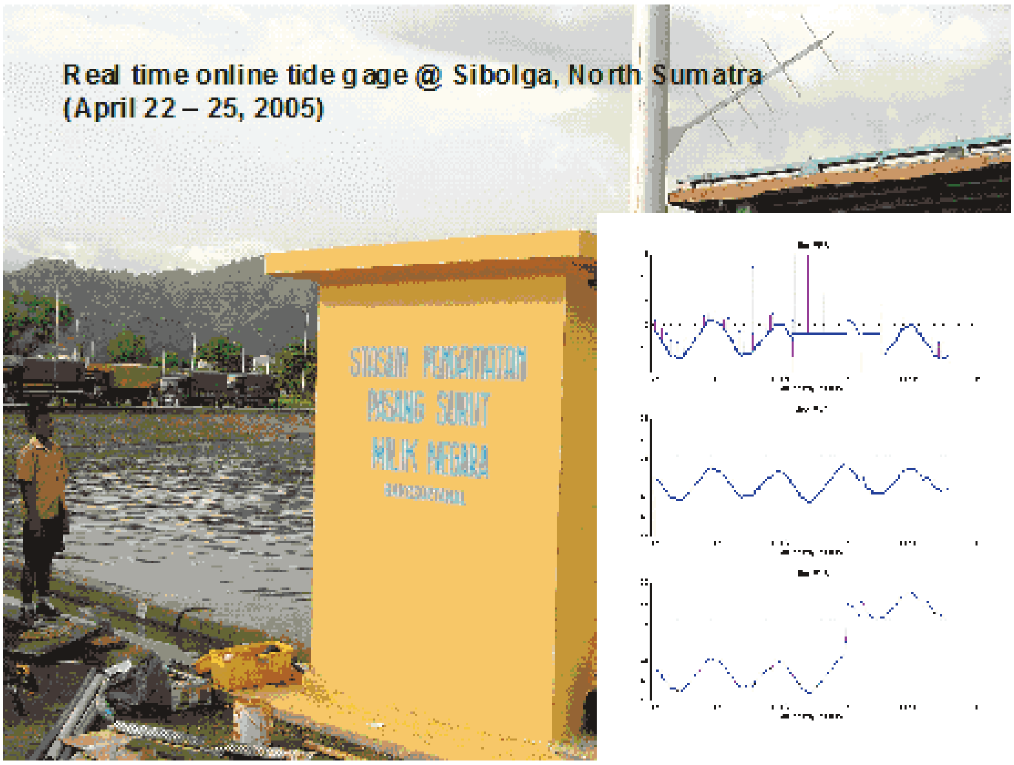


Fig. 7. Sample of preliminary data from tide gauge of Sibolga observed with pressure gauge (Sibo PRS) and shaft encoder (Sibo PRS). Data is transmitted in real time via GMS satellite.

THE COMMUNICATION NETWORK COMPONENT

The communication component will involve multimode media and incorporate quite a number of stakeholders, locally, nationally and internationally (see Fig. 8). In general, Information and Communication Technology (ICT) comprises two main bases: (1) upstream data communication (UDC); and (2) downstream information communication (DIC). Upstream data communication consists of transmission of data from the data acquisition system to the regional and national centers. The data are produced by:

- Automatic seismic data processing, in the form of earth quake parameters, such as origin time (OT), epicenter (EPIC), depth, Magnitude Bodywave (Mb), and Moment magnitude of P-wave (MwP)
- Automatic tide data processing, in the form of sea level data change
- Automatic Deep-ocean Assessment and Reporting Tsunamis (DART) data processing.
- Automatic GPS data processing in the form coordinate time series change.

Such data are required to determine whether tsunami will occur or not. The information resulted from the data processed in the UDC system is disseminated in the following process to the stakeholders through the DIC system.

UDC comprises 5 main components: equipment sensor, data submission, regional center, and national center and media transmission. While in the DIC will cover activities of information among regional centers, national centers, and government and authoritative officials in the local and national levels, which include governor, district mayor, Police, Indonesia Army, etc. The president and his cabinet ministers (as for alertness and decision-making) obtain the information from national center.

The transmission of data and/or dissemination of information may be conducted by telegraph, telephone (mobile, fix), facsimile, TV, radio, cellular operators, mosques, churches, kentongan (traditional sirene) and modern sirenes.

Information released by the national center must be authoritative and legal. Authorized information may be sent by using hand sign, stamps, recognize number, encrypted codes (fingerprint, etc) and through media organizations (national TEWS center).

Observed data transmitted to the national center will be transformed into readable information to be conveyed to the president, Ministers, police stations, local government officials, mosques, churches, viharas, temples, army stations, post offices, cellular operators, TV stations, and radio stations. Finally, the information released to the public. Technical information should be consulted with PBP, SATKORLAK, SATLAK, BASARNAS, PU, and PEMDA. Information from the national center is sent to the local government TEWS through modem to personal computers. The information is then sent to the receiver (which also receive data through telephone line), which transmit the information to the repeater to activate sirens, radio, and public alarm facilities.

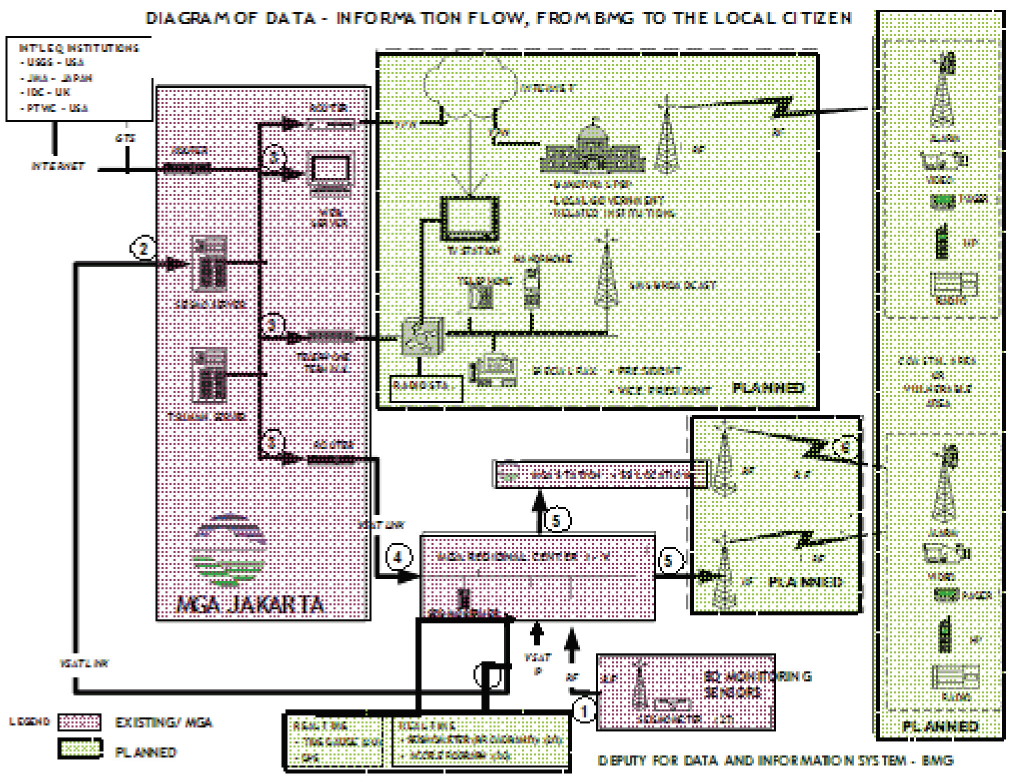


Fig. 8

TSUNAMI MODELING

We have identified that at least there are 12 tsunamigenic earthquake sources in Indonesia. Tsunami database and related modeling are underway. We have carried out numerical tsunami modeling of 9 historically proven tsunami areas in Indonesia (Fig. 9), covering Aceh, North Sumatra, West Suamtra, Krakatau, East Java, Flores, Toli-toli, Banggai and Biak. These ongoing and developing database and modeling (Fig. 10) will be gradually stored in the 10 regional centers and in the national center. Some other areas and improvement by adding and incorporating higher resolution data will be continuously conducted. Priority are given to areas in Sumatra, Java and Bali. tsunami simulation is very important to support the proposed TEWS in the Indonesian region.

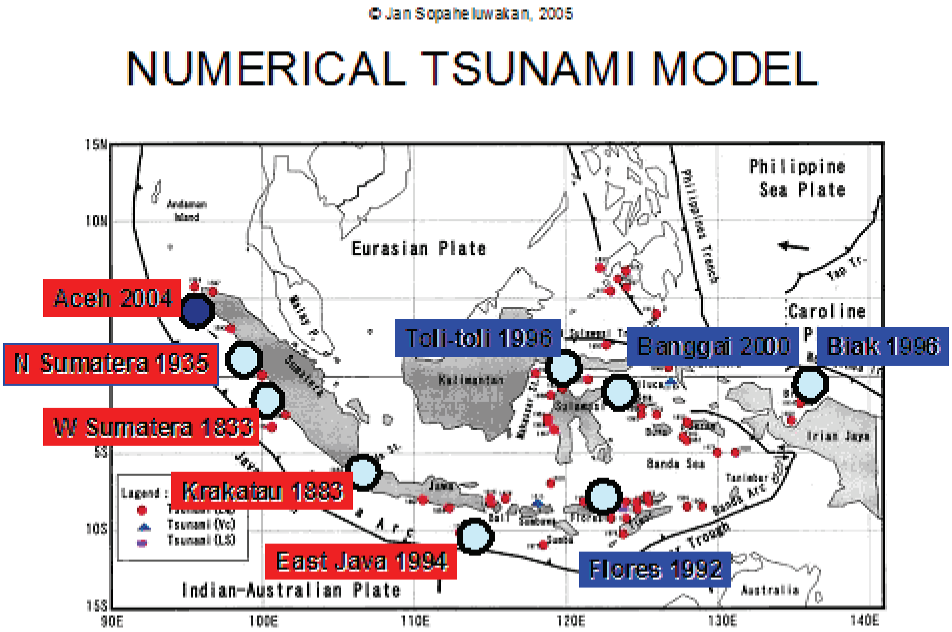


Fig. 9

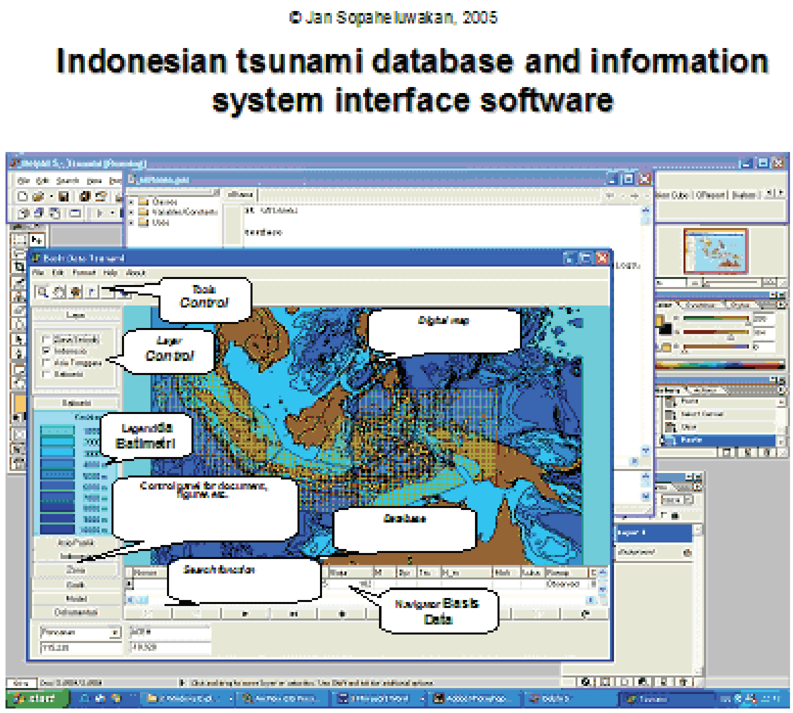


Fig. 10

COMMUNITY PREPAREDNESS AND PUBLIC AWARENESS

Community preparedness pilot project will be carried out in the city of Padang, a city that has been identified with high disaster risk based on vulnerability and the available scientific and historical data. The scenario to be developed is made based on the tsunami modeling of the past 1833 tsunami (Fig. 11) that depicts clearly the travel time of the tsunami traveling to particular coastal line and the type of the wave generated by the ensuing tsunami after the big earthquake of 9 SR. The preliminary attempt has been furthered by constructing the coarse grained low resolution inundation map of Padang, showing the areas that will be inundated and heights of several tsunami waves at any particular sites and their corresponding travel time to the concerned coastal points. (Fig. 12). From here, a city scale preliminary evacuation map (Fig. 13) has been developed to be further used by the emergency managers for evacuation and rapid emergency response. Based on this information, which is already distributed to the local mayor and already published (30 March 2005) in KOMPAS Newspaper (the largest newspaper in the country), quite a number excercises and drilling have been performed by the local government and community in Padang City, West Sumatra.

On the public awareness side, a series of initial attempts and selected public awareness campaigns and training have been carried out in Aceh and Padang, west Sumatra. These include also a number talks and presentations to the local governments, NGOs and the local eminent persons. Some limited public drills and training of the trainers have also been conducted since March interruptively. Dozens of TV talk shows, dedicated articles and documentaries were made, involving many resource persons from relevant institutions and expertise. Quite a number of public education and campaign materials have been produced, though they need to be republished and reproduced in a more massive way. A selection of these public campaign matrials is presented in Fig. 14.

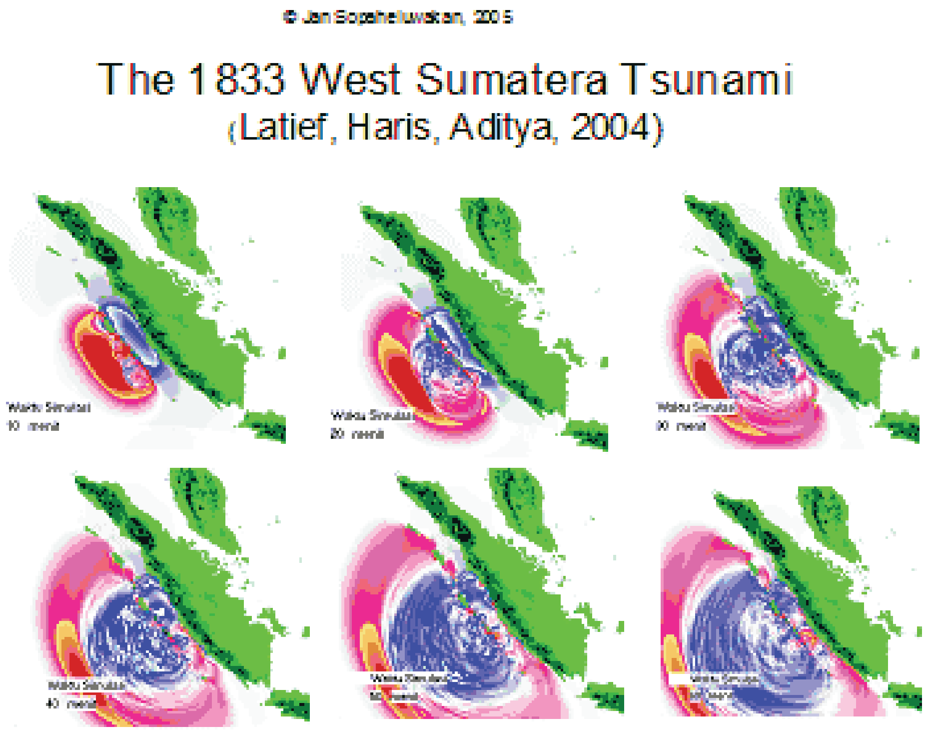


Fig. 11

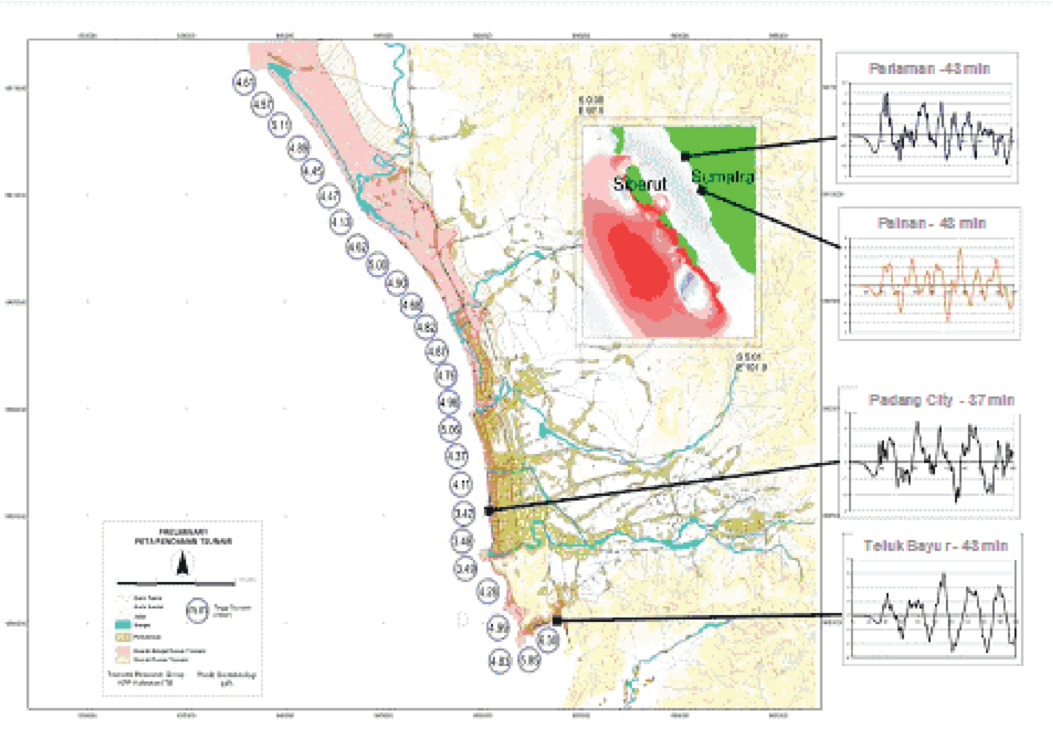


Fig. 12. Preliminary inundation map of the city of Padang, West Sumatra

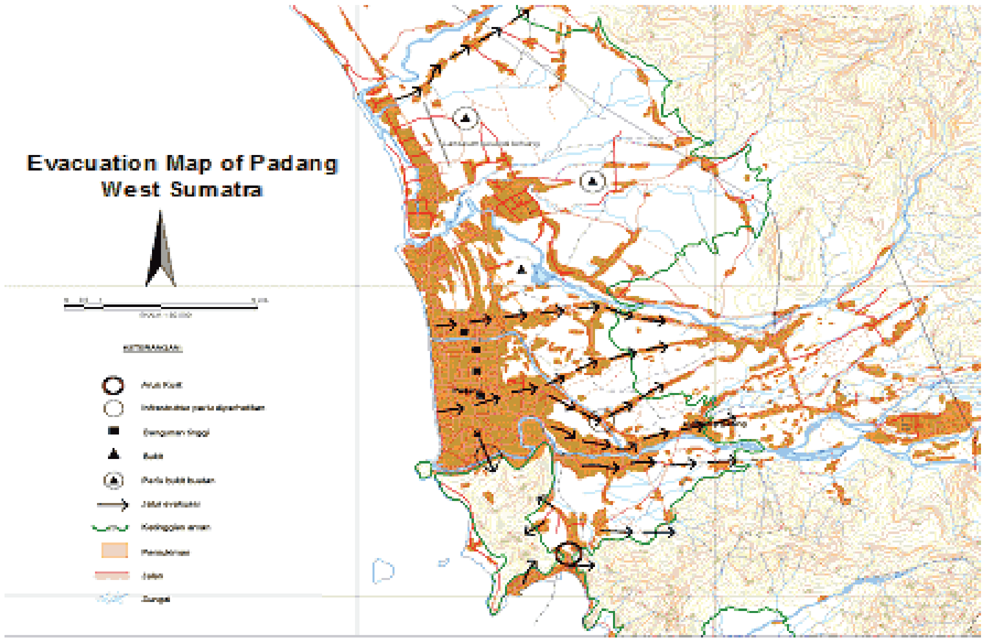


Fig. 13. Preliminary evacuation map of the city of Padang, showing the evacuation routes, vertical evacuation locations, strong current sites and save places.

The way forward

Continuous and ongoing improvement of the INA TWS is underway. This includes:

1. Improvement and densification of the observation sensors, better communication links between the regional and national centers, improving the analysis, processing and time of warning issuance.

2. Tsunami modeling and national database, which will be supported by the provision of newer and higher resolution data sets (oceanographic, bathymetry), production better tsunami inundation maps and evacuation maps.

3. Continuing the public education and awareness

4. Community preparedness in 3 selected areas, consisting among others:
   - Drilling and simulation in tsunami prone areas
   - Continuing (collaborative) research on
     - Understanding the nature of the earthquake-generated tsunamis in western Sumatra
     - Environmental baseline
   - Hazards assessment and disaster risk analysis in the highly vulnerable areas.

5. Contribution to the region
   - Data sharing on real time basis
   - Tsunami warning and advisory
   - Training of particular aspect of the TWS (modeling etc.) to member countries as part of the capacity building program for the region
   - Hosting the 3rd ICG Meeting (end June – early July 2006, Bali)
   - Participating in the ICG/IOTWS

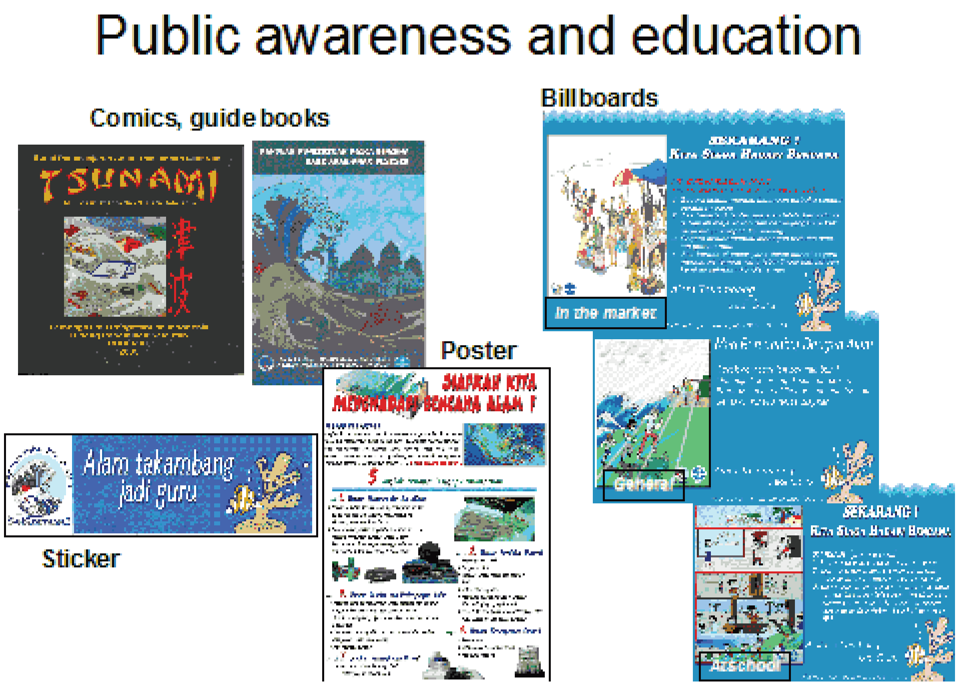


Fig. 14

MALAYSIA
By Low Kong Chiew, Malaysian Meteorological Service

1. Introduction

On 26 December 2004, a large earthquake of 9.0 on the Richter scale occurred west of Aceh in Sumatra, Indonesia. The epicenter was located at latitude 3.1ºN and longitude 95.5ºE, about 680 kilometres northwest of Kuala Lumpur and 590 kilometres west of Penang. This earthquake has generated a massive and disastrous Indian Ocean-wide tsunami that struck the coasts of a number of countries in the region with high "tidal" waves. This unprecedented tsunami had killed hundreds of thousands of people in several countries bordering the Indian Ocean. A total of 76 persons have been killed and many properties were destroyed along the northwest coastal areas in Peninsular Malaysia particularly the coastal areas of Penang, Kedah, Perlis and to a lesser extent Perak and Selangor

2. Need For National Tsunami Early Warning System

The tragedy happened because no country bordering the Indian Ocean had any experience and capability in the issuance of tsunami warning. The Government of Malaysia is very concerned with the lack of capability in carrying out tsunami watch and the issuance of early warning for tsunami in the nation.

In this regard, Malaysian government has decided to set up a national tsunami early warning system to overcome the above-mentioned limitations and lack of technical capabilities to provide early warning on tsunami that may affect Malaysia. In the absence of an effective tsunami warning system, the Government will not be in a position to provide any effective early warning to the public in the event of another tsunami generated in the Indian Ocean, South China Sea or the Pacific Ocean that will affect Malaysia.

The Government has decided that the National Tsunami Early Warning System to be set up shall have the following key features :

- Maintaining real-time continuous monitoring of earthquake occurrences and tsunami on a 24-hour basis throughout the year
- Issuance of information, advisory, notice, early warning and warning on the occurrence of earthquake and tsunami that threaten the security and safety of Malaysia
- The system shall be an integral part of the proposed Indian Ocean Tsunami Warning System to be coordinated by the Intergovernmental Oceanographic Commission, UNESCO.

3. Overview of Malaysian National Tsunami Early Warning System

The tsunami warning system will have several components comprising of various sub-systems that provide real-time monitoring, alert of seismic and tsunami activities as well as timely dissemination of earthquake/tsunami warning, advisory and information. These include

3.1 The Data & Information Collection Component which comprises of a few data collection networks sub-systems. This Component comprises the following sub-systems:

a. The seismic network sub-system which monitors and determines the location and magnitude of the earthquakes

b. A deep ocean buoy network sub-system for monitoring distant tsunamis

c. Tide gauge network sub-system to measure and monitor wave activities reaching the shores of Malaysia

d. Coastal camera network sub-system whereby strategically located cameras monitor and relay real-time pictures of sea state to the National Tsunami Warning Center

e. Linkage to Pacific Tsunami Warning Center and Japan Meteorological Agency

f. Linkage to IOTWS and other tsunami warning centers

3.2 A Processing Component and a Dissemination Component designed to disseminate advisory/warning and other information to all relevant personnel and agencies within 15 minutes after the occurrence of an earthquake.

3.3 Data acquisition and linkages to international earthquake/tsunami warning centers

4. Contributions of Observational Data to the Indian Ocean Tsunami Warning and Mitigation System (IOTWS)

Reaffirming Malaysia commitment to real time data sharing of tsunami related observational data, we will contribute our seismic, tidal gauges and ocean buoy network data to IOTWS. The details of our monitoring network are as below :

4.1 Seismic Network

4.1.1 <u>Existing Seismic Network</u>

The Malaysian Meteorological Department (MMD) operates a total of 12 seismological stations throughout the country namely: five stations located in Peninsular Malaysia at Kulim, Kuala Lumpur (FRIM), Ipoh, Kluang and Kuala Terengganu; four stations located in Sabah at Kota Kinabalu, Kudat, Tawau and Telupid (Sandakan) and three stations located in Sarawak at Kuching, Sibu and Bintulu.

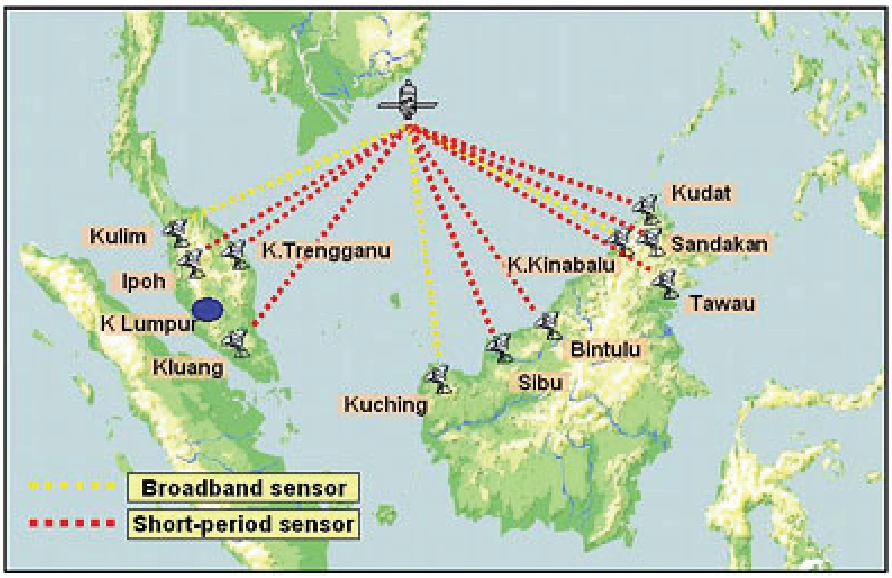


Fig. 1

Location of existing seismic stations

MMD's current real-time digital seismic network is able to detect earthquakes and acquire digital seismic waves in real-time from various Seismometers and Accelerometers distributed at nation-wide remote stations. Each remote seismological station is installed with three components weak motion seismometer and three components strong motion accelerometer.

The network consists of one field station (K. Lumpur) using digital leased line for real time data transmission and the remaining 11 field stations with VSAT telemetry and 128 kbps digital leased-line communication from the service provider's satellite gateway to the central processing centre in Kuala Lumpur for processing, analysis and dissemination.

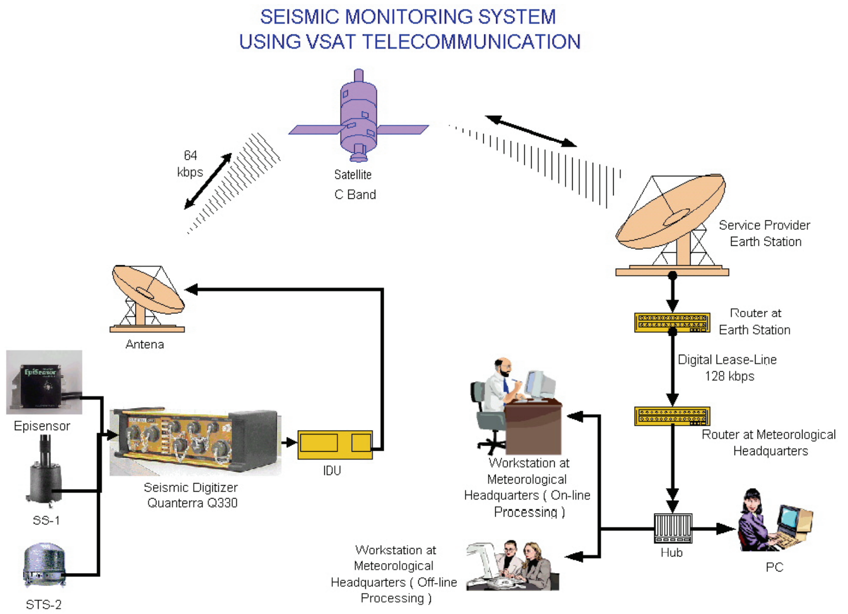


Fig. 2. Seismic Monitoring System

Currently three field stations in Kulim, Kuching and K.Kinabalu consists of Quanterra Q330 digitizer and Baler-14 connected to Streckeisen STS-2 broadband sensor and the Kinemetrics Episensor. The remaining 9 field stations consists of SS-1 short-period sensors and Episensors.

The central processing centre runs BRTT's Antelope 4.6 data acquisition and processing software on (2) SUN Blade 150 workstations for real-time processing and post processing. The Antelope Real-Time System (ARTS) is also providing automatic event detection, arrival picking, event location and magnitude calculation. It provides graphical display and reporting within near-real-time after a local or regional event occurred.

4.1.2 Real time Data Exchange of Seismic waveform Data

Malaysia is already linked with IRIS, USGS and Geoscience Australia through Internet and is contributing near real-time waveform data from its 3 broadband stations; Kulim, Kuching and K.Kinabalu for regional and international exchange.

Fig. 3

Location of 3 broadband seismic stations

Likewise, the system is also importing real time waveform data from the GSN seismic stations through the IRIS and USGS LISS's Server. The data sharing is crucial and helps to improve with better accuracy the determination of the location and magnitude of earthquakes.

4.1.3 <u>Future Plan of Upgrading Seismic Network</u>

Malaysia will strengthen its existing earthquake monitoring system. Two new seismic stations will be added to the network. The existing 2 seismic stations that equipped with short period sensors will be upgraded to broadband sensors. The upgrading of the seismic network is expected to be completed by end of year 2005. The picture below shows the location of the broadband stations.

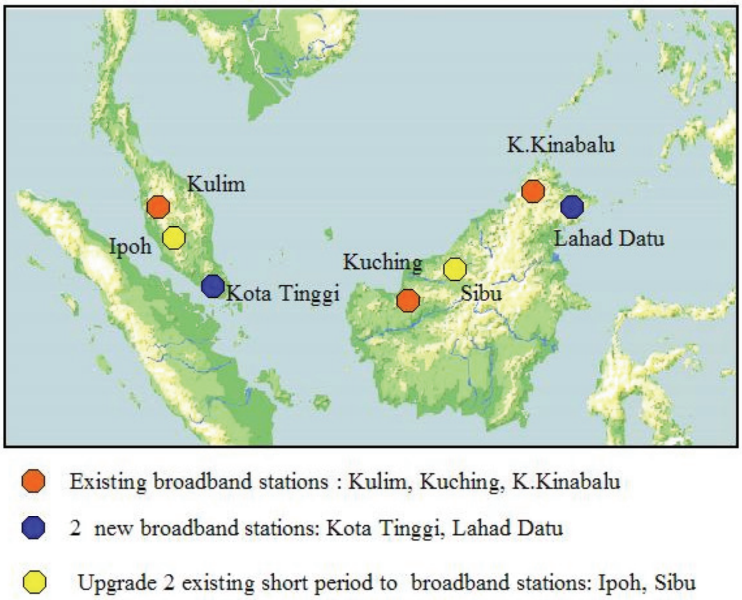


Fig. 4. Location of broadband seismic stations by end of year 2005

4.1.4 <u>Seismic stations locations and equipment</u>

A summary of the seismic stations location and the equipment is listed in the table below:

No.	Seismic Station	Latitude	Longitude	Dataloggers	Sensor	Remark
1	Kulim	5.3°N	100.7°E	Quanterra (Q330)	STS-2 Streckeisen	Broadband
2	Ipoh	4.6°N	101.0°E	Quanterra (Q330)	SS-1 Kinemetrics	Short period upgrade to broadband by end 2005
3	FRIM (Kuala Lumpur)	3.2°N	101.6°E	Quanterra (Q330)	SS-1 Kinemetrics	Short period
4	Kluang	2.0°N	103.3°E	Quanterra (Q330)	SS-1 Kinemetrics	Short period
5	Kuala Terengganu	5.3°N	103.1°E	Quanterra (Q330)	SS-1 Kinemetrics	Short period

No.	Seismic Station	Latitude	Longitude	Dataloggers	Sensor	Remark
6	Kuching	1.5°N	110.3°E	Quanterra (Q330)	STS-2 Streckeisen	Broadband
7	Sibu	2.5°N	112.2°E	Quanterra (Q330)	SS-1 Kinemetrics	Short period upgrade to broadband by end 2005
8	Bintulu	3.2°N	113.1°E	Quanterra (Q330)	SS-1 Kinemetrics	Short period
9	Kota Kinabalu	6.0°N	116.2°E	Quanterra (Q330)	STS-2 Streckeisen	Broadband
10	Kudat	6.9°N	116.8°E	Quanterra (Q330)	SS-1 Kinemetrics	Short period
11	Sandakan	5.6°N	117.2°E	Quanterra (Q330)	SS-1 Kinemetrics	Short period
12	Tawau	4.3°N	117.9°E	Quanterra (Q330)	SS-1 Kinemetrics	Short period
13	Kota Tinggi	1.8°N	103.9°E			Broadband (new station to be operational by end 2005)
14	Lahad Datu	5.0°N	118.3°E			Broadband (new station to be operational by end 2005)

4.2 Tide Gauges Network

4.2.1 Existing Tide Gauges Network

Malaysian Meteorological Department, Royal Malaysian Navy and Malaysian Survey&Mapping Department operate the tide gauges along the coastal waters of Malaysia. A list of all tide gauge stations is shown in diagram below. Most of the tidal gauges are not equipped for real time data transmission. Malaysian Meteorological Department installed 5 near real time tide gauges spanning across the country. These stations are located in Tanjung Keling, Pelabuhan Kuantan, Pelabuhan Bintulu, Kota Kinabalu and Sandakan. The recording of the data is on 10 minutes interval and the data is transmitted on hourly basis. GSM modem is used for the real time data transmission. The coverage for GSM is not very satisfactory at some stations which affect the performance of the network.

Fig. 5. Location of existing tide gauge stations in Malaysia

4.2.2 <u>A summary of the existing tide gauges stations operated by MMD is shown below</u> :

No.	Tide Gauge Station	Latitude	Longitude	Equipment
1	Kuantan	3.0°N	101.4°E	AANDERAA (RDCP 600)
2	Tanjung Beruas (Melaka)	2.21°N	102.16°E	AANDERAA (RDCP 600)
3	Bintulu	3.16°N	113.03°E	AANDERAA (RDCP 600)
4	Kota Kinabalu	5.98°N	116.06°E	AANDERAA (RDCP 600)
5	Sandakan	5.9°N	118.06°E	AANDERAA (RDCP 600)

4.2.3 <u>Future plan to upgrade the tide gauges network</u>

A total of 6 water level and tide monitoring stations is planned to be installed in 6 selected outpost islands. These monitoring stations serve as the first line monitoring system as they will detect the rise of water level. Each of the 6 new stations will have a water level meter coupled with a tide gauge to measure the rise and fall of water. VSAT satellite communication is used for real time data transmission of the tide gauges data to the central processing centre in Kuala Lumpur for analysis.

The location of the 6 new tide gauge stations has not been finalised. The 6 new tide monitoring stations will be selected from the list of 10 tide stations as depicted in the picture below. The expected date of installation and to be operational by end of year 2005.

Fig. 6.

Proposed new tide gauge stations

4.3 Deep Ocean Buoys Network

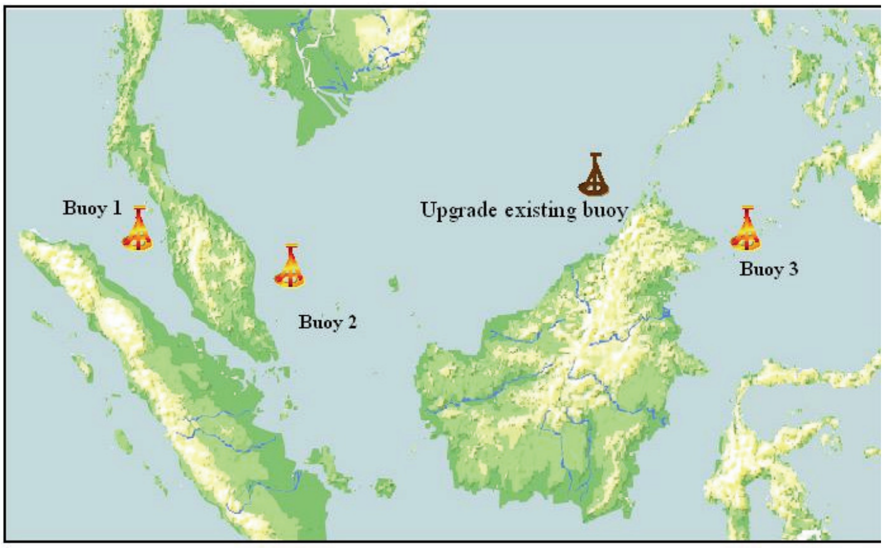
Buoys equipped with bottom pressure sensor positioned in the deep-ocean have been proven to detect the early passage of a tsunami before it reaches shallow waters and causes destruction along the coasts. These signals are very useful since it is the first set of instrumentation that confirms the generation of a tsunami and its probable size. The position of the buoy should be based on a study that would maximize the lead time of states to issue a warning to communities at risk.

In the event that a tsunami is generated, the equipments on the buoy will detect the tsunami wave and relay this information via satellite communication to the server in the National Tsunami Early Warning Center.

A total of three operational data buoys with seabed-mounted tsunami detection modules will be deployed at strategic locations in the Northwest Straits of Malacca, South China Sea and Sulu Sea for early detection of tsunamis. The expected date of completion is by end of year 2005.

The location for the three ocean buoys has not been finalized. The proposed locations are as below subject to requirement analysis:

Fig. 7. The proposed location for ocean buoys network



5. IOC proposal to upgrade the tide gauge station in Lumut

There are two tide gauges stations located in Lumut that are operated by the Royal Malaysian Navy and Survey&Mapping Department. IOC has initiated the upgrading of the tide gauge station in Lumut. The location of Lumut is situated inside the channel. It is recommended that site feasibility study by IOC experts may help to determine the suitability of the site.

ANNEX VI

STATUS REPORT ON WMO'S CONTRIBUTIONS TO THE DEVELOPMENT OF TSUNAMI EARLY WARNING SYSTEMS

WMO, together with UNESCO-IOC, ISDR and other key partners at the international, regional, and national levels, contributes to the development of end-to-end tsunami early warning systems in the Indian Ocean and other regions at risk. WMO will develop the capabilities of the National Meteorological and Hydrological Services (NMHSs) of the Indian Ocean Rim countries to establish an effective tsunami early warning system within a multi-hazard framework, particularly related to national multi-hazards alert and response mechanisms. However, the value of this effort applies not only to the Indian Ocean, but also to all regions at-risk.

As an immediate response to the December 2005 tsunami disaster, the WMO Secretary-General, Mr Michel Jarraud established a Tsunami task team at the Secretariat. WMO has committed to contributing its infrastructure (i.e., the Global Telecommunication System) and relevant technical capabilities to the development of the Indian Ocean Tsunami Warning System (IOTWS). WMO has developed an action plan, initiated several concrete projects and is mobilizing resources to assist its Members in the region. These projects are outlined below:

I. The WMO Global Telecommunication System (GTS) will be upgraded, where needed to address requirements for tsunami-related information exchange in the Ocean Indian Rim

WMO GTS is a dedicated network of telecommunication facilities operated by countries, which interconnect all NMHSs for the 24/7 exchange of meteorological and related data, forecasts and alerts. The GTS already provides for the exchange of advisories related to cyclones and severe weather, including in the Indian Ocean region, and supports the current Pacific TWS. The GTS will facilitate the exchange of tsunami alerts and related information in the Indian Ocean rim. It is being upgraded, where needed, for this purpose. A WMO multi-disciplinary workshop (March 2005, Jakarta, Indonesia), developed a plan for upgrading the GTS and identified 12 countries in need of GTS upgrades, including:

Asia: Bangladesh, Maldives, Myanmar, and Sri Lanka;
Arab Region: Yemen; Africa: Comoros, Djibouti, Kenya, Madagascar, Seychelles, Somalia, and Tanzania

WMO experts are visiting the NMHSs of these countries in July through September of 2005 to identify specific GTS equipment needs according the following schedule:

Schedule of GTS Upgrade Missions

Country	Mission dates
Sri Lanka	19-21/07/2005
Maldives	22-25/07/2005
Bangladesh	26-29/07/2005
Pakistan	1-3/08/2005
Myanmar	July 2005

Country	Mission dates
Kenya	2nd half Sept. 2005
Tanzania	2nd half Sept. 2005
Djibouti	2nd half Sept. 2005
Somalia	2nd half Sept. 2005
Yemen	TBD
Indonesia	July-August 2005

II. WMO will assist in the enhancement of multi-hazard national warning alert mechanisms of the NMHSs to support 24/7 dissemination of tsunami warnings, and to raise public awareness through development of their educational and public outreach programmes

WMO is working towards enhancement of multi-hazard national warning alert mechanisms provided through NMHSs to support around-the-clock dissemination of tsunami warnings to authorities, general public and the mariners. Furthermore, the NMHSs can assist in raising public awareness to enhance community preparedness through development of their educational and community outreach programmes.

WMO together with UNESCO-IOC and ISDR is participating in the national assessment expert visits to 19 countries in the Indian Ocean rim. As the first step WMO has carried out a preliminary survey of NMHSs to identify their needs related to enhancing warning dissemination and their education and outreach programmes. As part of the expert visits, WMO will investigate in detail the needs and requirements of the NMHSs, for dissemination of tsunami warnings as part of the multi-hazard approach and in particular in the following areas:

- Enhancement of the 24/7 operational capabilities of NMHSs for warning dissemination to authorities, public and for marine safety
- Increased public awareness of risks of multi-hazards threatening the countries (Tsunami, storm surge, tropical cyclones, etc.) through focused education and training programmes of the National Meteorological and Hydrological Services'. WMO will work with UNESCO-IOC in building on their existing tsunami related educational tools, modules, and materials and develop educational materials for the NMHSs
- Strengthening the interactions between NMHSs and the national entities responsible for disaster management.

III. WMO's Plan of Action for the coordination of a space system in support of a multi-hazard approach to early warning systems

WMO, through its Space Programme, is uniquely qualified as the sole intergovernmental organization responsible for the coordination of the complete global set of environmental satellites. Not only are satellite systems the only truly global observing system but they also provide for a global capability for data collection from remote sites including ocean areas as well as the ability to disseminate information immediately to users at the local, regional and global levels. Disaster prevention and mitigation for all hazards represent an area where satellite system capabilities are a fundamental tool to increase capacity building in all countries, especially in developing countries.

WMO has developed an action plan to identify specific capabilities presently available from satellite systems, but not yet utilized in alert mechanisms, data-collection needs as well as dissemination systems made possible through environmental satellites. The satellites will directly support NMHSs and other relevant agencies. A consolidated statement of needs, to which space agencies can respond, will be developed through a series of workshops as well as requirements for longer-term improvements.

WMO, together with its partners, will also ensure that the tsunami and other hazard observation and monitoring requirements are incorporated in the implementation plan for the Global Earth

Observing System of Systems (GEOSS) to ensure that this critical aspect is part of the GEOSS Work Programme.

IV. Multi-hazard approach to IO-TWS

WMO will continue to promote the benefits of a multi-hazard approach to the tsunami early warning system and its implementation. WMO has begun to define and develop a “multi-hazard” approach to early-warning system capabilities by defining synergies, economies and sustainablity aspects.

ANNEX VII

CLIVAR/GOOS INDIAN OCEAN PANEL
REPORT ON PLANS FOR SUSTAINED OBSERVATIONS FOR CLIMATE

Introduction

The purpose of this talk was to identify the commonalities and potential synergies between the climate observing system in the Indian Ocean and IOTWS. The CLIVAR/GOOS Indian Ocean Panel was formally established in 2003 by CLIVAR on behalf of World Climate Research Programme, the IOC-Perth Regional Office and the Indian Ocean GOOS regional association (IOGOOS), following earlier preliminary meetings since 2000. The Panel formally met twice (March 2004 in Pune, India and February 2005 in Hobart Australia) and produced the report entitled, "Understanding the role of the Indian Ocean in the climate system—an implementation plan for sustained observations." The report was briefly summarized at the ICG meeting, with a view toward promoting coordination, particularly with regard to deep sea mooring and instrumentation.

1. Climate Research Issues

The Indian Ocean research issues were initially identified in the CLIVAR Research Plan sections G2 and G4 prepared in 1997 (http://www.clivar.org/publications/wg_reports/index.htm). The issues and science-drivers have been updated in the IOP report. The goals requiring improved ocean observations are understanding, modelling and ability to predict :

- Seasonal monsoon variability in the ocean
- Intraseasonal disturbances and their interactions with the upper ocean
- The Indian Ocean Zonal Dipole Mode and its interaction with El Nino Southern Oscillation
- Decadal variability and warming trends
- Climate impacts from the extra-tropical South Indian Ocean, and
- Unique features of ocean circulation (Indonesian throughflow, shallow and deep overturning cells) that affect transport and storage of heat and exchange with the atmosphere.

The intraseasonal time-scale was emphasized as the fastest time scale of interest to climate research, and the goal that is most relevant to IOTWS, **particularly in the context of a multi-hazard warning system**, that will address a broad range of marine hazards, including tropical cyclones, coastal flooding, seasonal drought and storm surge.

2. The integrated ocean observing system for climate

An overview of the integrated observing system recommended for the Indian Ocean was presented. It includes basin-scale observations including fixed moorings, Argo floats, XBT lines, surface drifters and tide gauges. Detailed plans for each type of basin-scale observation are given in the IOP Report. The Report also recommends observations in some boundary regions including the Arabian Sea (ASEA), the Bay of Bengal (BOB), the Indonesian Throughflow (ITF) and the Mozambique Channel. The BoB and ITF are already in operation and are most relevant to IOTWS.

The basin scale mooring array was described to open the possibility that mooring sites can be shared with IOTWS. The moored buoy array for climate will be designed and implemented according to the following principles:

a. Design of the array will build on the experience gained in developing previous and ongoing moored buoy programs in the Indian Ocean and on the experience gained during TOGA and CLIVAR in designing and implementing TAO/TRITON and PIRATA;
b. The array will focus on those aspects of ocean dynamics, air-sea interaction, and climate variability that high temporal resolution, multi-variate moored time series measurements are uniquely suited to address;
c. The array will complement other components (satellite, in situ) of the Indian Ocean Observing System;
d. The array will be long term and sustained;
e. Implementation will rely on multi-national contributions;
f. Real-time data transmission will be a high priority in order to support operational climate analyses and forecasts;
g. Data will be freely and openly exchanged via the GTS and the WWW.

The marine meteorological variables to be measured include those needed to characterize fluxes of momentum, heat and fresh water across the air-sea interface, namely surface winds, SST, air temperature, relative humidity, downwelling short- and long-wave radiation, barometric pressure, and rain rate. Physical oceanographic variables include upper ocean temperatures, salinity, and horizontal currents. The moorings can also support sensors to measure CO_2 concentrations in air and sea water, nutrients, bio-optical properties, and ocean acoustics. The geographical coverage includes 44 moorings distributed across the basin at locations carefully selected to monitor the key regions of ocean atmosphere interaction, and to provide coverage in regions that were poorly sampled in the past. The mooring sites in the eastern tropical Indian Ocean are most relevant to IOTWS

3. Commonalities and potential synergies with IOTWS

- Obvious synergies in observing network and associated logistics for deep-sea
  - Ship time
  - Mooring sites
- Multi-hazard framework (e.g. tropical cyclones, flooding, storm surge)
  - Design of multi-hazard instrumentation package
  - Maximize use of assets will give stability, reliability to the observing system.
  - The observing system will routinely provide products of use to the public e.g. storm surge is more frequent than tsunami; tropical cyclones occur every year.
- Tide gauges need to be expanded for both, but take care to satisfy both needs
  - IOTWS needs continuous real time data

  - Climate needs maintenance of a long term datum to observe sea level rise

- Data management
  - Common repositories, adequately resourced to assemble integrated data sets from many different types of instrumentation
  - More open data exchange
- Much emphasis on coasts and vulnerability
- Opportunities for joint risk assessment work, e.g. TCs
- Climate and tsunami communities share the multi-hazard warning mandate

ANNEX VIII

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ANNEX IX

LIST OF ACRONYMS

AUD	Australian Dollars
ADPC	Asian Disaster Preparedness Center
AFTN	Aeronautical Fixed Telecommunications Network
ASEAN	Association of Southeast Asian Nations
CTBTO	Comprehensive Nuclear-Test-Ban Treaty Organization
CLIVAR	Climate Variability and Predictability
DART	Deep Ocean Assessment & Reporting of Tsunamis
DIPECHO	Directorate General (European Commission) for Humanitarian Aid
EMWIN	Emergency Managers Weather Information Network
EU	European Union
GDPFS	Global Data-Processing Meteorological Centre
GEOSS	Global Earth Observation System of Systems
GLOSS	Global sea Level Observing System
GMDSS	Global Maritime Distress & Safety System
GOOS	Global Ocean Observing System
GOS	Global Observing System
GTS	Global Telecommunication System
ICG/IOTWS	Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning & Mitigation System
IFRC	International Federation of Red Cross & Red Crescent Societies
IMO	International Maritime Organization
INCOIS	Indian Centre for Ocean Information Services
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IOGOOS	Indian Ocean GOOS
IOTEWS	Indian Ocean Tsunami Early Warning System
IOTWS	Indian Ocean Tsunami Warning System
ISDR	International Strategy for Disaster Reduction
ITSU	Tsunami Warning System in the Pacific
ITIC	International Tsunami Information Center (USA)
ITU	International Telecommunications Union
JMA	Japan Meteorological Agency
NMC	National Meteorological Centre
NMHSs	National Meteorological & Hydrological Services
OCHA	Office for the Coordination of Humanitarian Affairs
PTWC	Pacific Tsunami Warning System
RMSCs	Regional Specialized Meteorological Centre
RTCI	Regional Tsunami Information Centre
RTH	Regional Telecommunication Hub
TWI	Tsunami Watch Information
IOC	Workshop Report No. 198
UN	United Nations
UNDP	United Nations Development Programme
UNESCAP	United Nations Economic & Social Commission for Asia & the Pacific
UNESCO	United Nations Educational, Scientific & Cultural Organization
UNGA	United Nations General Assembly

WAPMERR	World Agency of Planetary Monitoring & Earthquake Risk Reduction
WMC	Word Meteorological Centre
WMO	World Meteorological Organization

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Reports of Governing and Major Subsidiary Bodies, which was initiated at the beginning of 1984, the reports of the following meetings have already been issued:

1.	Eleventh Session of the Working Committee on international Oceanographic Data Exchange	E, F, S, R
2.	Seventeenth Session of the Executive Council	E , F, S, R,Ar
3.	Fourth Session of the Working Committee for Training, Education and Mutual Assistance	E, F, S, R
4.	Fifth Session of the Working Committee for the Global Investigation of Pollution in the Marine Environment	E, F, S, R
5.	First Session of the IOC Sub-Commission for the Caribbean and Adjacent Regions	E, F, S
6.	Third Session of the *ad hoc* Task team to Study the Implications, for the Commission, of the UN Convention on the Law of the Sea and the New Ocean Regime	E, F, S, R
7.	First Session of the Programme Group on Ocean Processes and Climate	E, F, S, R
8.	Eighteenth Session of the Executive Council	E, F, S, R, Ar
9.	Thirteenth Session of the Assembly	E, F, S, R, Ar
10.	Tenth Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific	
11.	Nineteenth Session of the Executive Council, Paris, 1986	E, F, S, R, Ar
12.	Sixth Session of the IOC Scientific Committee for the Global Investigation of Pollution in the Marine Environment	E, F, S
13.	Twelfth Session of the IOC Working Committee on International Oceanographic Data Exchange	E, F, S, R
14.	Second Session of the IOC Sub-Commission for the Caribbean and Adjacent Regions, Havana, 1986	E, F, S
15.	First Session of the IOC Regional Committee for the Central Eastern Atlantic, Praia, 1987	E, F, S
16.	Second Session of the IOC Programme Group on Ocean Processes and Climate	E, F, S
17.	Twentieth Session of the Executive Council, Paris, 1987	E, F, S, R, Ar
18.	Fourteenth Session of the Assembly, Paris, 1987	E, F, S, R, Ar
19.	Fifth Session of the IOC Regional Committee for the Southern Ocean	E, F, S, R
20.	Eleventh Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific, Beijing, 1987	E, F, S, R
21.	Second Session of the IOC Regional Committee for the Co-operative Investigation in the North and Central Western Indian Ocean, Arusha, 1987	E, F
22.	Fourth Session of the IOC Regional Committee for the Western Pacific, Bangkok, 1987	E only
23.	Twenty-first Session of the Executive Council, Paris, 1988	E, F, S, R
24.	Twenty-second Session of the Executive Council, Paris, 1989	E, F, S, R
25.	Fifteenth Session of the Assembly, Paris, 1989	E, F, S, R
26.	Third Session of the IOC Committee on Ocean Processes and Climate, Paris, 1989	E, F, S, R
27.	Twelfth Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific, Novosibirski, 1989	E, F, S, R
28.	Third Session of the Sub-Commission for the Caribbean and Adjacent Regions, Caracas, 1989	E, S
29.	First Session of the IOC Sub-Commission for the Western Pacific, Hangzhou, 1990	E only
30.	Fifth Session of the IOC Regional Committee for the Western Pacific, Hangzhou, 1990	E only
31.	Twenty-third Session of the Executive Council, Paris, 1990	E, F, S, R
32.	Thirteenth Session of the IOC Committee on International Oceanographic Data and Information Exchange, New York, 1990	E only
33.	Seventh Session of the IOC Committee for the Global Investigation of Pollution in the Marine Environment, Paris, 1991	E, F, S, R
34.	Fifth Session of the IOC Committee for Training, Education and Mutual Assistance in Marine Sciences, Paris, 1991	E, F, S, R
35.	Fourth Session of the IOC Committee on Ocean Processes and Climate, Paris, 1991	E, F, S, R
36.	Twenty-fourth Session of the Executive Council, Paris, 1991	E, F, S, R
37.	Sixteenth Session of the Assembly, Paris, 1991	E, F, S, R, Ar
38.	Thirteenth Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific, Baja California, 1991	E, F, S, R
39.	Second Session of the IOC-WMO Intergovernmental WOCE Panel, Paris, 1992	E only
40.	Twenty-fifth Session of the Executive Council, Paris, 1992	E, F, S, R
41.	Fifth Session of the IOC Committee on Ocean Processes and Climate, Paris, 1992	E, F, S, R
42.	Second Session of the IOC Regional Committee for the Central Eastern Atlantic, Lagos, 1990	E, F
43.	First Session of the Joint IOC-UNEP Intergovernmental Panel for the Global Investigation of Pollution in the Marine Environment, Paris, 1992	E, F, S, R
44.	First Session of the IOC-FAO Intergovernmental Panel on Harmful Algal Blooms, Paris, 1992	E, F, S
45.	Fourteenth Session of the IOC Committee on International Oceanographic Data and Information Exchange, Paris, 1992	E, F, S, R
46.	Third Session of the IOC Regional Committee for the Co-operative Investigation in the North and Central Western Indian Ocean, Vascoas, 1992	E, F
47.	Second Session of the IOC Sub-Commission for the Western Pacific, Bangkok, 1993	E only
48.	Fourth Session of the IOC Sub-Cornmission for the Caribbean and Adjacent Regions, Veracruz, 1992	E, S
49.	Third Session of the IOC Regional Committee for the Central Eastern Atlantic, Dakar, 1993	E, F
50.	First Session of the IOC Committee for the Global Ocean Observing System, Paris, 1993	E, F, S, R
51.	Twenty-sixth Session of the Executive Council, Paris, 1993	E, F, S, R
52.	Seventeenth Session of the Assembly, Paris, 1993	E, F, S, R
53.	Fourteenth Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific, Tokyo, 1993	E, F, S, R
54.	Second Session of the IOC-FAO Intergovernmental Panel on Harmful Algal Blooms, Paris, 1993	E, F, S
55.	Twenty-seventh Session of the Executive Council, Paris, 1994	E, F, S, R
56.	First Planning Session of the IOC-WMO-UNEP Committee for the Global Ocean Observing System, Melbourne, 1994	E, F, S, R
57.	Eighth Session of the IOC-UNEP-IMO Committee for the Global Investigation of Pollution in the Marine Environment, San José, Costa Rica, 1994	E, F, S
58.	Twenty-eighth Session of the Executive Council, Paris, 1995	E, F, S, R
59.	Eighteenth Session of the Assembly, Paris, 1995	E, F, S, R
60.	Second Session of the IOC-WMO-UNEP Committee for the Global Ocean Observing System, Paris, 1995	E, F, S, R

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61.	Third Session of the IOC-WMO Intergovernmental WOCE Panel, Paris, 1995	E only
62.	Fifteenth Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific, Papetee, 1995	E, F, S, R
63.	Third Session of the IOC-FAO Intergovernmental Panel on Harmful Algal Blooms, Paris, 1995	E, F, S
64.	Fifteenth Session of the IOC Committee on International Oceanographic Data and Information Exchange	E, F, S, R
65.	Second Planning Session of the IOC-WMO-UNEP Committee for the Global Ocean Observing System, Paris, 1995	E only
66.	Third Session of the IOC Sub-Commission for the Western Pacific, Tokyo, 1996	E only
67.	Fifth Session of the IOC Sub-Commission for the Caribbean and Adjacent Regions, Christ Church, 1995	E, S
68.	Intergovernmental Meeting on the IOC Black Sea Regional Programme in Marine Sciences and Services	E, R
69.	Fourth Session of the IOC Regional Committee for the Central Eastern Atlantic, Las Palmas, 1995	E, F, S
70.	Twenty-ninth Session of the Executive Council, Paris, 1996	E, F, S, R
71.	Sixth Session for the IOC Regional Committee for the Southern Ocean and the First Southern Ocean Forum, Bremerhaven, 1996	E, F, S,
72.	IOC Black Sea Regional Committee, First Session, Varna, 1996	E, R
73.	IOC Regional Committee for the Co-operative Investigation in the North and Central Western Indian Ocean, Fourth Session, Mombasa, 1997	E, F
74.	Nineteenth Session of the Assembly, Paris, 1997	E, F, S, R
75.	Third Session of the IOC-WMO-UNEP Committee for the Global Ocean Observing System, Paris, 1997	E, F, S, R
76.	Thirtieth Session of the Executive Council, Paris, 1997	E, F, S, R
77.	Second Session of the IOC Regional Committee for the Central Indian Ocean, Goa, 1996	E only
78.	Sixteenth Session of the International Co-ordination Group for the Tsunami Warning System in the Pacific, Lima, 1997	E, F, S, R
79.	Thirty-first Session of the Executive Council, Paris, 1998	E, F, S, R
80.	Thirty-second Session of the Executive Council, Paris, 1999	E, F, S, R
81.	Second Session of the IOC Black Sea Regional Committee, Istanbul, 1999	E only
82.	Twentieth Session of the Assembly, Paris, 1999	E, F, S, R
83.	Fourth Session of the IOC-WMO-UNEP Committee for the Global Ocean Observing System, Paris, 1999	E, F, S, R
84.	Seventeenth Session of the International Coordination Group for the Tsunami Warning System in the Pacific, Seoul, 1999	E, F, S, R
85.	Fourth Session of the IOC Sub-Commission for the Western Pacific, Seoul, 1999	E only
86.	Thirty-third Session of the Executive Council, Paris, 2000	E, F, S, R
87.	Thirty-fourth Session of the Executive Council, Paris, 2001	E, F, S, R
88.	Extraordinary Session of the Executive Council, Paris, 2001	E, F, S, R
89.	Sixth Session of the IOC Sub-Commission for the Caribbean and Adjacent Regions, San José, 1999	E only
90.	Twenty-first Session of the Assembly, Paris, 2001	E, F, S, R
91.	Thirty-fifth Session of the Executive Council, Paris, 2002	E, F, S, R
92.	Sixteenth Session of the IOC Committee on International Oceanographic Data and Information Exchange, Lisbon, 2000	E, F, S, R
93.	Eighteenth Session of the International Coordination Group for the Tsunami Warning System in the Pacific, Cartagena, 2001	E, F, S, R
94.	Fifth Session of the IOC-WMO-UNEP Committee for the Global Ocean Observing System, Paris, 2001	E, F, S, R
95.	Seventh Session of the IOC Sub-commission for the Caribbean and Adjacent Regions (IOCARIBE), Mexico, 2002	E, S
96.	Fifth Session of the IOC Sub-Commission for the Western Pacific, Australia, 2002	E only
97.	Thirty-sixth Session of the Executive Council, Paris, 2003	E, F, S, R
98.	Twenty-second Session of the Assembly, Paris, 2003	E, F, S, R
99.	Fifth Session of the IOC Regional Committee for the Co-operative Investigation in the North and Central Western Indian Ocean, Kenya, 2002 (* Executive Summary available separately in E, F, S & R)	E*
100.	Sixth Session of the IOC Intergovernmental Panel on Harmful Algal Blooms, St. Petersburg (USA), 2002 (* Executive Summary available separately in E, F, S & R)	E*
101.	Seventeenth Session of the IOC Committee on International Oceanographic Data and Information Exchange, Paris, 2003 (* Executive Summary available separately in E, F, S & R)	E*
102.	Sixth Session of the IOC-WMO-UNEP Committee for the Global Ocean Observing System, Paris, 2003 (* Executive Summary available separately in E, F, S & R)	E*
103.	Nineteenth Session of the International Coordination Group for the Tsunami Warning System in the Pacific, Wellington, New Zealand, 2003 (* Executive Summary available separately in E, F, S & R)	E*
104.	Third Session of the IOC Regional Committee for the Central Indian Ocean, Tehran, Islamic Republic of Iran, 21-23 February 2000	E only
105.	Thirty-seventh Session of the Executive Council, Paris, 2004	E, F, S, R
106.	Seventh Session of the IOC-WMO-UNEP Committee for the Global Ocean Observing System, Paris, 2005 (* Executive Summary available separately in E, F, S & R)	E*
107.	First Session of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS), Perth, Australia, 3–5 August 2005	E only