Regional Tsunami Service Provider

Service User Guide

ver3 August 2011
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1. Introduction

The Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) was formed in response to the tragic tsunami on 26 December 2004. The main objective of the IOTWS is to identify and mitigate the hazards posed by local and distant tsunamis. The goal is to create a fully integrated end-to-end warning system, comprising three key components: hazard detection and forecasting; threat evaluation and alert dissemination; and community preparedness and response.

The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) is an international and intergovernmental institution, owned and managed by its Member States, for the generation and application of early warning information. RIMES evolved from the efforts of 26 countries in Africa and Asia, in the aftermath of the 2004 Indian Ocean tsunami, to establish a regional early warning system, within a multi-hazard framework, which generates and communicates early warning information, and builds capacity to prepare for and respond to trans-boundary hazards. RIMES was established on 30 April 2009, through the signing by collaborating countries of the RIMES regional cooperation agreement, and registered with the United Nations, under article 102 of the UN Charter, on 1 July 2009. Thirteen countries have thus far signed the RIMES cooperation agreement; other 16 countries are in various stages of consideration and approval. India chairs the RIMES Council, while Maldives serves as RIMES Secretariat. RIMES operates from its regional early warning center, located at the campus of the Asian Institute of Technology in Pathumthani, Thailand. Facilities for earthquake monitoring and tsunami warning were established through projects implemented by the Asian Disaster Preparedness Center, with support from UNESCAP; ownership was transferred to RIMES on 30 September 2010.

RIMES Master Plan 2010-2014, prepared by the RIMES Executive Board and approved by the RIMES Council, includes the establishment and maintenance of core regional observation and monitoring networks, provision of tsunami watch and coastal inundation forecasts within the IOC framework, and research and development for providing increasingly accurate and more detailed warning information, utilizing the latest low-cost, but efficient technologies. RIMES started sharing earthquake alerts and tsunami bulletins with RIMES Member States and collaborating countries on 2 April 2010, under IOC/IOTWS Service Level 1 standards. From June 2011, RIMES will provide information, as per IOC/IOTWS Service Level 2 standards, on a trial basis.

2. RIMES Tsunami Early Warning System Components

2.1 Regional observation and monitoring networks

RIMES regional seismic network consists of 4 real-time very broadband seismographic stations (Figure 1): SZP at 17-33.12N 120-27.30E in Santa, Ilocos Sur, Philippines; SLV at 21-57.91N 103-54.30E in Son La, Vietnam; DLV at 11-57.91N 108-28.89E in Dalat, Vietnam; and SIM at 20-07.98N 92-53.12E in Sittwe, Myanmar. These stations contribute data to the global seismic network. Established with UNESCAP support, ownership of these stations has been transferred to the countries, which now operate and maintain these stations. RIMES assists in the upkeep of these stations, when requested by the countries. Twenty (20) very broadband seismographic and 8 seismic cGPS stations are planned for installation in the Indo-Southeast Asian region (Nepal, Bhutan, and Myanmar) from 2011-2012, with funding support from the Government of India.
RIMES regional sea level observing network consists of 6 near real time sea level stations (Figure 2), established under GLOSS, with support from UNDP and UNESCAP: CURRI at 120-29N 18-0.88E in Currimao, Philippines; LUBA at 13-49N 120-12E in Lubang, Philippines; SUBI at 14-49N 120-17E in Subic, Philippines; KOTA at 98-25N 7-49E in Koh Taphao Noi, Thailand; QUIN at 13-46N 109-13E in Qui Nhon, Vietnam; and VTAU at 10-20.01N 107-4E in Vung Tau, Vietnam. Station ownership has been transferred to the countries, which now operate and maintain these stations; RIMES assists when requested by the countries.

Figure 1: RIMES primary seismic stations

Figure 2: RIMES sea level observation stations
2.2 Seismic data acquisition and processing

Seismic waves naturally travel much faster than tsunami waves. Seismic wave analysis can provide an early indication of a potentially tsunamigenic earthquake. Currently, real-time seismic data is acquired and processed at RIMES by using the “Antelope Seismic Software” and “SeisComp3” (Figure 3). Presently, the systems can connect to and import real-time seismic wave form from RIMES’ primary seismic station and other networks, namely IRIS, GSN, and GEOFON, including stations of JAMSTEC and Academia Sinica, Taiwan. Seismic data are then evaluated to estimate tsunamigenic sources. All earthquakes of magnitude greater than 5.0 can be detected within 8 minutes and 13 minutes, for areas inside and outside of RIMES Area of Responsibility (AOR), respectively. RIMES AOR covers the Indian Ocean and South China Sea.

![Figure 3: RIMES seismic data acquisition and processing software](image)

2.3 Tsunami forecasting system

Seismic parameters, used as indirect measurements of tsunami generation, are utilized as the basis for the initial tsunami warning decision. Warnings, based solely on seismic parameters, however, are not very reliable. Warning reliability is improved using sea level data from the nearest coastal tide gauge station, which are used to confirm the generation of a tsunami. RIMES uses the TUNAMI model, Tohoku University's Numerical Analysis Model for Investigation of Tsunami, (IUGG/UOC TIME Project, 1997), to simulate tsunami generation, trans-oceanic propagation, and inundation on the selected coastal sites.

2.3.1 PRECISE

RIMES developed the Portal for Regional Estimation of Coastal Tsunami Impacts using Sea-level and Earthquake Information (PRECISE) for determining tsunami arrival time, amplitudes, and inundation, using preliminary earthquake information (magnitude and epicenter location) and sea level information obtained from DART buoys and tidal gauges (Figure 4). PRECISE features a pre-computed tsunami database, developed using the unit-source concept, for Sunda, Makran, and Western Philippines subduction zones, which can generate destructive tsunamis in the Indian Ocean and South China Sea. Each unit source has a length of 100 km, width of 50 km, dislocation of 1 m, and a slip angle of 90°.

Since a number of DART buoys and tidal gauges have been installed and upgraded after the 2004 Indian Ocean Tsunami, real-time feeds from sea level sensors can be used to revise initial tsunami forecasts. Additionally, the inundation forecast can be performed at some key coastal sites, where data is available.
Pre-computed tsunami database

In the region under RIMES's tsunami watch, there are three main subduction zones: Sunda, Western Philippines, and Makran subduction zones. The appropriate fault parameters were determined from previous studies on the subduction zones. Profiles of fault planes in these zones were proposed by Gudmundsson and Sambridge (1998). Unit sources were aligned along fault planes, with dip angles corresponding to the profiles proposed by Gudmundsson and Sambridge (1998). There are totally 250, 51, and 22 unit sources for the Sunda, Western Philippines, and Makran subduction zones, respectively. Sea floor deformation was determined for each unit source using the formulation proposed by Mansinha and Smylie (1971). Tsunami propagation simulation was performed for all 323 cases, using the TUNAMI-F1 models. Time histories of tsunami amplitudes at all grid points were archived, and then retrieved for superposition to determine tsunami amplitudes, arrival time, and amplitudes at coastlines (Figure 5).

Figure 4: PRECISE for tsunami forecasting

(a) Tsunami travel time  (b) Tsunami directivity  (c) Coastal wave height

Figure 5: Graphical tsunami forecast products

Sea level inversion

PRECISE continuously archives and presents the sea-level data from GLOSS stations and DART bouys. Sea-level data from DART bouys is used to confirm the occurrence of tsunamis in the ocean, while data from tidal gauges is used to confirm the arrival of tsunamis at coastlines. Sea-level data can be utilized for inverse analysis to determine fault parameters, for more accurate prediction of tsunami amplitudes. Tidal gauge data is manually manipulated in PRECISE to extract tsunami
signals from astronomical tides. Inverse analysis is performed to revise the amount of slips of various unit sources. Then the values will be used for superposition of unit source database, for a revised forecast (Figure 6).

![Figure 6: Tsunami source revision in PRECISE by sea level inversion](image)

**Real-time coastal inundation simulation**

Under Service Level 3, RTSPs will deliver enhanced products and services to support NTWCs in hazard and risk assessments and inundation forecasts for specific coastal locations. RIMES has developed these capacities, with the development and application of PRECISE and the Internet-based Simulation Platform for Inundation and Risk Evaluation (INSPIRE) for tsunami inundation and risk evaluation.

PRECISE calculates tsunami inundation in real time to determine inundation depths at some coastal sites (Figure 7), and simulation results can be released on RIMES website, with password protection, by approximately 1 hour after earthquake detection. Table 1 lists sites where coastal inundation is predicted.

<table>
<thead>
<tr>
<th>Country</th>
<th>Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sri Lanka (Indian Ocean)</td>
<td>Kalmunai, Trinconmalee, Hambantota</td>
</tr>
<tr>
<td>Thailand (Indian Ocean)</td>
<td>Phuket (Kamala and Patong beach)</td>
</tr>
<tr>
<td>Vietnam (South China Sea)</td>
<td>Danang, Qui Nhon</td>
</tr>
</tbody>
</table>

Table 1: Locations for which RIMES currently provides coastal inundation forecasts

![a) Portal for inundation simulation in PRECISE](image) ![b) Inundation forecast from PRECISE at Phuket, Thailand](image)

Figure 7: Real-time tsunami inundation forecast at some key coastal sites by PRECISE

Annex 1 provides details on enhancement of PRECISE tsunami database and web-based interface for tsunami forecasting for the Indian Ocean.
2.3.2 Coastal forecast zones for the Indian Ocean

A standard spatial data of coastal forecast points (CFPs) and coastal forecast zones (CFZs) has been established, with consultation among RTSPs and verified by countries to ensure interoperability among RTSPs and NTWCs. Rectangular boxes of 100x50 km (along the coast and across the coast, respectively), representing the forecasted zones, are placed along the Indian Ocean rim to extract the quantitative tsunami forecast information from numerical model. Smaller size of the forecast zones is required for representing islands. The box of forecast zone starts offshore from a water depth of 30m, and each forecast zones are linked to national administration boundaries. Currently, 564 forecast zones are registered in the PRECISE database, for generating warning information products for NTWCs (Figure 8). RIMES Bulletins provide tsunami information, such as arrival times, and amplitude for each forecast zone under threat. Threat map is generated to spatially point out the area under threat (maximum amplitude of wave is greater than 0.5 m at shore).

![Figure 8: Standard spatial data of the coastal forecast zone for the Indian Ocean](image)

2.3.3 Coastal forecast points for the Indian Ocean

Each Coastal Forecast Zone contains a number of Coastal Forecast Points that provide common reference points for forecasts from different RTSPs. CFPs, representing place names, are actual locations to capture computed tsunami information from numerical modeling, and used as basis to generate warning information for each coastal forecast zone. Currently 1,656 forecast points are registered in PRECISE database for capturing tsunami waveforms (Figure 9). Most critical tsunami information on coastal forecast points in the same coastal forecast zone is selected to present the tsunami information on corresponding coastal forecast zone.
2.3.4 Tsunami Forecast Information for the Indian Ocean

Tsunami forecast products for the Indian Ocean include information about the threat and the qualitative tsunami wave for each coastal forecast zone, as shown in Table 2.

Table 2: Tsunami forecast information for the Indian Ocean

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Threat</strong></td>
<td>Forecast wave amplitude $\geq$ significant wave (0.5 m)</td>
</tr>
<tr>
<td><strong>No threat</strong></td>
<td>Forecast wave amplitude $&lt;$ significant wave (0.5 m)</td>
</tr>
<tr>
<td><strong>Max_beach</strong></td>
<td>Maximum positive wave amplitude at shoreline (using Green's function at water depth 1 m)</td>
</tr>
<tr>
<td><strong>Max_deep</strong></td>
<td>Maximum positive wave amplitude at deep water in each coastal zone (approximately 50 m depth)</td>
</tr>
<tr>
<td><strong>T1</strong></td>
<td>Time of arrival of the minimum detectable positive amplitude wave (2 cm)</td>
</tr>
<tr>
<td><strong>T2</strong></td>
<td>Time of first exceedance of threat threshold</td>
</tr>
<tr>
<td><strong>T3</strong></td>
<td>Time of arrival of maximum wave amplitude</td>
</tr>
<tr>
<td><strong>T4</strong></td>
<td>Time of last exceedance of threat threshold</td>
</tr>
<tr>
<td><strong>Depth</strong></td>
<td>Depth of offshore forecast point</td>
</tr>
</tbody>
</table>
2.3.5 Coastal forecast points for the South China Sea

RIMES Bulletins provided tsunami information to NTWCs in the South China Sea, referred to the 100 coastal forecast points (Figure 10). Time histories of tsunami amplitudes and the maximum tsunami amplitudes are available at the forecast points, for generating summary table of arrival times, and amplitude for each forecast point under threat.

![Figure 10: Forecast points in the South China Sea](image)

2.3.6 Tsunami forecast information for the South China Sea

Tsunami forecast products for the South China Sea include tsunami wave qualitative information for each coastal forecast point, as shown in Table 3.

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETA of significant wave</td>
<td>Time of first exceedance of significant wave (0.5 m)</td>
</tr>
<tr>
<td>ETA of 1st wave</td>
<td>Time of arrival of the minimum detectable positive amplitude wave (2 cm)</td>
</tr>
<tr>
<td>Max. amplitude of 1st wave</td>
<td>Maximum positive wave amplitude at shoreline of the 1st wave</td>
</tr>
<tr>
<td>Duration</td>
<td>Period of time when amplitude ≥ significant wave</td>
</tr>
<tr>
<td>Max. amplitude</td>
<td>Maximum positive wave amplitude at shoreline for the whole period of computation</td>
</tr>
</tbody>
</table>
3. Operating Procedure for Service Level 2 and Bulletin Types

RIMES provides information by issuing bulletins for undersea/coastal earthquake magnitudes ≥ 6.5, with origin in the area of the Indian Ocean or the South China Sea (RIMES AOR), or in areas outside of RIMES AOR but have potential of affecting RIMES Member States. RIMES shall provide four types of bulletins (Table 4) to NTWCs, in both the Indian Ocean and South China Sea, according to the ICG-IOTWS standard bulletin format.

Table 4: Types of bulletins issued by RIMES

<table>
<thead>
<tr>
<th>Information type</th>
<th>Supplementary Bulletins</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulletin Notification Message</td>
<td>None</td>
<td>Notification messages will be issued to alert NTWCs whenever a bulletin is issued, without tsunami forecast details.</td>
</tr>
<tr>
<td>Bulletin type 1 Earthquake Information</td>
<td>Only one &lt;Supplementary Bulletin: A&gt;</td>
<td>Preliminary earthquake parameters and initial quick evaluation of tsunamigenic potential of the earthquake.</td>
</tr>
<tr>
<td>Bulletin type 2 No Threat</td>
<td>None</td>
<td>Absence of threat based on pre-run model scenarios.</td>
</tr>
<tr>
<td>Bulletin type 2 Potential Threat</td>
<td>Several, based on need &lt;Supplementary Bulletin: A/B/C/D/ etc&gt;</td>
<td>Preliminary tsunami forecast information, based on earthquake information, including arrival time, wave amplitude and threat status.</td>
</tr>
<tr>
<td>Bulletin type 3 Confirmed Threat with Observations</td>
<td>Several Based on need &lt;Supplementary Bulletin: A/B/C/D/ etc&gt;</td>
<td>Updated tsunami forecast information, based on actual observation of sea level at coastal tide gauges and DART buoys, and revision of earthquake parameters from sea level inversion.</td>
</tr>
<tr>
<td>Bulletin type 4 Final Bulletin</td>
<td>None</td>
<td>Final information of tsunami threat, based on two criteria:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>a) No significant tsunami was generated from reading of sea level gauges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>b) 2 hours after the forecasted arrival time of last significant wave</td>
</tr>
</tbody>
</table>

Bulletin type 1 shall be issued for all earthquakes of magnitudes ≥ 6.5 with origin within or outside\(^1\) of RIMES AOR. Threat assessment bulletins (Bulletin type 2 and subsequent bulletin types as necessary) shall be issued for all earthquakes of magnitudes ≥ 6.5 with origin within RIMES AOR, and, in case of earthquakes with origin outside of RIMES AOR, only for magnitudes ≥ 8.0. RIMES shall also issue to its Member States, earthquake bulletins for inland earthquakes of magnitude ≥ 6.5 with origin within RIMES AOR. Annex 2 provides sample bulletins.

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\(^1\) Outside of RIMES AOR but have potential of affecting RIMES Member States
Bulletin format:

- Notification messages are issued in text format
- Bulletins are issued in text, PDF, and html formats
- Graphic maps are posted in jpg format on website
- Spatial data is made available in txt format through password protected website

4. RIMES DSS and Bulletin Content

RIMES developed a Decision Support System (DSS), incorporating capabilities of handling earthquake information and sea-level data, and generating and disseminating bulletins. Figure 11 shows the primary interface of the DSS.

![Figure 11: RIMES DSS to generate and disseminate tsunami information bulletins](image)

The DSS is integrated in the RIMES seismic and tsunami servers, and operates in real time along with these servers. The DSS has all the features to generate and disseminate:

a) GTS Bulletin Notification Messages

Prior to sending tsunami bulletins, RIMES will issue GTS Bulletin Notification messages (Figure 12) to all Indian Ocean States. GTS message format is completely compliant with IOC/IOTWS notification format. Please refer to Annex 2 for the detailed GTS bulletin notification format.
b) RIMES Tsunami Bulletin 1: Initial Earthquake Bulletin

This bulletin will be issued as first tsunami information bulletin from RIMES. This bulletin will contain only information about the earthquake and an initial quick evaluation of the tsunamigenic potential of the earthquake, based on earthquake source parameters (Figure 13). For detailed bulletin format, refer to Annex 2.

Figure 13: Structure of RIMES BULLETIN 1 messages

| HEADER SECTION: This section will mainly contain information regarding Bulletin Number, RIMES RTSP, Issue Time and Date |
| INFORMATION SECTION: This section will mainly contain earthquake information, an initial quick evaluation of the tsunamigenic potential of the earthquake, and additional advice to NTWCs for identifying location and website links for obtaining detailed bulletins and other spatial data for the bulletin |
| FOOTER SECTION: This section will include RIMES contact information |

| HEADER SECTION: This section will mainly contain information on Notification Message Number, RIMES RTSP, Issue Time and Date |
| INFORMATION SECTION: This section will mainly contain earthquake information and additional advice to NTWCs for identifying location and website links for getting detailed bulletins and other spatial data for the bulletin |
| FOOTER SECTION: This section will include RIMES contact information |

Figure 12: Structure of RIMES GTS notification messages

c) RIMES Tsunami Bulletin 2: Tsunami Information Bulletin

Two categories of bulletin type 2 may be generated by RIMES DSS, based on results of pre-run tsunami model scenarios, using earthquake information:

i. NO THREAT BULLETIN
ii. POTENTIAL THREAT BULLETIN

The Potential Threat Bulletin will contain tsunami wave arrival time, wave amplitude, and threat level for all forecast zones with estimated wave height exceeding 0.5m. Subsequent bulletins will be generated as earthquake source parameters and model scenarios are revised. These bulletins will be generated as <TSUNAMI BULLETIN NUMBER 2> <SUPPLEMENTARY BULLETIN: X> where X may be A/B/C/D and so on, as need arises. For detailed format refer to Annex 2.
d) RIMES Tsunami Bulletin 3: Confirmed Threat with Observations

This Bulletin contains updated tsunami forecast information, based on actual observation of sea level at coastal tide gauges and DART buoys, and sea level inversion. Bulletin will contain tsunami wave arrival time, wave amplitude, and threat level for all forecast zones with estimated wave height exceeding 0.5m (Figure 15). One category of bulletin type 3 will be generated by RIMES DSS:

i. CONFIRMED THREAT with SEA-LEVEL OBSERVATIONS

Several TSUNAMI BULLETIN 3 might be generated, as need arises. These subsequent bulletins will be generated as earthquake source parameters and model scenarios are revised. These bulletins will be generated as <TSUNAMI BULLETIN NUMBER: 3> <SUPPLEMENTARY BULLETIN: X> where X may be A/B/C/D and so on, as need arises. For detailed format, refer to Annex 2.

e) RIMES Tsunami Bulletin 4: Final Bulletin

This bulletin (Figure 16) will be the final information on tsunami threat, based on two criteria:

i. No significant tsunami was generated from reading of sea level gauges
ii. 2 hours after the forecasted arrival time of the last significant wave
This will be the final bulletin generated by RIMES after the THREAT IS OVER for all the forecast zones put under threat. For detailed format, refer to Annex 2.

ANNEX 2

HEADER SECTION: This section will mainly contain information regarding Bulletin Number, RIMES RTSP, Issue Time and Date

INFORMATION SECTION: Final tsunami bulletin with advice to all NTWCs within the region to cancel warnings

FOOTER SECTION: This section will include contact information of RTSP RIMES

Figure 16: Structure of RIMES BULLETIN 4 messages

Annex 3 provides details on the development of the Decision Support System.

5. Access to RIMES RTSP Products

RIMES provides the following Service Level 2 products:

a. Restricted NTWC products

Earthquake information and tsunami forecast from numerical model runs, of high spatial resolution, will be provided to NTWCs through various dissemination methods, including through the RIMES website (Figure 17), accessible with user name and password:

URL: http://www.rimes.int/earthquake/tsunami-bulletin
User Name: tsunami
Password: rimes.int

Figure 17: Login to RIMES Earthquake and Tsunami Information page
Figures 18-21 show RIMES Bulletins available on the RIMES website.

b. Public products

Earthquake information, potential of tsunami generation, sea level monitoring reports, and NTWC warning status (referred to NTWC contacts) will be posted to the public, except tsunami forecast information.
Figure 20: Threat Map

Figure 21: Information Bulletin
6. Dissemination Methods

- Notification messages will be sent to NTWCs through GTS and fax
- Text bulletin will be sent to NTWCs through GTS, fax, email, and password-protected RIMES website
- Graphical products, including Directivity Map, Travel Time Map, Threat Map, are posted on RIMES website, with username and password provided to NTWCs
- Spatial data will be exchanged through password-protected website.

RIMES notification messages distributed through the GTS shall have the header **WEIO29 VRMM**.

7. Manpower

For 24/7 operation, the RIMES regional facility is manned by operational watch standers on three working shifts per day, with a minimum of two personnel per shift on duty. Seven watch standers are from RIMES core scientists, including seismologist, seismic risk evaluation and mitigation scientist, coastal hydrodynamics scientist, system analysts, telecommunications specialist, and GIS specialist. The rest are from secondment from RIMES Member States (Table 5). This secondment arrangement aims at building Member States’ scientific and technological capacities through technology transfer, sharing of experience, and on-the-job training.

Table 5: List of secondments to RIMES (Earthquake monitoring and tsunami watch)

<table>
<thead>
<tr>
<th>Organization/Country</th>
<th>Start date</th>
<th>End date</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMH, Myanmar (K.K. Lin)</td>
<td>30 Oct 08</td>
<td>29 Sep 09</td>
</tr>
<tr>
<td>DMH, Lao PDR (S. Sittiphong)</td>
<td>20 Jul 09</td>
<td>19 Apr 10</td>
</tr>
<tr>
<td>NAMRIA, Philippines (N. Baloran)</td>
<td>1 Aug 09</td>
<td>1 Feb 10</td>
</tr>
<tr>
<td>IGP, Vietnam (D.Q. Van)</td>
<td>3 Aug 09</td>
<td>1 Feb 10</td>
</tr>
<tr>
<td>MMS, Maldives (A. Muslim)</td>
<td>1 Nov 09</td>
<td>31 Jan 10</td>
</tr>
<tr>
<td>IGP, Vietnam (N.T. Hung)</td>
<td>1 Apr 10</td>
<td>30 Sep 10</td>
</tr>
<tr>
<td>NAMRIA, Philippines (V.A. Medina)</td>
<td>15 Mar 10</td>
<td>14 Sep 10</td>
</tr>
<tr>
<td>RIMSI, Vietnam (N.X. Dao)</td>
<td>1 Apr 10</td>
<td>31 Aug 10</td>
</tr>
<tr>
<td>DMH, Myanmar (T.L. Kyaw)</td>
<td>1 Apr 10</td>
<td>30 Sep 10</td>
</tr>
<tr>
<td>RIMSI, Vietnam (D.D. Toan)</td>
<td>15 Sep 10</td>
<td>14 Sep 11</td>
</tr>
<tr>
<td>NAMRIA, Philippines (A. Amolo)</td>
<td>7 Oct 10</td>
<td>8 Apr 11</td>
</tr>
<tr>
<td>IGP, Vietnam (P.T. Truyen)</td>
<td>15 Oct 10</td>
<td>6 May 11</td>
</tr>
<tr>
<td>NAMRIA, Philippines (M. de Chavez)</td>
<td>15 May 11</td>
<td>20 Nov 11</td>
</tr>
<tr>
<td>DMH, Lao PDR (B. Phetphouthongdy)</td>
<td>3 May 11</td>
<td>2 May 12</td>
</tr>
<tr>
<td>IGP, Vietnam (B.T. Nhung)</td>
<td>1 June 11</td>
<td>30 Nov 11</td>
</tr>
<tr>
<td>GSMB, Sri Lanka (N. Thaldena)</td>
<td>1 June 11</td>
<td>30 Nov 11</td>
</tr>
</tbody>
</table>

16
8. RIMES Service on Tsunami Hazard and Risk Assessment

Risk assessment is an important process to assess and comprehend tsunami hazard and its effects on communities. Tsunami risk information can be utilized to raise public awareness and to develop preparedness plans and response capacity of communities in times of emergency, which is the ultimate goal of an end-to-end early warning system.

8.1 Tsunami hazard and risk assessment tool

To simplify and standardize the analytical process, while recognizing various skill levels of users in conducting tsunami hazard, vulnerability and risk assessment, RIMES developed INSPIRE for tsunami inundation and risk evaluation. INSPIRE is a web portal which provides modules for specifying tsunami sources, performing tsunami propagation and inundation, specifying exposure data, and performing risk assessment (Figure 22). INSPIRE, including its user manual, may be accessed through http://inspire.rimes.int/

![INSPIRE interface and outputs](image)

RIMES developed INSPIRE to simplify and standardize the analytical process, while recognizing various skill levels of users in conducting tsunami hazard, vulnerability, and risk assessments. The analysis modules are designed to be capable of handling multi-dimensional vulnerability data and different levels of data accuracy, reflecting the fact that data available from countries may range from low to high levels of accuracy. The system application has performed tsunami hazard and risk evaluations of pilot coastal sites in some countries in the Indian Ocean and South China Sea. RIMES provides INSPIRE services during non-emergency, for generating hazard and risk information (Figure 23) to support preparedness and planning activities in the countries.
8.2 Tsunami hazard and risk assessment program

In addition to hazard monitoring and providing warning services, RIMES is engaged in developing and implementing programs, in collaboration with member and collaborating states, to make use of scientific knowledge/technical information and new/emerging technologies for tsunami risk assessment and mitigation. Low-cost near-shore bathymetric and topographic survey and data generation methodologies and tsunami hazard and risk assessments were demonstrated in selected sites (Table 6). Technical workshops have been organized in pilot countries to transfer tools and analytical methodologies.

Table 6: List of countries involved in RIMES tsunami hazard and risk assessment program

<table>
<thead>
<tr>
<th>Country</th>
<th>Data generation</th>
<th>Tsunami hazard assessment</th>
<th>Tsunami risk assessment</th>
<th>Technology transfer (country workshop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indian Ocean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bangladesh</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Comoros</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maldives</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sri Lanka</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thailand</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South China Sea</td>
<td></td>
<td></td>
<td></td>
<td>Planned in Aug 11</td>
</tr>
<tr>
<td>Philippines</td>
<td></td>
<td></td>
<td></td>
<td>Planned in Aug 11</td>
</tr>
<tr>
<td>Vietnam</td>
<td></td>
<td></td>
<td></td>
<td>Planned in Aug 11</td>
</tr>
</tbody>
</table>

Countries involved in tsunami hazard and risk assessment program

10. RIMES Contact Details

Regional Integrated Multi-Hazard Early Warning System
Earthquake Monitoring and Tsunami Watch Provision

1st Fl. Outreach Bldg., Asian Institute of Technology Campus
58 Moo 9 Paholyothin Road, Klong Nung
(PO. Box4) Klong Luang, Pathumthani 12120, Thailand

Tel.: +662 516 5905 - 07
Fax: +662 516 5908 - 09
Email: tsunami@rimes.int
Website: http://www.rimes.int/earthquake
Annex 1
Enhancement of PRECISE Tsunami Database and Web-Based Interface for Indian Ocean Tsunami Forecast
(ver. May 2011)

1. Background

The Portal for Regional Estimation of Coastal tsunami Impacts using Sea-level and Earthquake information (PRECISE) was enhanced, for its products to conform with the standards of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) for Regional Tsunami Service Providers (RTSPs). The enhancement also enabled the development of additional pre-computed tsunami waveform database. This report presents the process and the products from the database development and program development for generating tsunami bulletin and tsunami threat map.

The process for enhancing PRECISE is summarized below:

1. Generation of pre-computed tsunami waveform database according to ICG/IOTWS standard and specification
2. Modification of PRECISE program for generating table for tsunami bulletin
3. Development of program for generating tsunami threat map

Outputs include:

1. Pre-computed tsunami waveform database according to ICG/IOTWS requirements for RTSPs
2. Data for tsunami threat map and summary table for tsunami bulletin

2. Tsunami Waveform Database

The pre-computed tsunami waveform database was generated using the TUNAMI F1 model, run for the domain shown in Figure A1-1, and using ETOPO2 of 2 arc-minute resolution as bathymetry data and unit source scenarios from Sumatra and Makran subduction zones (Figures A1-2 and A1-3).

Figure A1-1: Domain of computation
Figure A1-2: Unit sources on the Sumatra subduction zone

Figure A1-3: Unit sources on the Makran subduction zone
3. Forecast Points and Zones

As prescribed by ICG/IOTWS, 1,656 forecast points in the Indian Ocean (Figure A1-4) and 564 forecast zones along Indian Ocean coasts (Figure A1-5) were used in the database development.

Figure A1-4: ICG/IOTWS forecast points

Figure A1-5: ICG/IOTWS forecast zones
4. Tsunami Bulletin and Threat Map

The Indian Ocean (IOC) Standard Bulletin Builder was developed using FORTRAN language for generating the table of tsunami forecast bulletin and tsunami threat map, according to ICG/IOTWS standards. Figure A1-6 shows the scheme of the IOC Standard Bulletin Builder.

![Scheme of the IOC Standard Bulletin Builder](image)

Figure A1-6: Scheme of the IOC Standard Bulletin Builder

4.1 Inputs

Inputs to the IOC Standard Bulletin Builder consist of 2 main parts – the tsunami waveform database and parameter settings:

a) *Tsunami Waveform Database* contains the time history of each forecast point
b) *Slip Distribution* from the Earthquake Monitoring server, which shall be superimposed to obtain the tsunami waveform forecast
c) *Significant Wave*, the minimum tsunami height for calculating the table of tsunami bulletins. Generally, the significant wave is set at 0.50 meters.
d) *Detective Wave*, the minimum tsunami height for arrival time detection. Generally, the detective value is set at 0.02 meters.

4.2 Main Program

The Bulletin Builder was developed using FORTRAN language, with Intel Fortran Complier, which calculates tsunami waveform forecast by superposition technique, and generates the table of bulletins and tsunami threat map.
4.3 Products

Products of the IOC Standard Bulletin Builder include:

- **Tsunami waveform forecast**, which contains combined responses at all forecast points
- **Tsunami bulletin at offshore forecast points**, with sample provided in Table A1-1
- **Tsunami bulletin at coastal forecast zones**, with sample provided in Table A1-2
- **Threat map data**, with sample provided in Figure A1-7

Table A1-1: Sample tsunami bulletin at offshore forecast points

<table>
<thead>
<tr>
<th>Code</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>Max. Beach</th>
<th>Max. Deep</th>
<th>Depth</th>
<th>Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFP664</td>
<td>667.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>0</td>
</tr>
<tr>
<td>CFP1359</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>183</td>
<td>0</td>
</tr>
<tr>
<td>CFP1743</td>
<td>735.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>81</td>
<td>0</td>
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<tr>
<td>CFP1068</td>
<td>66.4</td>
<td>138</td>
<td>229.3</td>
<td>971.4</td>
<td>1.82</td>
<td>0.8</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>CFP1484</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>CFP1443</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td>CFP505</td>
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<td>35</td>
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<td>33</td>
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<tr>
<td>CFP735</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>33</td>
<td>0</td>
</tr>
</tbody>
</table>

Notes:
- **T1**: Time of arrival of 2 cm wave in minutes
- **T2**: Time of first exceedance of Threat Threshold of 0.5 m in minutes
- **T3**: Time of arrival of wave with maximum amplitude in minutes
- **T4**: Time of last exceedance of Threat Threshold in minutes
- **Max. Beach**: Maximum wave amplitude at shoreline from Green's function in meter
- **Max. Deep**: Maximum wave amplitude in deep water in meter
- **Depth**: Depth of offshore forecast point in meters
- **Threat level**: 1=Threat, 0=No threat

Values of the forecast zones were derived from the most conservative values of the forecasted points in each zone.

Table A1-2: Sample tsunami bulletin at coastal forecast zones

<table>
<thead>
<tr>
<th>Zone</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
<th>Max. Beach</th>
<th>Max. Deep</th>
<th>Depth</th>
<th>Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>129</td>
<td>152.7</td>
<td>189.2</td>
<td>291.5</td>
<td>1074.5</td>
<td>1.88</td>
<td>0.79</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>130</td>
<td>151.1</td>
<td>156.9</td>
<td>161.8</td>
<td>1069.6</td>
<td>2.79</td>
<td>1.18</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>131</td>
<td>129.9</td>
<td>134.4</td>
<td>695.3</td>
<td>1080</td>
<td>2.54</td>
<td>1.19</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>132</td>
<td>128.9</td>
<td>131.8</td>
<td>156.6</td>
<td>1074.7</td>
<td>8.26</td>
<td>3.54</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>133</td>
<td>186.6</td>
<td>233.8</td>
<td>1050.8</td>
<td>1070.3</td>
<td>2.12</td>
<td>0.87</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>134</td>
<td>241.9</td>
<td>593.2</td>
<td>921.8</td>
<td>923.2</td>
<td>1.35</td>
<td>0.63</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>434</td>
<td>129.3</td>
<td>535.2</td>
<td>571.1</td>
<td>926.5</td>
<td>1.68</td>
<td>0.83</td>
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<td>1</td>
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<tr>
<td>436</td>
<td>119.5</td>
<td>678.6</td>
<td>923.4</td>
<td>1018.4</td>
<td>1.43</td>
<td>0.67</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>457</td>
<td>94.0</td>
<td>227.8</td>
<td>228.4</td>
<td>229.2</td>
<td>1.22</td>
<td>0.54</td>
<td>2.5</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes:
- **T1**: Time of arrival of 2 cm wave in minutes
- **T2**: Time of first exceedance of Threat Threshold of 0.5 m in minutes
- **T3**: Time of arrival of wave with maximum amplitude in minutes
- **T4**: Time of last exceedance of Threat Threshold in minutes
- **Max. Beach**: Maximum wave amplitude at shoreline from Green's function in meter
- **Max. Deep**: Maximum wave amplitude in deep water in meter
- **Depth**: Depth of offshore forecast point in meters
- **Threat level**: 1=Threat, 0=No threat

Values of the forecast zones were derived from the most conservative values of the forecasted points in each zone.
Figure A1-7: Tsunami threat map (red is threat, green is no threat)

5. Web Portal for PRECISE

5.1 Software Landscape and its Components

PRECISE consists of multiple tools and various system development techniques for building the forecasting system and ensuring interoperability. All of the components are built from open-source software that runs on Linux-like system, such as Fedora, CentOS, Redhat or UNIX family platform, for compatibility and stability. A combination of scripting and compiled languages, such as PHP, LINUX SHELL and FORTRAN, was used. Furthermore, third-party software, such as ImageMagick and Open D Data Explorer, are included, with compatibility checked.

The front end of PRECISE uses an open-source framework for controlling webpage elements and handling events from end-user interaction with the system, via the web browser. Only Mozilla Firefox is used for browsing the PRECISE system with the selected JavaScript framework, JQuery. Cascading style sheet version 3 (CSS3), which works well with JQuery, was used for styling of the user interface.

For the back end, PHP was used for job management, simulation, and visualization, as well as job monitor, job submitter and job runner. The submitted job is compiled and executed for automatic superposition calculation and visualization. In parallel, when the job monitor detects some visualizable output, it transfers the job to the back end, for data visualization with OpenDX and data finalization and transformation with ImageMagick. Finally, the job monitor, written by JavaScript, fetches the necessary outputs and displays these on the webpage.

Submitted job is saved into the relational database management system, MySQL server, by the job submitter. Figure A1-8 shows the front end and back end interactions in PRECISE.
Figure A1-8: PRECISE system landscape
5.2 Visualization

The human-readable text output from the superposition process is visualized with Open Data Explorer as command line execution mode, and transformed to web accessible format, mostly PNG. Figure A1-9, details the visualization rendering by the job runner.

Figure A1-9: Data visualization

5.3 Relational Database and Flat-File Database

MySQL server, the world's most popular open source database (www.mysql.com), is used in PRECISE for collecting data in a structured tabular format, with functionality of searching, sorting, and indexing. PRECISE collects, from the database, data such as forecast points, earthquake events, simulation cases, tidal data, and other information. The resource file for calculation, called unit source database, is stored as a flat-file and indexed by runtime system.

Figure A1-10 shows the relational database and flat-file that are used by the back end in response to request from the front end such, as reporting of job progress, fetching job data, calculating the superposition process, and rendering the tidal wave.
6. System Modification

6.1 IOC-PRECISE Extension Requirements

IOC Calculation
A new map, called region, was calculated on superposition process, using super.txt that contain the slip distribution. This process is handled by the back end, with outputs collected from the job directory. The output is raw bulletin data containing the forecast points and zones, displayed on the web portal.

IOC Visualization
Data for rendering the threat map is then created. Visualization at the back end transforms the data into an image, and displayed on the web portal.

IOC Data Export
The data exporter exports the bulletin file format CSV (comma separated value) for interoperation with other systems.

6.2 Job Execution

The job execution program, located at apps/cli-job-runner.php (called the job runner), receives parameters from apps/cli-job-submitter.php (called the job submitter). For job submission, all parameters are submitted and created at the web front-end, such as slip distribution, earthquake ID, time export, and magnitude. The job runner is mainly used for executing all scripts of the job (Figure A1-11).

The job runner consists of some resource files that are used in a runtime (main directory is apps/IOC/super_pz/), such as BOX information file (forecast_pnts_H_BOX.txt), threshold of the height of the first wave file (threat.txt), height of significant wave file (threshold.txt), and location file of IOC’s zone (output_zone_z.txt). Calculation for the IOC threat map and normal superposition are simultaneously done, both for the main process and visualization. Job computation time is measured and written as a log file, text file. Speed of computation depends on the hardware and main memory. Output is produced and collected at the superposition result directory (db_superposition/<case-id>/ioc/).

The IOC package contains the following resource files:

- basemap.png is the visualized result of topography and bathymetry file of the region of interest
- forecast_pnts_H_BOX.txt is the human-readable text file which contains the group of forecast points around the base map
- export-kmz.php is the script file for generating the IOC threat map as a KMZ format; end-user can open with Google Earth to see the level of threat
- output_zone_z.txt is the file which contains the location of the forecast points around base map
- super_pz.txt is the slip distribution file
- super_pz_ioc_for is the FORTRAN source code for calculating and identifying IOC threat level on the base map
- threat.txt is the threshold of the height of significant wave
- threshold.txt is the wave significant value
- run-ioc.sh is the batch script for submitting the IOC job in the background

When the job is finished, the below files are produced for visualization and bulletin generation for other systems, or displayed as a webpage in the frontend:
- **BULLETIN1.OUT** is the text file for generating the bulletin that contains IOC forecast points.
- **BULLETIN2.OUT** is the text file for generating the bulletin that contains IOC forecast zones.
- **THREATMAP.OUT** is the text file for visualizing the IOC threat map as an image for the web or other system.

---

Figure A1-11: The job runner at the back end
6.3 Visualization

This section presents the main program of the job runner and the visualization mechanism until the IOC threat map is produced (Figure A1-12).

![Data Visualization in PRECISE](image)

When the resource files for simulation are generated, visualization is initialized for each time section, and data is passed through the Open Data Explorer as a network of module file (.net), configuration file (.cfg), and description of the input file (.general). Results of computation are placed in the web front-end, and may be accessed by an authenticated user. The visualization results page (Figure A1-13) has 4 main sub-menus:

a) SCS is the bulletin for South China Sea (SCS) region  
b) IOC Points are the forecast points in the IOC base map  
c) IOC Zones are the forecast zones in the IOC base map  
d) Threat Map is the visualized threat map that (Figure A1-16) contains the threat level for each zone around the base map

**Full Screen** is the menu that allows the user to open a new window for the best view (figure A1-17).

The user can export the bulletin as a CSV/Excel format (Figures A1-14 and A1-15). For this modification, support menus have been added at the bottom of the results page. The functionality of these menus is described below:

- **Download the result** is downloadable URL of the compressed job package  
- **Download IOC-KMZ** is downloadable file in KMZ format that opens with Google Earth to view the threat map  
- **Go to result directory** is navigator URL that allows the end-user to go to the job directory
Figure A1-13: Sample visualization results page

Figure A1-14: Sample Indian Ocean forecast point results page, downloadable as CSV file.
Figure A1-15: Sample Indian Ocean forecast zone results page, downloadable as CSV file

Figure A1-16: Sample Indian Ocean threat map
Figure A1-17: Output panel in full screen mode

6.4 System Feed and Export Data

For interoperation between other systems and PRECISE, an accessible URL allows a remote host to fetch the latest table of bulletins as a CSV format and standard RSS feed format. The address http://<hostname>/export/bulletin/ provides the bulletin for the South China Sea, while the address http://<hostname>/export/bulletin/index-ioc.php provides the bulletin for the Indian Ocean, with some query string.

The following parameters are contained in the query string for the Indian Ocean bulletin:

- refer_id is the case number (job identification number)
- threat_level with possible values as 1, 0, and ALL for reading the Indian Ocean forecast zones or points

For RSS feed format, the end-user can subscribe to the simulation case in PRECISE via http://<hostname>/export/ Figure A1-18 shows a sample result from PRECISE subscription with Google Reader.
Figure A1-18: RSS feed reader containing IOC feed extension on PRECISE
Annex 2
RIMES Notifications and Bulletins

A. NOTIFICATIONS

1. GTS Bulletin Notification Message

WEIO29 VRMM 150605

TSUNAMI BULLETIN NOTIFICATION MESSAGE NUMBER 1
REGIONAL TSUNAMI SERVICE PROVIDER - RTSP RIMES
ISSUED AT 0605 UTC WEDNESDAY 15 JUNE 2011

TO:   ALL INDIAN OCEAN NATIONAL TSUNAMI WARNING CENTRES (NTWCs)
FROM: RTSP RIMES

NOTIFICATION:
RTSP RIMES HAS JUST ISSUED TSUNAMI BULLETIN NUMBER 1 FOR THE INDIAN OCEAN, BASED ON THE FOLLOWING EARTHQUAKE EVENT:

MAGNITUDE:   9.0 MWP
DEPTH:       10 KM
DATE:        15 JUNE 2011
ORIGIN TIME: 0600 UTC
LATITUDE:    7.20N
LONGITUDE:   92.90E
LOCATION:    NICOBAR ISLAND, INDIA

TO VIEW THE BULLETIN GO TO RTSP RIMES WEBSITE AT:

http://www.rimes.int/earthquake/tsunami-bulletin

NOTE: THIS IS A RESTRICTED-ACCESS WEBSITE CONTAINING TECHNICAL DATA FOR NATIONAL TSUNAMI WARNING CENTRES ONLY. IT IS NOT FOR GENERAL PUBLIC ACCESS.

GENERAL PUBLIC INFORMATION FOR THIS EVENT IS AVAILABLE FROM:

REGIONAL INTEGRATED MULTIHAZARD EARLY WARNING SYSTEM (RIMES)
OUTREACH BUILDING, AIT CAMPUS, PATHUMTHANI, THAILAND
PHONE: +662-516-5905 to 07
FAX: +662-516-5908 to 09
EMAIL: TSUNAMI@RIMES.INT
WEB: WWW.RIMES.INT

END OF NOTIFICATION MESSAGE

---------------------------------------------------------------------
2. Fax Bulletin Notification Message

TSUNAMI BULLETIN NOTIFICATION MESSAGE NUMBER 1
REGIONAL TSUNAMI SERVICE PROVIDER - RTSP RIMES
ISSUED AT 0605 UTC WEDNESDAY 15 JUNE 2011

TO: INDIAN OCEAN NATIONAL TSUNAMI WARNING CENTRES (NTWCs)
FROM: RTSP RIMES

NOTIFICATION:
RTSP RIMES HAS JUST ISSUED TSUNAMI BULLETIN NUMBER 1 FOR THE INDIAN OCEAN, BASED ON THE FOLLOWING EARTHQUAKE EVENT:

MAGNITUDE: 9.0 MWP
DEPTH: 10 KM
DATE: 15 JUNE 2011
ORIGIN TIME: 0600 UTC
LATITUDE: 7.20N
LONGITUDE: 92.90E
LOCATION: NICOBAR ISLAND, INDIA

TO VIEW THE BULLETIN GO TO RTSP RIMES WEBSITE AT:

http://www.rimes.int/earthquake/tsunami-bulletin

NOTE: THIS IS A RESTRICTED-ACCESS WEBSITE CONTAINING TECHNICAL DATA FOR NATIONAL TSUNAMI WARNING CENTRES ONLY. IT IS NOT FOR GENERAL PUBLIC ACCESS.

GENERAL PUBLIC INFORMATION FOR THIS EVENT IS AVAILABLE FROM:

REGIONAL INTEGRATED MULTIHAZARD EARLY WARNING SYSTEM (RIMES)
OUTREACH BUILDING, AIT CAMPUS, PATHUMTHANI, THAILAND
PHONE: +662-516-5905 to 07
FAX: +662-516-5908 to 09
EMAIL: TSUNAMI@RIMES.INT
WEB: WWW.RIMES.INT

END OF NOTIFICATION MESSAGE
B. BULLETINS

1. Bulletin Type 1 Earthquake Information

RTSP-RIMES-20110615-0605-001

TSUNAMI BULLETIN NUMBER 1
REGIONAL TSUNAMI SERVICE PROVIDER – RTSP RIMES
issued at 0605 UTC Wednesday 15 JUNE 2011

--- . . . . EARTHQUAKE INFORMATION BULLETIN . . .

1. EARTHQUAKE INFORMATION
RTSP RIMES has detected an earthquake with the following preliminary information:

   Magnitude: 9.0 Mwp
   Depth: 10 km
   Date: 15 Jun 2011
   Origin Time: 0600 UTC
   Latitude: 7.20N
   Longitude: 92.90E
   Location: Nicobar Island, India

2. EVALUATION
RTSP RIMES is evaluating this earthquake to determine if a tsunami has been generated.

Further information on this event will be available at:
http://www.rimes.int/earthquake/tsunami-bulletin

3. ADVICE
This bulletin is being issued as advice. Only national/state/local authorities and disaster
management officers have the authority to make decisions regarding the official threat and
warning status in their coastal areas and any action to be taken in response.

4. UPDATES
Additional bulletins will be issued by RTSP RIMES for this event as more information becomes
available.

Other RTSPs may issue additional information at:
RTSP INDIA: http://www.tsunami.incois.gov.in/ITEWS
RTSP INDONESIA: http://rtsp.bmkg.gov.id

In case of conflicting information from RTSPs or the IAS (PTWC, JMA), the more conservative
information should be used for safety.

5. CONTACT INFORMATION
REGIONAL INTEGRATED MULTI-HAZARD EARLY WARNING SYSTEM (RIMES)
Address: Outreach Building, AIT Campus, Pathumthani 12120 Thailand
Tel.: +662-516-5905 to 07
Fax: +662-516-5908 to 09
Email: tsunami@rimes.int
Website: www.rimes.int

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END OF BULLETIN

-----------------------------------------------
2. Tsunami Bulletin Type 2 No Threat

RTSP—RIMES—20110615—0605—002

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TSUNAMI BULLETIN NUMBER 2
REGIONAL TSUNAMI SERVICE PROVIDER — RTSP RIMES
issued at 0615 UTC Wednesday 15 JUNE 2011

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... NO TSUNAMI THREAT IN THE INDIAN OCEAN ... 

1. EARTHQUAKE INFORMATION
RTSP RIMES has detected an earthquake with the following details:

Magnitude: 9.0 Mwp
Depth: 10 km
Date: 15 Jun 2011
Origin Time: 0600 UTC
Latitude: 7.20N
Longitude: 92.90E
Location: Nicobar Island, India

2. EVALUATION
Based on pre-run model scenarios, there is NO THREAT to countries in the Indian Ocean.

3. ADVICE
This bulletin is being issued as advice. Only national/ state/ local authorities and disaster management officer have the authority to make decisions regarding the official threat and warning status in their coastal areas and any action to be taken in response.

4. UPDATES
No further bulletins will be issued by RTSP RIMES for this event unless other information becomes available.

Other RTSPs may issue additional information at:
RTSP INDIA: http://www.tsunami.incois.gov.in/ITEWS
RTSP INDONESIA: http://rtsp.bmkg.gov.id

In case of conflicting information from RTSPs or the IAS (PTWC, JMA), the more conservative information should be used for safety.

6. CONTACT INFORMATION
REGIONAL INTEGRATED MULTI-HAZARD EARLY WARNING SYSTEM (RIMES)
Address: Outreach Building, AIT Campus, Pathumthani 12120 Thailand
Tel.: +662-516-5905 to 07
Fax: +662)-516-5908 to 09
Email: tsunami@rimes.int
Website: www.rimes.int

END OF BULLETIN

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3. Tsunami Bulletin Type 2 Potential Threat

RTSP-RIMES-20110615-0605-002

TSUNAMI BULLETIN NUMBER 2
REGIONAL TSUNAMI SERVICE PROVIDER - RTSP RIMES
issued at 0615 UTC Wednesday 15 JUNE 2011

... POTENTIAL TSUNAMI THREAT IN THE INDIAN OCEAN ...

1. EARTHQUAKE INFORMATION
RTSP RIMES has detected an earthquake with the following details:

Magnitude: 9.0 Mwp
Depth: 10 km
Date: 15 Jun 2011
Origin Time: 0600 UTC
Latitude: 7.20N
Longitude: 92.90E
Location: Nicobar Island, India

2. EVALUATION
Earthquakes of this size are capable of generating tsunamis. However, so far, there is no confirmation about the triggering of a tsunami.

An investigation is under way to determine if a tsunami has been triggered. This RTSP will monitor sea level gauges and report if any tsunami wave activity has occurred.

Based on pre-run model scenarios, the zones listed below are POTENTIALLY UNDER THREAT.

3. TSUNAMI THREAT FOR THE INDIAN OCEAN
The list below shows the forecast arrival time of the first wave estimated to exceed 0.5m amplitude at the beach in each zone, and the amplitude of the maximum wave predicted for the zone. Zones where the estimated wave amplitudes are less than 0.5m at the beach are not shown.

The list is grouped by country (alphabetic order) and ordered according to the earliest estimated times of arrival at the beach.

Please be aware that actual wave arrival times may differ from those below, and the initial wave may not be the largest. A tsunami is a series of waves, and the time between successive waves can be five minutes to one hour.

The threat is deemed to have passed two hours after the forecast time for last exceedance of the 0.5m threat threshold for a zone. As local conditions can cause a wide variation on tsunami wave action, CANCELLATION of national warnings and ALL CLEAR determination must be made by national/ state/ local authorities.

AUSTRALIA
CHRISTMAS ISLAND  1012Z  15 Jun 2011  1.57m Threat

BANGLADESH
COXS BAZAR 0852Z 15 Jun 2011 2.42m Threat
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**INDONESIA**

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SUMBAR PASAMAN–BARAT 0708Z 15 Jun 2011 1.34m Threat
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SUMUT NIAS T 0716Z 15 Jun 2011 3.20m Threat
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KOLUFURI 0923Z 15 Jun 2011 2.75m Threat

MAURITIUS
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CARGADOS CARAJOS 1150Z 15 Jun 2011 1.49m Threat
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<tr>
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<td>0731Z</td>
<td>15 Jun 2011</td>
<td>11.81m</td>
<td>Threat</td>
</tr>
<tr>
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<tr>
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<tr>
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<td>15 Jun 2011</td>
<td>2.53m</td>
<td>Threat</td>
</tr>
</tbody>
</table>
4. ADVISE
This bulletin is being issued as advice. Only national/ state/ local authorities and
disaster management officers have the authority to make decisions regarding the official
threat and warning status in their coastal areas and any action to be taken in response.

5. UPDATES
Additional bulletins will be issued by RTSP RIMES for this event as more information becomes
available.

Other RTSPs may issue additional information at:
RTSP INDIA: http://www.tsunami.incois.gov.in/ITEWS
RTSP INDONESIA: http://rtsp.bmkg.gov.id

In case of conflicting information from RTSPs or the IAS (PTWC, JMA), the more conservative
information should be used for safety.

6. CONTACT INFORMATION
REGIONAL INTEGRATED MULTI–HAZARD EARLY WARNING SYSTEM (RIMES)
Address: Outreach Building, AIT Campus, Pathumthani 12120 Thailand
Tel.: +662-516-5905 to 07
Fax: +662)-516-5908 to 09
Email: tsunami@rimes.int
Website: www.rimes.int

END OF BULLETIN

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4. Tsunami Bulletin Type 3 Confirmed Threat with Observations

RTSP-RIMES-20110615-0605-003

TSUNAMI BULLETIN NUMBER 3
REGIONAL TSUNAMI SERVICE PROVIDER - RTSP RIMES
issued at 0745 UTC Wednesday 15 JUNE 2011

... CONFIRMED TSUNAMI THREAT IN THE INDIAN OCEAN ...

1. EARTHQUAKE INFORMATION
RTSP RIMES has detected an earthquake with the following details:

Magnitude: 9.0 Mwp
Depth: 10 km
Date: 15 Jun 2011
Origin Time: 0600 UTC
Latitude: 7.20N
Longitude: 92.90E
Location: Nicobar Island, India

2. EVALUATION
Sea level observations have confirmed that a TSUNAMI WAS GENERATED. Maximum wave amplitudes observed so far:

<table>
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<th>TIME</th>
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<tr>
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<td>95.33E</td>
<td>0625Z</td>
<td>15 Jun 2011</td>
<td>5.4m</td>
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<td>96.22E</td>
<td>0633Z</td>
<td>15 Jun 2011</td>
<td>5.2m</td>
</tr>
<tr>
<td>Telukdakam (Indonesia)</td>
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<td>97.82E</td>
<td>0642Z</td>
<td>15 Jun 2011</td>
<td>2.9m</td>
</tr>
<tr>
<td>Kirinda (Sri Lanka)</td>
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<td>81.32E</td>
<td>0648Z</td>
<td>15 Jun 2011</td>
<td>8.4m</td>
</tr>
<tr>
<td>Koh Tapho Noi (Thailand)</td>
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<td>92.98E</td>
<td>0655Z</td>
<td>15 Jun 2011</td>
<td>4.1m</td>
</tr>
<tr>
<td>Triconmalee (Sri Lanka)</td>
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<tr>
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<tr>
<td>Gan (Maldives)</td>
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<td>73.15E</td>
<td>0725Z</td>
<td>15 Jun 2011</td>
<td>5.2m</td>
</tr>
<tr>
<td>Langwai (Maldives)</td>
<td>6.42N</td>
<td>99.77E</td>
<td>0725Z</td>
<td>15 Jun 2011</td>
<td>3.1m</td>
</tr>
<tr>
<td>Male (Maldives)</td>
<td>4.19N</td>
<td>73.53E</td>
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<tr>
<td>Rodrigues (Mauritius)</td>
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<tr>
<td>Diego Garcia (British Indian Ocean)</td>
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<td>72.43E</td>
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</table>

Based on pre-run model scenarios, the zones listed below are POTENTIALLY UNDER THREAT.

3. TSUNAMI THREAT FOR THE INDIAN OCEAN
The list below shows the forecast arrival time of the first wave estimated to exceed 0.5m amplitude at the beach in each zone, and the amplitude of the maximum beach wave predicted for the zone. Zones where the estimates wave amplitudes are less than 0.5m at the beach are not shown.

The list is grouped by country (alphanumerical order) and ordered according to the earliest estimated times of arrival at the beach.
Please be aware that actual wave arrival times may differ from those below, and the initial wave may not be the largest. A tsunami is a series of waves, and the time between successive waves can be five minutes to one hour.

The threat is deemed to have passed two hours after the forecast time for last exceedance of the 0.5m threat threshold for a zone. As local conditions can cause a wide variation on tsunami wave action, CANCELLATION of national warnings and ALL CLEAR determination must be made by national/ state/ local authorities.

<table>
<thead>
<tr>
<th>Location</th>
<th>Time</th>
<th>Date</th>
<th>Threat</th>
<th>Type</th>
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<tr>
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<tr>
<td>CHRISTMAS ISLAND</td>
<td>1012Z</td>
<td>15 Jun 2011</td>
<td>1.57m</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Time</th>
<th>Date</th>
<th>Threat</th>
<th>Type</th>
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<tbody>
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<td>BANGLADESH</td>
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<td>1.40m</td>
<td>Threat</td>
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<tr>
<td>KUTUBDIA ISLAND</td>
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<td>1.61m</td>
<td>Threat</td>
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<tr>
<td>BARGUNA</td>
<td>0924Z</td>
<td>15 Jun 2011</td>
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</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Time</th>
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<th>Type</th>
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<table>
<thead>
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<th>Location</th>
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<th>Date</th>
<th>Threat</th>
<th>Type</th>
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KANYAKUMARI 0926Z 15 Jun 2011 3.53m Threat
ALLEPPEY ALAPPUZHA 0941Z 15 Jun 2011 1.25m Threat
COCHIN 1011Z 15 Jun 2011 1.33m Threat

INDONESIA
NAD KOTA-BANDA-ACEH 0626Z 15 Jun 2011 4.87m Threat
NAD NAGAN-RAYA 0628Z 15 Jun 2011 5.84m Threat
NAD ACEH-UTARA B 0630Z 15 Jun 2011 6.04m Threat
NAD KOTA-SABANG P. WEH 0631Z 15 Jun 2011 5.77m Threat
NAD ACEH-JAYA 0632Z 15 Jun 2011 7.00m Threat
NAD ACEH-TAMLANG 0637Z 15 Jun 2011 5.37m Threat
NAD ACEH-UTARA T 0638Z 15 Jun 2011 3.96m Threat
NAD BIREUEN 0641Z 15 Jun 2011 4.11m Threat
SUMBAR PESISIR-SELATAN S 0642Z 15 Jun 2011 6.85m Threat
SUMBAR PADANG-PARIAMAN S 0656Z 15 Jun 2011 6.04m Threat
NAD PIDIE 0656Z 15 Jun 2011 3.86m Threat
NAD ACEH-BESAR P. PENASI 0701Z 15 Jun 2011 3.54m Threat
SUMBAR AGAM 0702Z 15 Jun 2011 2.36m Threat
NAD KOTA-SABANG P. RONDO 0704Z 15 Jun 2011 5.03m Threat
SUMBAR PASAMAN-BARAT 0708Z 15 Jun 2011 1.34m Threat
NAD KOTA-LHOKSEUMAWE 0709Z 15 Jun 2011 3.21m Threat
NAD KOTA-LANGSA 0711Z 15 Jun 2011 6.30m Threat
SUMBAR PADANG-PARIAMAN U 0711Z 15 Jun 2011 3.90m Threat
NAD ACEH-BESAR P. BREUEH 0711Z 15 Jun 2011 2.91m Threat
SUMUT NIAS T 0716Z 15 Jun 2011 3.20m Threat
SUMBAR KOTA-PARIAMAN 0717Z 15 Jun 2011 2.61m Threat
SUMBAR KOTA-PADANG U 0720Z 15 Jun 2011 2.29m Threat
BENGKULU BENGKULU-UTARA U 0723Z 15 Jun 2011 2.44m Threat
NAD ACEH-BESAR B 0725Z 15 Jun 2011 2.70m Threat
SUMUT NIAS B 0728Z 15 Jun 2011 2.61m Threat
SUMUT MANDAILING-NATAL S 0733Z 15 Jun 2011 2.05m Threat
BENGKULU BENGKULU-UTARA S 0737Z 15 Jun 2011 1.51m Threat
SUMUT DELISERDANG 0738Z 15 Jun 2011 1.36m Threat
SUMUT LABUHANBATU 0739Z 15 Jun 2011 1.44m Threat
BENGKULU BENGKULU-UTARA P. ENGGANO 0746Z 15 Jun 2011 1.43m Threat
SUMUT MANDAILING-NATAL U 0802Z 15 Jun 2011 1.29m Threat
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SUMUT TAPANULI-SELATAN 0831Z 15 Jun 2011 1.67m Threat
NAD ACEH-TIMUR 0835Z 15 Jun 2011 1.73m Threat
NAD ACEH-BARAT 0835Z 15 Jun 2011 1.73m Threat
SUMUT TAPANULI-TENGAH S 0854Z 15 Jun 2011 1.34m Threat
SUMUT TAPANULI-TENGAH KEP. MURSALA 0900Z 15 Jun 2011 1.19m Threat
NAD ACEH-SELATAN S 0925Z 15 Jun 2011 1.59m Threat
NAD ACEH-SELATAN U 0940Z 15 Jun 2011 1.25m Threat
NAD ACEH-SINGKIL KEP. BANYAK 1006Z 15 Jun 2011 1.63m Threat
NAD ACEH-SINGKIL 1017Z 15 Jun 2011 1.44m Threat
NAD SIMEULUE P. SIMEULUE 1108Z 15 Jun 2011 1.45m Threat

MALAYSIA
PULAU LANGKAWI 0908Z 15 Jun 2011 2.92m Threat
SUNGI PETANI 0922Z 15 Jun 2011 2.01m Threat
BAGAN AYER ITAM 0957Z 15 Jun 2011 1.79m Threat
MALDIVES
MAMIGILI 0903Z 15 Jun 2011 6.47m Threat
FURADU 0903Z 15 Jun 2011 6.25m Threat
GAN 0905Z 15 Jun 2011 5.33m Threat
HITADDU 0906Z 15 Jun 2011 3.58m Threat
GOADU 0906Z 15 Jun 2011 4.87m Threat
MALE 0916Z 15 Jun 2011 3.64m Threat
DIYAGLI 0920Z 15 Jun 2011 2.38m Threat
KOLUFURI 0923Z 15 Jun 2011 2.75m Threat

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CARGADOS CARAJOS 1150Z 15 Jun 2011 1.49m Threat

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LITTLE COCO ISLAND 0711Z 15 Jun 2011 2.61m Threat
PREPARIS ISLAND 0720Z 15 Jun 2011 2.03m Threat
GREAT WESTERN TORRES ISLAND 0727Z 15 Jun 2011 2.60m Threat
LORD LOUGHBOROUGH ISLAND 0732Z 15 Jun 2011 3.39m Threat
THAN KYUN 0733Z 15 Jun 2011 3.44m Threat
BAILEY ISLAND 0735Z 15 Jun 2011 2.41m Threat
NATHAHU 0738Z 15 Jun 2011 1.74m Threat
TAZIN 0739Z 15 Jun 2011 2.38m Threat
CLARA ISLAND 0741Z 15 Jun 2011 3.07m Threat
DANI 0743Z 15 Jun 2011 1.79m Threat
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CHEDUBA ISLAND 0750Z 15 Jun 2011 2.40m Threat
MAWYEN 0752Z 15 Jun 2011 1.88m Threat
MAGYIGYAING 0753Z 15 Jun 2011 1.97m Threat
KYAUKPYU 0808Z 15 Jun 2011 1.86m Threat
TENASSERIM 0809Z 15 Jun 2011 1.55m Threat
SITTWE 0816Z 15 Jun 2011 1.82m Threat
THAWINCHAUNG 0821Z 15 Jun 2011 1.67m Threat
AUK BOK 0838Z 15 Jun 2011 2.68m Threat
PHARPON 0840Z 15 Jun 2011 1.98m Threat
YANGON–S 0842Z 15 Jun 2011 1.64m Threat
MALI KYUN 0854Z 15 Jun 2011 1.53m Threat
KAINGHAUNG ISLAND 0854Z 15 Jun 2011 2.00m Threat
HEINZE BOK 0901Z 15 Jun 2011 2.00m Threat
DANI–THAGYA 0909Z 15 Jun 2011 1.53m Threat

SRI LANKA
KATTANKUDI 0735Z 15 Jun 2011 7.74m Threat
POTTUVIL 0739Z 15 Jun 2011 8.55m Threat
YALA 0739Z 15 Jun 2011 8.73m Threat
PULMODDAI 0740Z 15 Jun 2011 7.28m Threat
ANAITIVU 0741Z 15 Jun 2011 7.86m Threat
MATARA 0755Z 15 Jun 2011 7.26m Threat
CHUNDIKKULAM 0756Z 15 Jun 2011 4.99m Threat
HIKKADUWA 0806Z 15 Jun 2011 4.92m Threat
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NEGOMBO 0819Z 15 Jun 2011 3.01m Threat
COLOMBO 0819Z 15 Jun 2011 3.68m Threat
MUNDAL LAKE 0832Z 15 Jun 2011 2.58m Threat
MANNAR ISLAND
0844Z 15 Jun 2011 2.40m Threat

SOMALIA
DARIMOHO
1320Z 15 Jun 2011 1.38m Threat
EYL
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XARARDHEERE
1328Z 15 Jun 2011 1.37m Threat
CEEL DHEER
1336Z 15 Jun 2011 1.16m Threat

THAILAND
BAN KHAO BA
0731Z 15 Jun 2011 11.81m Threat
PHUKET
0732Z 15 Jun 2011 6.69m Threat
KO RACHA YAI
0740Z 15 Jun 2011 3.95m Threat
KO SURIN TAI
0746Z 15 Jun 2011 4.09m Threat
KO LANTA YAI
0823Z 15 Jun 2011 2.53m Threat
KO RA WI
0830Z 15 Jun 2011 2.77m Threat

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RTSP INDONESIA: http://rtsp.bmkg.gov.id

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information should be used for safety.

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REGIONAL INTEGRATED MULTI-HAZARD EARLY WARNING SYSTEM (RIMES)
Address: Outreach Building, AIT Campus, Pathumthani 12120 Thailand
Tel.: +662-516-5905 to 07
Fax: +662)-516-5908 to 09
Email: tsunami@rimes.int
Website: www.rimes.int

END OF BULLETIN
5. Tsunami Bulletin Type 4 Final

RTSP–RIMES–20110615–0605–004

TSUNAMI BULLETIN NUMBER 4
REGIONAL TSUNAMI SERVICE PROVIDER – RTSP RIMES
issued at 0800 UTC Wednesday 15 JUNE 2011

... FINAL TSUNAMI BULLETIN IN THE INDIAN OCEAN ...

1. EARTHQUAKE INFORMATION
RTSP RIMES has detected an earthquake with the following details:

    Magnitude: 9.0 Mwp
    Depth: 10 km
    Date: 15 Jun 2011
    Origin Time: 0600 UTC
    Latitude: 7.20N
    Longitude: 92.90E
    Location: Nicobar Island, India

2. EVALUATION
Data from sea level gauges confirmed that a tsunami was generated.

The expected period of significant tsunami waves is now over for all threatened Indian Ocean countries, based on RTSP RIMES modeling.

Because local conditions can cause a wide variation in tsunami wave action, CANCELLATION of national warnings and ALL CLEAR determination must be made by national/ state/ local authorities. Please be aware that dangerous currents can continue for several hours after the main tsunami waves have passed.

3. TSUNAMI WAVE OBSERVATIONS
Listed below are maximum wave amplitudes recorded at the specified locations. Note that wave amplitude is measured relative to normal sea level; it is NOT the crest-to-trough wave height.

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>LAT</th>
<th>LON</th>
<th>TIME</th>
<th>DATE</th>
<th>AMPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nancowry (India)</td>
<td>7.96</td>
<td>93.53E</td>
<td>0615Z</td>
<td>15 Jun 2011</td>
<td>10.0m</td>
</tr>
<tr>
<td>Port Blair (India)</td>
<td>11.66</td>
<td>92.76E</td>
<td>0657Z</td>
<td>15 Jun 2011</td>
<td>6.0m</td>
</tr>
<tr>
<td>Chennai (India)</td>
<td>13.10</td>
<td>80.30E</td>
<td>0814Z</td>
<td>15 Jun 2011</td>
<td>4.0m</td>
</tr>
</tbody>
</table>

4. ADVICE
This bulletin is being issued as advice. Only national/ state/ local authorities and disaster management officers have the authority to make decisions regarding the official threat and warning status in their coastal areas and any action to be taken in response.

5. UPDATES
No further bulletins will be issued by RTSP RIMES for this event, unless additional information becomes available.

Other RTSPs may issue additional information at:
RTSP INDIA: http://www.tsunami.incois.gov.in/ITEWS
RTSP INDONESIA: http://rtsp.bmkg.gov.id

In case of conflicting information from RTSPs or the IAS (PTWC, JMA), the more conservative information should be used for safety.

6. CONTACT INFORMATION
REGIONAL INTEGRATED MULTI-HAZARD EARLY WARNING SYSTEM (RIMES)
Address: Outreach Building, AIT Campus, Pathumthani 12120 Thailand
Tel.: +662-516-5905 to 07
Fax: +662)-516-5908 to 09
Email: tsunami@rimes.int
Website: www.rimes.int

END OF BULLETIN
Annex 3

RIMES Decision Support System

Development and integration of RIMES Decision Support System (DSS) with the Portal for Regional Estimation of Coastal tsunami Impacts using Sea-level and Earthquake information (PRECISE) is completed. This Decision Support tool provides an interface between RIMES Seismic computing systems and Tsunami Modeling system to generate Bulletins and integrate graphical products. Figures A3-1 and A3-2 show user interfaces of the DSS, Figures A3-3 to A3-6 the tsunami bulletins in text format, and Figures A3-7 to A3-11 the graphical products generated by the DSS.

Figure A3-1: DSS Primary Interface pulls data from seismic server and tsunami modeling server
Figure A3-2: Tsunami and earthquake data gathering and generation of bulletins and notifications
Figure A3-3: Initial Earthquake Bulletin for web (Tsunami Bulletin No 1 with initial threat assessment)
Figure A3-4: Tsunami bulletin with model scenarios (Tsunami Bulletin No 2 with pre-run model scenarios and earthquake parameters)
Figure A3-5: Tsunami bulletin with revised solution (using sea level inversion) includes sea level observation data and (Tsunami Bulletin No 3)
Figure A3-6: Tsunami bulletin for cancellation of all tsunami threats within the region (Tsunami Bulletin No 4)
Figure A3-7: Graphical Product 1 Tsunami wave height Map

Figure A3-8: Graphical Product 2 Tsunami Travel Time Map
Figure A3-9: Graphical Product 3 Tsunami Coastal Threat Map

Figure A3-10: Graphical Product 4 Tsunami Coastal Hazard Map
Figure A3-11: Graphical Product 5 Earthquake Epicenter Map