Indian Tsunami Early Warning System

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Ministry of Earth Sciences

Mission

Provide Ocean Information and Advisory Services to Society, Industry, Government Agencies and Scientific Community through Sustained Ocean Observations and Constant improvements through Systematic and Focussed Research

Operational Services to User community

- Fishing
- Marine Fishery Forecast
- Marine Fishery Forecast Value-Added Services
- Marine Fishery Forecast Constant improvements through Systematic and Focussed Research

Web-based Dissemination

- To Users

Ocean Information Bank

- Data Sources and Flow
- Ocean State Forecast
- Ocean State Forecast Components of the Indian Early Warning System
- Tsunami Early Warning Information

Value-Added Services

- Fishing Community
  - IMD, Navy, NHO
  - Coast Guards

- Coastal States
  - IMD, Navy, NHO
  - Coast Guards

- Off-shore and Shipping
  - Ports and Harbours
  - Off-shore and Shipping

IT Infrastructure of INCOIS

- Research Institutions
- Academia
Vulnerability of the Indian Ocean Coastline

- More than 50 Nations around
- Many are Developing Countries
- More than 1.5 Billion Population
- More than 66,500 km coastline

- 26% of Indian Population live within 100 Km from the shoreline
- Most of the coastal areas are low lying and vulnerable to oceanogenic disasters such as Tsunamis, Storm Surges, Sea-level rise
- Dec 26, 2004 Tsunami resulted in a loss of 18,045 deaths and 6,47,599 persons displaced
Tsunamis are primarily caused due to large undersea earthquakes.

For a tsunami to hit Indian coast, it is necessary that a tsunamigenic earthquake occurs and its magnitude should be larger than M7. Possible locations of such events are enclosed in ellipse

Earthquakes with Slow Rupture Velocities are most efficient Tsunami Generators

75% of earthquake energy is released in the circum-Pacific belt – 900 Tsunamis in 20th Century

20% in the Alpine-Himalayan belt – 6 Tsunamis in 20th Century

Historical Tsunami in India
12 Apr, 1762 (BoB EQ) – 1.8 M
31 Dec, 1881 (Car Nicobar EQ)
27 Aug, 1883 (Krakatoa) – 2 M
26 Jun, 1941 (Andaman EQ)
27 Nov, 1945 (Makran EQ) – 12 M
26 Dec, 2004 (Sumatra EQ)

Landslides, Volcanoes & Meteor Impacts can also generate Tsunamis
Sequence & Components of Tsunami Warning System

Generation of Tsunami

Occurrence of Earthquake

Detection of Seismic Wave

Determination of Magnitude and Hypocenter

Evaluation of Tsunami

Issuance of Tsunami Bulletin (Info/Warning/Watch/Adv)

Issuance of Upgradation/Cancellation

Components of Tsunami Warning System

Network of seismometers

Real time transmission of seismic data

Real time data processing system

DSS - Criteria Based on EQ magnitude / Based on Model Scenarios

Communication facility to disseminate Tsunami Warning

Network of BPR/tide gauge to confirm/monitor tsunami

Re-evaluation Of Tsunami (Inversion/Scenario/Modelling)
An end-to-end System Design

Warnings

Tsunami Warning Centre
INCOIS, TCS

Data Communication
ISRO

CB, Edu.Trg
- Historic Data
- Bathymetry
- Coastal Topography
- Coastal Vulnerability
  NRSC, INCOIS, NHO

R & D
Numerical Modelling
- Tsunami
- Storm Surge
  ICMAM, INCOIS, WAPMERR

Coastal Radars
NIOT

Upper Ocean, Surface Met-Ocean Observations

Coastal Vulnerability
NRSC, INCOIS, NHO

Tide Gauge Network
SOI

Network of Seismic Stations
IMD

Bottom Pressure Recorders
NIOT
Heterogeneous Real-Time Data from a variety of Sensors

- Data Acquisition, Display, Processing, Archival
- Numerical Modeling and Decision Support
- Generation of Advisories and Dissemination
- Mission Critical - Infrastructure to be highly available
Mission-Critical Data Centre Facilities

Hardware
- Two high-end server consolidations & network components of active-active clustering in load balanced environment in Primary Site
- One high-end server consolidation in DR Site

Software
- ETL, Staging & Central Databases
- Web Application Server
- GIS software
- Spatial data of model outputs.
- Application Software for real time data reception, display, analysis and generation of bulletins based on the SOP.

Technical support facilities
- UPS for 2 Hr Back up, 2 DG Sets, TVSS, STS
- Fire detection system, FM 200-based Fire Suppression, VESDA system, Fire rated walls and doors,
- WLDS, Rodent Repellent System,
- CCTV system, Access control systems, Building Management System

24 x 7 operations
Real Time Seismic Monitoring Network

- Network of 27 Indian broadband seismic stations
- Data from International stations
- Data Acquisition, Processing, Auto location and Archival using Response Hydra as well as SESICOMP 3
- TWC reported and monitored 140 earthquakes of M > 6.0 (Jul 08 to July 09)
- 32 under-sea events of M > 6.5
- Earthquakes of > M6 are being auto-located within 5 - 12 Min of Occurrence
- EQ parameters conform well with those put out by USGS / GEOFON
- Upgrades to Seiscomp System - Mwp algorithm implemented
Deep Ocean Assessment and Reporting System for Detection of Tsunamis

- Network of 12 Tsunami Buoys are used to detect any significant water level changes due to tsunami
- Has a Bottom Pressure Recorder and a Surface Buoy System with Acoustic communication
- Capable of Measuring 1 cm water level change in 6000 m water column
- 4 values of 15 minutes average for every one hour in Normal Mode
- 4 values of 15 seconds average for every one minute in Tsunami Mode
- Automatic Tsunami Detection Algorithm in the BPR
Tide Gauge Network

- Currently Tide Gauges installed and operational at 26 strategic locations along the Indian Coast
- More being planned in 12 locations in the next 1 year
Modelling for Operational Forecasting

The TUNAMI N2 model is customized for Indian Ocean region

- This model had been extensively validated using the December 26 2004 Tsunami observations

For operational forecast
- A large database of open ocean propagations scenarios
- For epicenters separated by 100 km all along two Tsunamigenic zones
- Scenarios for different magnitudes (6.5, 7.0, 7.5, 8.0, 8.5, 9.0 & 9.5) and depths (10, 20, 40, 60, 80 & 100 km)

Travel times
Surge heights
Directivity maps

Each simulation covers the entire Indian Ocean domain with 15 hours simulation time and a time step of 5 seconds. Out put profiles are generated at 30 m bathymetry for about 1800 coastal forecast points (CFPs) covering the entire Indian ocean rim countries.
Coastal Inundation scenarios simulated for 5 historical Earthquakes using TUNAMI N2 model and the predicted inundation areas have been overlaid on cadastral level maps of 1:5000 scale.

Coastal Bathymetry: Maps of Special Order are required (Accuracy 0.5 M)

Coastal Topography: Contour Intervals of 0.5 M at 1:25,000 Scale are required

Topography Data being generated using Cartosat and ALTM Surveys

Bathymetric Survey conducted for a few vulnerable areas. Detailed survey being planned for other areas.
Types of Bulletins

- **EQ Info:** 20 Min: MHA
- **Warning (Evacuation):** 30 Min: MHA, Public
- **Alert (Vigilant):** 30 Min: MHA, Public
- **Watch:** 30 Min: MHA

- Tsu. Info – Upgrade/Downgrade/All Clear
  - Warning/Alert/Watch based on EQ Parameters, a regions’ proximity to the Earthquake Zones (Travel Times) & Expected Run-up from Pre-run Model Scenarios
  - Warnings to Far Source Regions only after confirmation of tsunami triggering based on real-time water-level observations & Correction of Scenarios
  - This will reduce possibility of False Warnings
  - Decision support system

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**DSS and SOP**

**Earthquake**

**SEISMIC NETWORK**

Hypocenter, Magnitude

**Land/Ocean**

- **Mag > 7.5**
- Depth > 100 Km
- Bathymetry > 1000 M

**Tsunami Information**

- No Tsunami Expected (MoES, MHA)

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**Scenario Database**

**Travel Times: Run up Heights: Directivity Maps**

<table>
<thead>
<tr>
<th>Travel Times &lt; 60 MIN</th>
<th>Travel Times &gt; 60 MIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Run Up</td>
<td>Expected Run Up</td>
</tr>
<tr>
<td>&gt; 2 M</td>
<td>&gt; 2 M</td>
</tr>
<tr>
<td>ALERT</td>
<td>ALERT</td>
</tr>
<tr>
<td>0.5 M to 2 M</td>
<td>0.5 M to 2 M</td>
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<tr>
<td>ALERT</td>
<td>WATCH</td>
</tr>
<tr>
<td>&lt; 0.5 M</td>
<td>&lt; 0.5 M</td>
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<tr>
<td>WATCH</td>
<td>WATCH</td>
</tr>
</tbody>
</table>

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**Confirm triggering of tsunami**

- **Upgrade Status**
  - ALERT
  - WATCH

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**ALL CLEAR**

- Sent to MoES, MHA, Public
- (NO MORE Dangerous waves are expected)

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**Detection of Tsunamigenic Earthquake**

- Tsunami Information
  - No Tsunami Expected (MoES, MHA)

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**Decision of Triggering of Tsunami**

- BPR (Open Ocean)
  - > 30 min
  - Yes

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**Real-time Water Level Observations**

- Tide Gauge: Shallow water
  - > 0.5 M
  - Yes

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**To + 20 Min First Bulletin**

**To + 30 Min Second Bulletin**

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**Warning/Alert/Watch based on EQ Parameters, a regions’ proximity to the Earthquake Zones (Travel Times) & Expected Run-up from Pre-run Model Scenarios**

- Decision support system
EQ Info: Mag mb = 5.1
TimeStamp: 06 Jan 2009 14:51:55 (IST)
06 Jan 2009 09:21:55 (UTC)
Lat.: -16.01
Long.: -176.01
Depth: 501.0 Km
Bathy: -249.0 mt
Region: Fiji Islands Region

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Handling of the Event by Warning Centers

Southern Sumatra Earthquake of M8.0 on 30th Sep 2009 at 10:16:07 (UTC)
This earthquake generated a local tsunami near the epicenter especially at Padang, Indonesia (30 cm). The event did not generate any water level changes in Indian Coasts.

Different SOPs for the IO Region
India: Eq info + Model Simulations + WL data
PTWC: Eq info + WL data
JMA: Eq info + WL data

Conflicting Bulletins

Padang Tide gauge Station Plot
30-September-2009 09:00:00 - 23:59:00

Water Level (m)
Date & Time (UTC)
Significant role in the Indian Ocean

1. India—a key player major in the international coordination on arrangements for Indian Ocean region [Kobe (Jan 05), Phuket (Jan 05), Paris (Mar 05), Mauritius (Apr 05) and Paris (Jun 05)]

2. India is the only country that is developing capability to detect tsunami generated in the two tsunamigenic zones that would affect Indian Ocean

3. India served as Chairman of International Coordination Group set up by UNESCO/IOC for Indian Ocean Ocean Tsunami Warning and Mitigation System, a network of national systems

4. India is the First Country in the Indian Ocean to operationalise the TEWS that has been recognised as the most modern. ICG/IOTWS accepted Indias’ offer to be Regional Tsunami Watch Provider for the Indian Ocean.
Achievements / Awards received in 2008

Geospatial Excellence Award 2008 for the Usage of Geospatial Technology for Disaster Management by GIS Development, a Global Geospatial Technology Magazine

Geospatial Solution of the year Award Under The Indian Geospatial Awards 2008 by Geospatial Today, a premier Geospatial Technology Magazine

Silver Award of National Awards for e-Governance 2008-09 under the Best Government Website Category

Special Achievement in GIS (SAG) 2009 Award from ESRI
Thank you for your kind attention