Mitigating Tsunami Risk in the Indian Ocean

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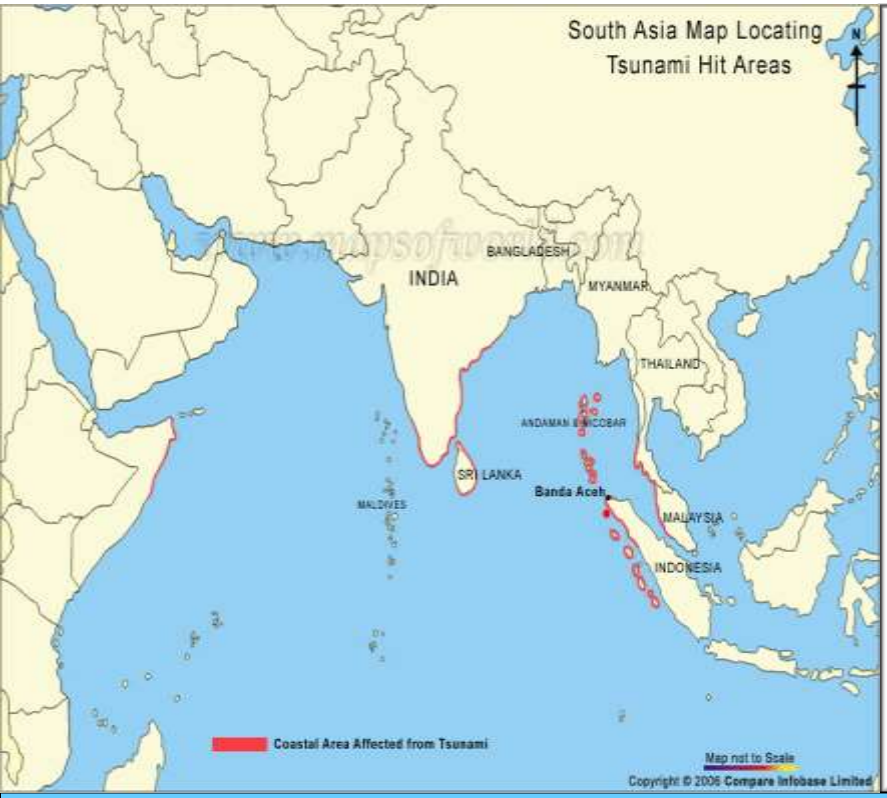
Indian Ocean Tsunami of December 26, 2004



- The worst tsunami in recorded history.
- Magnitude 9.2 (third strongest earthquake recorded). Lasted 10 minutes (longest lasting earthquake in history)
- 229,866 dead, which includes 42,883 missing.
- > $7 billion dollars damage

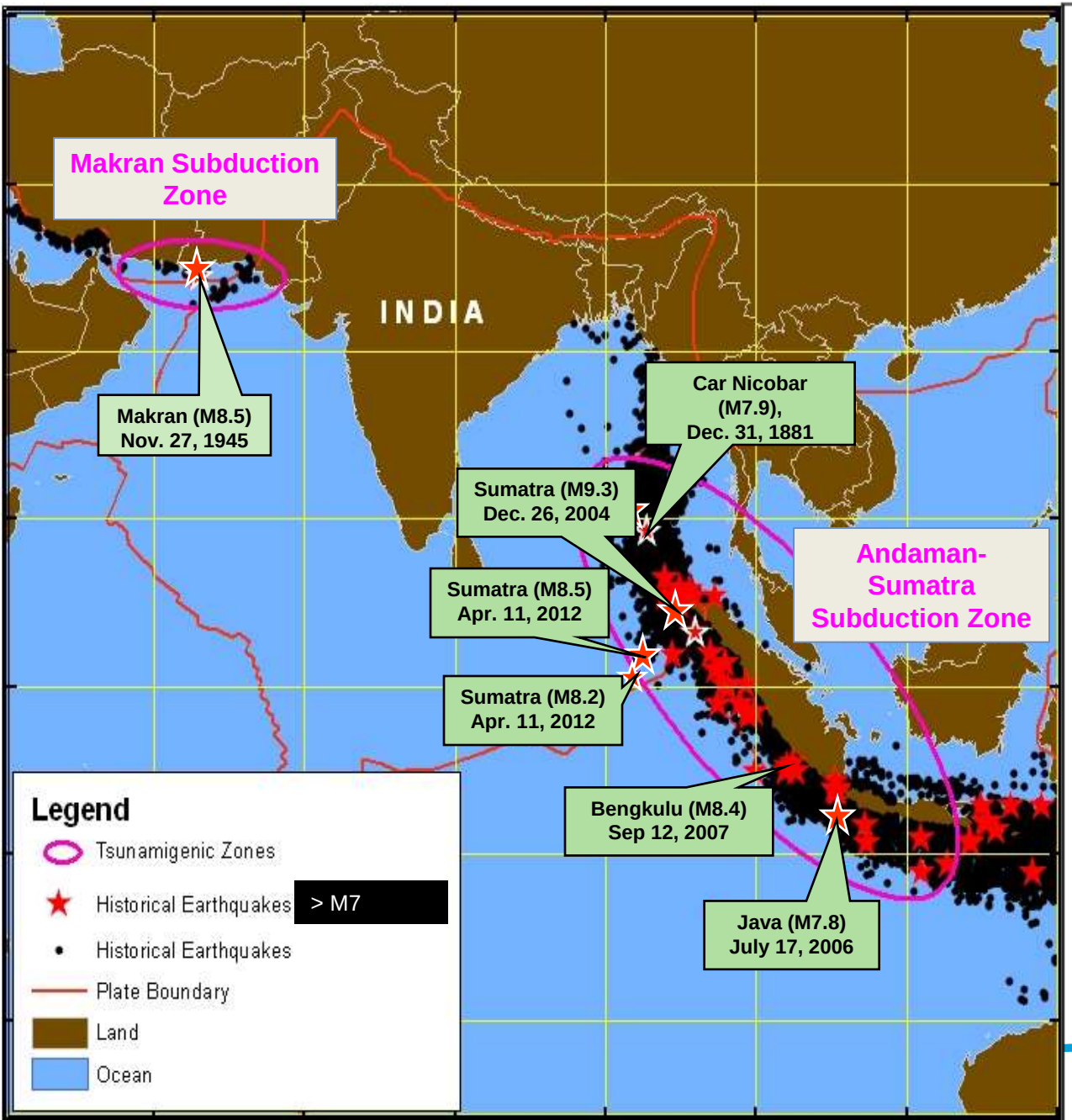
Reasons for huge loss…..

- Many nations in the Indian Ocean were not aware of "tsunami"
- Absence of a Tsunami Early Warning Systems
- No tsunami preparedness programs in place
- Absence of knowledge on tsunami wave led to inappropriate actions

Tsunami Wave - Characteristics

- A system of ocean gravity waves formed as a result of large-scale displacement of sea surface.
- Travel long distances without losing energy.
  - Long wave length (of several 100 km)
  - Periods of a few minutes to about an hour
  - 500 to 1000 km per hour in Deep Ocean
  - About 30 km per hour near shore
  - Less than a metre in the Deep Ocean
  - Grows to Tens of meters near shore

Tsunami Risk Assessment



➢ Historical Tsunamis in the Indian Ocean

- 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
- 19 Aug, 1977 (Sunda EQ) – 5 M
- 26 Dec, 2004 (Sumatra EQ) – 30 m
- 28 Mar, 2005 (Sumatra EQ) – 4 m
- 12 Set, 2007 (Sumatra EQ) – 0.6 m
- 11 Apr, 2012 (Sumatra EQ) – 1 m

➢ Tsunamigenic potential EQs for India

- Andaman-Sumatra & Makran subduction zones
- EQ Mag > 6.5
- Earthquakes under or near ocean
- Depth < 100km
- Vertical movement of the sea-floor

Mitigation of Tsunami Risk

- Development of Early Warning System
- Satellite–based communication system for acquisition of data,GPS, etc., seismic, sea level, and dissemination of advisories.
- Computation of earthquake parameters, tsunami and inundation modelling
- High-resolution satellite data for coastal totopgraphy
- GIS for integration and providing web and location-based services.
- Development of Response System
- Development of Human System

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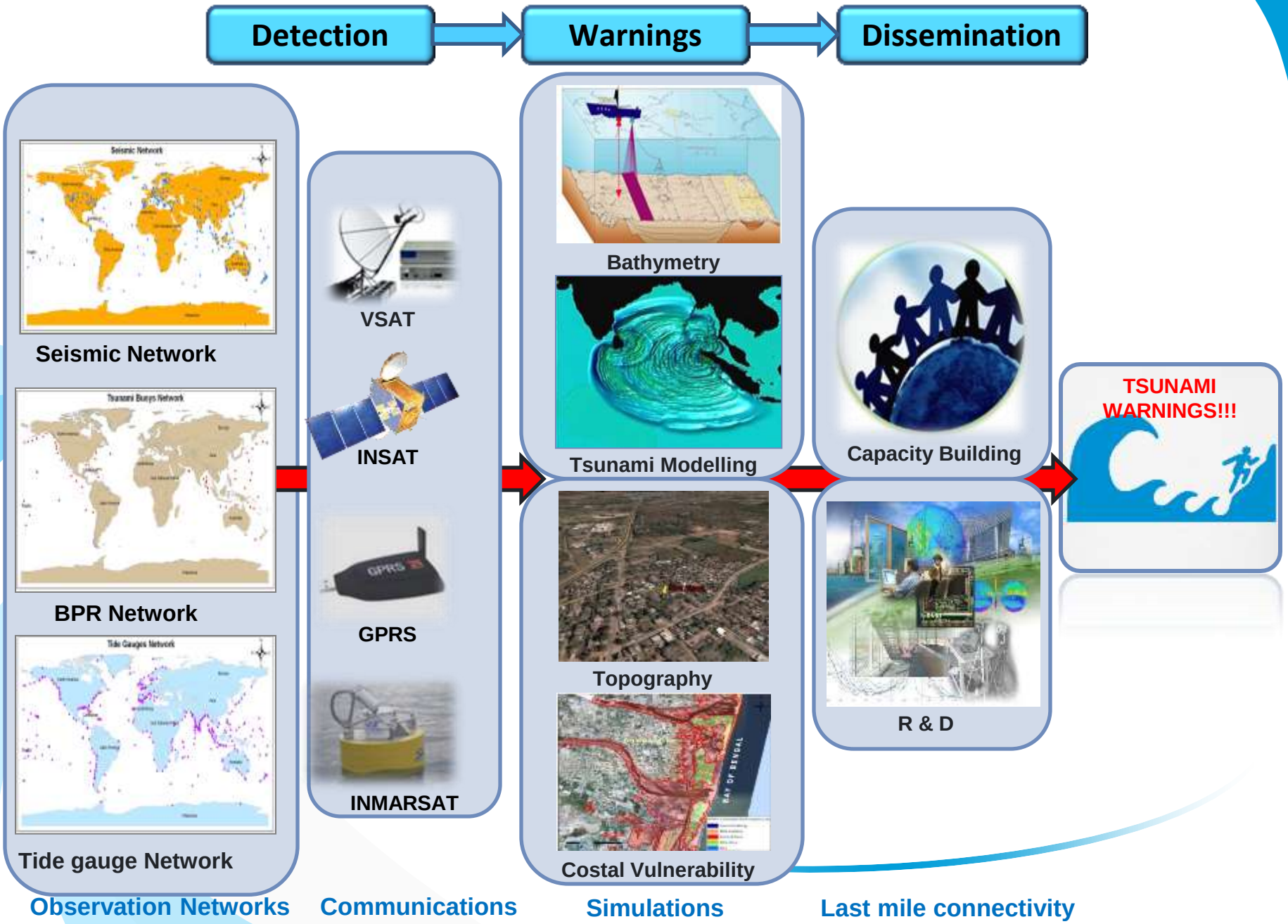
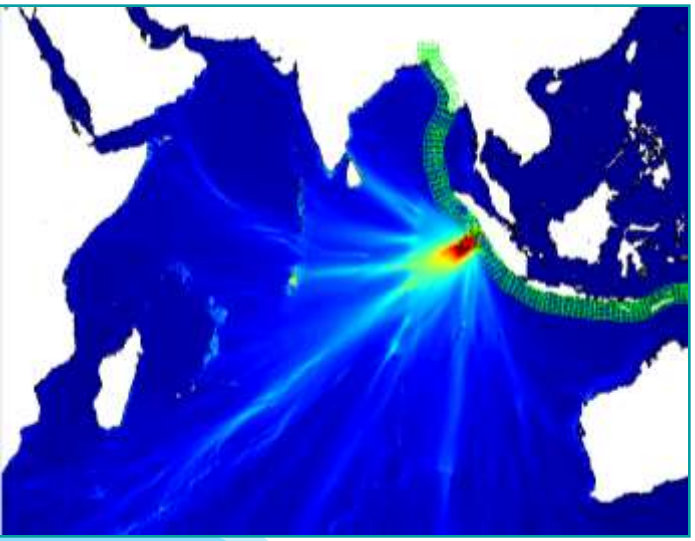
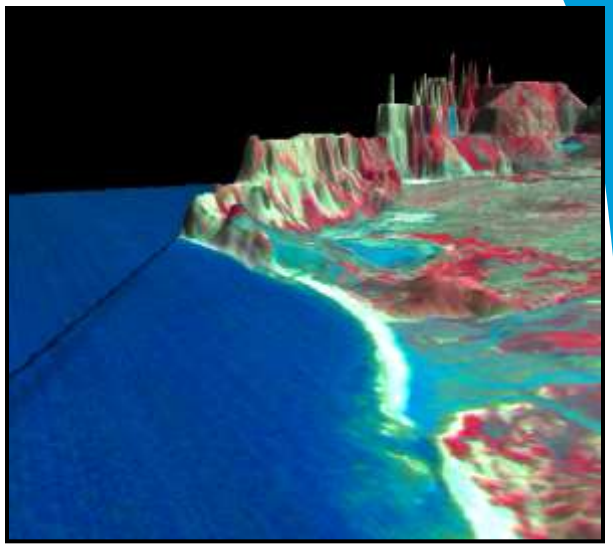
Components of Tsunami Early Warning System



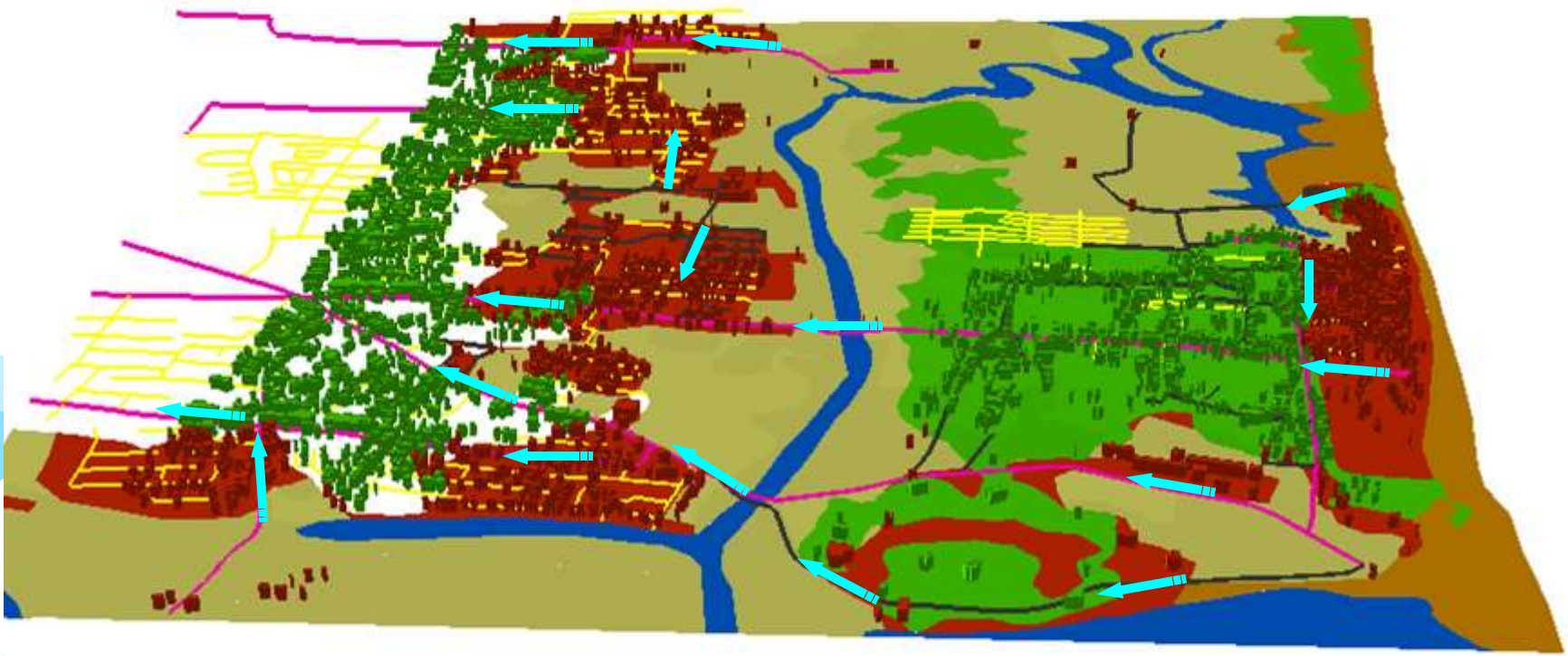
Tsunami Modelling





- **Open Ocean**
  - Database of Scenarios covering both the Tsunamigenic Zones
  - Each unit source is of 100 X 50 km area representing rupture caused by EQ of M 7.5 with slip as 1m
  - Depending on EQ's location and magnitude basic unit source open ocean propagation scenarios are either scaled up or down
- **Inundation**
  - Tsunami Inundation Modelling and Vulnerability mapping for Historic Earthquakes & Worst Case Scenarios is prepared
  - Field Surveys for Assessment of 2004 tsunami impact

Vulnerable Areas & Evacuation Routes



Risk

- High
- Moderate
- Low
- No Risk

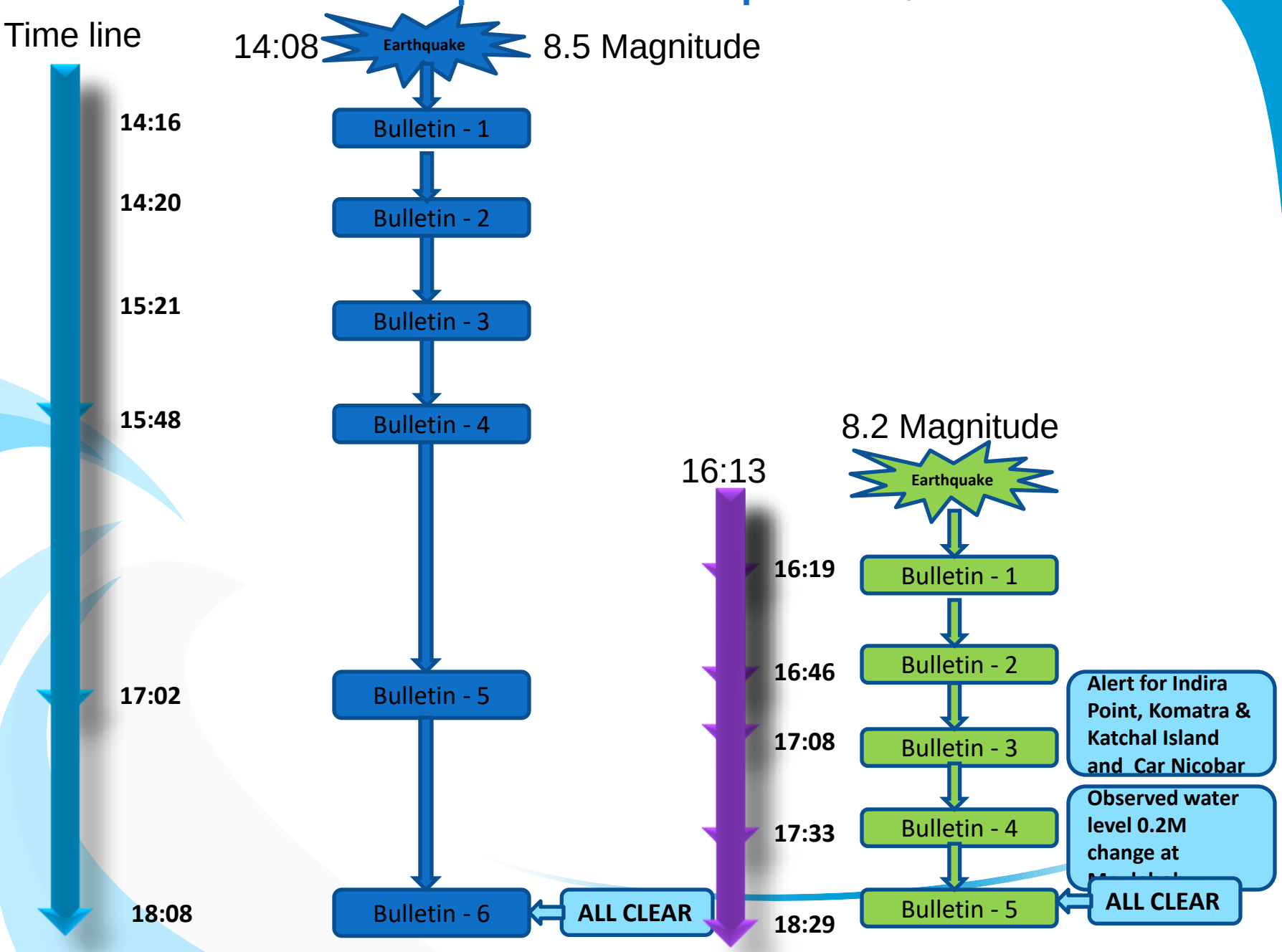
Buildings

- Hazard
- Safe

Roads

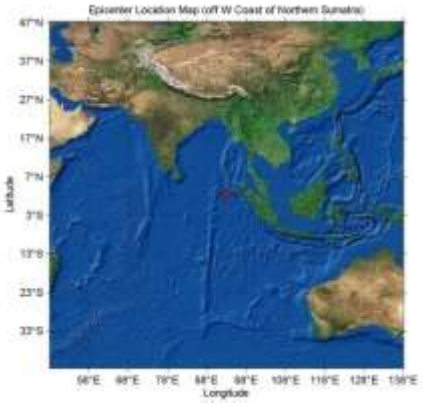
- Major
- Minor
- Streets
- Evacuation Routes

8.5 M earthquake on April 11, 2012

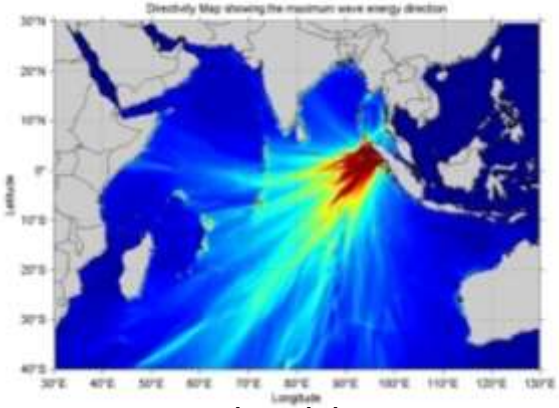


8.5 M earthquake on April 11, 2012

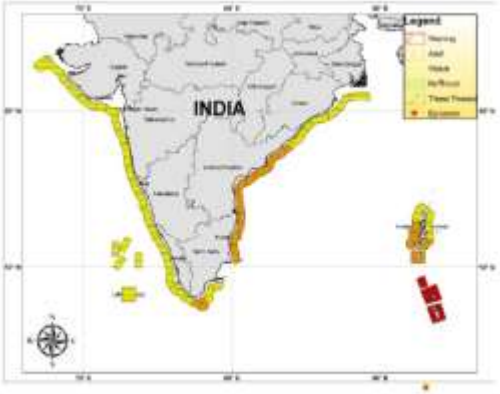
ESSO-INCOIS	PTWC	JMA
Location Specific: Warning - Indira Point, Car-nicobar and Komatra & Katchal islands of A & N. Alert -Tamilnadu, Andhra Pradesh and rest of the Andaman Islands. Watch – Parts of the East Coast Minor water level observations changes observed. Tsunami Warning/ Alert/ Watch Cancelled	Entire Indian coast under tsunami Watch (Under Threat). Later cancelled	Entire Indian coast under tsunami Watch (Under Threat).



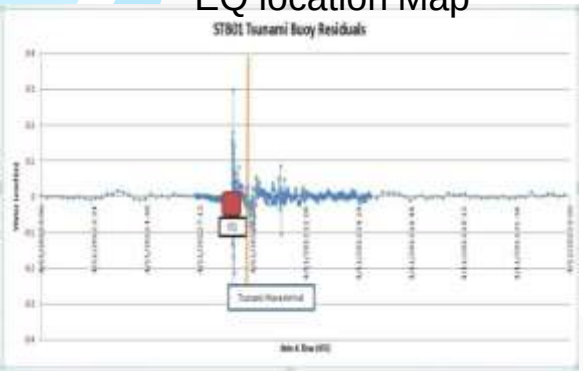
EQ location Map

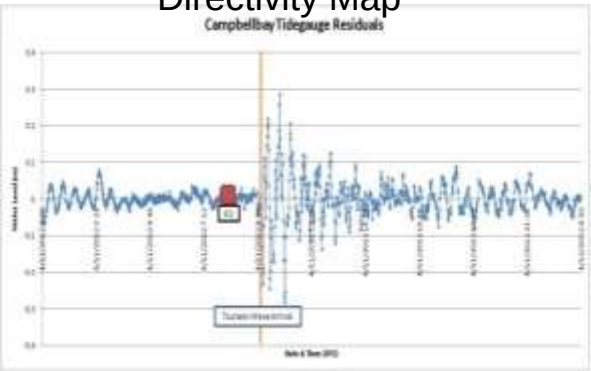


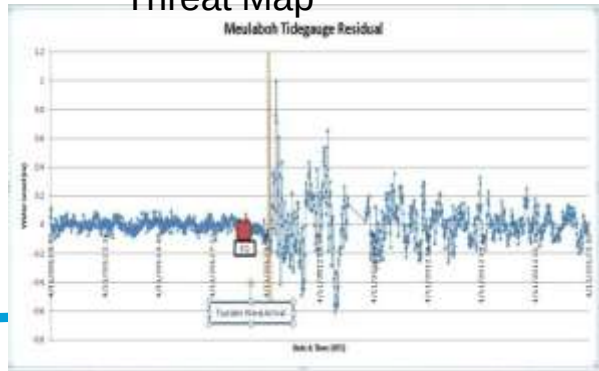
Directivity Map



Threat Map







Sea-level Changes

Prime Minister's Appreciation

101th Science Congress, Jan. 3, 2014.

"Our decision to set up a new Ministry of Earth Sciences following the Indian Ocean Tsunami in 2004 and to invest in world-class tsunami forewarning system in 2007 has been amply rewarded. We now has ability to issue alerts within 13 minutes of a tsunami-genic event. This has established India's leadership in the Indian Ocean Region."

Asian Ministerial Conference on Disaster Risk Reduction, Nov. 3, 2016.

"…We have now a fully functional Indian Ocean Tsunami warning System. Along with its Australian and Indonesian counterparts, the Indian National Centre for Ocean Information Services is mandated to issue regional tsunami bulletins."

Tsunami Mock Drills-IOWave

- Mock drills are conducted in 2009, 2011, 2014.

- To Validate the Warning Centre dissemination process for stake holders.
- To Hone the organizational decision making process about public warnings and evacuations
- To evaluate proper communication methods used to notify and instruct the public.
- To Record and assess the elapsed time until the public would be notified and instructed.

- Evaluation of Communications Methods

- Email are received within 5-14 minutes
- SMS are within 6-8 minutes
- Fax take 30-110 minutes

- Time Taken to Notify Public

- Odisha, Puducherry ~20 minutes
- Maharashtra ~ 80 minutes

Capacity Building, Education and Training

- Workshops, seminars, Trainings (national & international), Exhibitions
- Public on responding to earthquakes & tsunami warnings
- Coastal administrators, disaster management officials and public on SOPs, use of tsunami inundation maps, etc.
- Include disaster awareness and response related topics in primary, secondary and high school curriculum.

- Operations Handbook & User guide, films for Administrators, General public and Children, posters, Leaflets

Challenges & New Initiatives

- Under-estimation of Initial Magnitude and Tsunami wave heights
  - Tohoku-Oki Earthquake on March 11, 201
  - Great earthquakes especially for near-source regions
- Over-estimation of Forecasted Tsunami wave heights
  - Unknown fault mechanism especially displacement direction
- Non-Seismic Causes
  - Submarine land slides, volcanoes, etc.
- ✓ Estimation of size of ruptures and linking to magnitude – use of GPS and Accelerometers
- ✓ Real-time modelling, water level inversion
- ✓ Study of paleo-tsunami deposits – understanding repeat cycles
- ✓ 3D GIS and visualization tools

International Collaboration

- Intergovernmental Coordination Group for Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS)
  - Standardisation of Bulletin formats & content to Administrators
  - Concept of Coastal Forecast Zones
  - Public Bulletins
  - Performance Indicators
  - NTWC Trainings / Workshops
  - Communication Tests & Tsunami Drills
- Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG)
  - Global Harmonization

Concluding Remarks

- Ability of forecast an event and provide advisories is not enough to mitigate risks.
- A social system – political, economic and industrial structures – are equally important to provide resilience to society.
- An ability to local administration to respond to an event and effective communication to people is very critical.
- An education system that produces scientists and managers to implement such approach is needed.
- Capacity building at regional, national, institutional and individual level is vital.


Thank You