Indian Tsunami Early Warning System, **SOP & Products**

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Regional Workshop on Standard Operating Procedure (SOP)
for Broadcasting Media in Tsunami Warning Chain
September 7-9, 2021

e-Class room, INCOIS on 08 Sep 2021

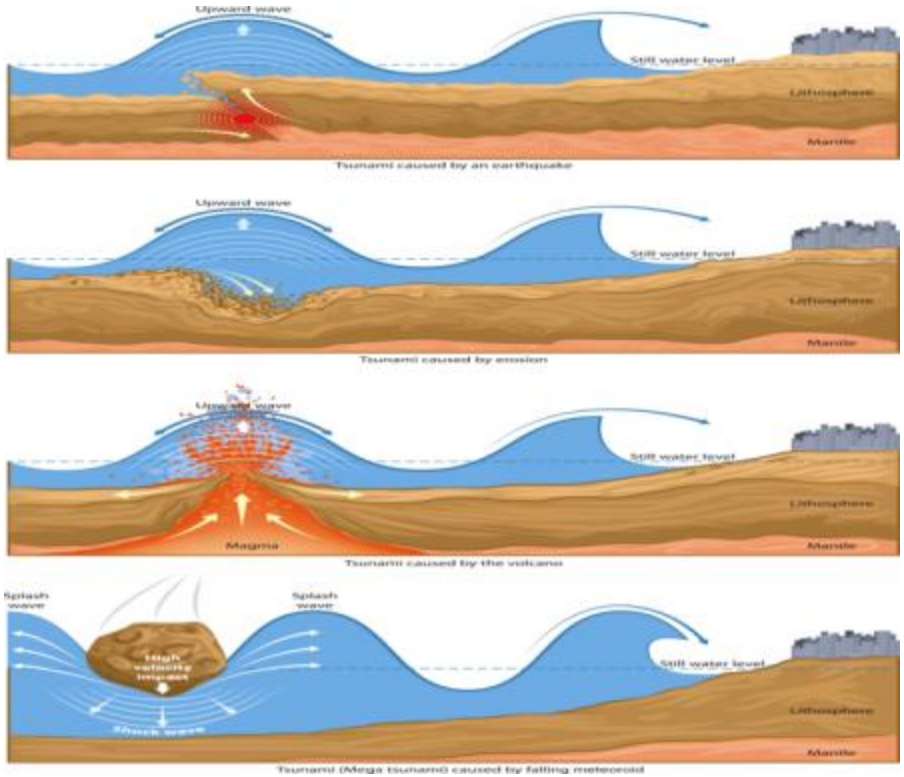
Vulnerability of the Indian Ocean Coastline to Oceanogenic Disasters

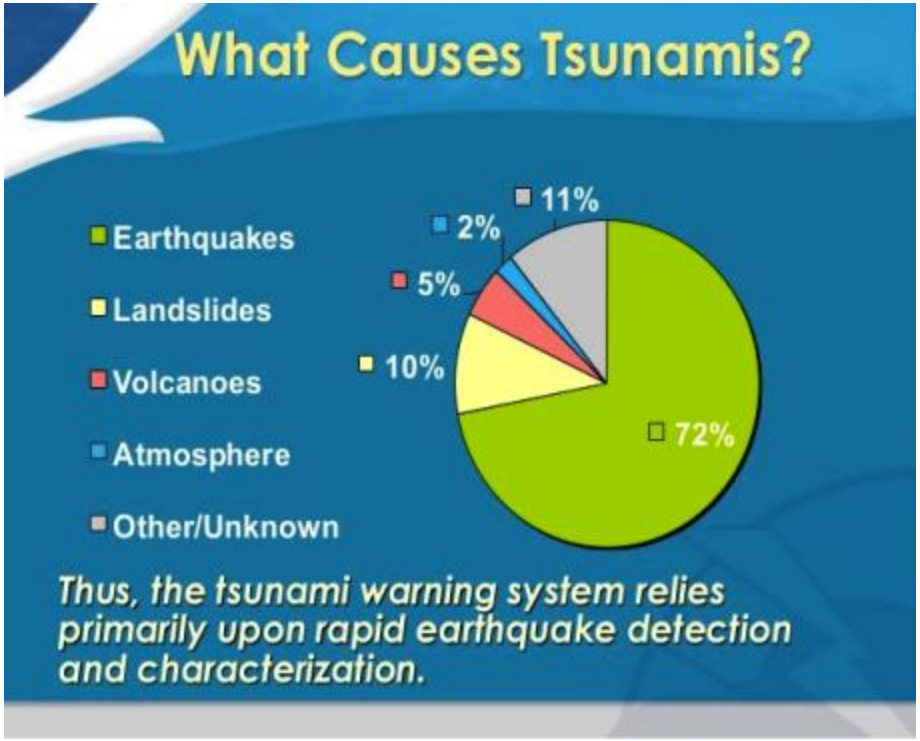
- Around 40 Nations
- Many are Developing Countries
- More than1.5 Billion Population
- More than 66,500 km coastline
- Exposed to weather related hazards, tsunamis, earthquakes etc

- Coastal regions are densely populated and important focus of development, therefore, very vulnerable to hazards as tsunamis.
- Efficient functioning of Early Warning Systems is one of the crucial aspects of disaster risk reduction
- Risk reduction is based on scientific knowledge and even the most sophisticated scientific techniques have some degree of uncertainty.

What is Tsunami?

- Tsunami is a series of long period waves created by an abrupt disturbance that displaces a large amount of water





Indian Ocean Tsunami of December 26, 2004

- The worst tsunami in recorded history on December 26, 2004
- Magnitude 9.3 (second strongest earthquake ever recorded on a seismograph)
- Lasted 10 minutes (longest lasting earthquake in history)
- 229,866 confirmed dead, which includes 42,883 missing and never accounted for
- More than $7 billion dollars damage

Reasons for huge loss…..

- Many nations in the Indian Ocean did not even recognize the word “tsunami”
- None had tsunami preparedness programs in place
- Absence of a Tsunami Early Warning System (TEWS) in India
- Ignorance of the natural signs of a tsunami led to inappropriate actions

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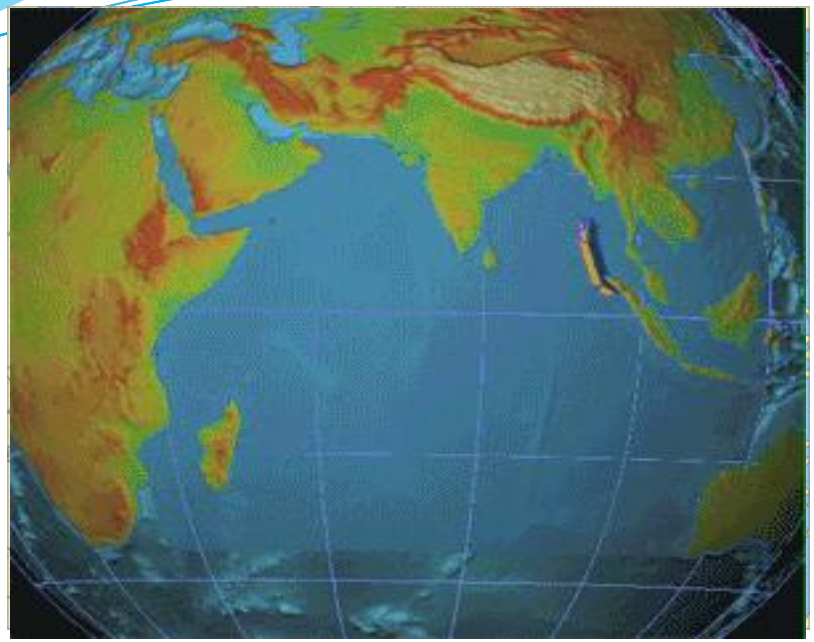

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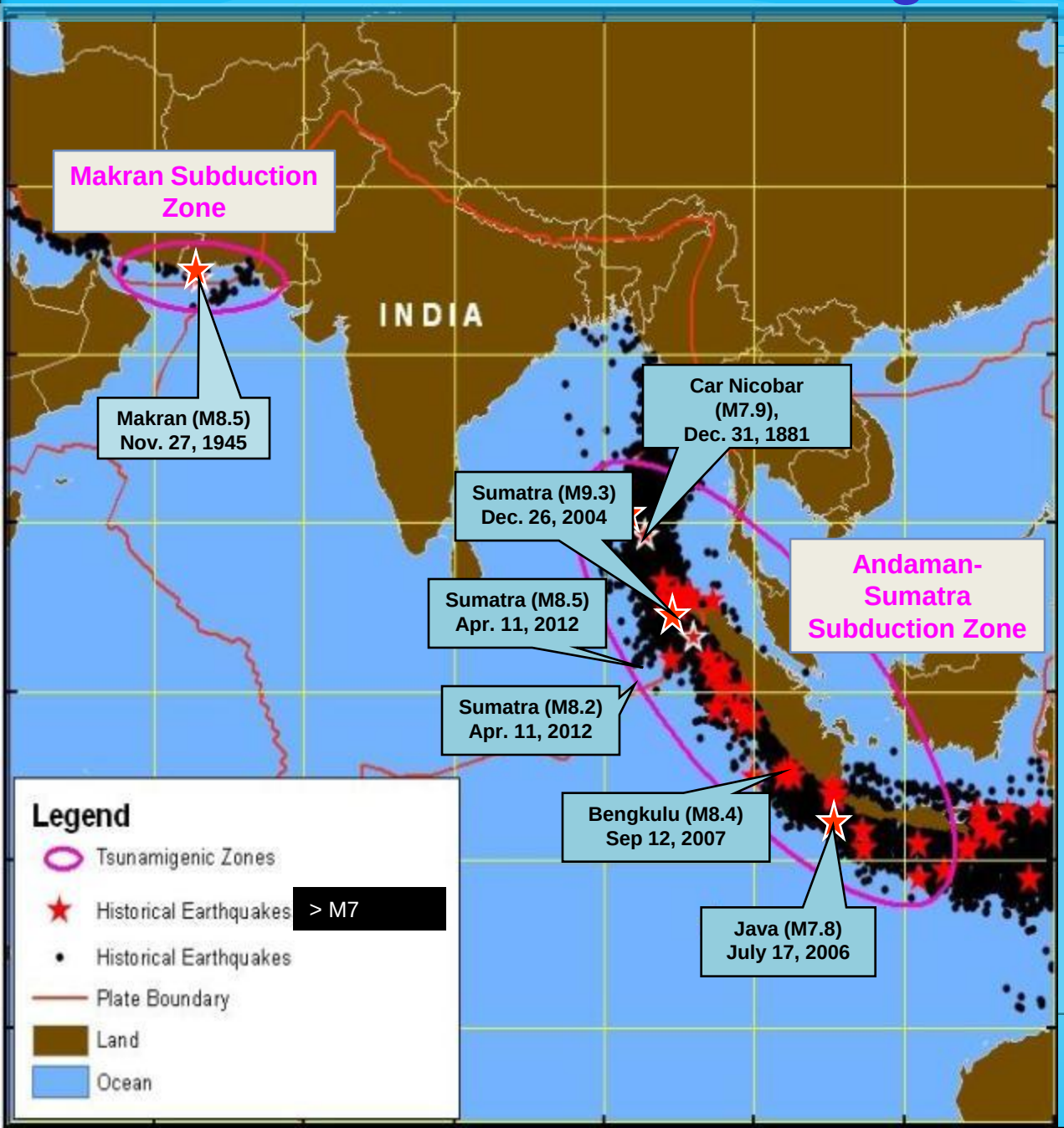
Potential Tsunamigenic Zones



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 M 7. 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)

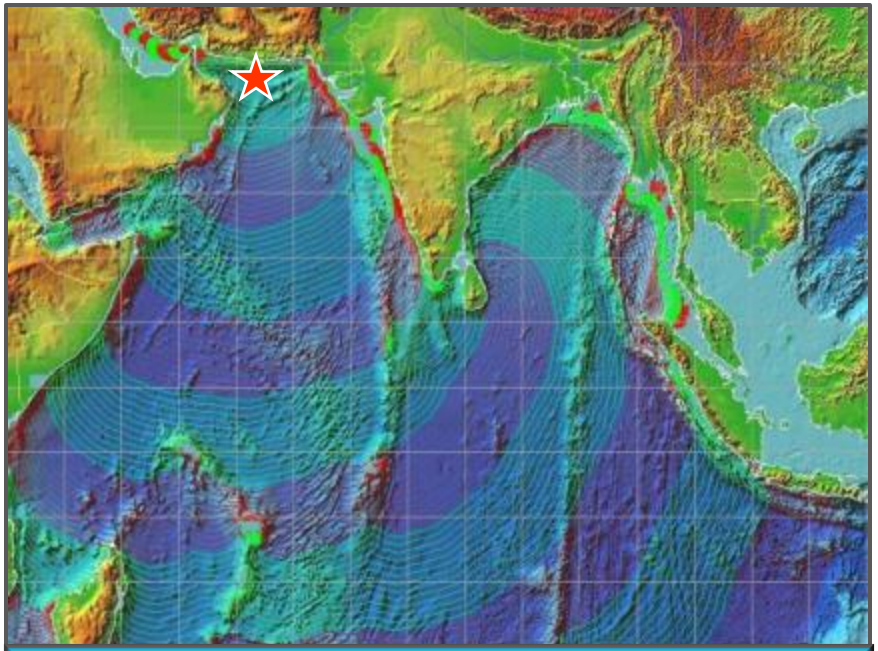
Landslides, Volcanoes & Meteor Impacts can also generate Tsunamis

Tsunami Risk Assessment

Tsunami Travel Times & Response time

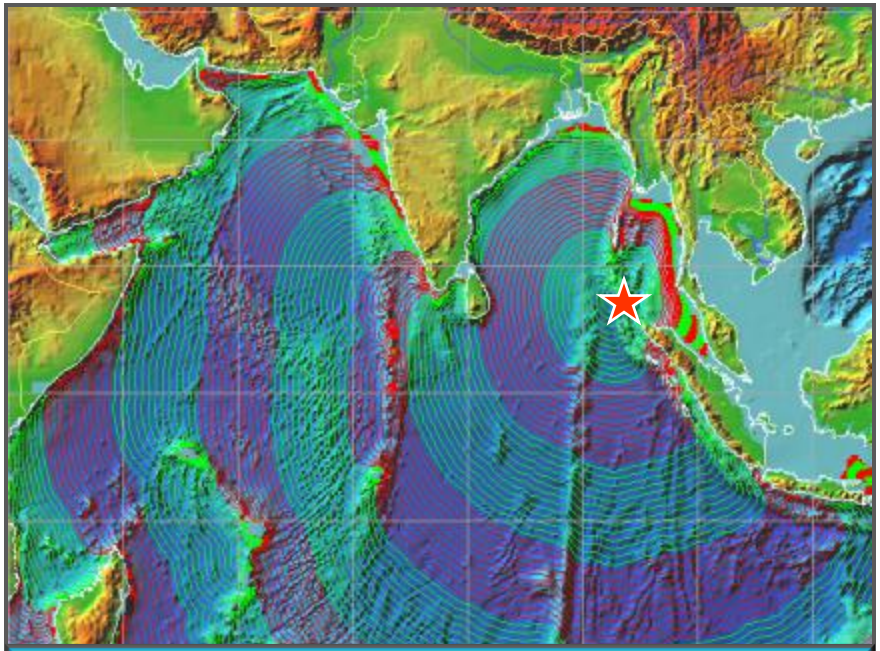
- Depending upon the Earthquake location (Makran/Andaman-Sumatra Subduction Zone) the response time for evacuation of coastal population could range between 10 min to few hours.
- As Andaman & Nicobar Islands situated right on subduction zone the available response time is very short

Makran Subduction Zone



- **If Earthquake occurs at Makran Subduction zone, Travel Time to nearest Indian Coast (Gujarat) are 2 to 3 hrs**

Andaman-Sumatra Subduction Zone

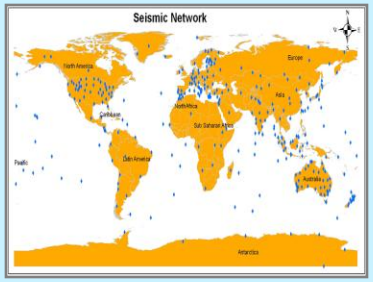


- **If Earthquake happens at Nicobar Islands , travel times to nearest coast (A&N Islands) are 20 to 30 min**
- **For Indian main land travel times are 2 to 3 hrs**

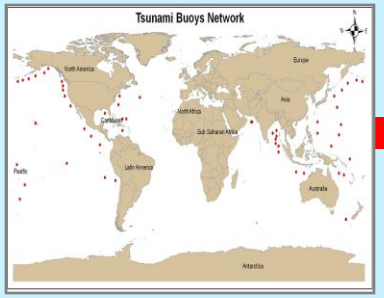
Tsunami Early Warning System

Detection → Warnings → Dissemination

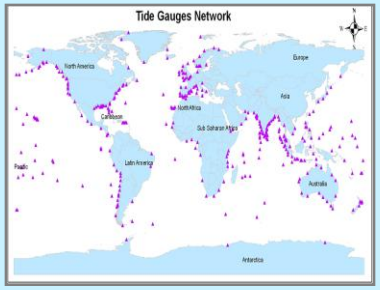
Participating Institutions
IMD, NIOT, ICMAM, SOI, NRSC, INCOIS
MHA, NDMA, Coastal States



Seismic Network



BPR Network



Tide gauge Network

Observation Networks

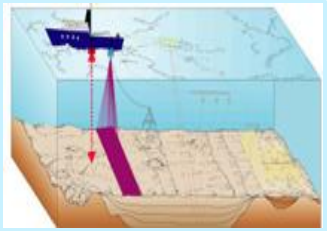

VSAT

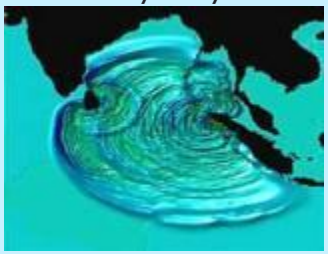

INSAT

GPRS


INMARSAT

Communications


Bathymetry


Tsunami Modelling


Topography


Costal Vulnerability

Modelling

COMMS Tests
Tsunami Drills
Trainings
Publicity Material


Capacity Building


R & D

Paleo-tsunami Modelling
GNSS Data Use

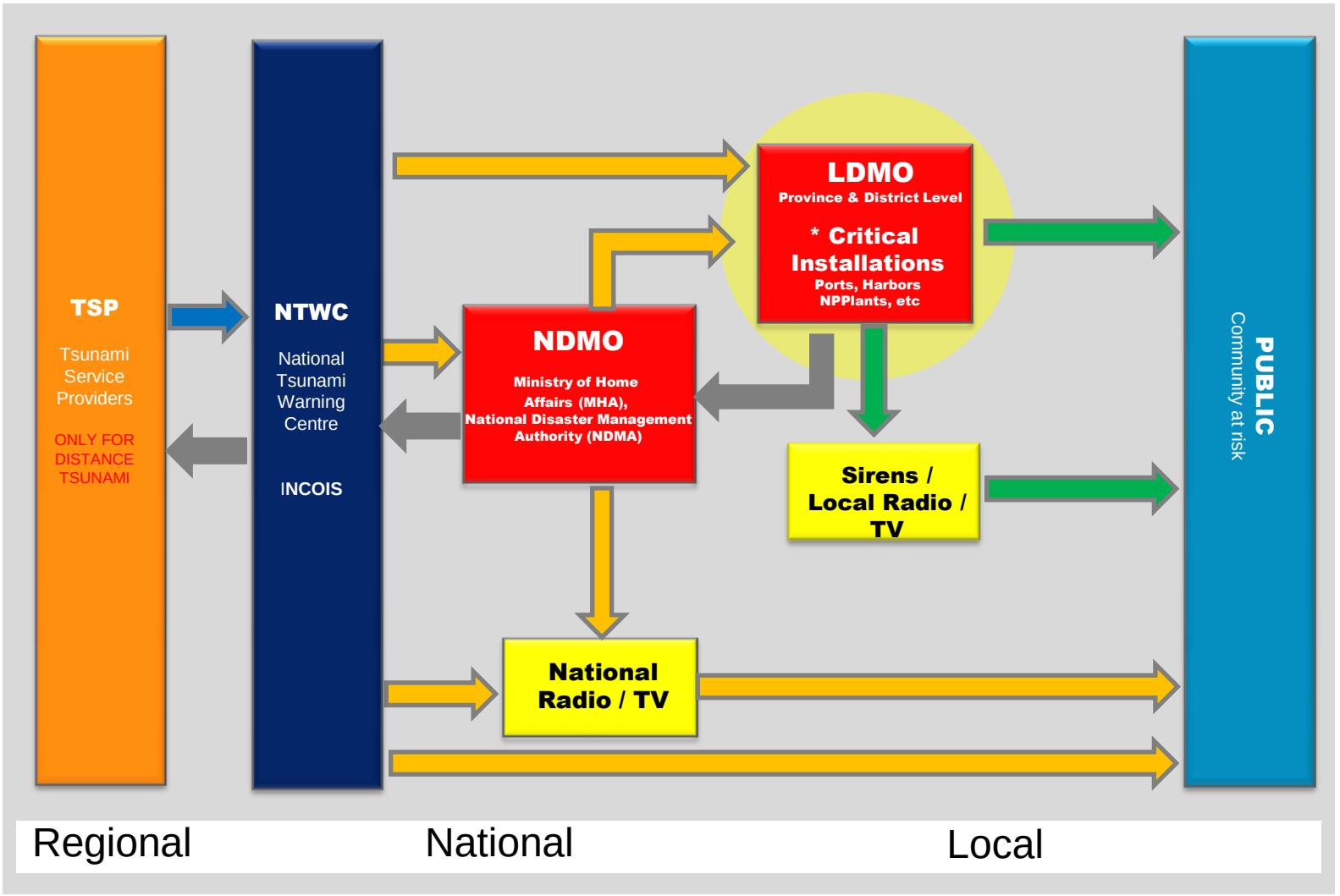
Last mile connectivity

India Tsunami Warning Chain

10Min

20 Min

Timeline (Minutes after EQ)



Information

Warning

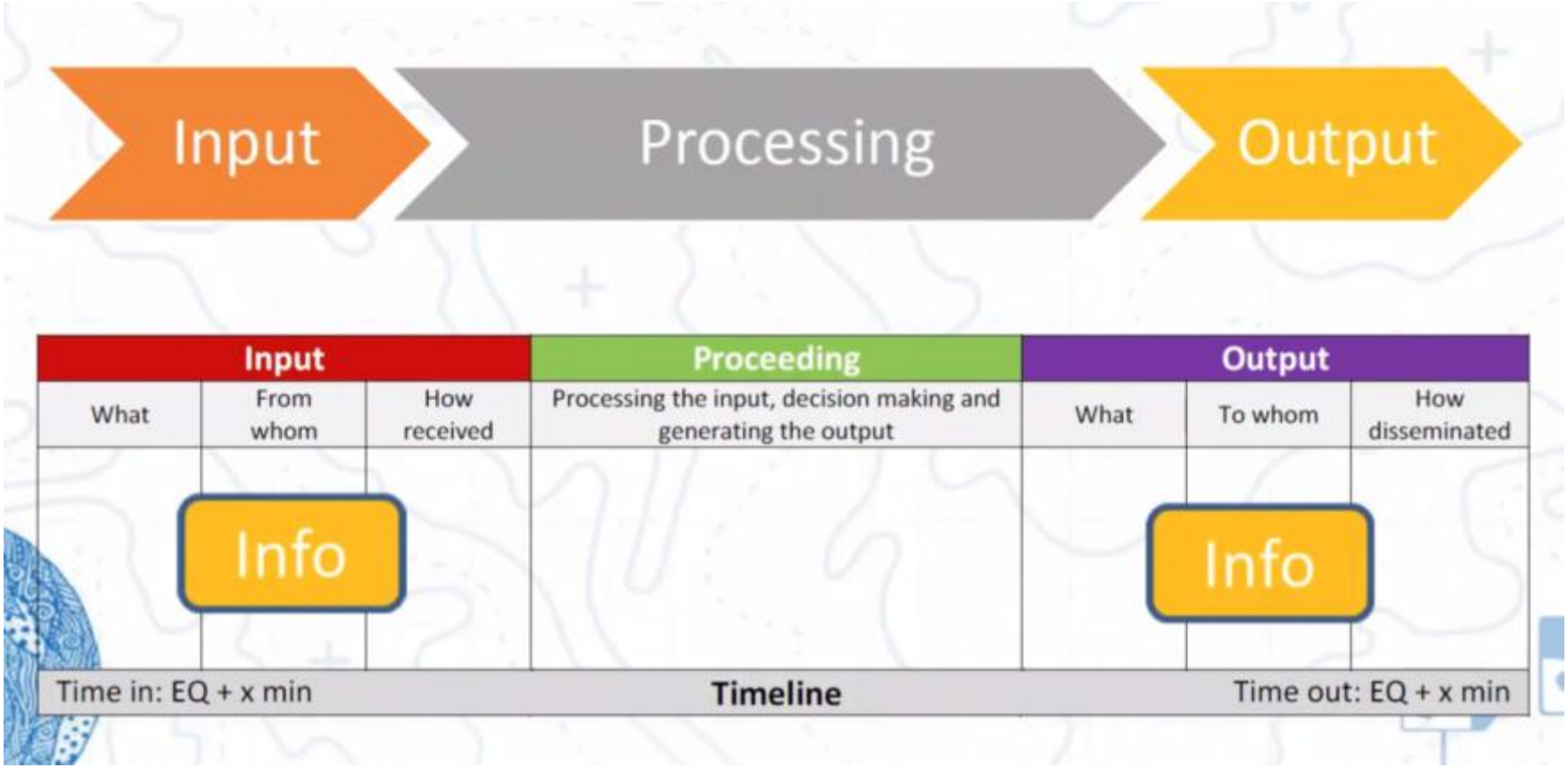
Warning and Advice

Official call for evacuation

Feed Back

*** Critical Installations evacuation call only at Institution level**

Media SOP in Warning Chain



Tsunami Early Warning Centre




24 x 7 operations

Heterogeneous Real-Time Data from a variety of Sensors

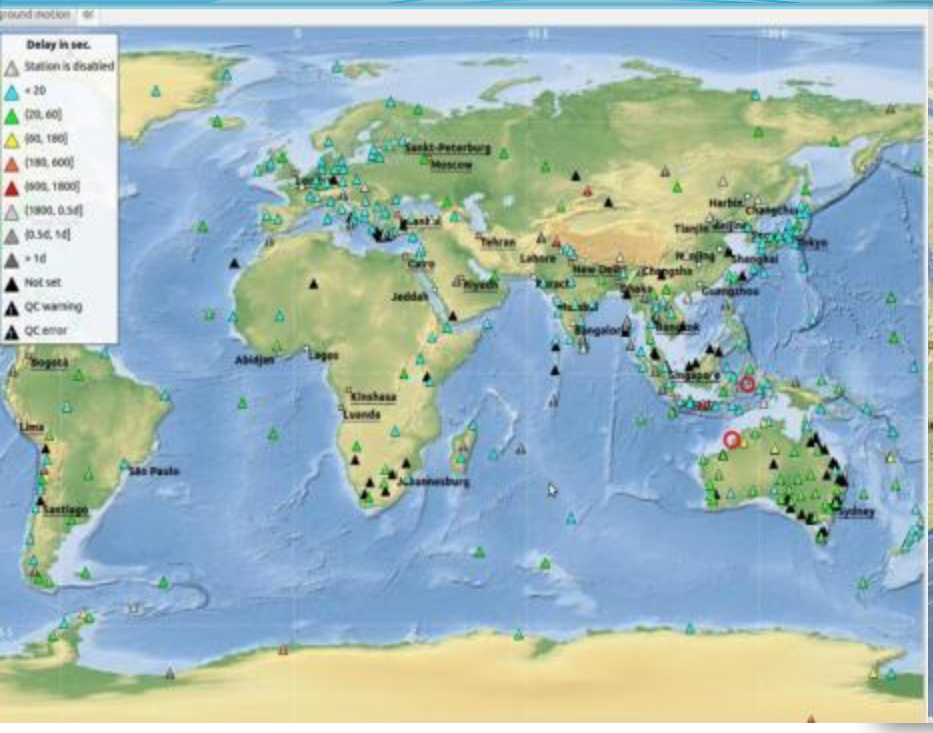
•Data Acquisition, Display, Processing, Archival

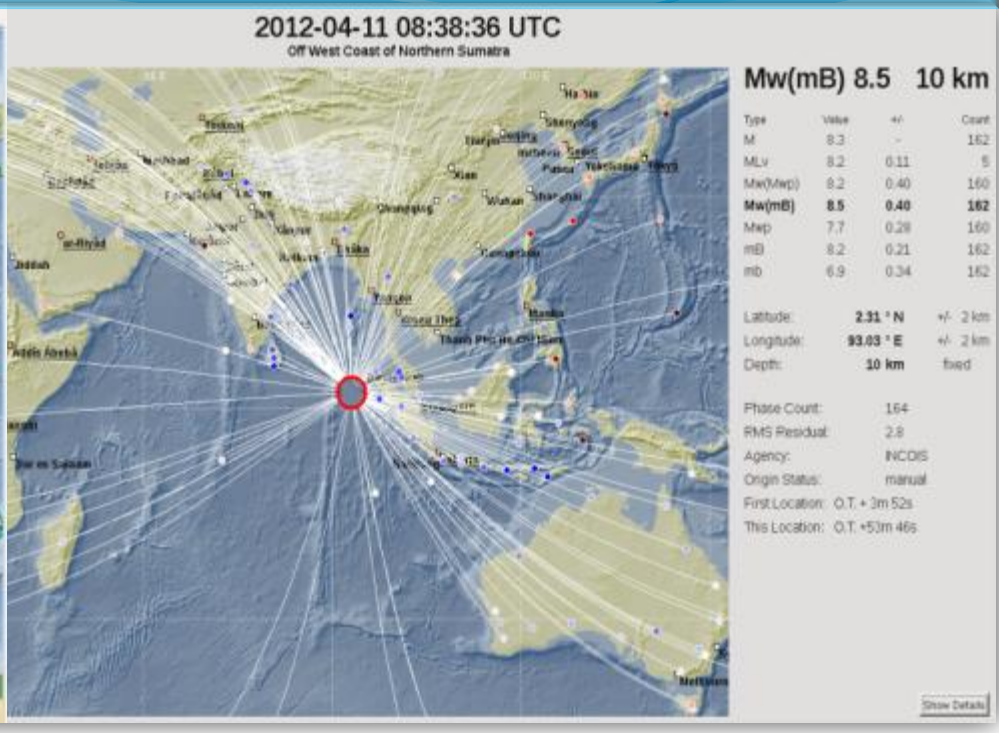
Numerical Modeling and Decision Support

Generation of Advisories and Dissemination

•Mission Critical - Infrastructure to be highly available

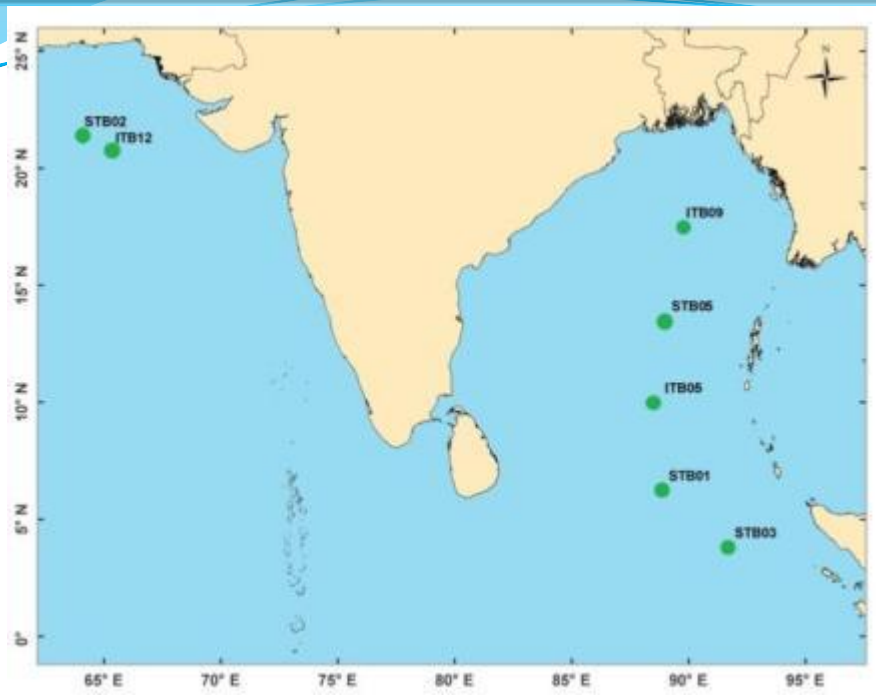
Seismic Network



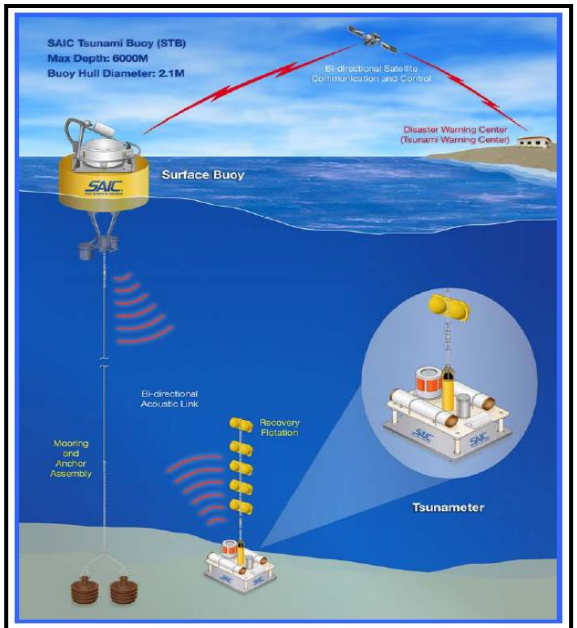


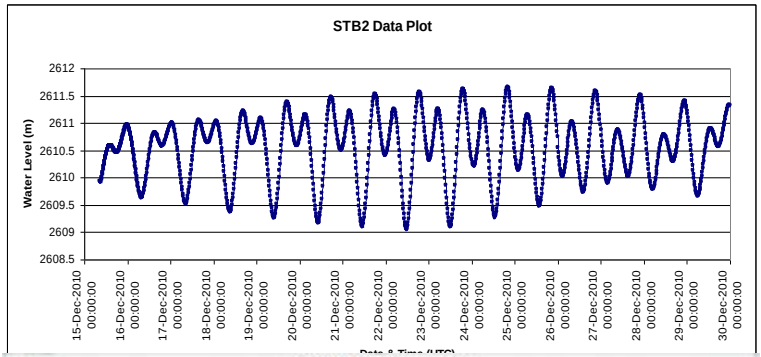
- Real-time Seismic Monitoring Network of 27 broadband seismic stations
- Seismic data from International stations (GEOFON / IRIS)
- Data Acquisition, Processing, Auto location and Archival using Response SeisComP 3.0 and Response Hydra 1.47
- Autolocation within 5 to 12 min of occurrence of an earthquake
- EQ parameters matching well with those put out by USGS / GEOFON
- 10 More stations have been installed and VSAT connectivity for real-time data reception is under progress

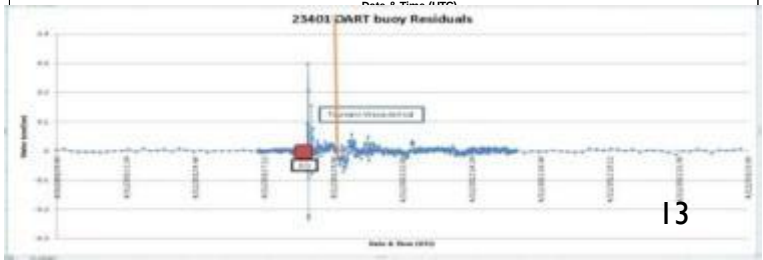
Indian Tsunami Buoy Network



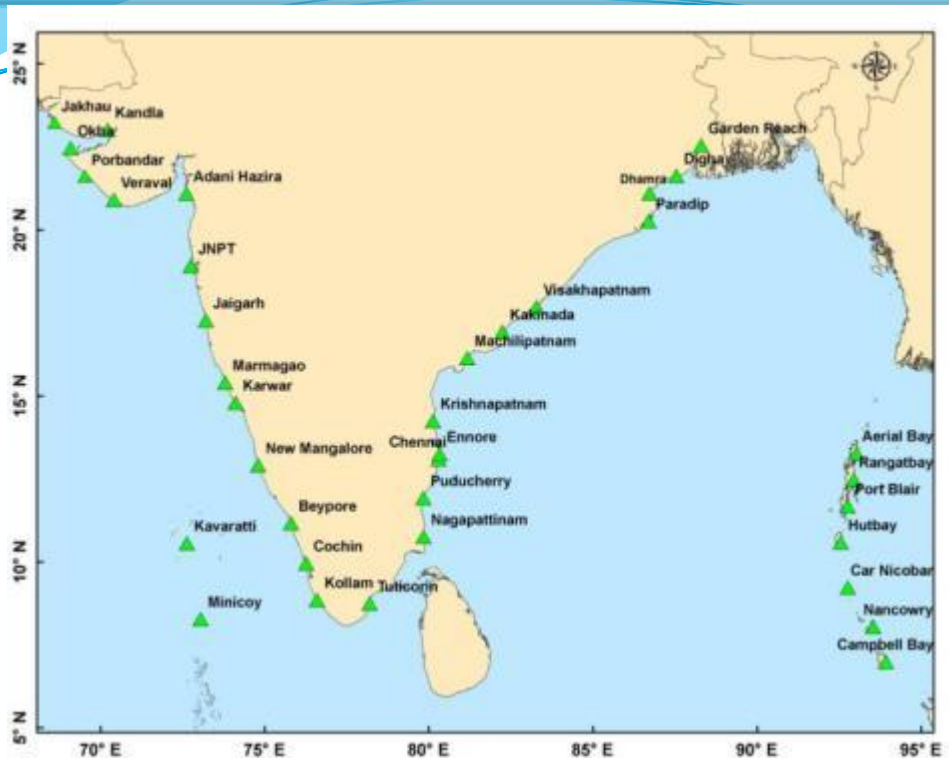
- **Indian Tsunami Buoys Network**
  - Real-time Network of 7 tsunami buoys in the Indian Ocean
  - Out of the total 7 stations, 4 occupied by STBs and the remaining 3 stations by NIOT Buoys
  - Data is being received in real-time via acoustic & Satellite links
  - Seven tsunami buoys (STB01, STB02, STB03, STB05, ITB05, ITB09, and ITB12) data sharing to NDBC/NOAA



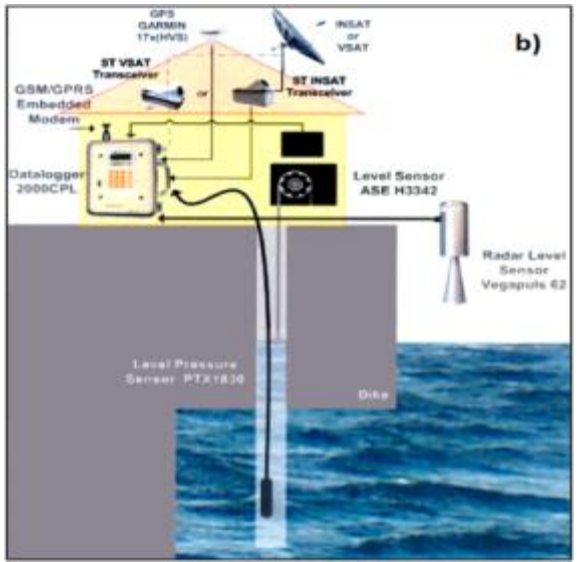


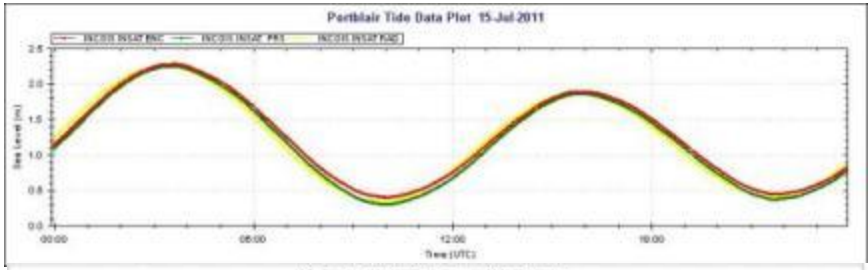


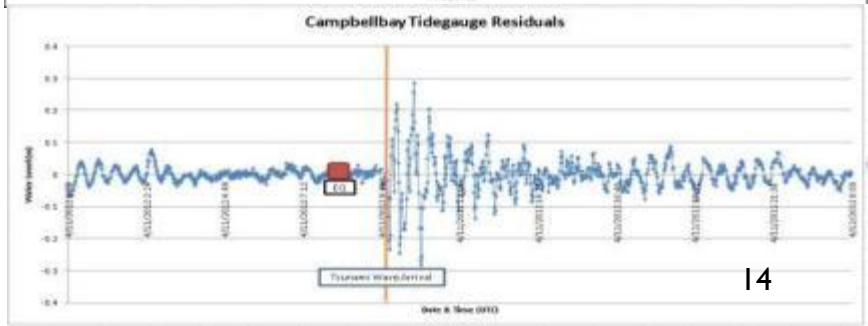
Indian Tide gauge Network



- **Indian Tide gauge Network**
  - INCOIS installed 36 tide gauge station along Indian coast line and Islands
  - Communication through INSAT/GPRS/FTP
  - Eight Tide gauges data (Chennai, Kochi, Nancowry, Portblair, Visakhapatnam, Minicoy, Marmagao and Veraval) to IOC Sea level stations monitoring facility

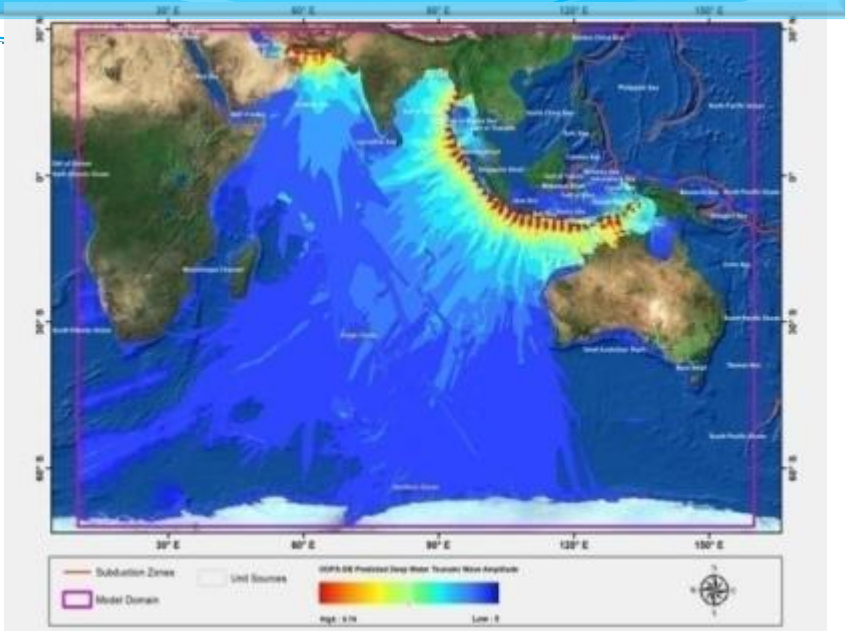






Operational Tsunami Forecast

- Sunda and Makaran Tsunamigenic Zones with extended New Indian Ocean Model Domain with 3.2 million grids
  - **A**pplication of **B**asic geophysical equations for **C**alculations and generation **of O**pen **O**cean **P**ropagation **S**cenario **D**ata**B**ase (ABC of OOPSDB).
    - ✓ The Global geophysical relations for Seismic moment and Fault parameters in Global subduction zones (Papazoches etal 2004)
    - ✓ The theory of Seismic moment and Moment Magnitude definition (Scholz 2002) Mw=((Log10(Mo))-9.1)*(2/3); Mo = μ x L x W x D
  - Large Database of open ocean propagation scenarios (oops db) covering both Tsunamigenic Zones generated using **TUNAMI FF** in spherical coordinates (https://github.com/tunamiff2011cuda/tunamiff2011) in size **35 TB**
  - Depending on EQ's location and magnitude basic unit source open ocean propagation scenario database scenarios are either scaled up or down - **ABC of OOPSDB**
  - Expected Wave Arrival & Amplitude forecasts at 4380 Costal Forecast Points (CFPs) in the Indian Ocean Coast;



Model Output Parameters

- **T1** (Time of arrival of the minimum detectable positive amplitude wave)
- **T2** (Time of first exceedance of the Threat Threshold)
- **T3** (Time of arrival of max_beach)
- **T4** (Time when the last exceedance of the Threat Threshold is forecast)
- **max_beach** (Maximum Positive wave amplitude at the shore line)
- **max_deep** (Maximum positive wave amplitude in deep water in each coastal zone)
- **Depth** (Depth of the water where the max_deep occurs)

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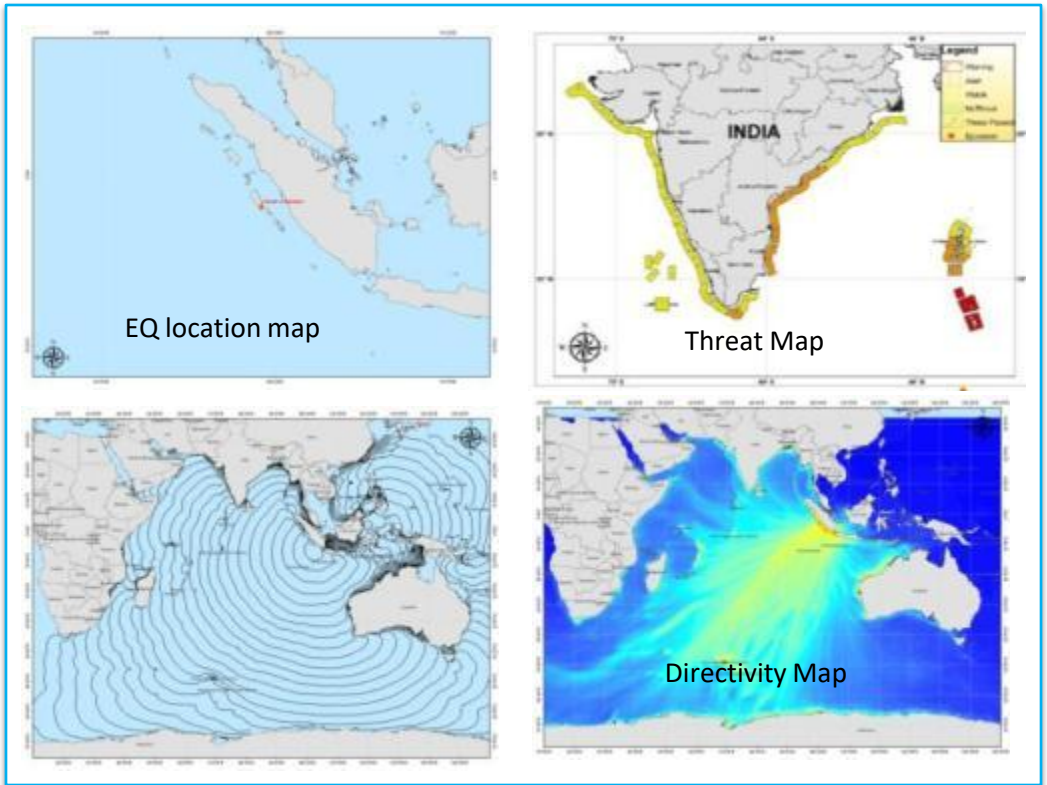

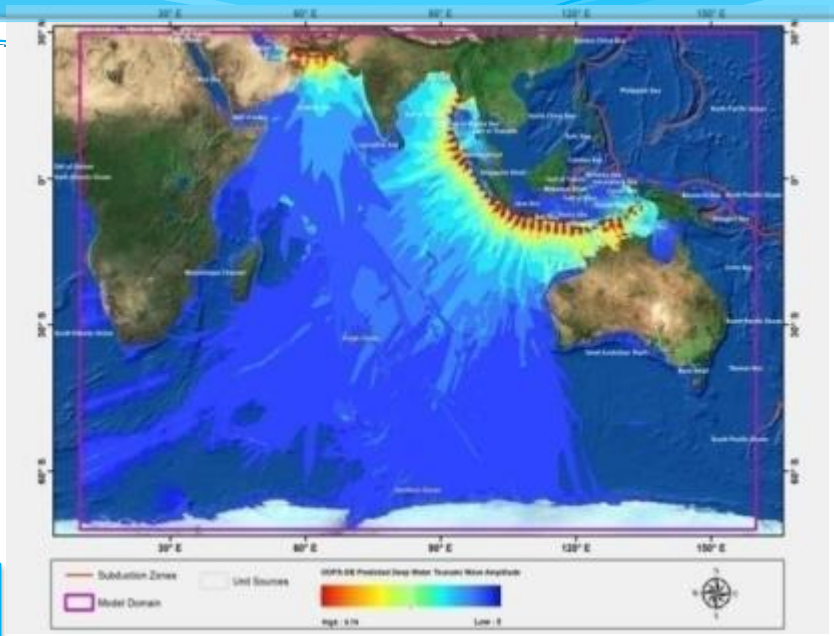

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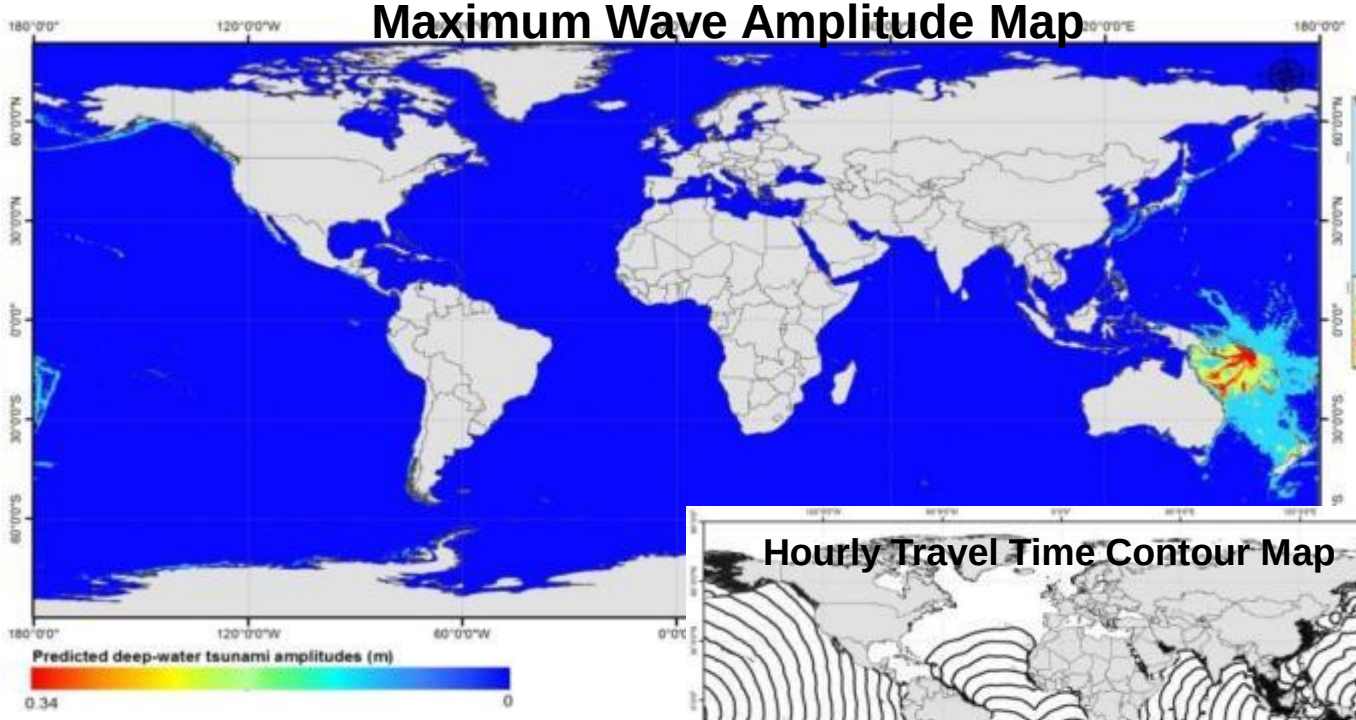
Operational Tsunami Forecast for Global

Real time Model Launch for Global Earthquakes(RML GE) of Magnitude M >=8.0

- Tsunami Model - Numerical simulation of Far-Field tsunamis using TUNAMI-FF (Tohoku University's Numerical Analysis Model for Investigation of Far-Field tsunamis) made operational with CUDA GPU computations. Currently 15 to 20 min of computational time for a single simulation on HPC with CPU parallelisation of OMP. (TUNAMI FF User Manual: https://mega.nz/#F!oqhVVA4a!VPdVav4bQQVsJTuYbMIOFw)
- TUNAMI-FF simulates all stages of a tsunami from the origin and the propagation (in the linear approximation of the long-wave theory in spherical coordinates) in the ocean to the arrival at the coast and wave amplitudes at beach (~ 1 m water depth) by application of Greens' law

Maximum Wave Amplitude Map



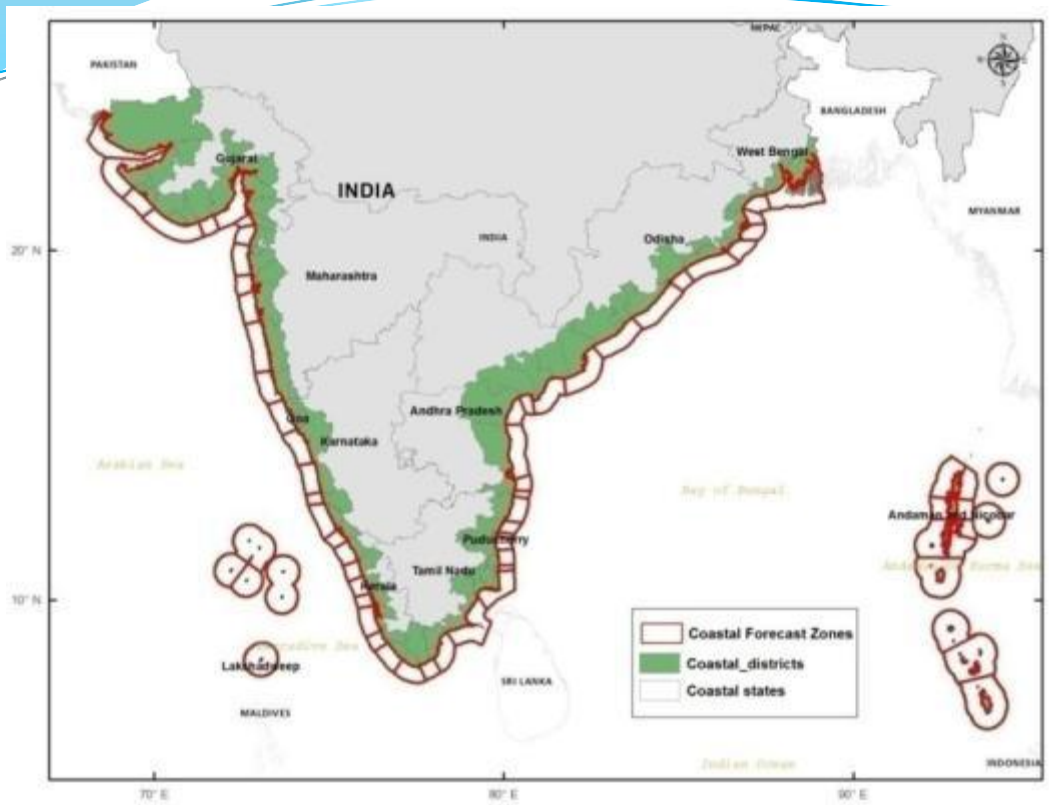
National Threat Map

Regional Threat Map

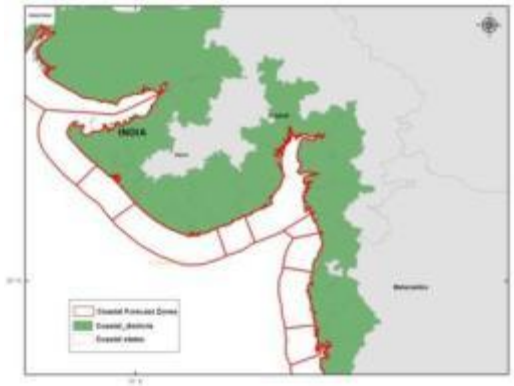
Hourly Travel Time Contour Map

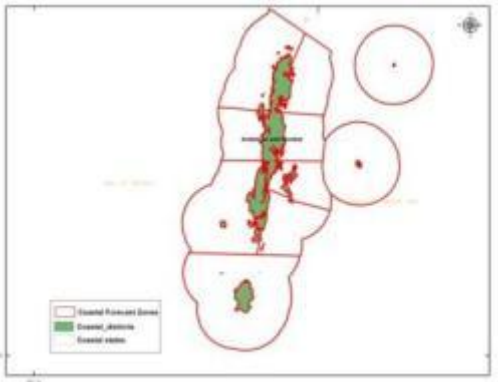
User Manual: https://github.com/tunamiff2011cuda/tunamiff2011
Source Code: https://mega.nz/#F!oqhVVA4a!VPdVav4bQQVsJTuYbMIOFw

Coastal Forecast Zones (CFZs)



- ❖The spatial dataset of CFZs are generated using GIS
- ❖Each CFZ is represented by a buffer of 50 Km in width (across the coast and starts from caostline
- ❖ The CFZs are reappropriated to match one or a group of coastal districts to enable easy use at the local administrative level
- ❖In case of smaller districts & gulfs, a group of districts have been clubbed into one coastal forecast zone.
- ❖For Islands circular buffer zones of 50 km generated





Fields	Details
District/Region Name	Name of the District
State/Territory	Name of the State/Territory
EWA	Expected Wave Arrival in IST
MWH	Maximum Wave Height in meters
Status	Areas under Warning /Alert/Watch

National Threat level Info and Mapped actions

Magnitude (Mw)	Qualitative Tsunami Evaluation (Based on Earthquake Information)
Mw ≥ 6.5	Possibility of triggering of potential tsunamis

WARNING

Quantitative Tsunami Evaluation (Based on Pre-run Model Scenarios)

ETA ≤ 60 mins		ETA > 60 mins	
EWA (M)	**Threat Status**	**EWA (M)**	**Threat Status**
> 2	WARNING	> 2	ALERT
0.5 to 2	ALERT	0.5 to 2	WATCH
0.2 to 0.5	WATCH	0.2 to 0.5	WATCH

ALERT

Quantitative Tsunami Evaluation (Upon Confirmation of Tsunami generation & Based on Pre-run Model Scenarios)

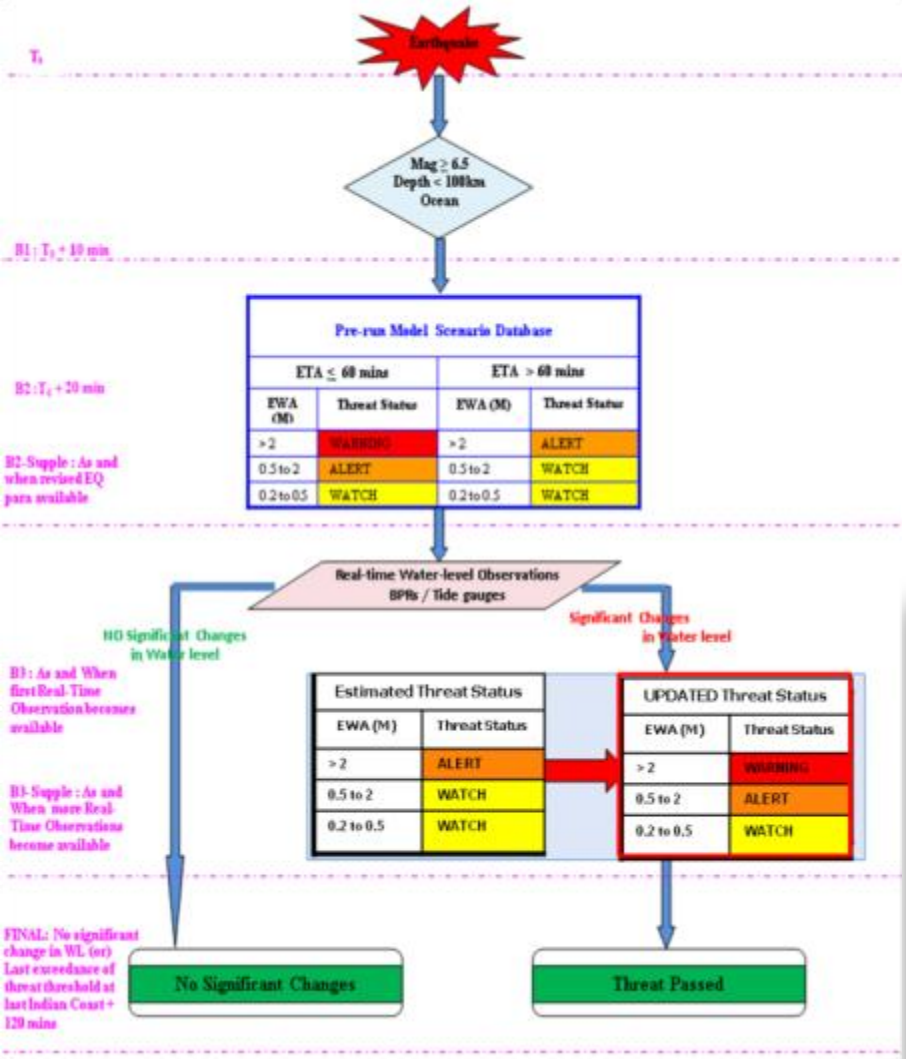
EWA (M)	Threat Status
> 2	WARNING
0.5 to 2	ALERT
0.2 to 0.5	WATCH

WATCH

THREAT PASSED

ETA: Estimated Tsunami Arrival times ; EWA – Estimated Tsunami Wave Amplitudes (Max_beach)

Standard Operating Procedure

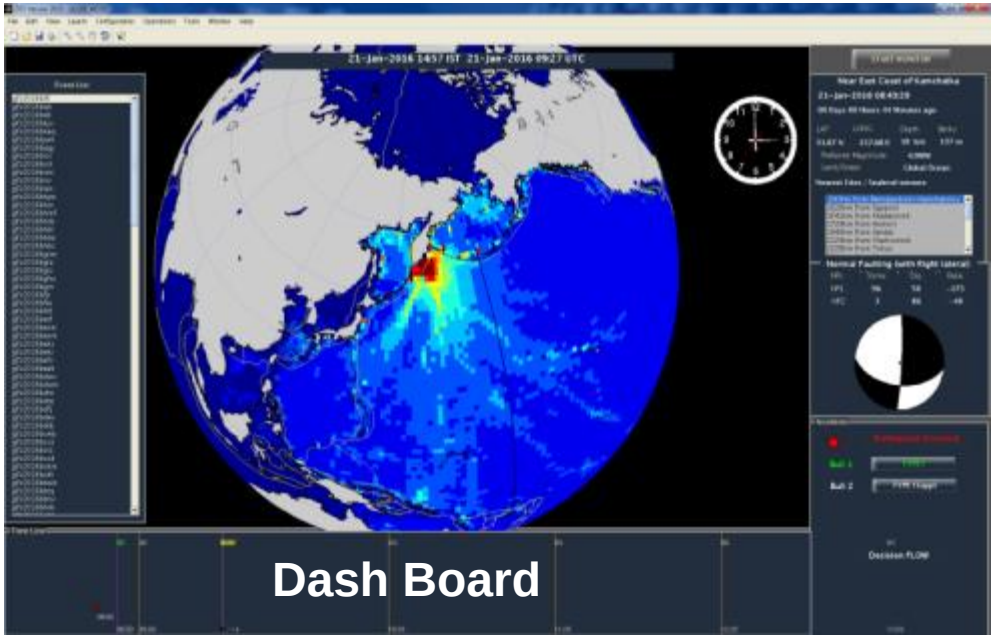


- The Indian Tsunami Early Warning Centre (ITEWC) services for an event commence whenever an earthquake is recorded with M ≥ 6.5 within the Indian Ocean and M ≥ 8.0 outside of the Indian Ocean
- Uniquely designed SOP for generation of timely and accurate tsunami bulletins to handle both near-source and far-source coastal regions
- Based on proximity of a coastal zone to the tsunamigenic earthquake source regions and Expected Wave Heights from Models
- 4 Threat Levels corresponding to different public responses and mapped to NDMA guidelines

SOP – Public Response and Threat Levels in Bulletins

Threat Status	Action to be taken	Dissemination to
WARNING	Public should be advised to move inland towards higher grounds. Vessels should move into deep Ocean	MoES, MHA, NDMA, NCMC, NDRF Battalions, SEOC, DEOC, Public, Media
ALERT	Public should be advised to avoid beaches and low-lying coastal areas. Vessels should move into deep Ocean	MoES, MHA, NDMA, NCMC, NDRF Battalions, SEOC, DEOC, Public, Media
WATCH	No immediate action is required	MoES, MHA, NDMA, NCMC, NDRF Battalions, SEOC, DEOC, Media
THREAT PASSED	All clear determination to be made by the local authorities	MoES, MHA, NDMA, NCMC, NDRF Battalions, SEOC, DEOC, Public, Media

Tsunami Decision Support System



➢Decision Support System 2016:

Dash Board

✓Captures real-time earthquake information from multiple sources and display earthquake location with focal mechanism

Situation Analysis

✓Access to **Open Ocean Propagation Scenario Database** (OOPS DB) in optimized way

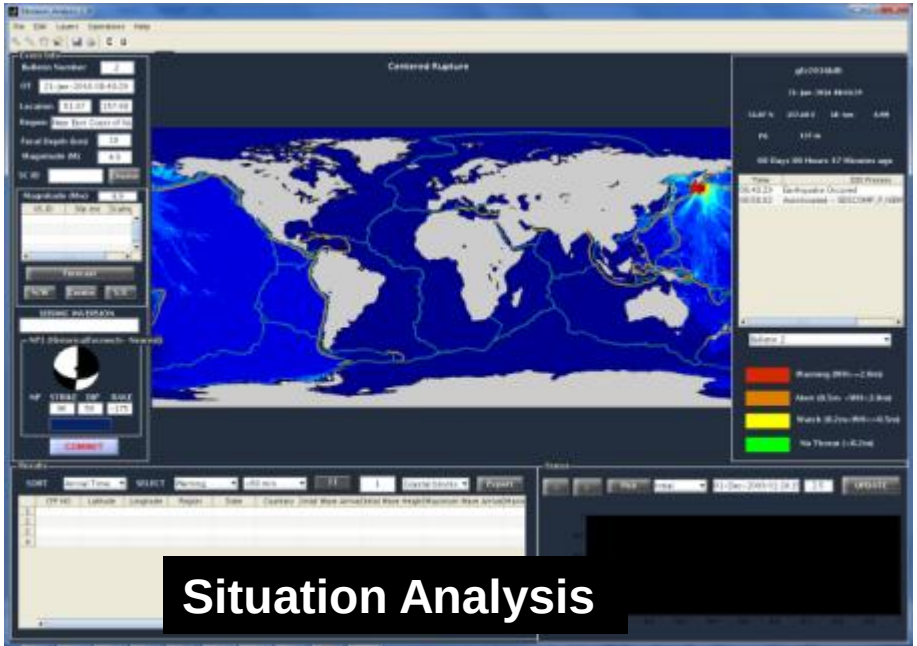
✓Near **real time Tsunami Model launch** with available Focal Mechanism for **Open Ocean Propagation** results

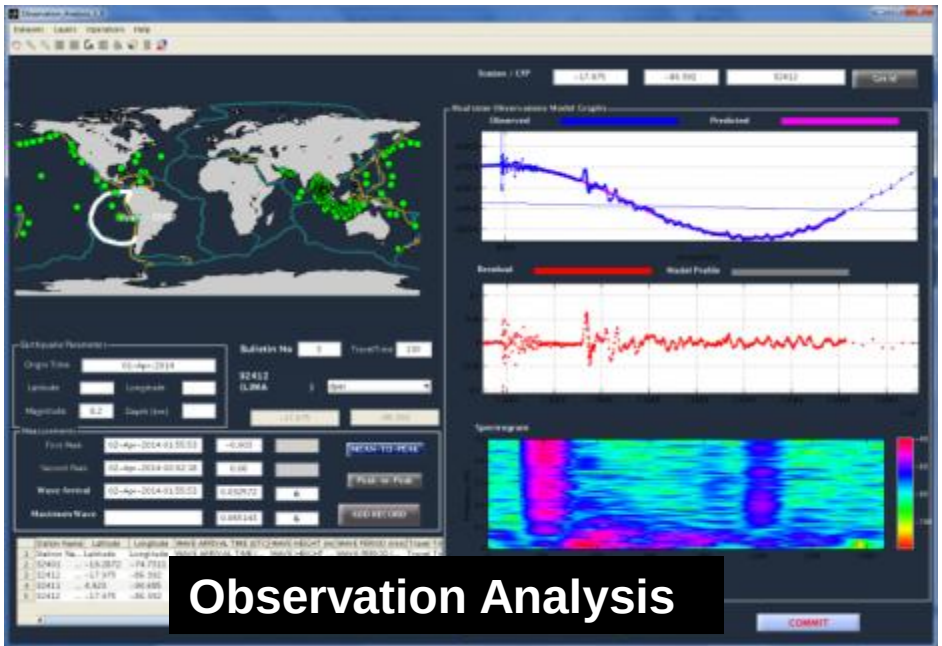
Observation Analysis

✓**Real-time access** to all National and **International Sea level stations** data

✓Real-time calculations of residual data

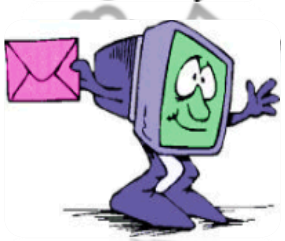
✓**Sea level inversion** to get slip distribution of tsunamigenic source





Product Formats & Dissemination

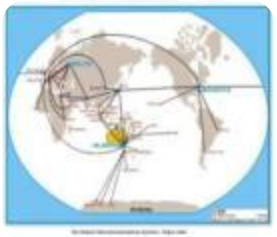
Fax



Email

SMS

Web



GTS

- **Notification Messages** are issued in **text** format
- **Bulletins** are generated in both text and **HTML formats** on the websites
- **Graphics** are generated in jpg or png format on the websites
- **Spatial** data is also available in dbf format on the websites

International Level

All 25 Indian ocean rim countries

National Level

MHA, NDMA, MoES, NDRF Head quarters, IMD & CWC

State Level

Principal Secretaries (Revenue) of Andaman & Nicobar Islands, Andhra Pradesh, Gujarat, Goa, Karnataka, Kerala, Maharashtra, Orissa, Tamilnadu, West Bengal, Lakshadweep and Puducherry

District Level

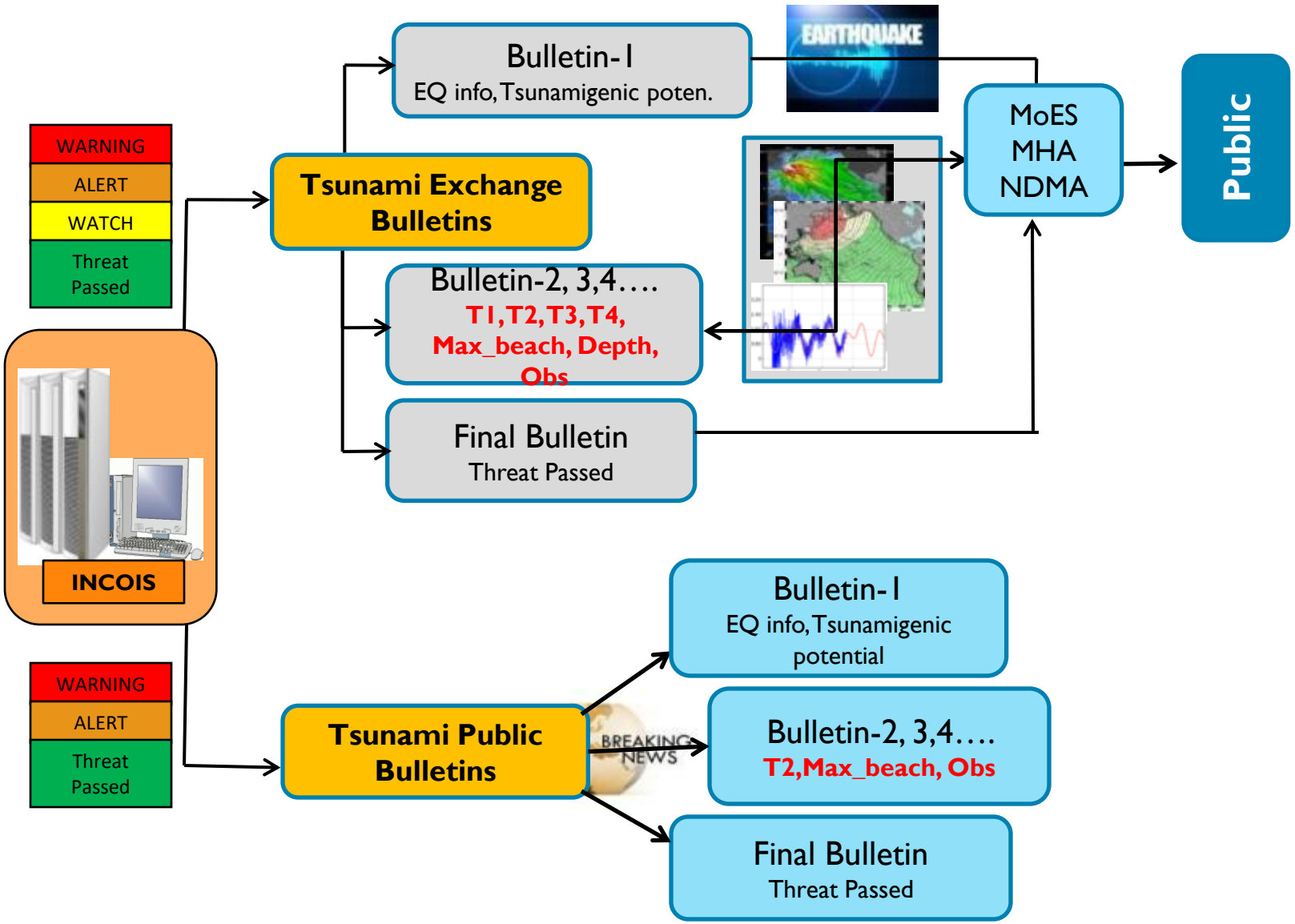
DROs of Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasham, and S.P.S Nellore

Institutional

1-10 NDRF Battalions, ALL control rooms of A&N Islands, HQWNC, HQENC, HQANC, HQSNC, NOIC Tamilnadu, Gujarat, West Bengal, NPCIL, Mumbai, Madras Atomic Power Station, Tarapur Atomic Power Station (1&2, 3&4), Kudankulam Atomic Power Unit, SHAR, MRCC, Coast Guards, Port Officers, Coastal Industries (Reliance) Media & Public subscriptions

Bulletin Types & Content

(i) Tsunami Exchange and (ii) Tsunami Public



Bulletins & Timelines

Bulletin	Information	Time of issue (Earthquake Origin time as T_0) minutes
Bulletin-1 **(Tsunami genesis)**	Preliminary EQ Parameters and LAND / NO THREAT Information based on EQ Location, Magnitude & Depth.	**T_0 + 10**
	Preliminary EQ Parameters and **Qualitative Tsunamigenic potential** based on EQ Location, Magnitude & Depth	
Bulletin-2 **(Potential Threat)**	Preliminary EQ Parameters and NO THREAT Information from Model Scenarios	**T_0 + 20**
	Preliminary EQ Parameters and **Quantitative Tsunami Threat** (**WARNING / ALERT / WATCH**) Information from Model Scenarios	
Bulletin-2 Supplementary - xx	Revised EQ Parameters and Quantitative Tsunami Threat (WARNING / ALERT / WATCH) Information from Model Scenarios - If revised EQ Parameters are available much before the real-time water level observations are reported.	as and when revised earthquake parameters are available or after Earthquake Elapsed Time + 60 mins
Bulletin-3 **(Confirmed Threat)**	Revised EQ Parameters and **Quantitative Tsunami Threat** (WARNING / ALERT / WATCH) Information from Model Scenarios and **Real-time water level observations** indicating Tsunami Generation.	**as and when the first real-time water level observation is available**
Bulletin-3 Supplementary – xx	Revised EQ Parameters and Quantitative Tsunami Threat (WARNING / ALERT / WATCH) Information from Model Scenarios and Real-time water level observations indicating Tsunami Generation Threat PASSED information for individual Zones	**Hourly update / as and when the subsequent real-time water level observations are available**
Bulletin-4 **(Final)**	Issued when water levels from multiple gauges confirm that no significant tsunami was generated.	
	120 minutes after a significant tsunami passes the last Indian threat zone; **Final bulletin** and **no further bulletins will be issued** unless additional information becomes available	**Issued 2 hours after last arrival time in the Indian coast of a wave over 0.5m:**

Tsunami Events Webpage (WWW.incois.gov.in)

ESSO - Indian National Centre for Ocean Information Services

(An Autonomous Body under the Ministry of Earth Sciences, Govt. of India)

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FLASH UPDATES :

*** Latest Earthquake/Tsunami Information Bulletin ***

Our Mission

To provide ocean information and advisory services to the society, industry, government and scientific community through sustained ocean observations and constant improvements through systematic and focused research.

Our Chairman

Our Director

Employee's Corner

Services

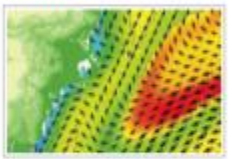
ISO 9001:2008 Certified QMS (PFZ, OSF and TEWS only)

POTENTIAL FISHING ZONES

Potential fishing zones in the seas..

Read more..

OCEAN STATE FORECAST



Integrated Indian Ocean Forecast System.

Read more..

TSUNAMI EARLY WARNINGS

Minimizing loss due to oceanographic ...

Read more..

Latest News

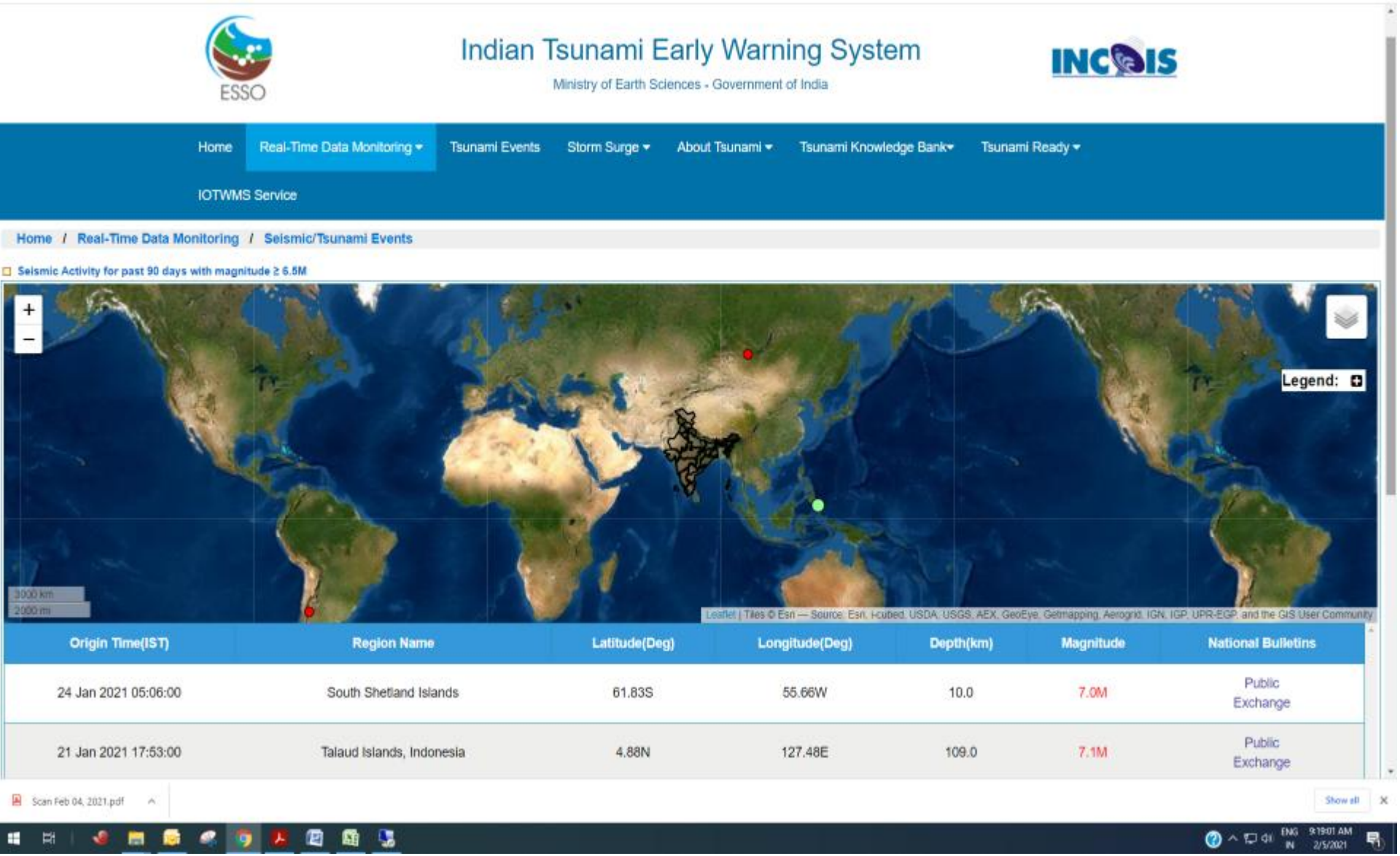
List of Selected Candidates for the ITCOocean-Training Course on "Fish-catch Time-Series Forecasting with R" during 24 - 28, September 2018 NEW

Awards

National Award for Excellence 2018 by MoES NEW

Young Researcher Award 2018 by MoES NEW

Tsunami events Webpage



Origin Time(IST)	Region Name	Latitude(Deg)	Longitude(Deg)	Depth(km)	Magnitude	National Bulletins
24 Jan 2021 05:06:00	South Shetland Islands	61.83S	55.66W	10.0	7.0M	Public Exchange
21 Jan 2021 17:53:00	Talaud Islands, Indonesia	4.88N	127.48E	109.0	7.1M	Public Exchange

https://tsunami.incois.gov.in/TEWS/

Bulletin-I : Tsunamigenisis

TSUNAMI BULLETIN NUMBER 1
INDIAN TSUNAMI EARLY WARNING CENTRE INCOIS HYDERABAD (ITEWC)

ISSUED AT: 0835 IST Wednesday 05 September 2018

... EARTHQUAKE BULLETIN ...

Location Map | Information

EARTHQUAKE INFORMATION

Magnitude (Preferred) :	8.5 M
Depth:	10 km
Date :	05 Sep 2018
Origin Time:	0830 IST
Latitude:	3.3 N
Longitude:	96 E
Location:	Northern Sumatra, Indonesia

EVALUATION

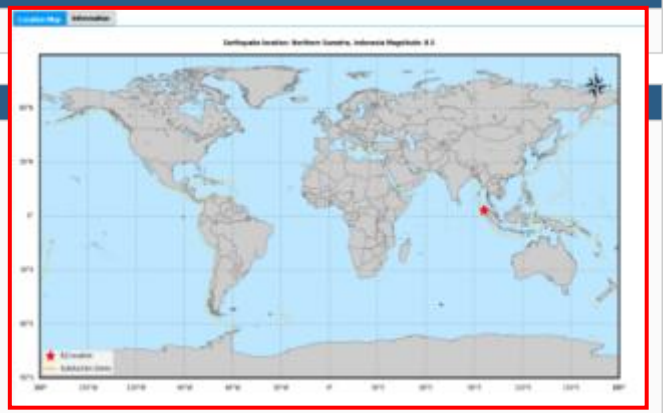
Earthquakes of this size sometimes have potential to generate tsunamis. However, so far there is no confirmation about the triggering of a tsunami. An investigation is under way to determine if a tsunami has been triggered. ITEWC INCOIS will monitor sea level gauges near epicenter and report if any tsunami wave activity has occurred.

ADVICE

This is only a Heads-up message to the national/state/local authorities and disaster management offices. No immediate public action is required. This Bulletin is being issued as an advice. Only national/state/local authorities and disaster management offices have the authority to make decisions regarding the official threat status in their coastal area and any action to be taken in response.

UPDATES

Additional bulletins will be issued by ITEWC INCOIS for this event as more information becomes available.



CONTACT INFORMATION

Indian Tsunami Early Warning Centre (ITEWC)

Indian National Centre for Ocean Information Services (INCOIS)

Address:"Ocean Valley", Pragathi Nagar (BO), Nizampet (SO),

Hyderabad - 500 090, India.

Tel: 91-40-23895011

Fax: 91-40-23895012

Email: tsunami@incois.gov.in

Website: www.incois.gov.in

Bulletin-II: Potential Tsunami Threat / No Threat

Indian Tsunami Early Warning Centre
Ministry of Earth Sciences,Government of India

Print KML TXT DBF

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TSUNAMI BULLETIN NUMBER 2

INDIAN TSUNAMI EARLY WARNING CENTRE INCOIS HYDERABAD (ITEWC)

ISSUED AT: 0845 IST Wednesday 05 September 2018

*** TEST TEST TEST TEST TEST TEST TEST TEST TEST ***
*** THIS IS NOT A REAL TSUNAMI EVENT ***

...POTENTIAL THREAT TO INDIAN COAST...

Threat Map | Tsunami Information | Directivity Map | Travel Times map

EARTHQUAKE INFORMATION (Revised)

Magnitude (Preferred) :	8.8 M
Depth:	10 km
Date :	05 Sep 2018
Origin Time:	0830 IST
Latitude:	3.3 N
Longitude:	96 E
Location:	Northern Sumatra, Indonesia

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. ITEWC 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.

TSUNAMI THREAT FOR THE INDIAN OCEAN

The list below shows the forecast arrival time (T) of the first wave estimated to exceed 0.2 m amplitude at the beach in each zone, and the amplitude of the maximum beach wave predicted for the zone. Zones where the estimated wave amplitudes are less than 0.2m at the beach are not shown.

The list is grouped by State (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 in tsunami wave action, CANCELLATION of national warnings and ALL CLEAR determination must be made by national/state/local authorities.

Contd…

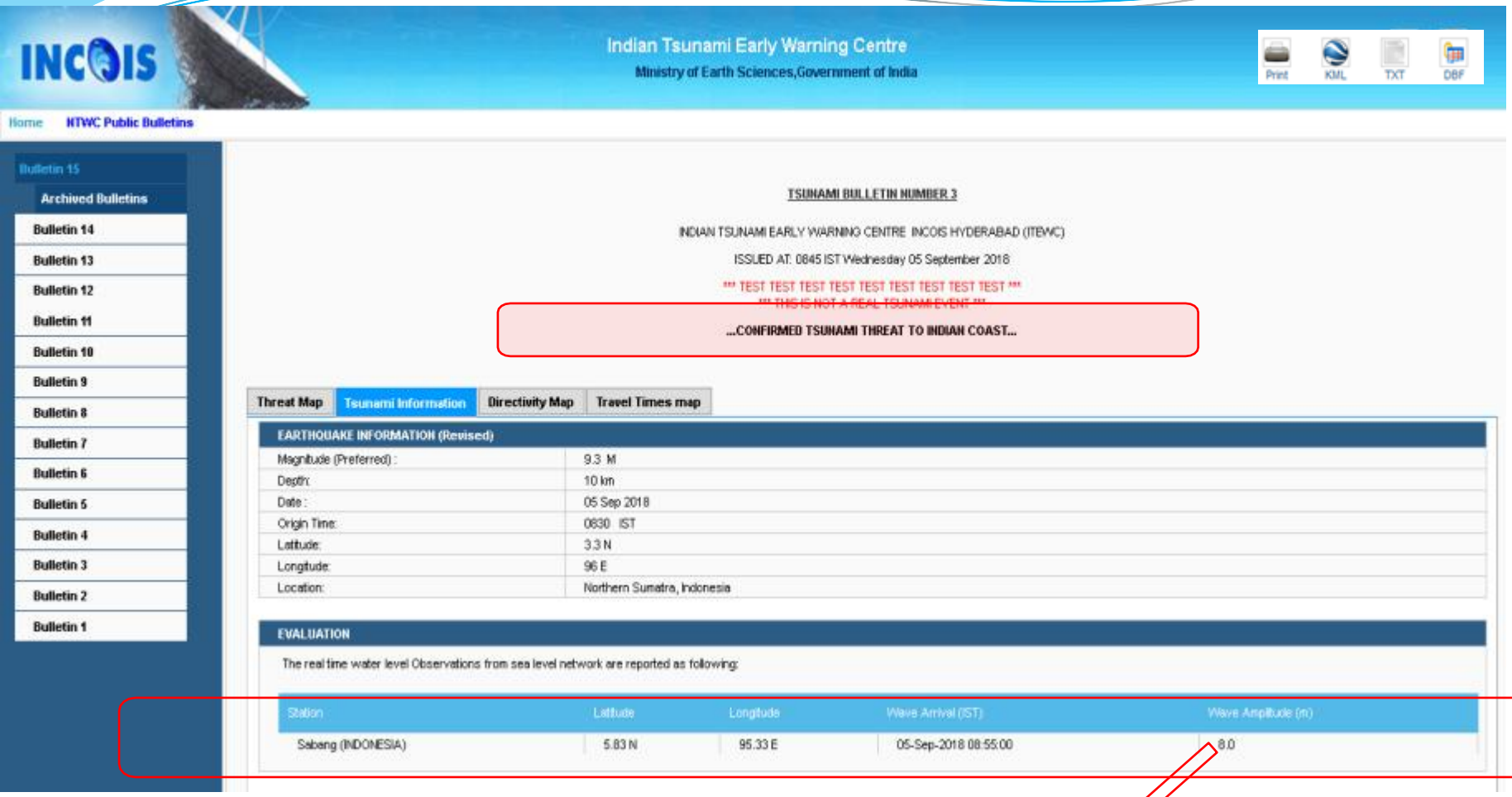
Bulletin-II: Potential Tsunami Threat / No Threat

Country	State/Teritory	Zone	T2(IST)	Amplitude(m)	max deep(m)	depth(m)	Threat Status
INDIA	ANDAMAN AND NICOBAR	INDIRA POINT	05-Sep-2018 09:08	2.4	1.0	47	Warning
INDIA	ANDAMAN AND NICOBAR	KOMATRA & KATCHAL ISLAND	05-Sep-2018 09:33	2.5	1.0	42	Alert
INDIA	ANDAMAN AND NICOBAR	CAR NICOBAR	05-Sep-2018 09:51	1.7	0.6	46	Watch
INDIA	ANDAMAN AND NICOBAR	LITTLE ANDAMAN	05-Sep-2018 10:10	3.5	1.3	41	Alert
INDIA	ANDAMAN AND NICOBAR	BARREN ISLAND	05-Sep-2018 10:11	0.3	0.1	167	Watch
INDIA	ANDAMAN AND NICOBAR	PORT BLAIR	05-Sep-2018 10:20	2.3	0.9	54	Alert
INDIA	ANDAMAN AND NICOBAR	NARCONDAM ISLAND	05-Sep-2018 10:27	0.3	0.1	42	Watch
INDIA	ANDAMAN AND NICOBAR	HAVELOCK	05-Sep-2018 10:29	1.3	0.4	43	Watch
INDIA	ANDAMAN AND NICOBAR	NORTH SENTINEL ISLAND	05-Sep-2018 10:34	1.3	0.6	36	Watch
INDIA	ANDAMAN AND NICOBAR	RANGATH BAY	05-Sep-2018 10:44	1.3	0.4	57	Watch
INDIA	ANDAMAN AND NICOBAR	DIGLIPUR	05-Sep-2018 10:59	1.0	0.3	48	Watch
INDIA	TAMIL NADU	POOMBUHAR	05-Sep-2018 11:28	1.9	0.8	36	Watch
INDIA	TAMIL NADU	CUDDALORE	05-Sep-2018 11:28	1.3	0.5	35	Watch
INDIA	TAMIL NADU	PUDUCHERRY	05-Sep-2018 11:28	1.5	0.6	33	Watch
INDIA	TAMIL NADU	MARAKKANAM	05-Sep-2018 11:29	1.3	0.6	40	Watch
INDIA	TAMIL NADU	KARAIKAL	05-Sep-2018 11:35	1.8	0.8	29	Watch
INDIA	TAMIL NADU	ENNORE	05-Sep-2018 11:36	1.8	0.8	34	Watch
INDIA	TAMIL NADU	CHENNAI	05-Sep-2018 11:38	1.8	0.8	33	Watch
INDIA	TAMIL NADU	MAHABALIPURAM	05-Sep-2018 11:40	2.1	0.9	32	Alert
INDIA	ANDHRA PRADESH	SRIHARIKOTA	05-Sep-2018 11:42	2.4	1.0	37	Alert
INDIA	ANDHRA PRADESH	MACHILIPATNAM	05-Sep-2018 11:48	1.4	0.6	44	Watch
INDIA	ANDHRA PRADESH	KAKINADA	05-Sep-2018 11:55	1.2	0.5	30	Watch
INDIA	TAMIL NADU	NAGAPATTINAM	05-Sep-2018 12:03	1.4	0.6	33	Watch
INDIA	ANDHRA PRADESH	KALINGAPATNAM	05-Sep-2018 12:08	1.6	0.7	30	Watch
INDIA	ANDHRA PRADESH	VISAKHAPATNAM	05-Sep-2018 12:10	1.0	0.4	31	Watch
INDIA	ORISSA	PURI	05-Sep-2018 12:14	0.8	0.3	35	Watch
INDIA	ORISSA	GOPALPUR	05-Sep-2018 12:16	1.2	0.5	37	Watch
INDIA	ANDHRA PRADESH	PERUPALEM	05-Sep-2018 12:19	1.0	0.4	35	Watch

CFZ
Information with Threat Status

Contd…

Bulletin-III: Confirmed Threat



Confirmed tsunami Observations

Contd…

Bulletin-III: Confirmed Threat

Country	State/Teritory	Zone	T2(IST)	Amplitude(m)	max deep(m)	depth(m)	Threat Status
INDIA	ANDAMAN AND NICOBAR	INDIRA POINT	05-Sep-2018 08:32	8.0	3.5	47	Warning
INDIA	ANDAMAN AND NICOBAR	KOMATRA & KATCHAL ISLAND	05-Sep-2018 08:55	6.7	2.6	42	Warning
INDIA	ANDAMAN AND NICOBAR	CAR NICOBAR	05-Sep-2018 09:14	3.8	1.5	46	Warning
INDIA	ANDAMAN AND NICOBAR	LITTLE ANDAMAN	05-Sep-2018 09:32	8.2	3.0	41	Warning
INDIA	ANDAMAN AND NICOBAR	PORT BLAIR	05-Sep-2018 09:37	4.2	1.6	54	Warning
INDIA	ANDAMAN AND NICOBAR	BARREN ISLAND	05-Sep-2018 09:41	1.1	0.3	167	Alert
INDIA	ANDAMAN AND NICOBAR	HAVELOCK	05-Sep-2018 09:46	3.5	1.4	43	Warning
INDIA	ANDAMAN AND NICOBAR	NORTH SENTINEL ISLAND	05-Sep-2018 09:52	3.2	1.3	36	Warning
INDIA	ANDAMAN AND NICOBAR	RANGATH BAY	05-Sep-2018 09:55	3.5	1.2	57	Warning
INDIA	ANDAMAN AND NICOBAR	NARCONDAM ISLAND	05-Sep-2018 09:58	1.1	0.4	42	Alert
INDIA	ANDAMAN AND NICOBAR	DIGLIPUR	05-Sep-2018 10:01	1.8	0.6	48	Alert
INDIA	ANDAMAN AND NICOBAR	WEST & LANDFALL ISLAND	05-Sep-2018 10:25	2.2	0.9	31	Warning
INDIA	ANDAMAN AND NICOBAR	FLAT ISLAND	05-Sep-2018 10:28	3.0	1.2	31	Warning
INDIA	TAMIL NADU	MARAKKANAM	05-Sep-2018 11:03	2.5	1.0	40	Warning
INDIA	TAMIL NADU	PUDUCHERRY	05-Sep-2018 11:04	2.8	1.1	33	Warning
INDIA	TAMIL NADU	CUDDALORE	05-Sep-2018 11:05	2.5	1.0	35	Warning
INDIA	TAMIL NADU	POOMBUHAR	05-Sep-2018 11:06	3.2	1.2	36	Warning
INDIA	TAMIL NADU	ENNORE	05-Sep-2018 11:10	3.9	1.6	34	Warning
INDIA	TAMIL NADU	MAHABALIPURAM	05-Sep-2018 11:11	5.8	2.4	32	Warning
INDIA	TAMIL NADU	NAGAPATTINAM	05-Sep-2018 11:14	4.8	2.0	33	Warning
INDIA	ANDHRA PRADESH	MACHILIPATNAM	05-Sep-2018 11:15	3.5	1.5	44	Warning
INDIA	ANDHRA PRADESH	SRIHARIKOTA	05-Sep-2018 11:16	3.4	1.4	37	Warning
INDIA	TAMIL NADU	CHENNAI	05-Sep-2018 11:16	4.7	2.0	33	Warning
INDIA	TAMIL NADU	KARAIKAL	05-Sep-2018 11:17	4.8	2.1	29	Warning
INDIA	ANDHRA PRADESH	PERUPALEM	05-Sep-2018 11:19	2.9	1.2	35	Warning
INDIA	ANDHRA PRADESH	KAKINADA	05-Sep-2018 11:21	4.5	2.0	30	Warning
INDIA	TAMIL NADU	MALLIPATTINAM	05-Sep-2018 11:22	3.1	1.3	32	Warning
INDIA	TAMIL NADU	MUTHUPET	05-Sep-2018 11:22	3.2	1.3	33	Warning

CFZ
Information with Threat Status

Contd…

Final Bulletin

Indian Tsunami Early Warning Centre
Ministry of Earth Sciences,Government of India

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FINAL BULLETIN
TSUNAMI BULLETIN NUMBER 15

INDIAN TSUNAMI EARLY WARNING CENTRE INCOIS HYDERABAD (ITEWC)

ISSUED AT: 2030 IST Wednesday 05 September 2018

*** TEST TEST TEST TEST TEST TEST TEST TEST TEST *** *** THIS IS NOT A REAL TSUNAMI EVENT ***

...FINAL BULLETIN...

EARTHQUAKE INFORMATION (Revised)

Magnitude (Preferred) :	9.3 M
Depth:	10 km
Date :	05 Sep 2018
Origin Time:	0830 IST
Latitude:	3.3 N
Longitude:	96 E
Location:	Northern Sumatra, Indonesia

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 coastal areas, based on ITEWC INCOIS modelling.
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.

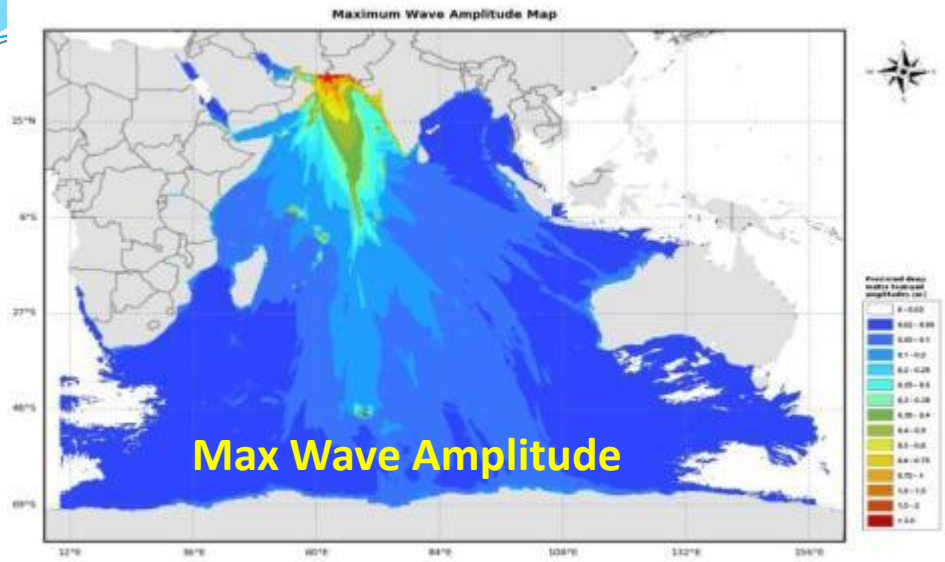
TSUNAMI WAVE OBSERVATIONS

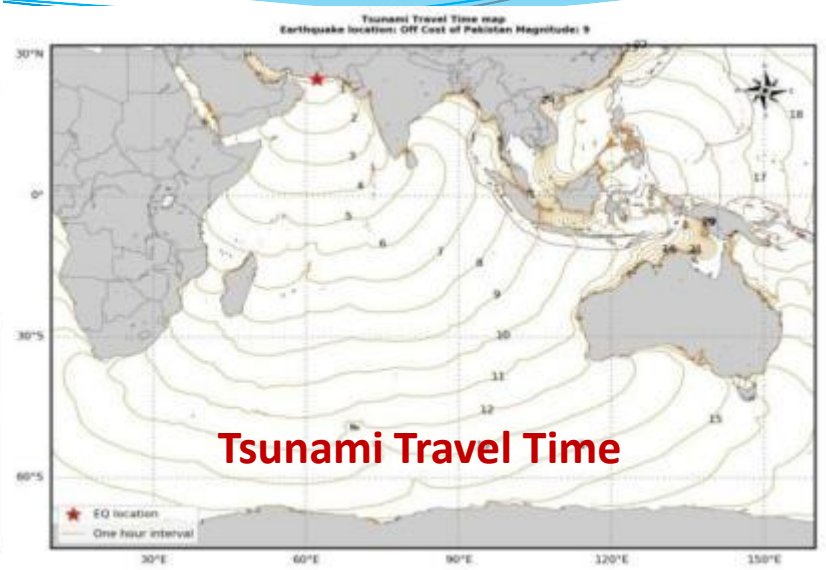
Listed below are maximum wave amplitudes recorded at the specified locations. Note that wave amplitude is measured relative to normal sea level; it is NOT the crest-to-trough wave height

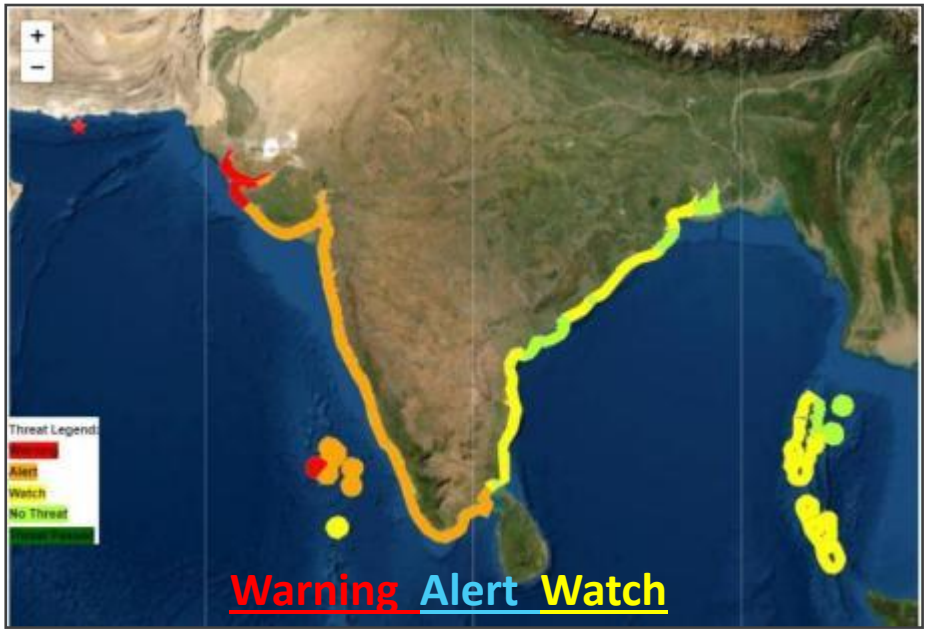
Station	Latitude	Longitude	Wave Arrival (UTC)	Wave Amplitude (m)
Sabang (INDONESIA)	5.83 N	95.33 E	05-Sep-2018 08:55:00	8.0
Meulaboh (INDONESIA)	4.13 N	96.13 E	05-Sep-2018 09:10:00	8.0
Telukdalam (INDONESIA)	0.55 N	97.82 E	05-Sep-2018 09:15:00	6.00
23227 (INDIA)	6.25 N	88.79 E	05-Sep-2018 09:49:00	0.46

Contd…

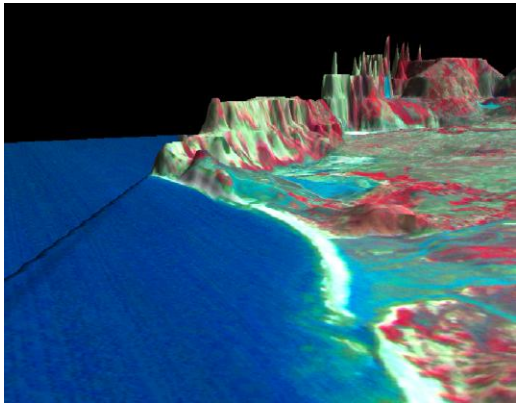
Graphic Products on Website

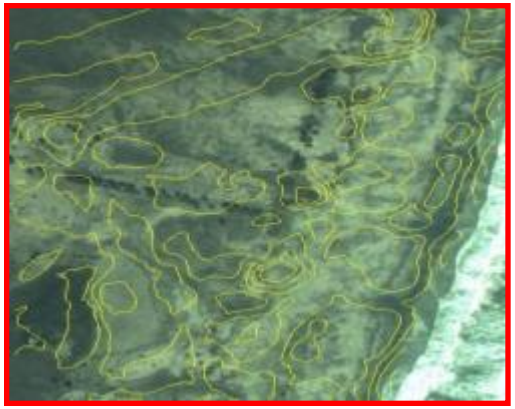




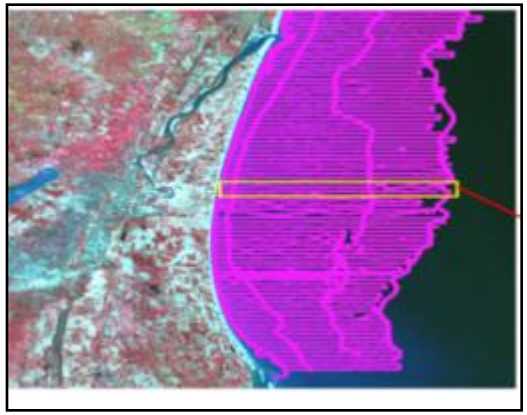


Coastal Inundation Mapping

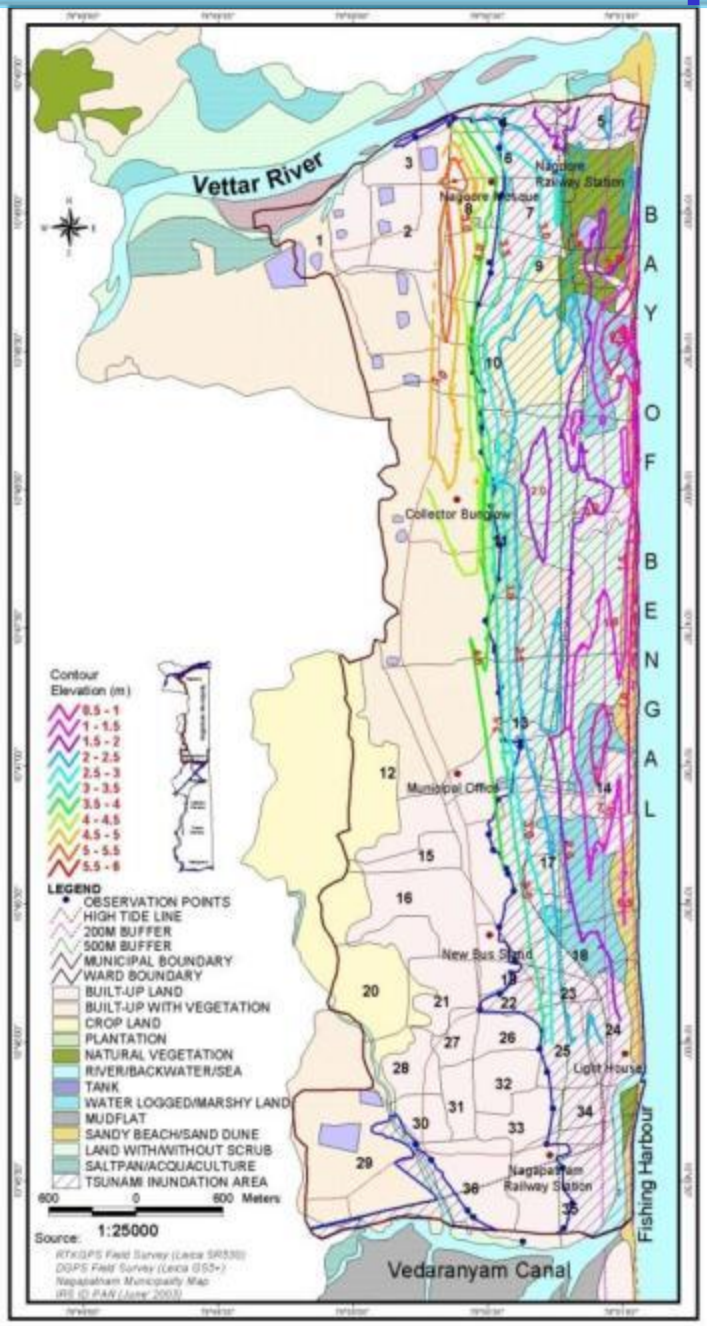




1m contours overlaid on ortho image

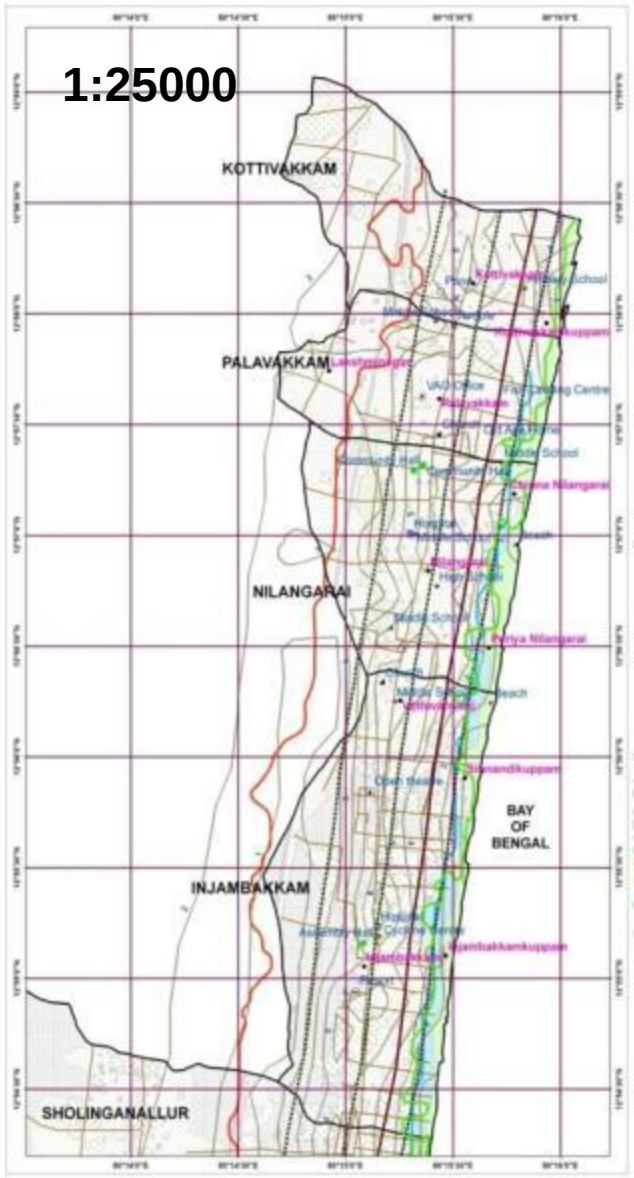


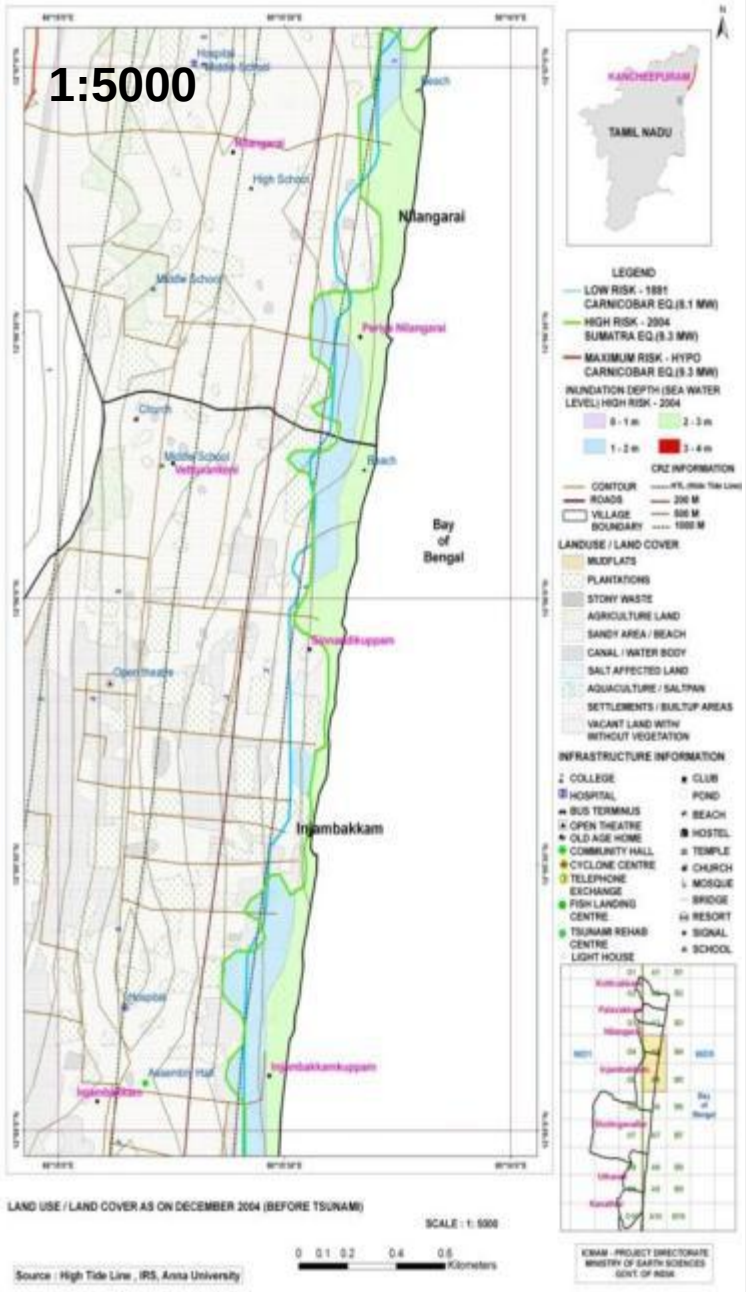
Bathymetric Survey for Cuddalore



- 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.

Tsunami Vulnerability Map of Kancheepuram





I. Vulnerability classification

Low risk – Carnicobar Eq (8.1.Mw)
High risk – Sumatra Eq (9.3Mw)
Maximum risk – Hypo. Carnicobar Eq (9.3 Mw)

II. Inundation Depth

(sea water level due to Sumatra 2004)

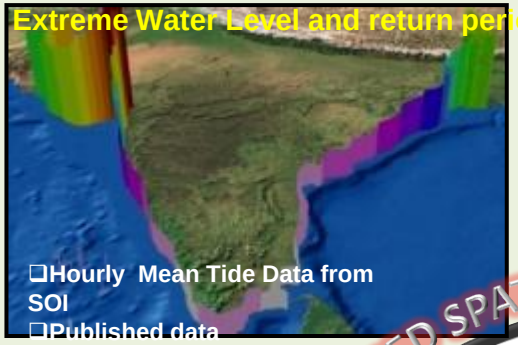
III. Others details

- From Satellite Imagery (entire Village)
  - Landuse
- From DC images (upto 2 km from coast)
  - Elevation Contours
  - Infrastructure details
  - Trees
  - Roads
  - Railways
  - Buildings
- Secondary data
  - Cadastral boundaries and Survey Nos
  - Administrative boundaries

Coastal Multi-Hazard Vulnerability Assessment

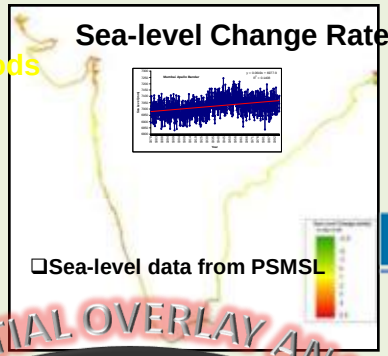
INPUTS

Extreme Water Level and return periods



❑Hourly Mean Tide Data from SOI
❑Published data

Sea-level Change Rate



❑Sea-level data from PSMSL

Shoreline Change Rate

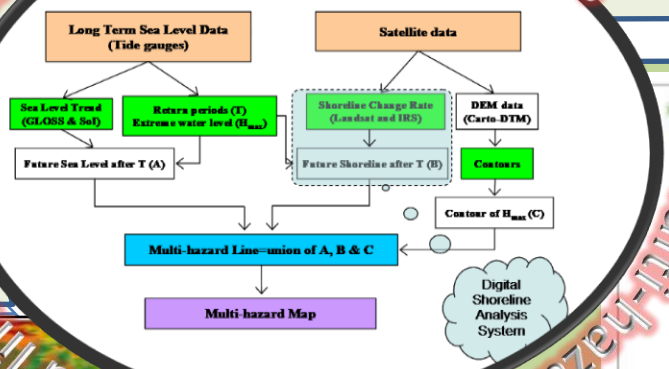
❑IRS and Landsat

High Resolution Topography

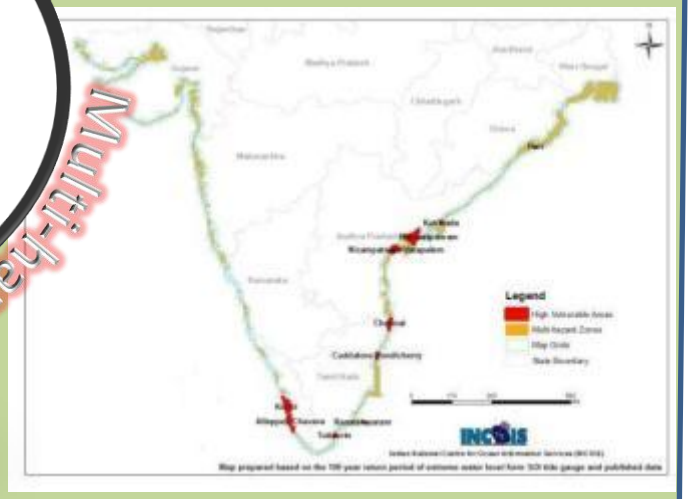
❑ACarto DTM
❑LTM

SYNTHESIZED SPATIAL OVERLAY ANALYSIS

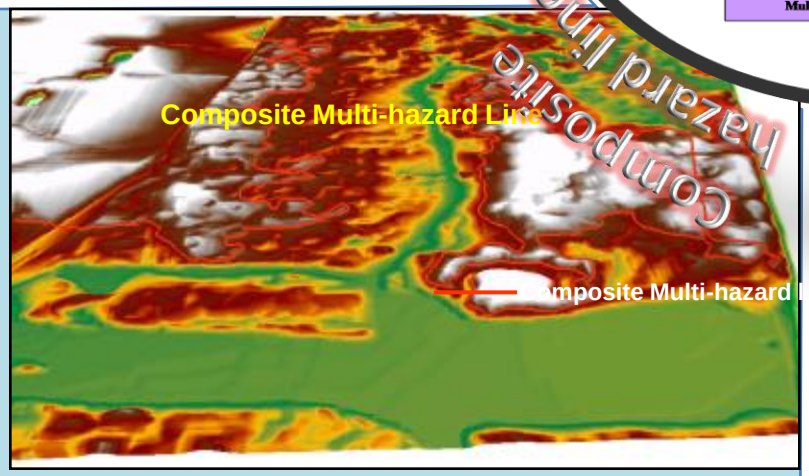
MHVM Methodology



Multi-hazard Maps



Composite Multi-hazard Line



3D – GIS Mapping

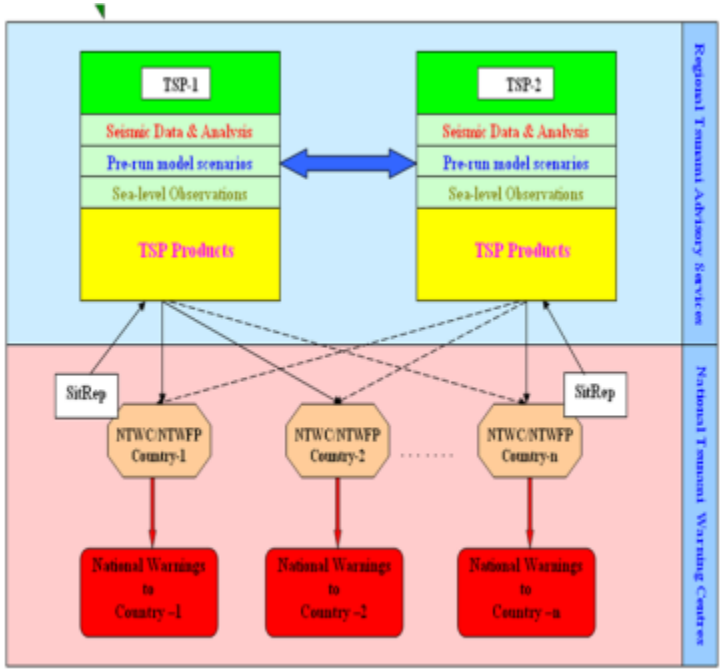
Risk assessment at Building level

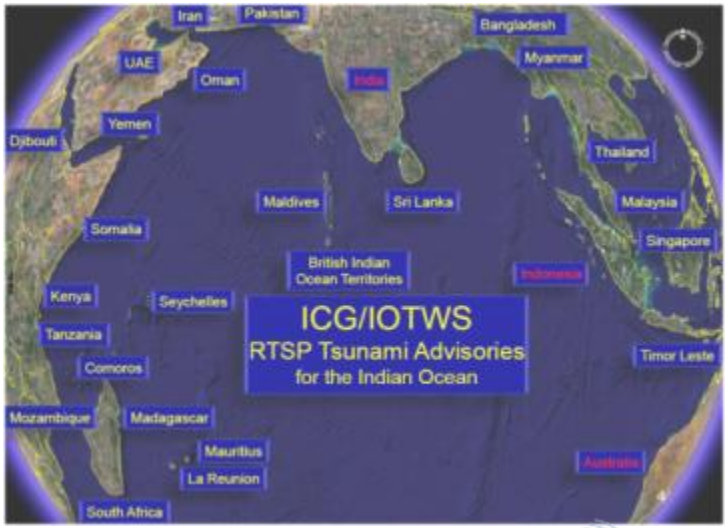
Evacuation Route

India as Tsunami Service Provider (TSP)

ITEWC is playing major role in UNESCO/IOC Tsunami Warning Initiatives

- Indian Scientists played a major role in designing the IOTWMS system
- India had been Founding Chair of ICG/IOTWMS
- India had been vice-chair for IOWave Task Team
- India is Chair for Task Team on Tsunami Watch Operations which is working towards Global Harmonization
- IOTWS is a network of National Systems consisting of **TSPs** and **NTWCs/NTFPs**
- TSPs distribute products to NTWCs and other TSPs within a region and as a backup of each region there should be **more than one RTSP** for each region
- **NTWCs/NTFPs are solely responsible for providing warnings to their citizens based on their analysis of the situation**
- India first to initiate exchange of Earthquake information (SL-1) in 2008
- In 2011 formally India started exchanging Model based advisories (SL-2)
- On October 12, 2011 UNESCO handed over the responsibility of Indian Ocean tsunami advisories to the Tsunami Service Providers India, Australia, Indonesia
- As a Tsunami Service Provider (TSP) India is providing bulletins to all Indian Ocean rim countries, together with TSPs Australia & Indonesia





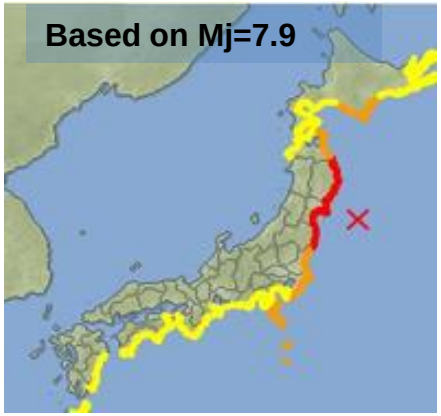
Parameter	Targets	Achievements
Elapse Time from EQ to Initial EQ info issuance (Local/Distant)	10/15 min	10 Min
Probability of Detection of IO EQ with Mw >= 6.5	100 %	Achieved
Accuracy of Hypocenter Location	within 30 km	9.5 km
Accuracy of Hypocenter Depth	within 25 km	22.5 km
Accuracy of Earthquake Mw Magnitude	0.3	0.2
Reliability of RTWP Operations (Power, Computer, Communications)	99.5%	Achieved

INCOIS

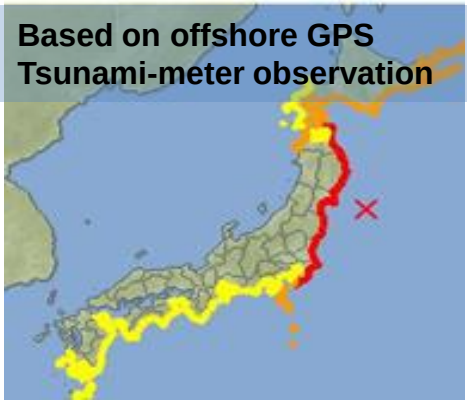
Challenges in Tsunami Threat Assessment

Japan Earthquake on Mar 11, 2011

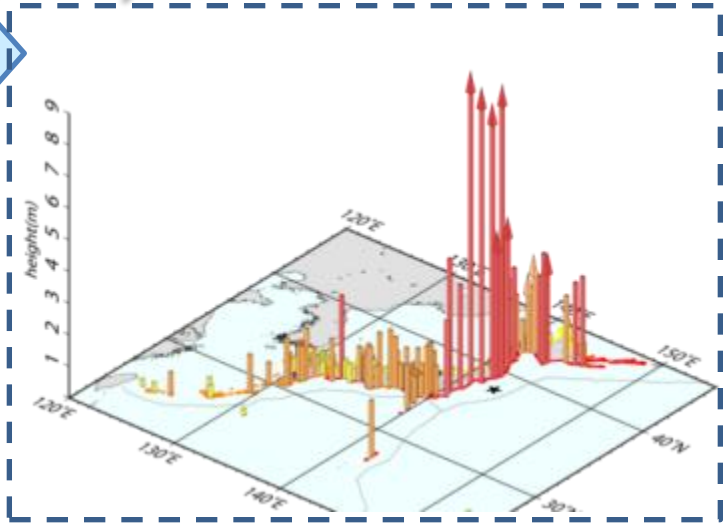
The first Warning in 3 minutes → **Updated warning in 28 minutes**



Iwate : 3m
Miyagi : 6m
Fukushima : 3m



Iwate : 6m
Miyagi : over 10m
Fukushima : 6m



Observed Tsunami Amplitude

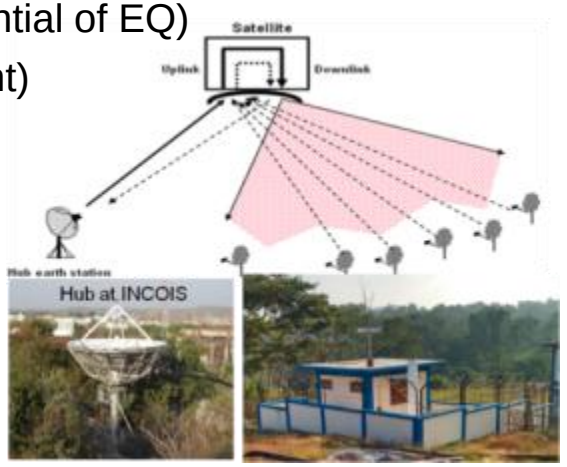
Under-estimation of Magnitude and Tsunami wave heights

- Though JMA was given the first tsunami warning in 3 minutes, that was based on underestimated magnitude of 7.9
- Announced tsunami amplitude estimate “3m” led to delays in evacuation
- Failed to calculate Mw (Moment magnitude) automatically due to waveform data over-scale for most of the domestic broadband seismometers, and consequently, could NOT update the warning
- Collected unsaturated oversea broadband waveform data, and calculated Mw = 8.8 in 54 minutes and that was too late for the warning update based on the seismic data

How to face these Challenges ??

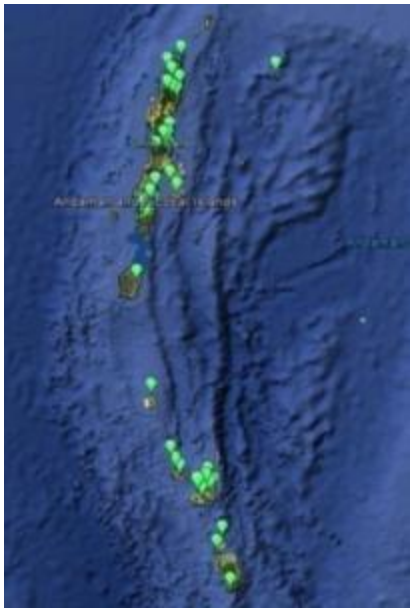
Major Challenges…

- First few minutes are very crucial only seismic data will be available that is used to estimate
  - Moment Magnitude (~ 30 min) (To know tsunamigenic potential of EQ)
  - Fault parameters (~ 45 min to hours) (To know displacement)
- Emergency communication



Future Plans…

- **Strong Motion data for Magnitude calculation**
- **GPS data for Displacement estimation**
- **Sirens connected via VSAT or VHF or wireless technology**
- **Community awareness and preparedness**



- **Setting up GPS & Strong Motion Network at 35 Locations in Andaman & Nicobar Islands**
- **Real-time Communication through VSATs**
- **Use VSATs to enable Emergency communication**

➢ Communications Tests (Comms Test)

- To validate the dissemination and reception processes of advisories in all possible communication modes and to determine transmission times of messages

➢ SOP Workshops

- For DMOs to build their own SOPs detailing actions to be taken upon receipt of bulletins from the warning centre

➢ Tabletop Exercises

- To stimulate the development, training, testing and evaluation of Emergency Response Plans, SOPs and assess procedures followed (Conducted in a conference room environment)

➢ Mock Drills

- Full scale mock Tsunami Drill to evaluate and improve the effectiveness of SOPs of TWC and DMOs, in responding to a potentially destructive tsunami

➢ Tsunami Ready Programme

- IOC-UNESCO Tsunami Ready Programme is a community performance based programme to strengthen tsunami preparedness of coastal communities through a structural and systematic approach

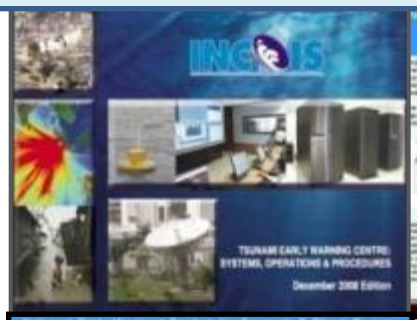
Capacity Building

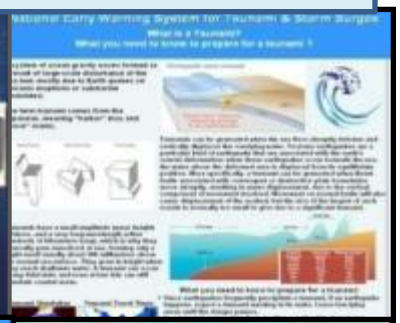
- Workshops, seminars, Trainings (national & international), Exhibitions
- Capacity building to public (especially in near-source vulnerable coastal areas) on responding to earthquakes & tsunami warnings
- Capacity building to coastal administrators, disaster management officials and public on SOPs,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

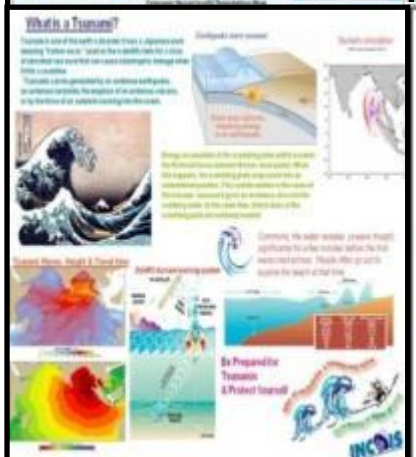


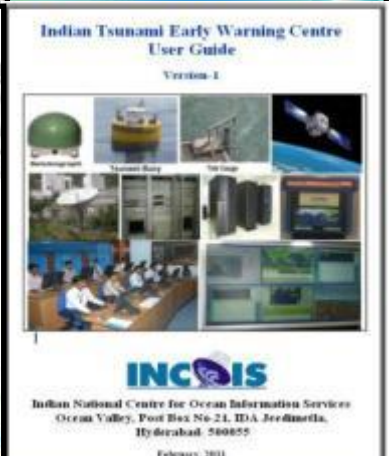








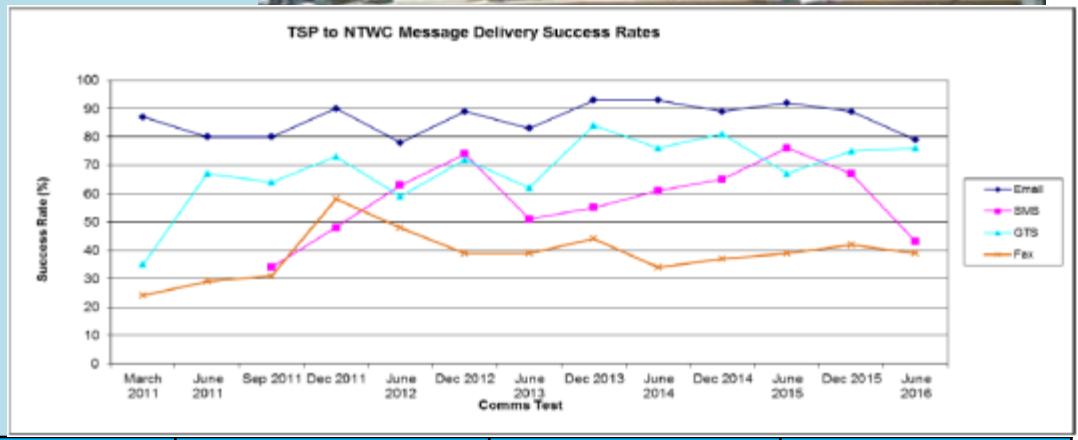




Communication Tests

1. March 16, 2011 (NTWCs)
2. June 15, 2011 (NTWCs & National DMOs)
3. September 14, 2011 (NTWCs & National DMOs)
4. December 14, 2011 (NTWCs)
5. June 13, 2012 (NTWCs)
6. December 12, 2012 (NTWCs)
7. June 13, 2013 (NTWCs & National DMOs)
8. December 11, 2013 (NTWCs)
9. June 11, 2014 (NTWCs)
10. December 10, 2014 (NTWCs)
11. June 10, 2015 (NTWCs)
12. Dec 9, 2015 (NTWCs)
13. Jun 8, 2016 (NTWCs)

- Modes of Communication
  - International: Email, Fax, GTS, SMS, Web
  - National: Email, Fax, SMS, Web
- Performance till now:
  - Compared 13 COMMs test results
  - Email the most significant mode of communication



	16 Mar 2011		15 Jun 2011		14 Sep 2011		14 Dec 2011		13 Jun 2012		12 Dec 2012	
Mode	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)
Email	19/23	0 – 48	20/22	0 – 48	22/23	0 – 15	17/19	0 – 9	18/21	0 – 2	15/17	0 – 4
Fax	7/23	0 – 61	10/22	0 – 91	12/23	0 – 93	13/19	0 – 35	12/21	0 – 35	6/17	0 – 32
GTS	12/23	0 – 5	17/22	0 – 17	17/23	0 – 26	16/19	0 – 25	15/21	0 – 7	12/17	0 – 14
SMS	--	--	--	--	13/23	0 – 13	15/19	0 – 23	15/21	0 – 1	14/17	0 – 3

	12 Jun 2013		11 Dec 2013		11 Jun 2014		10 Dec 2014		10 Jun 2015		9 Dec 2015		8 Jun 2016	
Mode	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)	No. of NTWCs Received	Time Delay (Mins)
Email	19/20	0-5	21/21	0 - 16	21/23	0 - 28	23/24	0 - 2	20/21	0 - 2	18/20	0 - 2	20/23	0-2
Fax	15/20	0- 184	18/21	0- 32	13/23	0 - 20	17/24	0 - 15	12/21	0 - 15	16/20	0 - 15	15/23	0-15
GTS	14/20	0 – 40	17/21	0 - 4	19/23	0 - 10	20/21	0 - 16	17/21	0 - 10	18/20	0 - 3	18/23	0 - 3
SMS	14/20	0 - 9	15/21	0 - 2	14/23	0- 37	20/23	0- 2	19/21	0- 2	18/20	0- 2	18/23	0 - 3

Tsunami Mock drills

Objectives of Mock Drill:

- Validate the Warning Centre dissemination process for issuing Tsunami Advisory Bulletins to national disaster management authorities and other participating agencies.
- Evaluate the processes and procedures of agencies receiving and confirming Tsunami Bulletins.
- Hone the organizational decision making process about public warnings and evacuations.
- Identify the proper communication methods that would be used to notify and instruct the public.
- Record and assess the elapsed time until the public would be notified and instructed.

Previous Drills

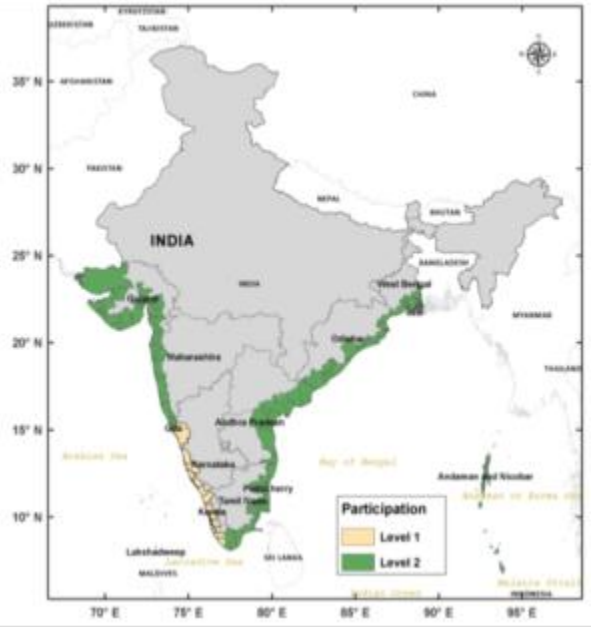
- IOWave09 on October 14, 2009
- IOWave11 on October 12, 2011
- A&N Islands on November 22, 2013
- IOWave14 on September 9 & 10, 2014
- East Coast of India on September 26, 2015
- Kerala Coast on March 10-11, 2016
- IOWave16 Exercise September 7-8, 2016
- Mega mock drill for East Coast of India on November 24, 2017
- IOWave18 Exercise September 4-5, 2018
- IOWave20 Exercise October 13 and 20, 2020

IOWave18 Exercise

IOWave18 Tsunami mock Exercise on Sept 4-5, 2018

- The IOWave18 Exercise was very successful which improved awareness and preparedness among the coastal people of India
- Around 375 villages from 44 districts of 8 coastal States/UTs were involved and evacuated during the IOWave18 exercise
- More than 1,04,000 people were evacuated to shelters/safe places during mock exercise
- Evaluated the Indian Ocean Tsunami Ready (IOTR) indicator in 6 coastal communities in Odisha
- Ovarall response time less than 30 minutes to notify the public
- Different modes of communication Telephone, SMS, Whatsapp, Twitter, Public radio, TV, website, Siren, Public Alert System, Police, Door-to-door, Mega phone, VHF, etc. were used
- Most recipients agreed the exercise was very satisfactory and suggested to conducts regular Mock exercise to create more awareness and preparedness

State/UT	Districts	Total Time to notify public	No of people participated
A & N Islands	3 - North & Middle Andaman, South Andaman, Nicobar	13 min	3,949
West Bengal	3 - North 24-Paraganas, South 24-Paraganas, Purba Medinipur	5 min	1,262
Odisha	6 - Balasore, Bhadrak, Kendrapada, Jagatsingpur, Ganjam and Puri	15 min	78,061
Andhra Pradesh	9 - Srikakulam, Viziangaram, Vizag, East Godavari, West Godavari, Krishna, Guntur, Prakasam and SPS Nellore	9 min	5,823
Puducherry	1 - Karaikal	14 min	68
Tamil Nadu	13 - Chennai, Cuddalore, Kancheepuram, Kanniyakumari, Nagapattinam, Pudukottai, Ramanathapuram, Thoothukudi, Thanjavur, Tirunelveli, Tiruvallur, Tiruvarur and Viluppuram	15 min	6,051
Goa	2 - North Goa and South Goa	30 min	3,250
Maharashtra	5 - Palghar, Raigad, Ratnagiri, Sindhudurg and Thane	12 min	4,162
Gujarat	2 - Kutch and Jamnagar	10 min	1,700



IOWave20 Exercise

- IOWave20 Exercise conducted by ICG/IOTWMS on 6th, 13th and 20th October, 2020.
- ITEWC issued bulletins to all NTWCs in Indian Ocean Region on 3 days of exercises as a Tsunami Service Provider (TSP). At National level, India participated the exercise on 13th and 20th October, 2020.
- Considering the COVID-19 pandemic situation, limited the Exercise to test communication channels instead of full-scale exercise.
- The IOWave20 Exercise focused to identify and fix any gaps in communication channels and their SOPs for an impending tsunami.
- 13th October 2020 – Andaman Scenario: 6 Provinces of Andaman & Nicobar Islands, West Bengal, Odisha, Andhra Pradesh, Tamil Nadu and Puducherry took active participation in the exercise.
- 20th October 2020 – Makran Scenario: 7 Provinces of Kerala, Lakshadweep Islands, Puducherry, Karnataka, Goa, Maharashtra, and Gujarat participated in the exercise.
- In both days Indian Navy, Coast Guard, National Disaster Response Force, Nuclear power plants and Port &Harbors also participated in the exercise.
- DMOs have tested their communication protocols and conducted "virtual" tabletop exercises to assess the organizational SOPs, plans and policies.
- Using IOWave20 exercise as an opportunity, Odisha State Disaster Management Authority (OSDMA), Odisha evaluated IOC-UNESCO Tsunami ready indicators in all piloted Tsunami Ready villages with limited number of participation on 13th October 2020.

Education Material for Tsunami Preparedness

Tsunami Preparedness Material

- Tsunami Warning Centre operations Handbook & User guide
- Tsunami awareness films for Administrators, General public and Children
- Tsunami awareness & preparedness posters, leaflets

➢ Key Priorities

- Distribution of tsunami User guide to Local, State and National disaster management authorities
- Tsunami Videos for improving the awareness
- Preparing all capacity building material in local languages

Preparation of Evacuation Route Maps and Sign Boards

- **Key Priorities**
  - Community involvement in preparation of tsunami evacuation maps
  - Setting of tsunami signboards in the vulnerable coastal regions indicating evacuation routes

Tsunami Ready Programme

- The IOC-UNESCO Tsunami Ready Programme is a community performance based programme
- The Programme to strengthen tsunami preparedness of coastal communities through a structural and systematic approach through fulfilling a few best-practice indicators (11 Nos) set by ICG/IOTWMS.
- The main objective of Tsunami Ready programme is to improve coastal community preparedness for tsunami emergencies and to minimise the loss of life and property.
- Based on the recommendations of the National Board, INCOIS has initiated capacity building programme to familiarize the Coastal States and UTs for implementation the Tsunami Ready Programme in India.
- Odisha implemented Tsunami Ready Programme on pilot basis in 6 villages

Experience the Wave of Change

Thank you