TSP India Status Report
On Service Updates

Agenda item 2.3

Chodavarapu Patanjali Kumar
INCOIS
patanjali@incois.gov.in

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TSP India Developments since last WG2 Meeting (Virtual, 10 Dec 2020)

- During the reporting period, In total, 38 Tsunamiginc earthquakes monitored globally and for 24 events issued first bulletins as per Service Definition
- Tsunami Warning centre – 24 X 7 Operational Services
- Participated in IOTWMS 22ndCommunication Test conducted on 09 June 2021
- Upgrading the Decision Support System- R&D on Atypical source Tsunamis.
- Real-time tsunami modeling for global tsunamigenic earthquakes on GPUs
- Real-time tsunami modeling using ADCRIC and Proof of Concept (POC) of Service Level –III
- Implementation of CAP for National and TSP services
- Event Database and KPI Generator
- TSP India Performance

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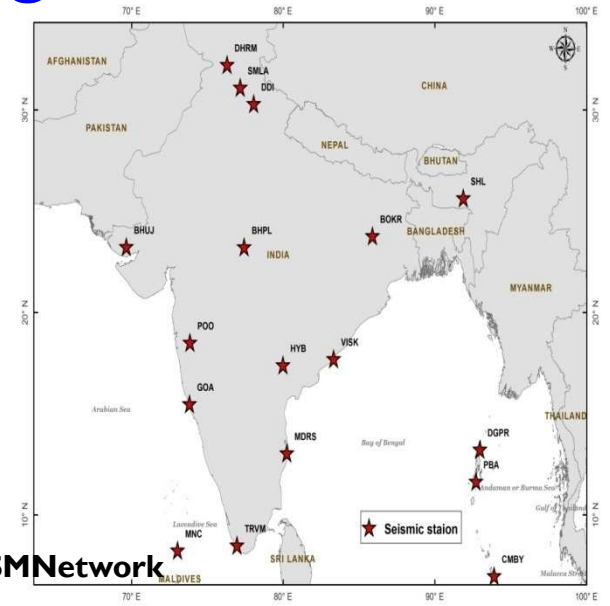
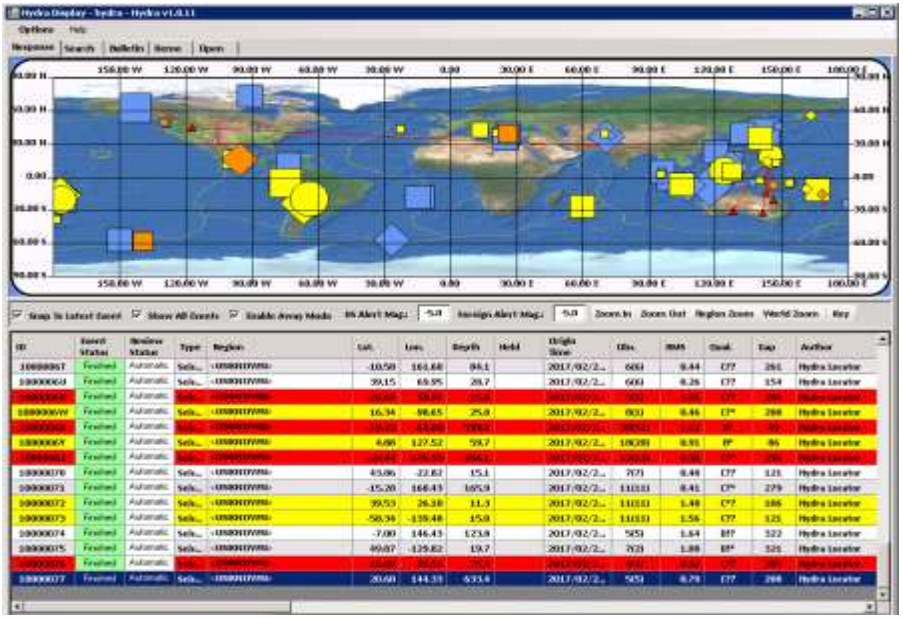
Real-time Seismic Monitoring Network

➢ Seismic Network for Tsunami Early Warning

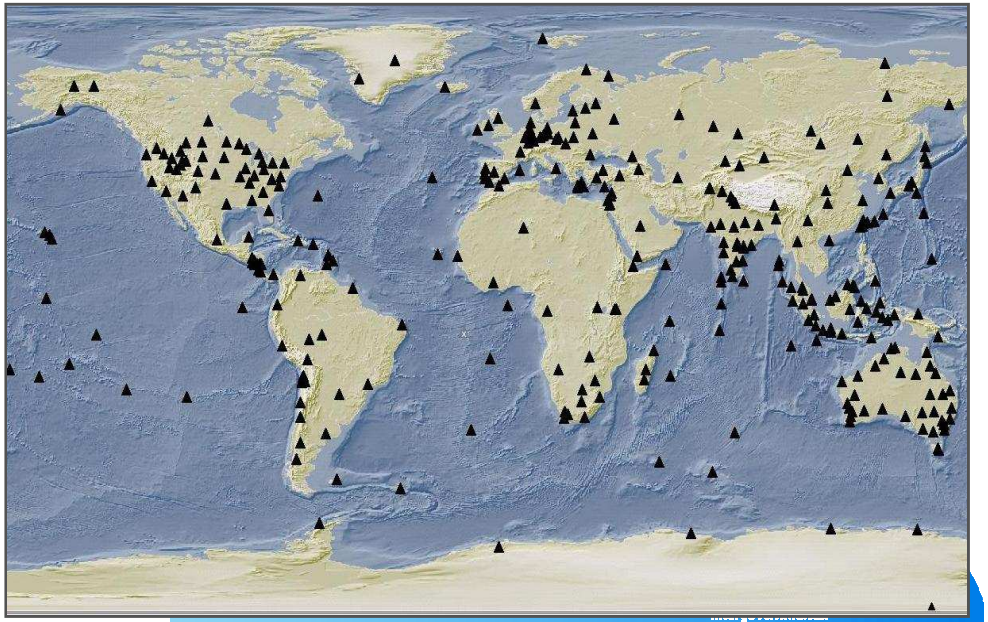
- 17 national broadband stations & around 400 International Stations
- Acquisition of data using NaqsServer, Apollo Server and Seedlink Server. SeisComP3.0 and Bulletin Hydra for real time processing
- Average detection time 3 – 10 min
- There is no impact due to COVID-19 on data reception & processing



RTSMNetwork

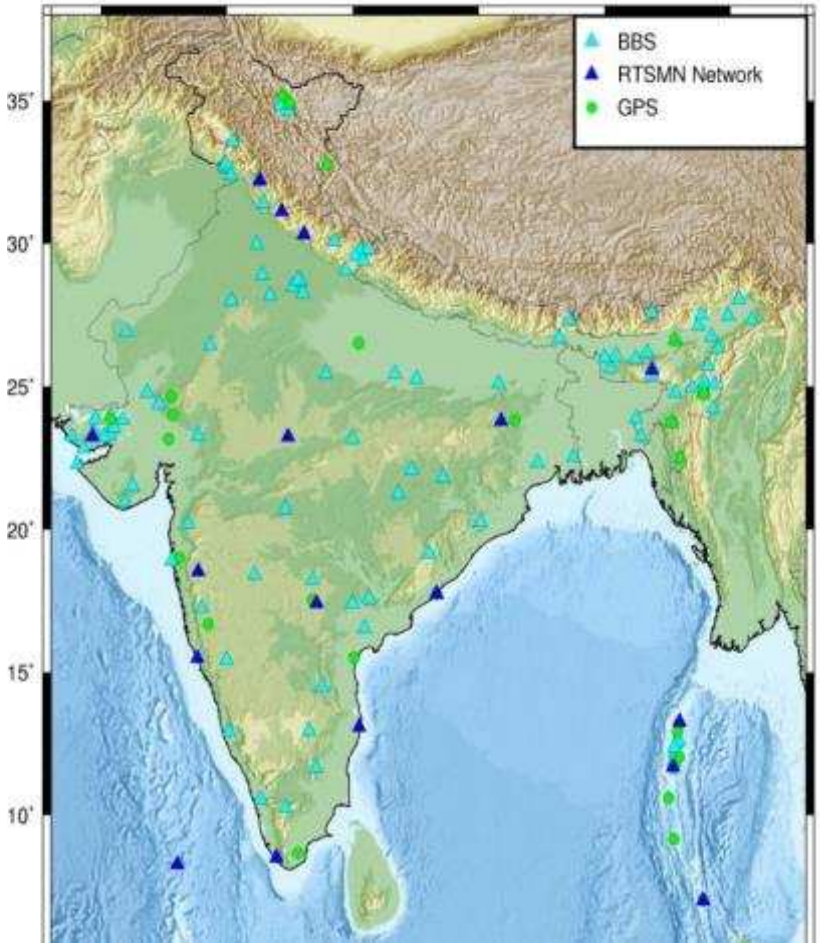


Bulletin Hydra Software



International Network

Indian Seismic and GNSS Network



- 35 National GNSS stations in Andaman & Nicobar Islands planned and 30 are in operation
- Receiving data from Seismic and GNSS stations operated by various national agencies under ISGN which is maintained by NCS, New Delhi
- GNSS & SMA data inversion for estimating source parameters
- ➢ Currently VSAT antennas orientation for GNSS & SMA network is under progress.

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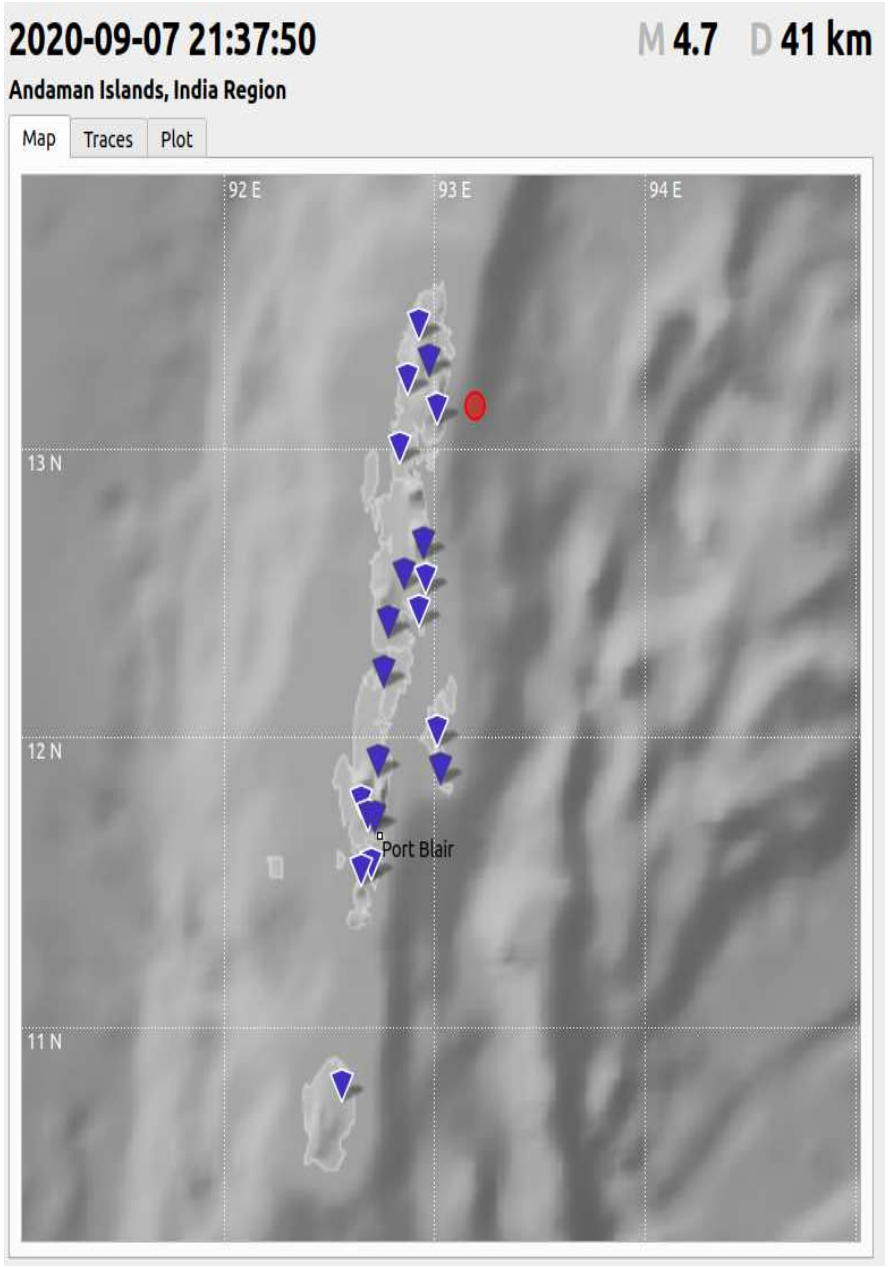
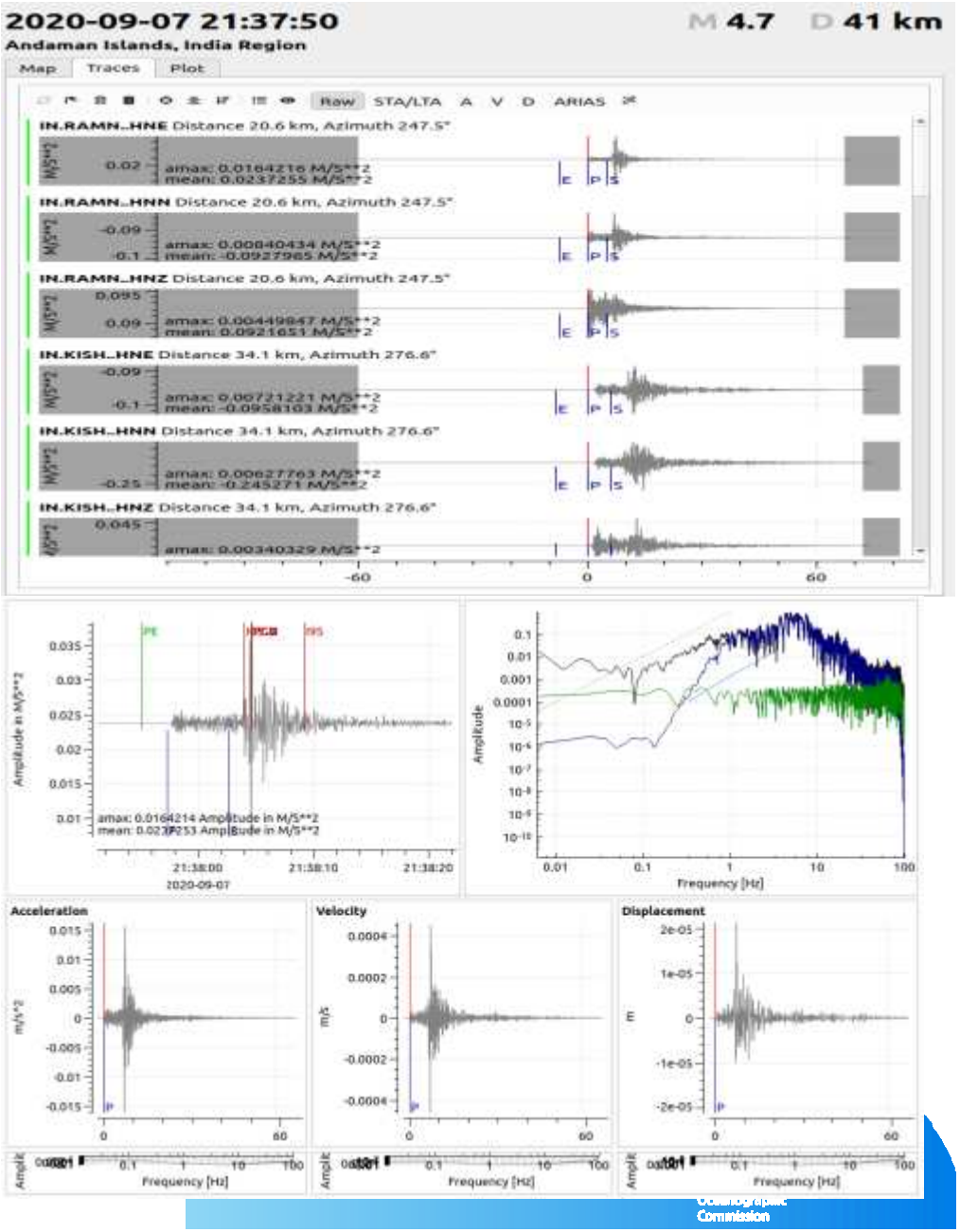
Strong Motion Data Processing



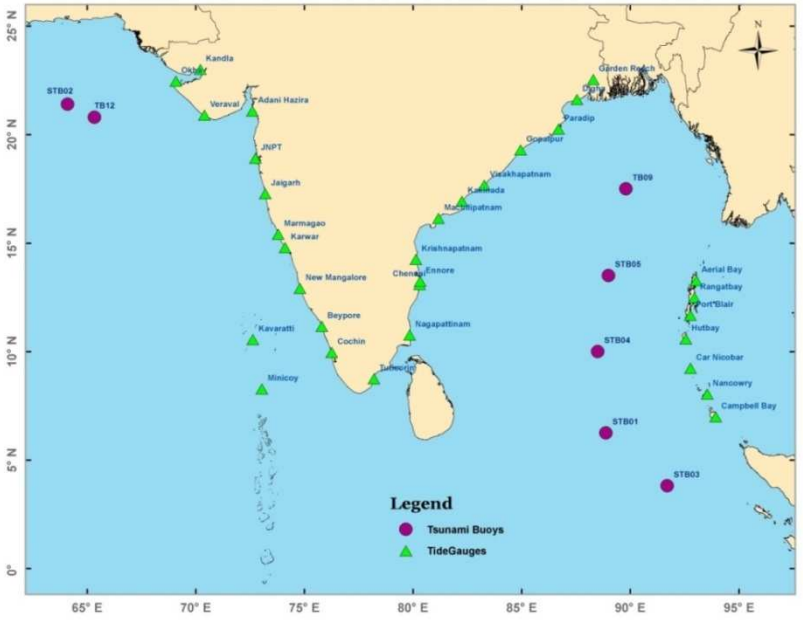


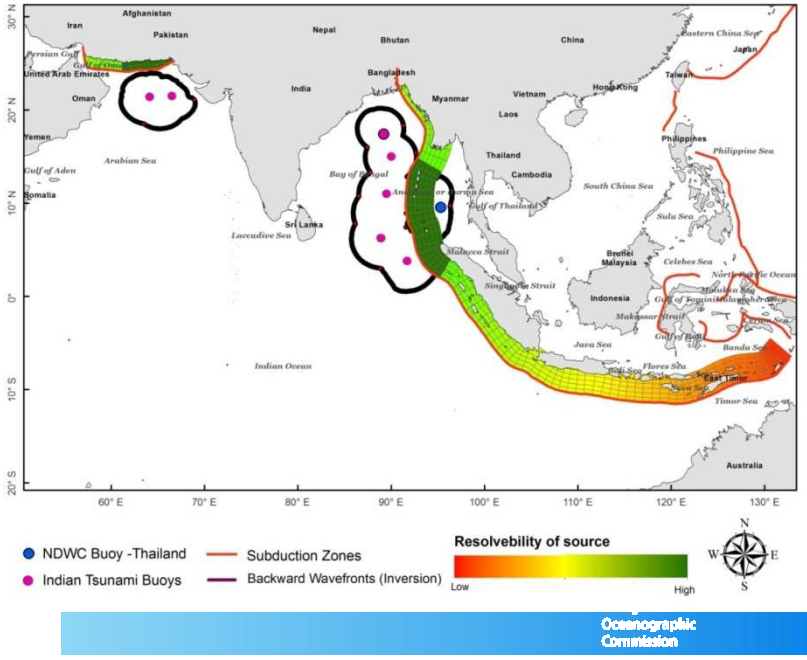
Sea Level Network

- **Tsunami Buoys**
  - Network of **7** Tsunami Buoys
  - **5** in Bay of Bengal & **2** in Arabian Sea
  - Real-time data is being received at INCOIS & NIOT
  - Receiving data from ~ 50 international real-time tsunami buoys
- **Tide gauge Network**
  - Network of **36** Tide gauges
  - **21** stations with **3** sensors (RAD, PRS, ENC) and 15 stations with single sensor (RAD)
  - Receiving data from 400 international real-time tide-gauge stations

There is no impact due to COVID-19 on data Reception & Processing

- With appropriate coverage of BPR network in optimum locations , Andaman Sources as well Eastern sources of Makran subduction zone can be well resolved. Inclusion of Tide gauge observations compliments constraints on the rapture area





Impact of Covid-19 pandemic on TSP-India observational network and Services

➢ Immediate Impact

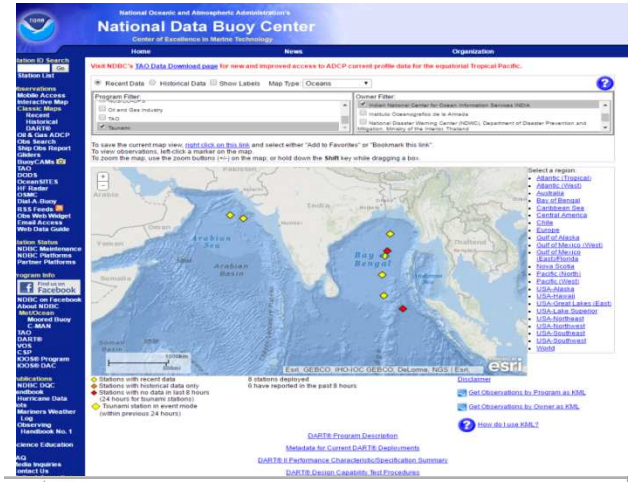
- Observational components:
  - 1) Tide Guauge (6 out of 36 are impacted)
  - 2) Tsunami Buoys (2 out of 7 are impacted)
  - 3) Seismic network has no impact“
- Operations: There is no immediate impact, however, due to national lockdown, ITEWC functioned with minimal manpower with longer duty hours and engaged operational staff in shifts who resides at campus

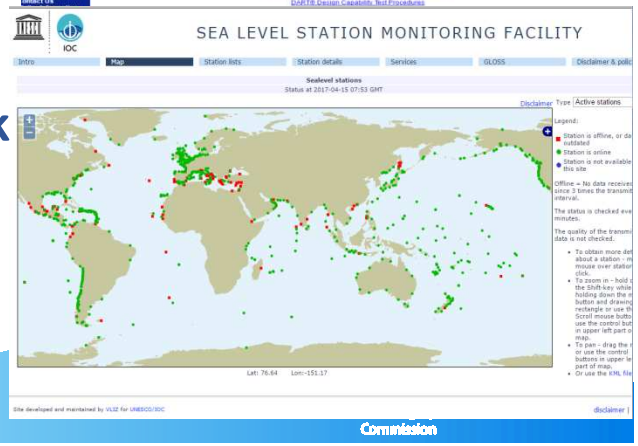
➢ Near-term Impact

- Observational components: Equipment maintenance activity got delayed due to lockdown and transport issues
- Operations: No impact. ITEWC planned according to the situation

➢ Long-term Impact

- Observational components: No impact. ITEWC planned according to the situation
- Operations: No impact. ITEWC planned according to the situation

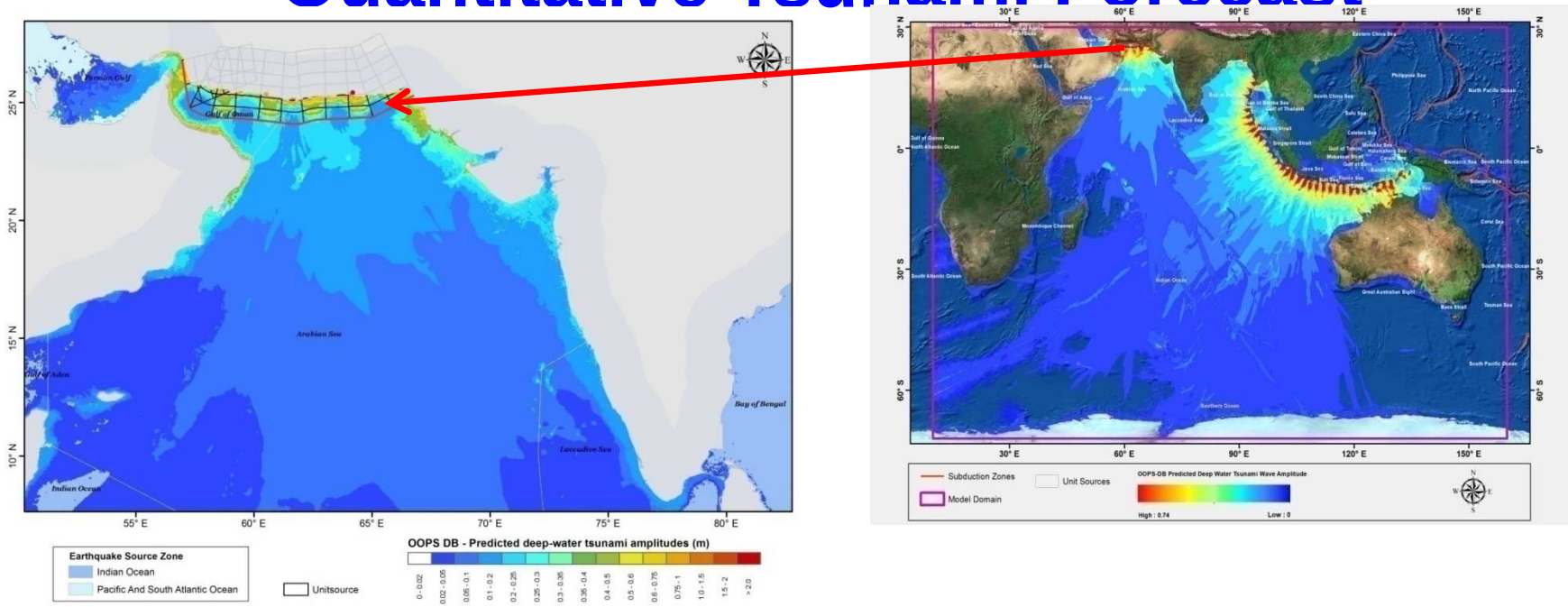




Indian stations as part of IOTWMS Observation Network

- 3 seismic stations are Minicoy, Port Blair & Shillong
- 7 Tsunami Buoys are 23217, 23218, 23219, 23223, 23226, 23227 and 23228
- 8 Tide gauges are Chennai, Cochin, Minicoy, Marmagao, Nancowry, Port Blair, Veraval and Visakhapatnam

Quantitative 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 Makran and Sunda Tsunamigenic Zones generated using **TUNAMI FF** (https://github.com/tunamiff2011cuda/tunamiff2011) in spherical coordinates and migrated to New hardware as part of Tsunami Technology Refreshment
- 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**

POC – Tsunami Forecast with application of Neural networks

Data Science - Application of ML & AI concepts

Open Ocean Propagation Scenario Database (OOPS DB) that generated by TUNAMI-FF (source: https://github.com/tunamiff2011cuda/tunamiff2011) in spherical coordinates using Neural networks (Deep Learning) is initiated

POC Done

Considering the OOPSDB 2009 scenarios of worst-case of different magnitudes (6.5, 7.0, 7.5, 8.0, 8.5, 9.0 & 9.5) and different depths (10 km, 20 km, 33 km, 40 km , 60 km, 80 km and 100 km) the Neural Network Technique (MLP with BP) is used for estimating Maximum wave deep water amplitudes, travel times and tsunami profiles at specified locations. Andaman-Nicobar sources are considered for the "**typical**" source locations in this POC study.

In this method (soft computing), the NN technique is used to process the selected scenarios results of OOPSDB (hard computing) for Area of Interest (AOI) and those inputs fed to input layers of Multilayer perceptron are multiplied with interconnection weights of neurons in first hidden layer and summed up and subsequently fed to process by a selected non-linear activation function and same will be repeated with remaining hidden layers to produce the output. Then the output of MLP is compared with original output in order to compute the error.

Then the computed error is then fed back (back propagated) to MLP neural network and used to adjust the weights such that the error decreases with each iteration and the neural model becomes closer to produce the desired output of soft computing.

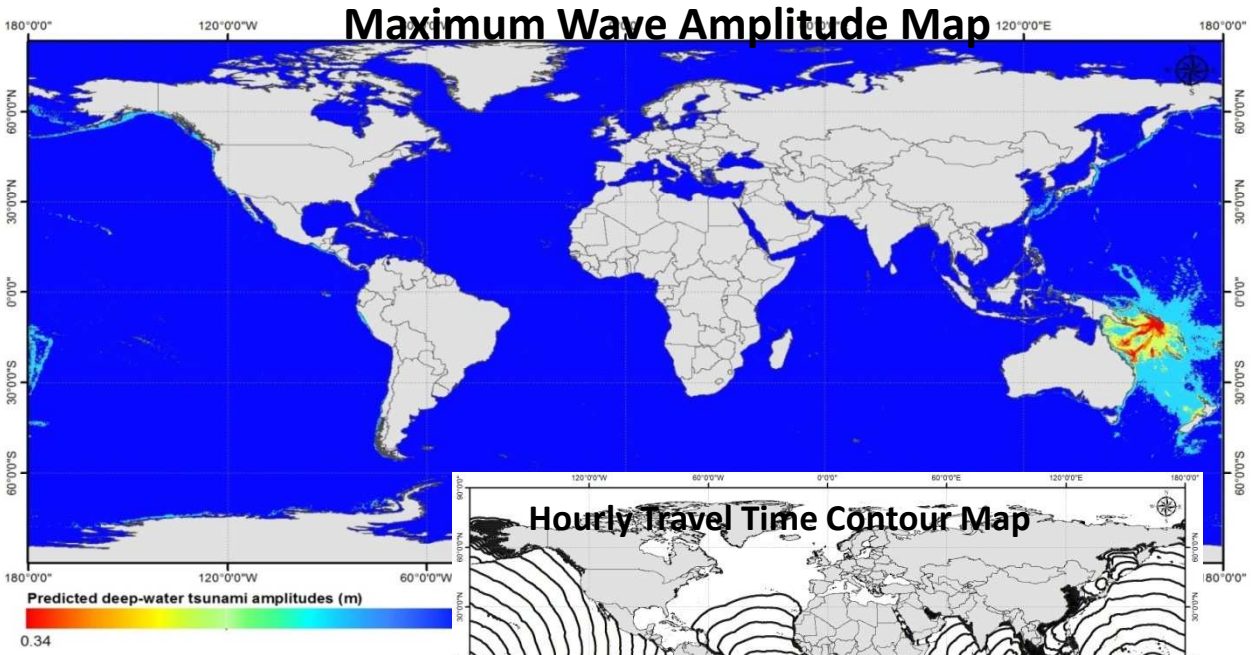
This method is proposed to scale up for Entire Indian Ocean and Global Ocean Scenarios.

Operational Tsunami Forecast for Global Earthquakes

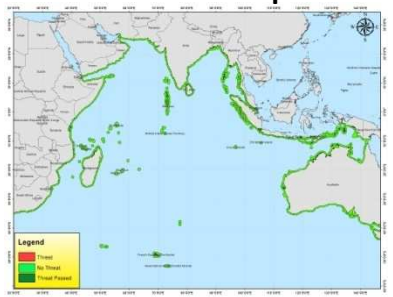
Real time Model Launch for Global Earthquakes(RML GE) of Magnitude M >=8.0

- 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. **Migrated to New Hardware with GPU cards NVIDIA QUADRO P4000 (VCQP4000-SB) with 1792 cuda cores & 8GB GDDR5 memory as part of Tsunami Technology Refreshment.**
- 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

TSUNAMIFF URL: **https://github.com/tunamiff2011cuda/tunamiff2011**

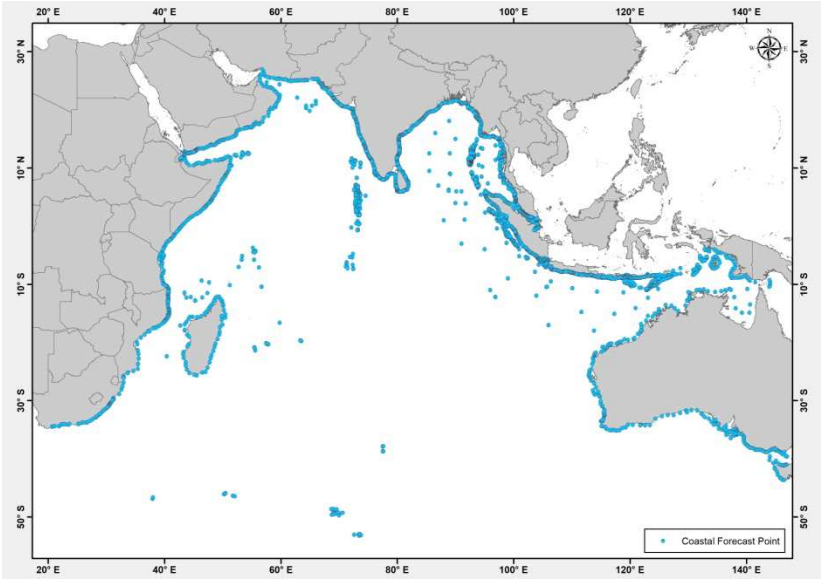


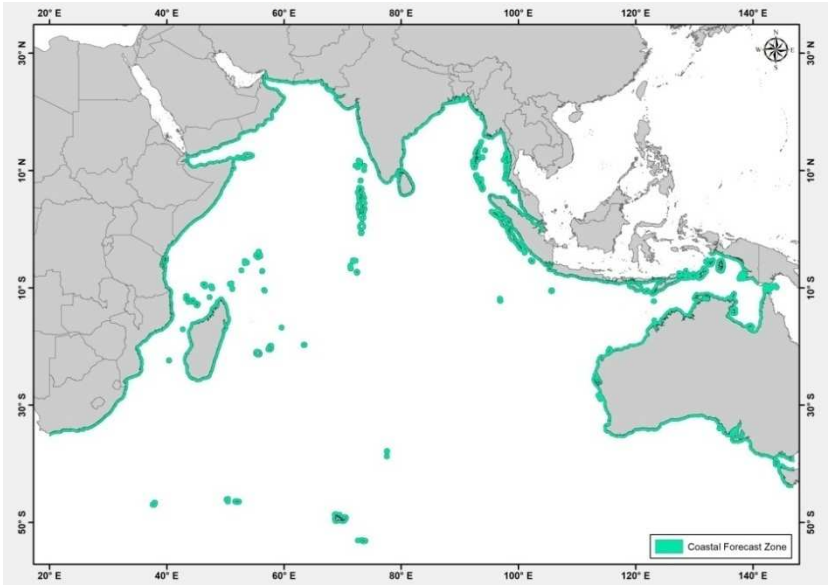
Threat Map



UPDATES In CFP and CFZ Version 2018 Mar 14

- Total CFZs and CFPs are 581 and 2251 respectively.
- As part of NTWC SL III operational requirements , in addition to **9** newly added CFZs, modification of 1 CFZ for Indian region. More Coastal districts are added in consultation with NDMA. In total **79** CFZ are identified for India and generated for official list of Tsunami hazard Districts approved by NDMA, India
- Linking CFZs With new GADM (Version 3.6), Place names, District, State/Province and Country names cross verification, naming standards against the ISO standard documents is under progress.
- CFZ files will be circulated to TSP Australia and Indonesia for comments and suggestions and will be released as a new version with approved date.





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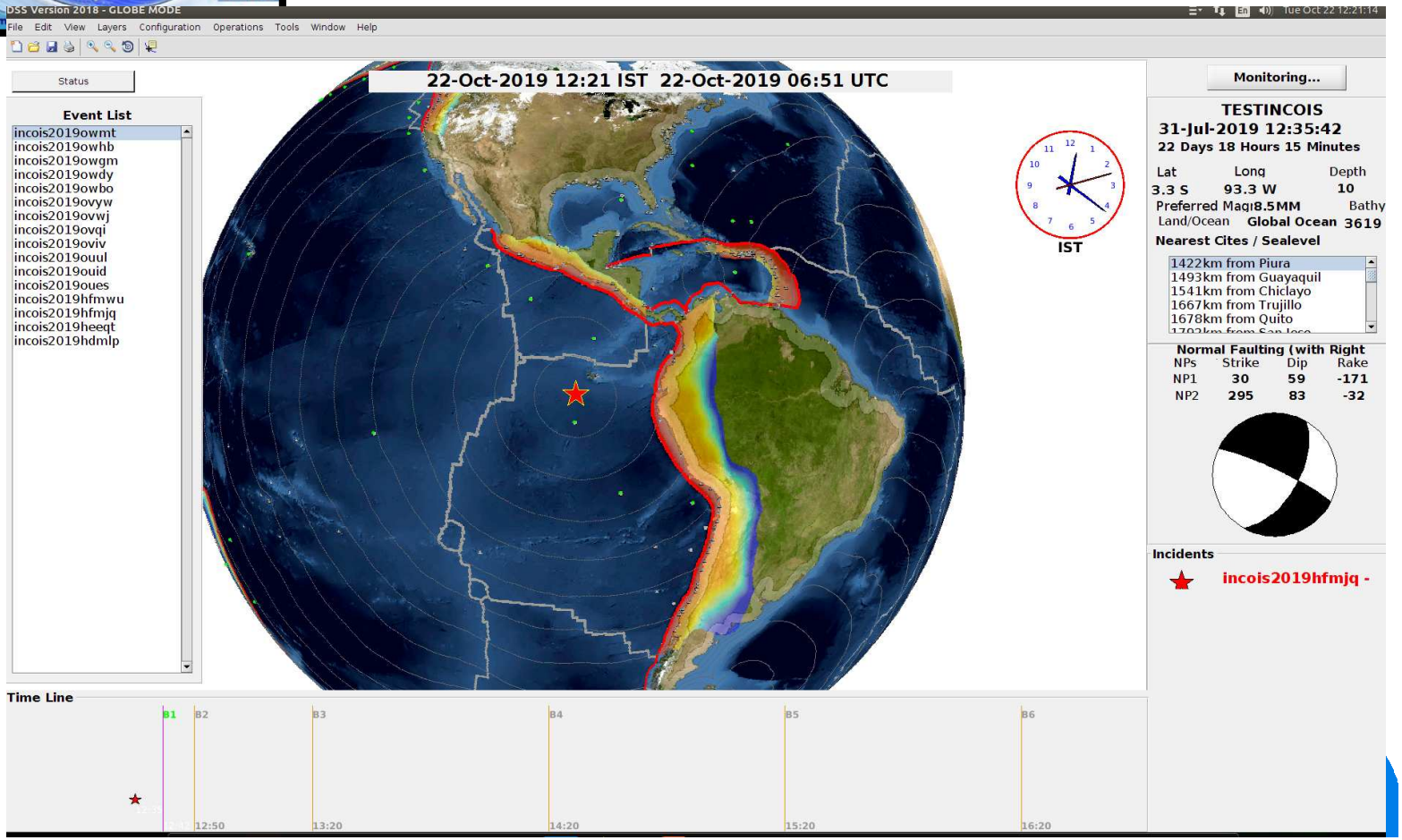
New– DSS Version (under Development & Testing)

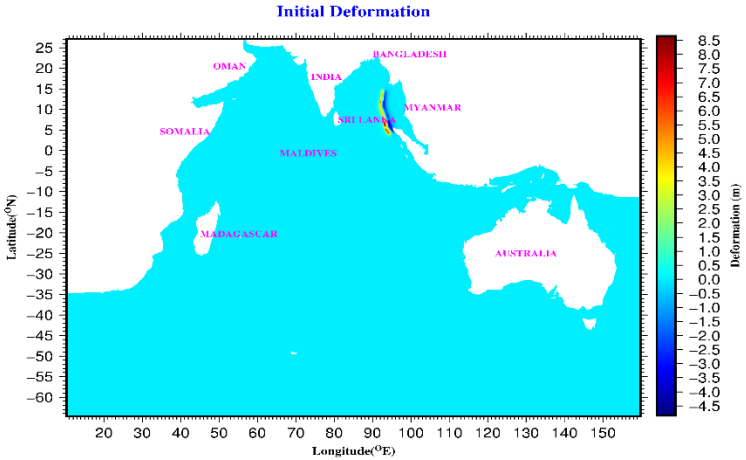
- New Decision Support System 2020 is under development and Environment setup is under progress
- Access to SEISCOMP system for real-time Seismic information
- Integrated with International Sea level Data (Tsunami Buoys & Tide gauges)
- Integrated with OOPSDB for Service Level - II for Indian Ocean Events- **ABC of OOPSDB**
- Integrated with **ADCIRC** real-time inundation modeling for Service Level –III
- Integrated with **TUNAMI-FF** for real-time modeling of Global Earthquakes M>=8.0
- Integration of Dissemination Mechanism and Database for Web publishing in **development environmen**t under progress.
- **Integrated approac**h including sea level inversion integration under progress

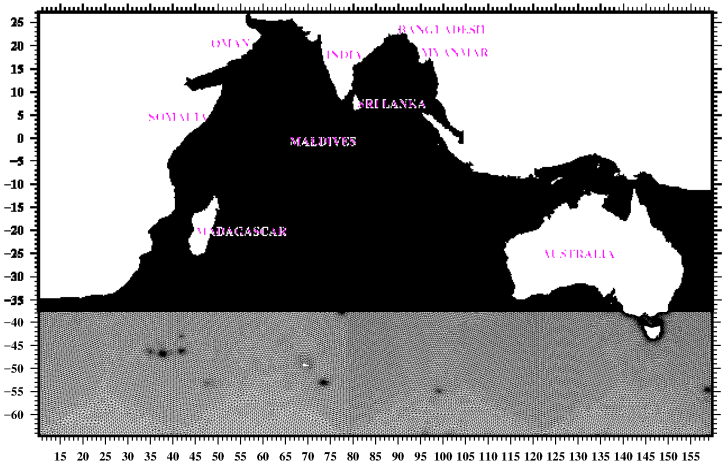
DASH BOARD

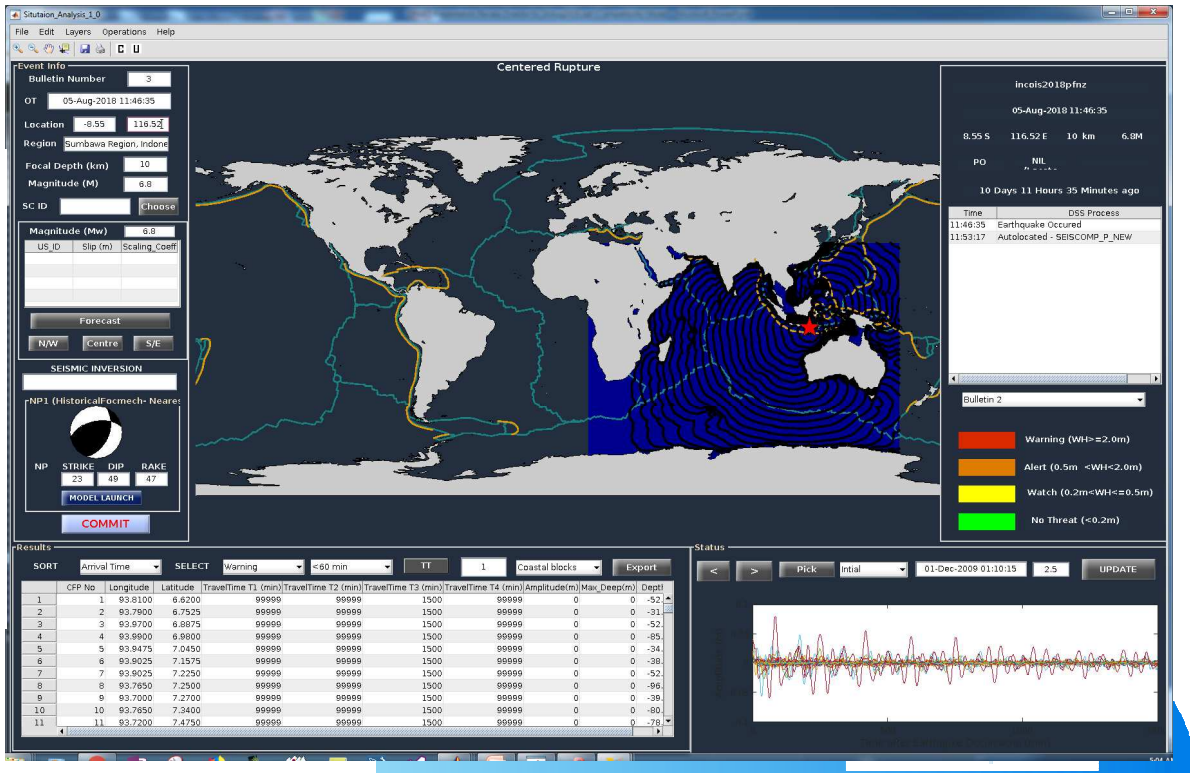


Real-time tsunami modeling using ADCRIC

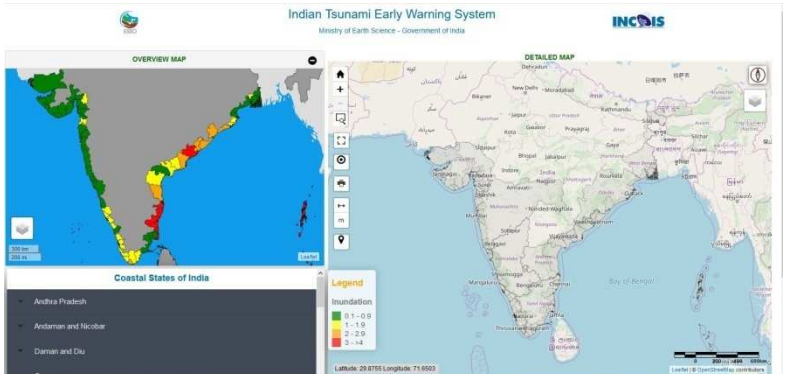
- **Real-time tsunami Modelling for propagation and inundation** using ADCRIC model.
- This model has been tested against the Dec 26, 2004 tsunami event and results are in good agreement.
- Initiated for BM Tests

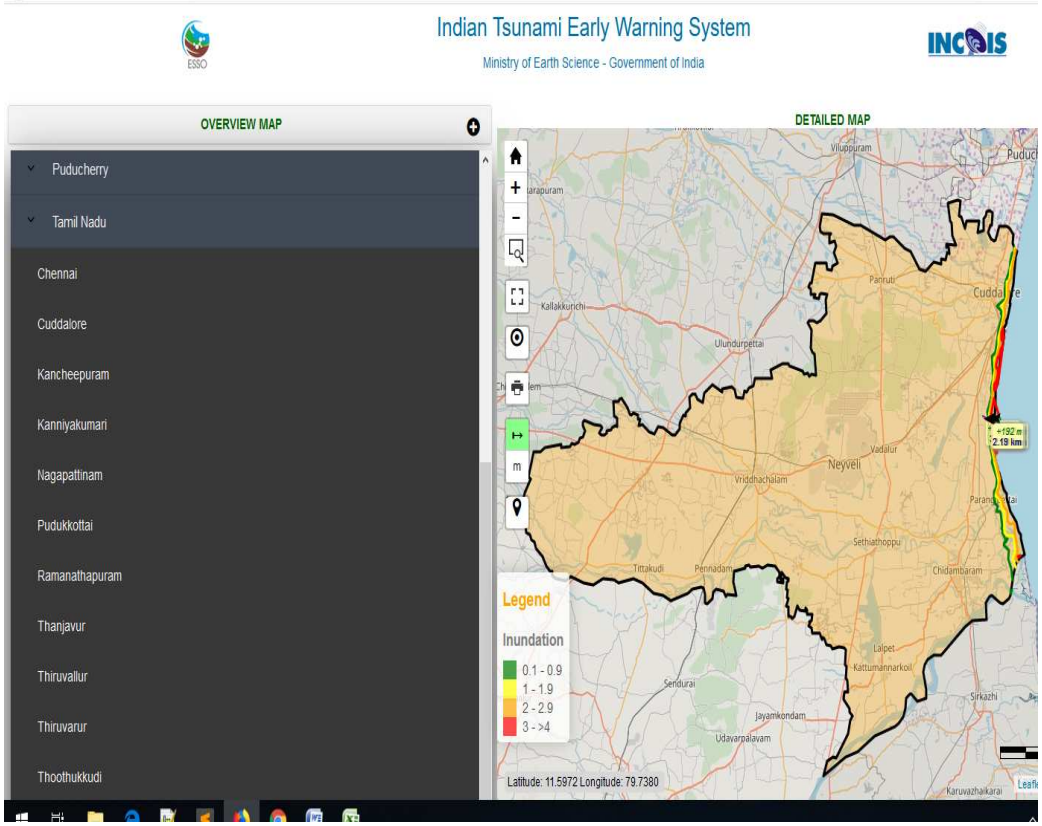


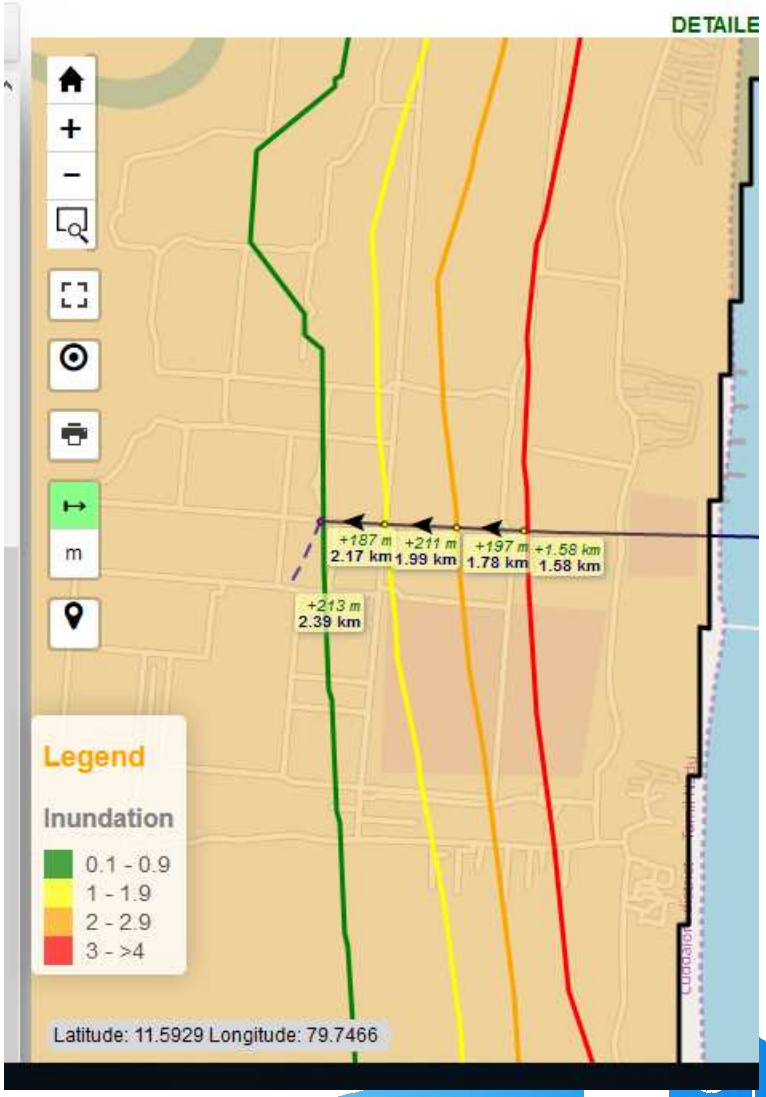




Service Level –III POC (Tsunami Inundation for Indian Coast)







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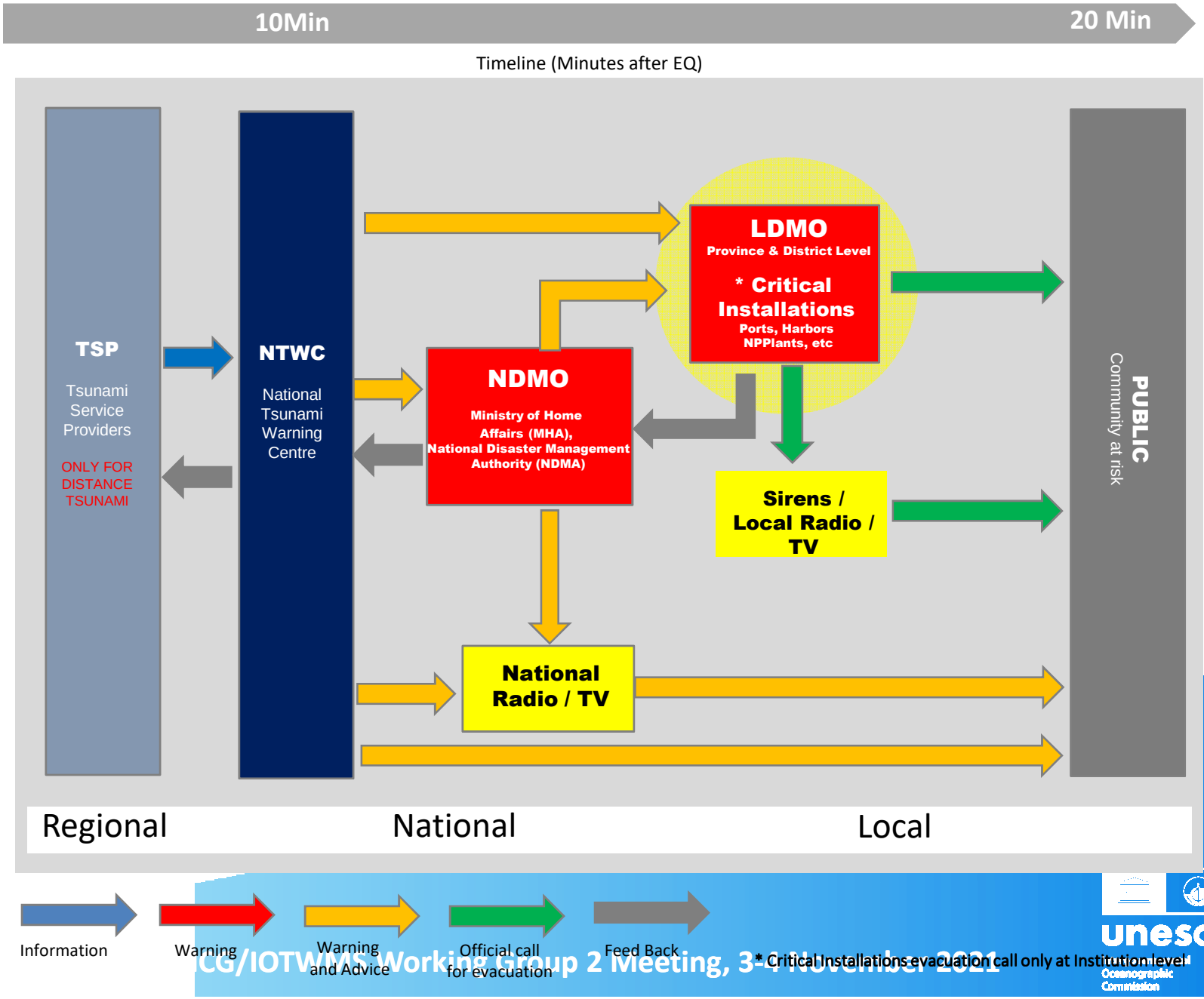
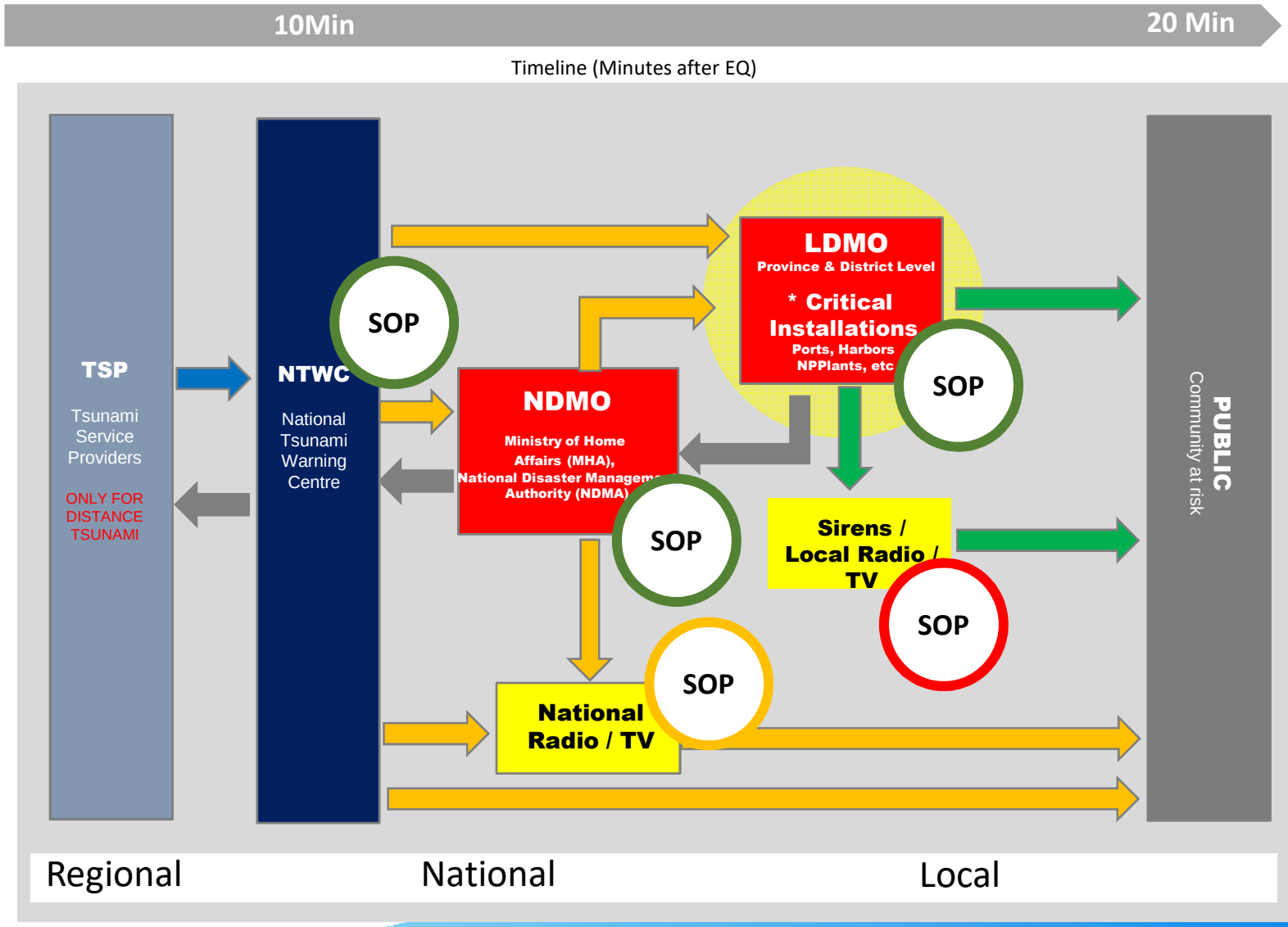
India Tsunami Warning Chain

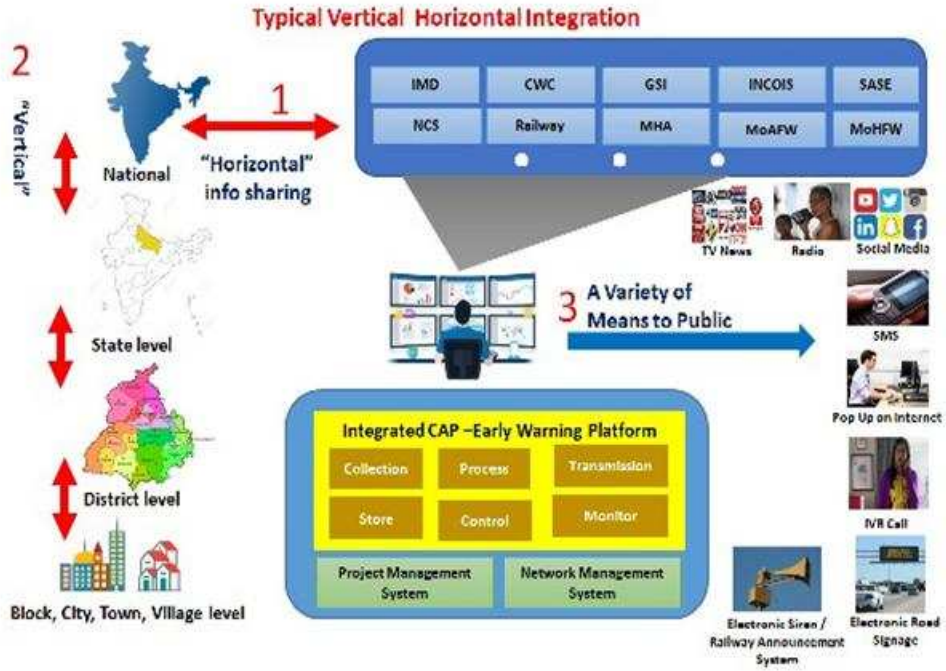


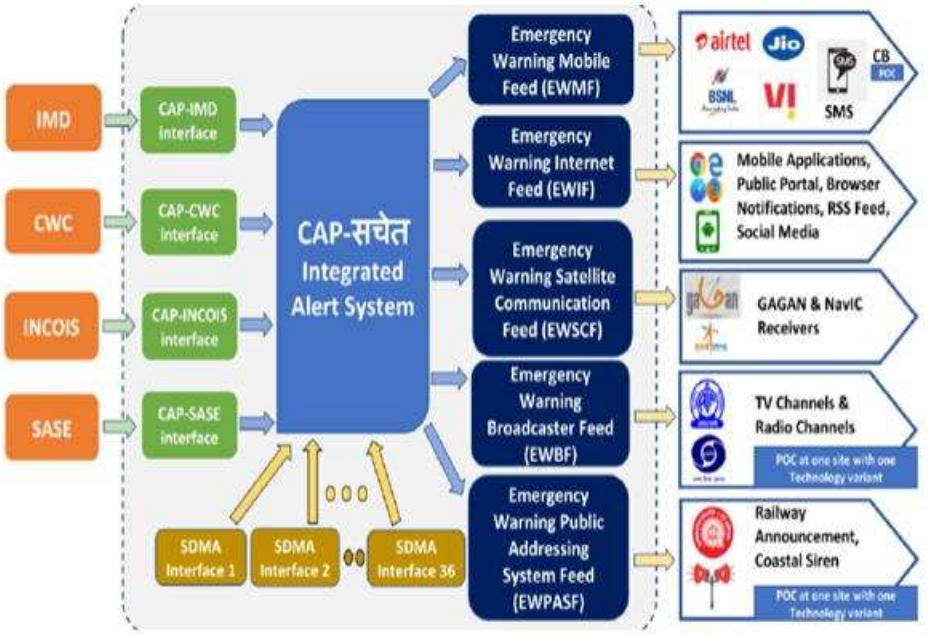
India Tsunami Warning Chain



Implementation of CAP for National and TSP services

- TSP-India is producing messages in CAP on test basis .
- As a NTWC, ITEWC is also generating the CAP files for NTWC service on real-time basis and made available to consume by the stakeholders.
- National Disaster Management Agency (NDMA) is planning to implement the CAP enabled integrated alerting system for PAN India covering all hazards.
- As a pilot program, INCOIS is currently working with NDMA to integrate the tsunami services.





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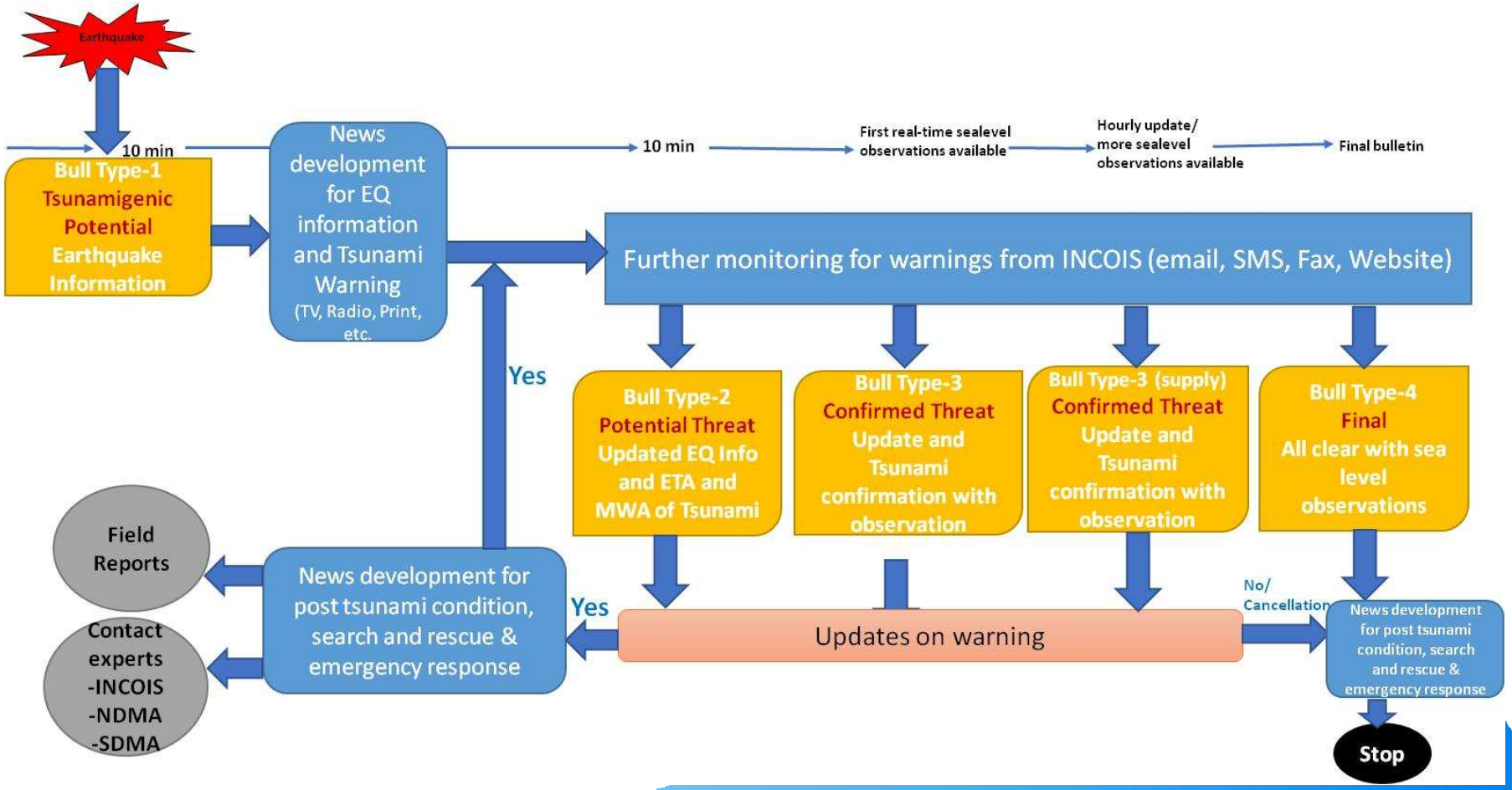
India Media SOP - DRAFT



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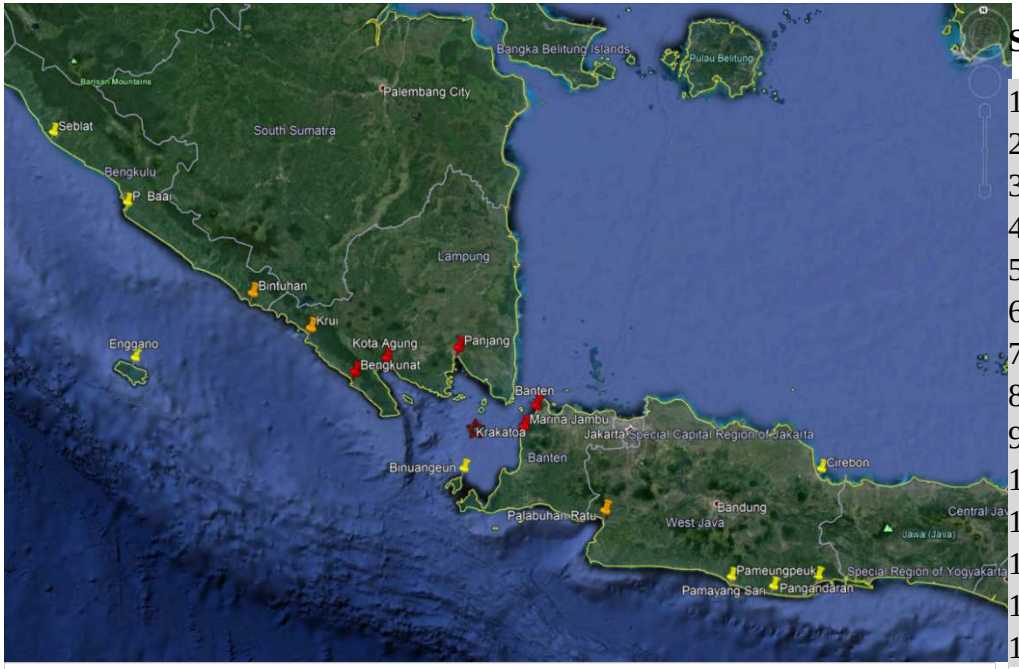
Research on Atypical source tsunamis

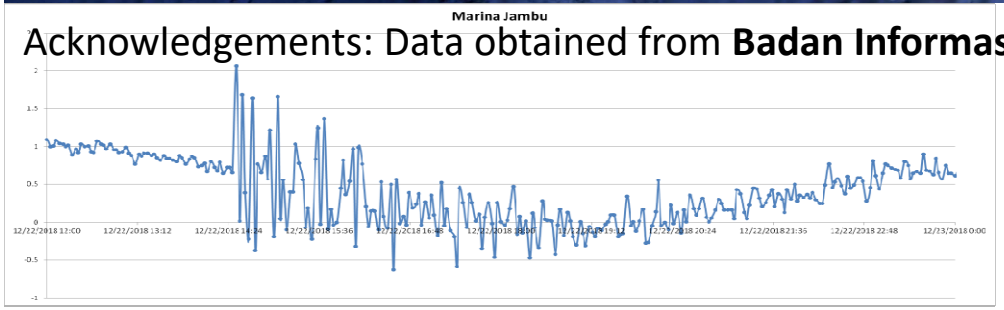
Krakatoa volcano was triggered a tsunami on 22 December 2018

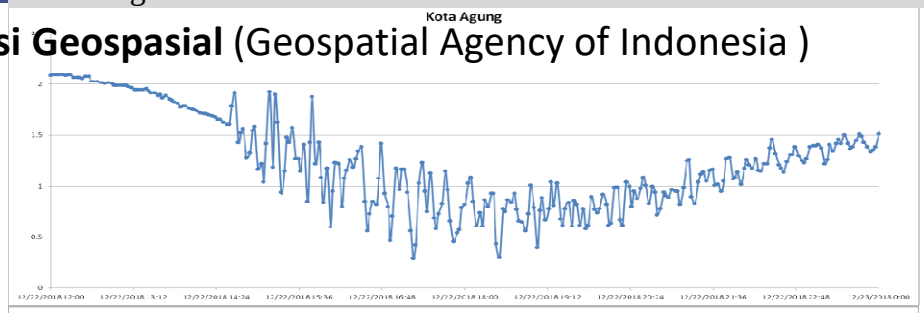


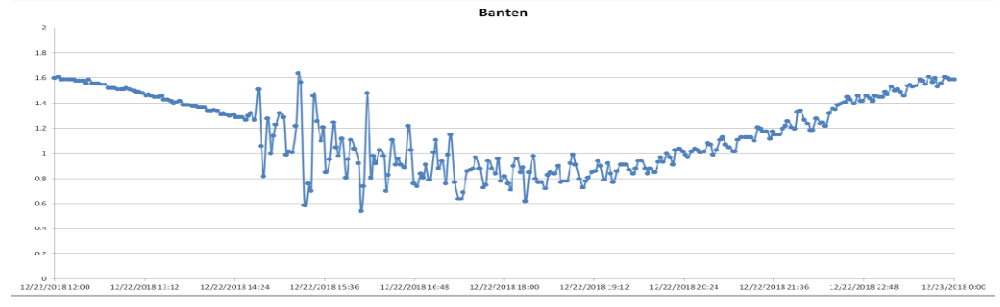
Sea level Observations of tsunami

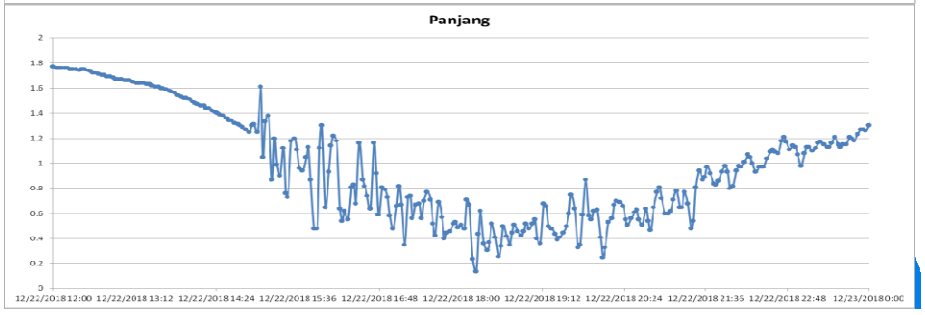
S No	Station Name	Latitude	Longitude	Travel time (UTC)	Observations (m)
1	Marina Jambu	--	--	14:27	1.4
2	Kota Agung	-5.5	104.616	14:33	0.51
3	Banten	-6.0166	105.966	14:40	0.52
4	Panjang	-5.45	105.283	14:53	0.41
5	Bengkunat	--	--	15:35	0.25
6	Palabuhan Ratu	-6.983	106.55	15:57	0.45
7	Bintuhan	-4.833	103.416		
8	Binuangeun	-6.5	105.316		
9	Cirebon	-6.733	108.583		
10	Enggano	-5.333	102.266		
11	Krui	-5.183	103.933		
12	Pamayang Sari	-7.766	108.083		
13	Pameungpeuk	-0.65	107.683		
14	Pangandaran	-7.7	108.5		

Acknowledgements: Data obtained from **Badan Informasi Geospasial** (Geospatial Agency of Indonesia)



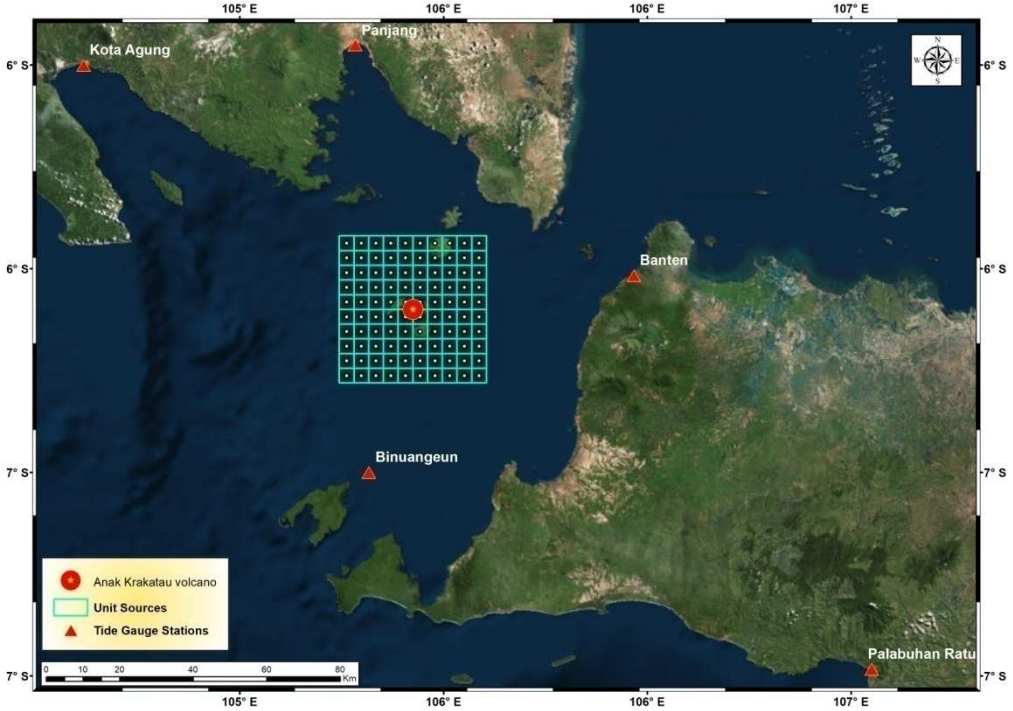




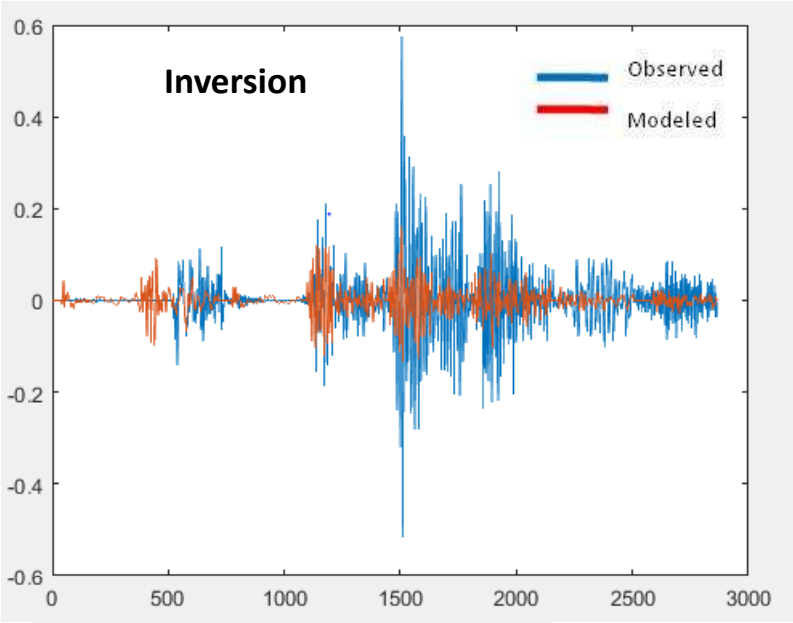


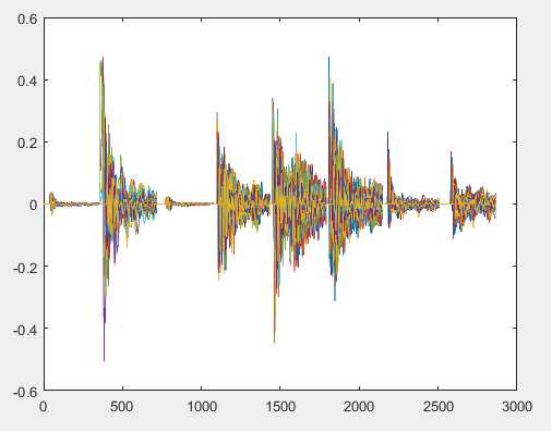
Research on Atypical source tsunamis

Greens Function Setup (**preliminary**)

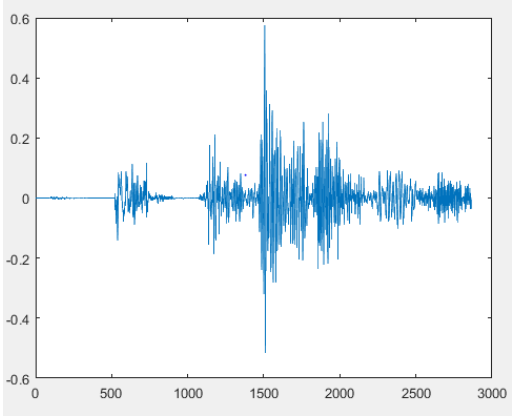


Preliminary Results (VSM)

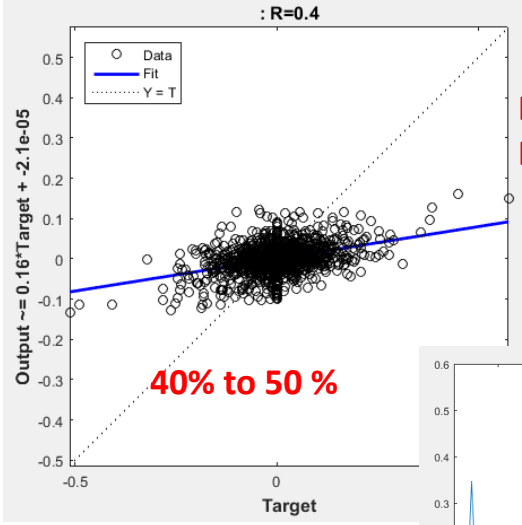




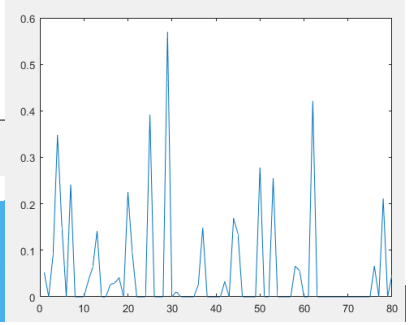
Greens function matrix



Observation matrix



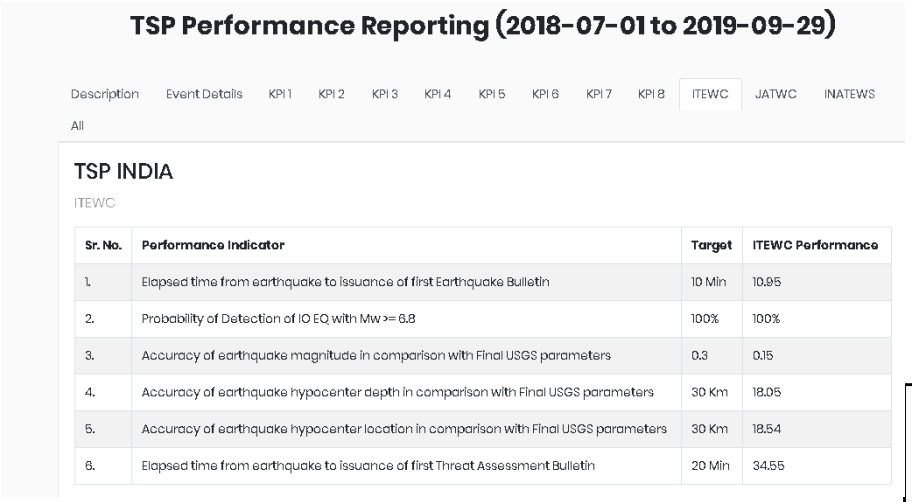
Limitations
Bathymetry(TG)

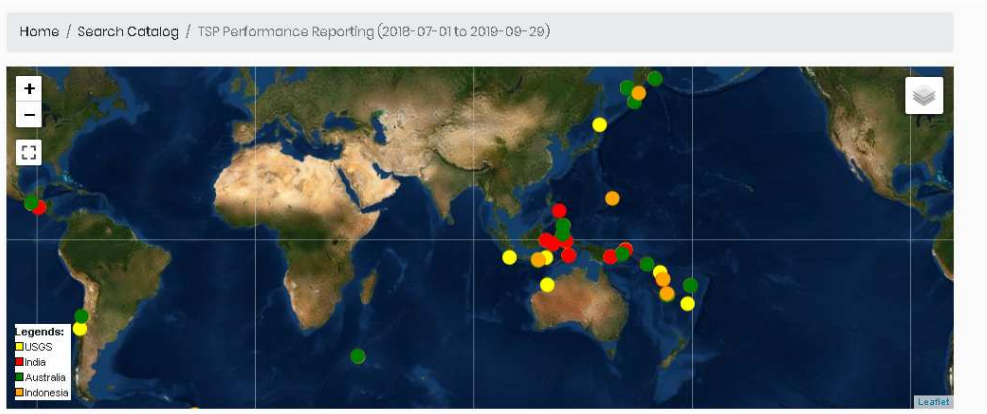


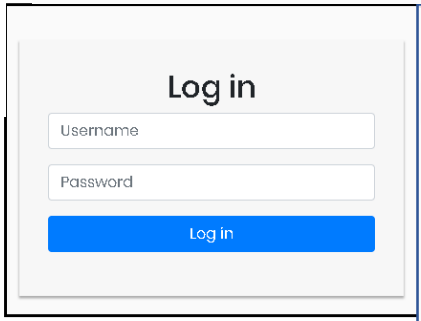
Slip distribution

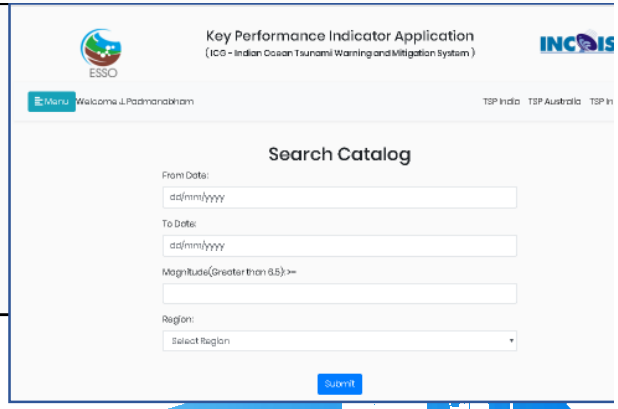
Event Database and KPI Generator

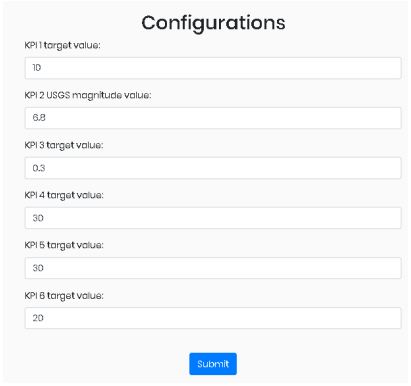
- TSP India has developed the Key Performance Indicator Application for ICG – IOTWMS.











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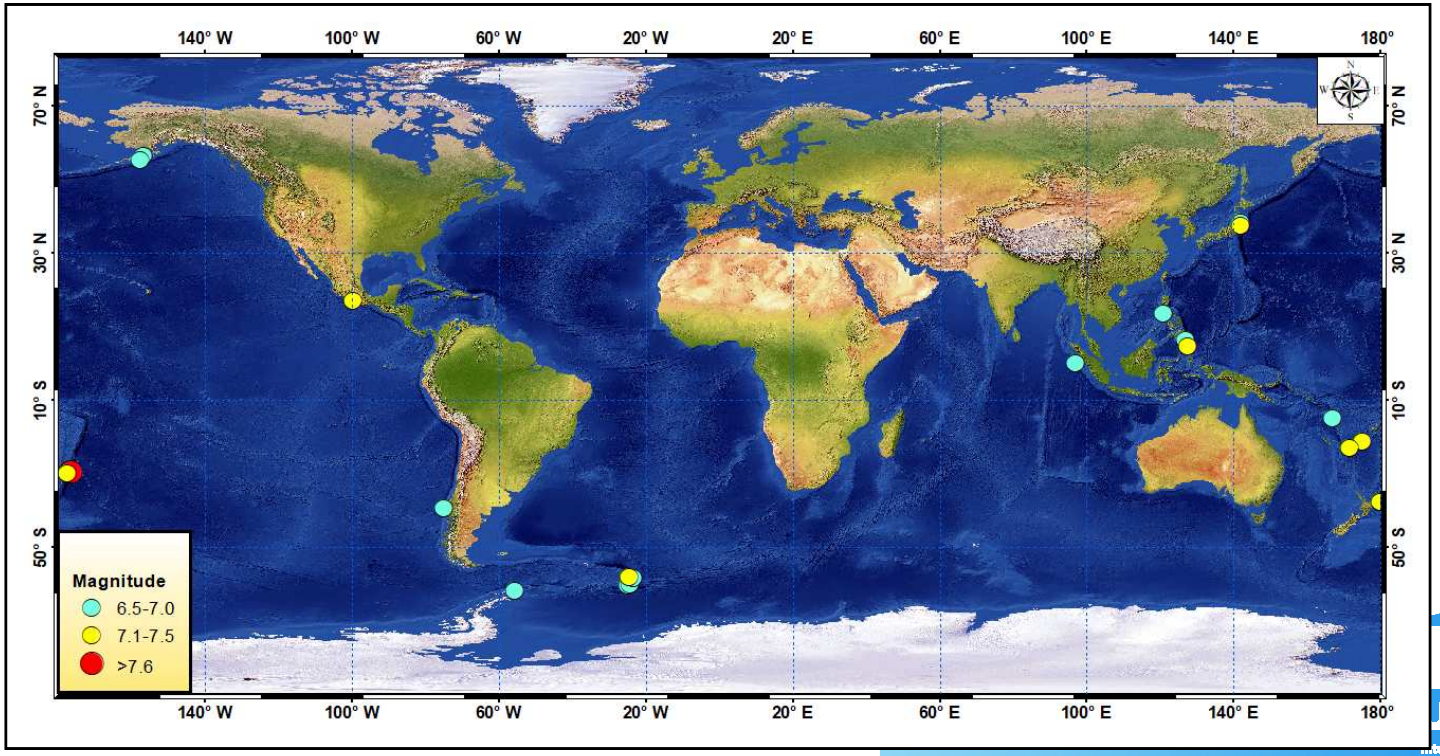
TSP India Performance

KPI 1: Elapsed Time of Issuing First Earthquake Bulletin after Earthquake – Target 10 minutes

Reporting Period Dec 01, 2020 to October 31, 2021	
Total Number of Global Earthquakes M≥6.5	38#
Number of TSP INDIA events those crossed the USGS final M≥6.5	24@
Number of events those issued first bulletin by TSP INDIA	24
Average Elapsed Time to issue first Bulletin	12.2 min

USGS final magnitudes ≥ 6.5 were located in IOTWMS Earthquake Source Zone
@ for non-issue of earthquake bulletin for these events is because the initial magnitude was less than 6.5



TSP India Performance

KPI 2-Probability of Detection of Indian Ocean Earthquakes with Magnitude 6.8 or above – Target 100%

Reporting Period December 01, 2020 to October 31, 2021	
Total Number of Indian Ocean Earthquakes M≥6.8 (USGS)	0
Number of Indian Ocean Events detected by TSP INDIA	0
Number of events those issued first bulletin	0

Target = 100%; Result = 100%

During the reporting period there was only one tsunamigenic earthquake of 6.6M on 14 May 2021 0633UTC at Off West Coast of Northern Sumatra for which TSP India has issued 2 bulletins.

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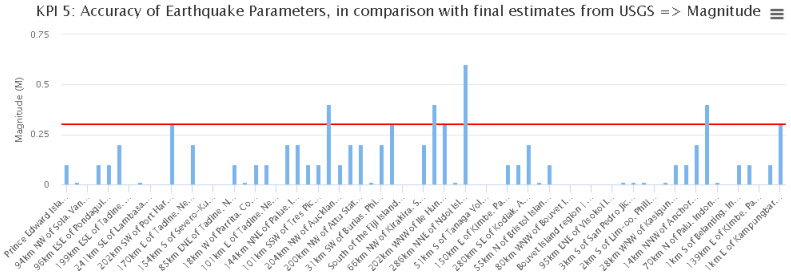
TSP India Performance

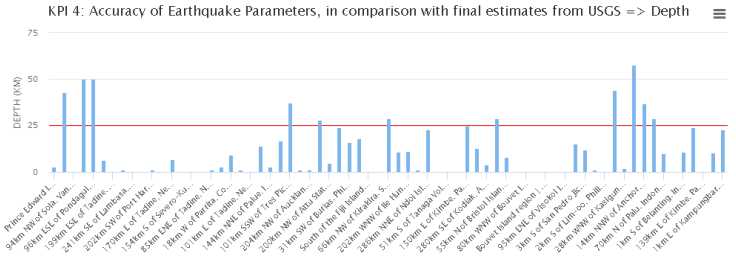
KPI 3: Accuracy of Earthquake Magnitude (Target 0.3)
KPI4:Accuracy of earthquake hypocenter Depth (Target 30km)
KPI 5: Accuracy of earthquake hypocenter Location (Target 30km)

Reporting Period December 01, 2020 to October 31, 2021	
Total Number of Global Earthquakes M≥6.5	38#
Number of events those issued first bulletin	24*

USGS final magnitudes ≥ 6.5 were located in IOTWMS Earthquake Source Zone (Indian Ocean, Pacific Ocean, South Atlantic

* for non-issue of earthquake bulletin for these events is because the initial magnitude was less than 6.5





Magnitude difference: 0.16

Location difference: 18.01 km

Depth difference: 18.25 km

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TSP India Performance

KPI 6: Elapsed Time of Issuing First Tsunami Threat Assessment Bulletin after Earthquake – Target 20 min

Reporting Period December 01, 2020 to October 31, 2021	
As per USGS final magnitude Number of Events Threat Assessment Bulletin need to be issued	1
Number of Events Threat Assessment Bulletin issued	2#
Number of Events for which **"THREAT"** Bulletin issued	0
Number of Events for which **"NO THREAT"** Bulletin issued	2
Average Elapsed Time for all Events	29 min

7.4 M South Sandwich Islands Region on 12 Aug 2021 : Though this event has no threat for the Indian Ocean, since there could be a wave activity as per TSP- Australia, TSP-India had also monitored this event closely and issued the type-II No threat Bulletin and Type=-IV Final bulletin with recorded sea-level observations.

Since the 7.4 magnitude is below the threshold of 8.0, hence, this event may not be considered for the KPI6 evaluation as per the SDD.

Event	Elapsed Time of First EQ Bulletin (min)	Elapsed Time of First Threat Assessment Bulletin (min)	Threat Assessment Threat Zones and Countries	No of Bulletins	Threat Cancel Time (mins)
M6.6 Off West Coast of Northern Sumatra on 14 May 2021	09	29	-	2	No Threat Issued

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TSP India Performance

KPI 7: Probability of detection of tsunamis above threat threshold - Target: 100%

Reporting Period December 01, 2020 to October 31, 2021	
Number of events those generated above threat threshold waves (> 50 cm)	None

KPI 8: Accuracy of tsunami wave height predictions - Target: factor of 2

Event	Elapsed Time of First EQ Bulletin (min)	Elapsed Time of First Threat Assessment Bulletin (min)	Threat Assessment		Number of Bulletins Issued	Threat Cancel Time (mins)
			Threat Zones and Countries	Highest Predicted Wave Amplitude		
NA	NA	NA	NA	NA	NA	NA

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TSP India Performance

Summary of Performance Indicators dring reporting period

S. No	Performance Indicator	Target	TSP India Performance
PI 1	Elapsed time of issuing first earthquake bulletin after earthquake	10 min	**12.2**min
PI 2	Probability of Detection of IO EQ with Mw >= 6.5	100 %	**100**%
	Accuracy of Earthquake Parameters, in comparison with final estimates from USGS		
PI 3	Magnitude	0.3	**0.16**
PI 4	Depth	25 km	**18.25** km
PI 5	Location	30 km	**18.0** km
PI 6	Elapsed time of issuing first tsunami threat assessment bulletin after earthquake	20 min	**29** min
PI 7	Probability of detection tsunamis above threat threshold	100%	**NA**
PI 8	Accuracy of tsunami wave height predictions	Factor of 2	**NA**

Future Plans

- Operationalize the auto KPI system.
- Work on Operational procedures (SOP) for atypical tsunami sources such as Submarine landslides, Volcanic eruption and meteoric sources.
- Utilization of real-time GNSS & SMA data for rupture characterization of the tsunamigenic earthquakes.
- Mounting efforts on Integrated inversions for tsunami source characterisation
- CAP enabled TSP service
- Implementation of Service Level 3 inundation modeling for National Indian coastal zones.
- Mounting efforts on tsunami hazard assessment and modelling studies
- Continue to contribute strongly to IOTWMS activities in the next intersessional period, including:
  - The planning, conduct and reporting of biennial IOWave exercises
  - The planning, conduct and reporting of 6-monthly Communication Tests
  - Regular NTWC/DMO/Media SOP Training Workshops
  - ICG/IOTWMS Working Groups and Task Teams

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Thank you

Chodavarapu Patanjali Kumar
INCOIS
patanjali@incois.gov.in

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