Strom Surge Early Warning System @ INCOIS

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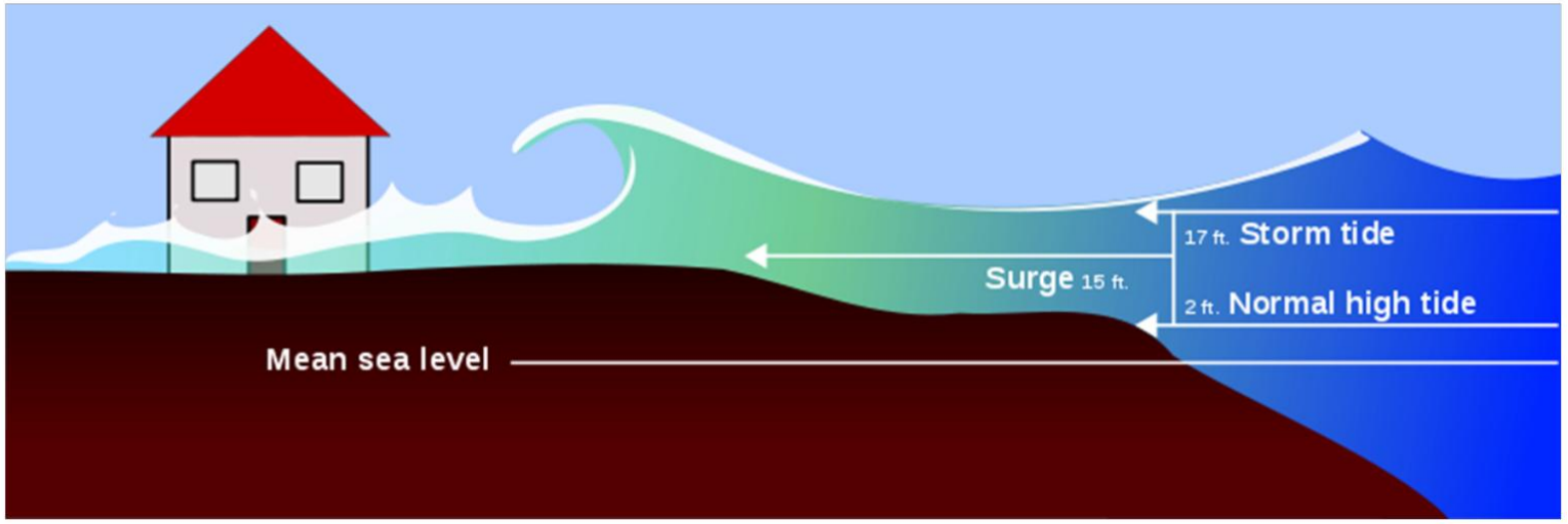
Storm Surge ???

Storm surge is an abnormal raise in sea level at the coast due to a high winds of a tropical storm.

How it all piles up the water:

- *Low pressure system (storm)* generates wind
- Wind blows across the sea surface
- Friction between the wind and water pushes the water in the direction of wind
- Tides caused by the gravity of the sun and moon contribute to the rise in ocean surface
- The sea level starts to pile up along the coastline due to approaching storm.



"Piling up of water at the coast"

Factors contributing storm surge:

- Wind – Usually associated with a tropical storm
  speed , direction, angle of approach to the coast
- Storm forward speed

Strong wind + large fetch + long time + track perpendicular to the coast = Highest surge

where,

Fetch – The distance over which the wind interacts with the surface of the ocean

Time – The length of time wind blows over an area of the ocean

$$\Delta\eta = -\Delta p/\varrho g$$

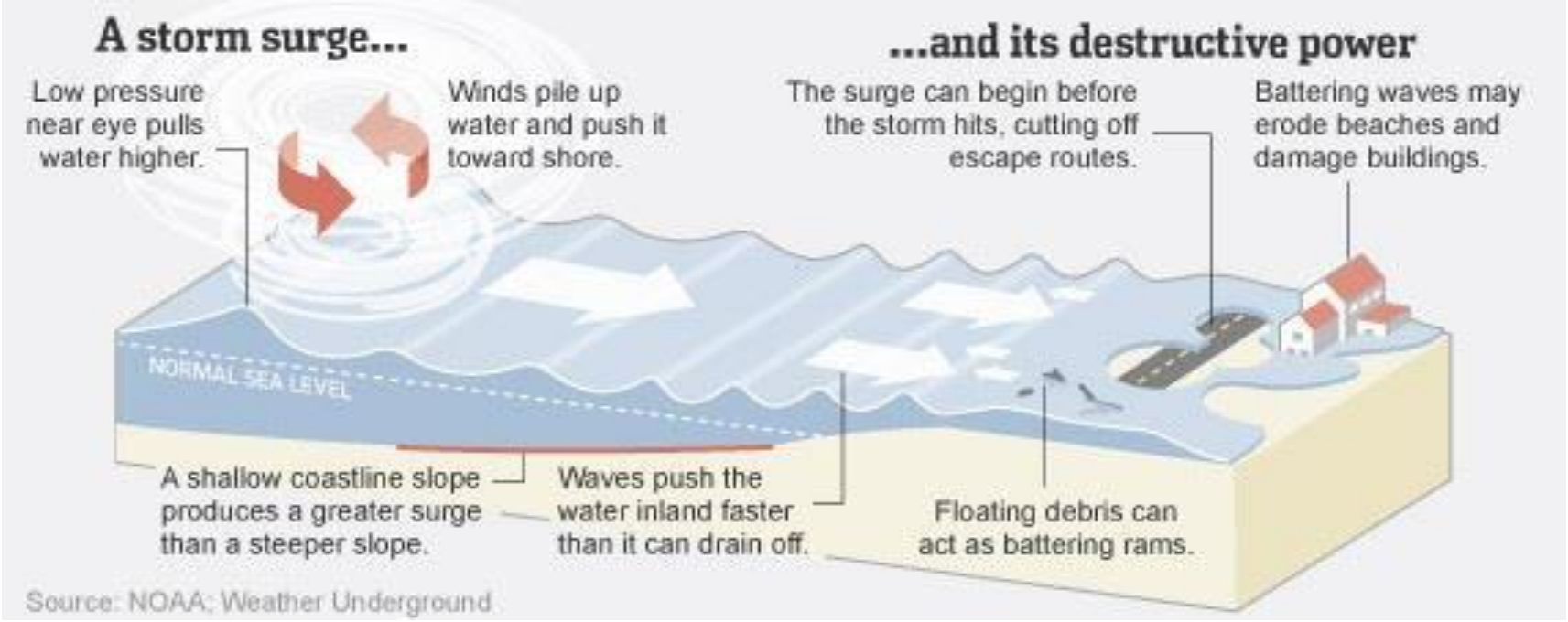
- Low storm pressure over the ocean
- Tides – phase of the tides contribute to storm surge height
- Slope and width of the continental shelf
  - wide, shallow shelves are prone to larger storm surges.

$$\eta = \frac{\tau_s}{\varrho g h} L$$

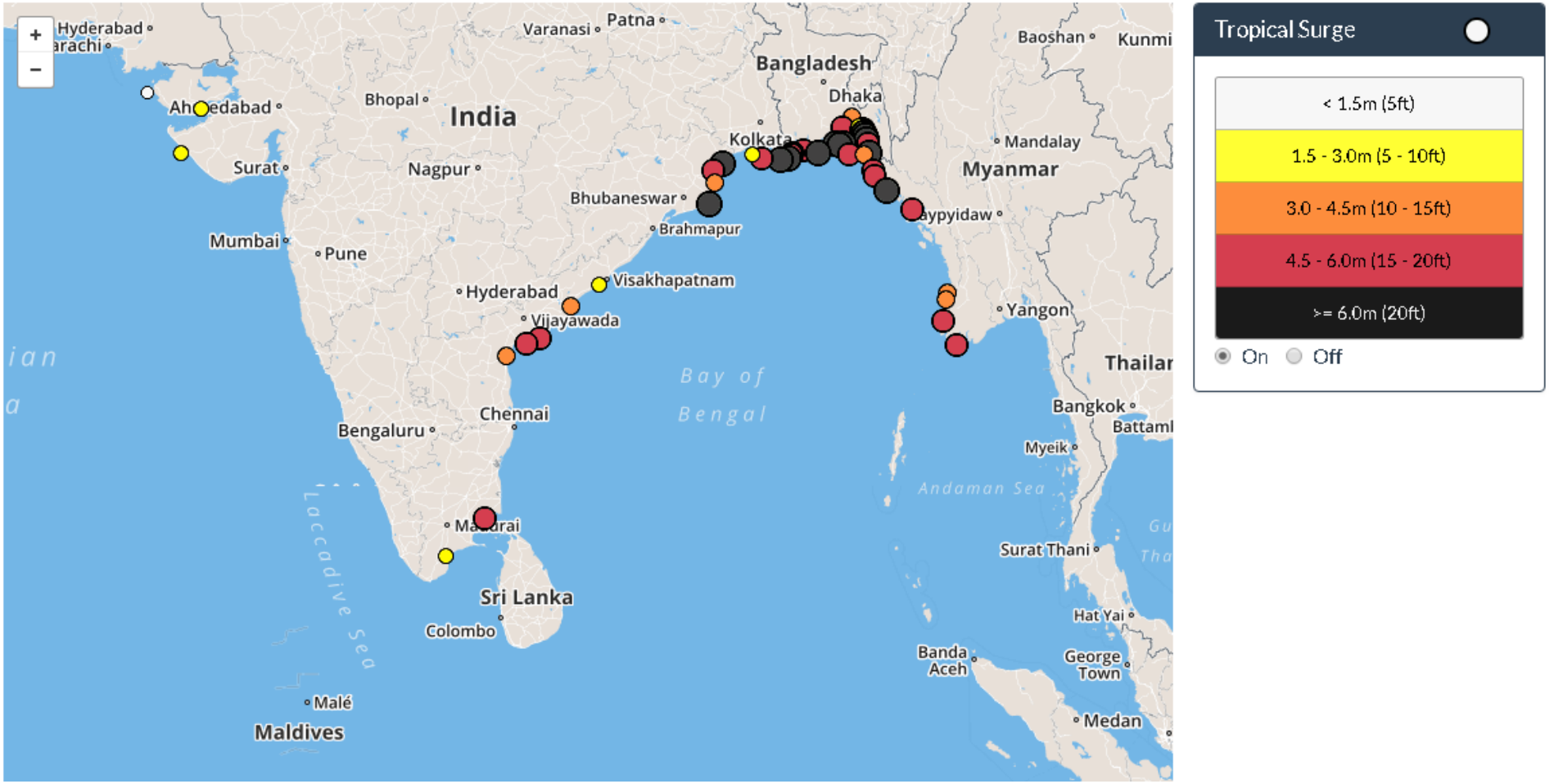
Factors contributing storm surge:

- Coastal geometry:

Storm surge is much depend on the shape of the coast line.



Historical Events (Peak Surge Map)



Architecture of Storm Surge Early Warning System

Track From IMD (E-mail)

Multi Sensor Data from various sub systems over VSAT, INSAT, GPRS, e-mail, internet

Track Generator

Spatial model data Visualization

DSS GUIs

Observations Module

Product module

Data Acquisition & Processing

Web services Database Flat Files Geo -Spatial Layers

Storm Surge Modeling (HPC server)

Visualization

Risk Analysis | Model Launch | SOP

Spatial Engine to process model outputs

Decision Support System (DSS)

Sea level monitoring | Bulletins Generation

Dissemination

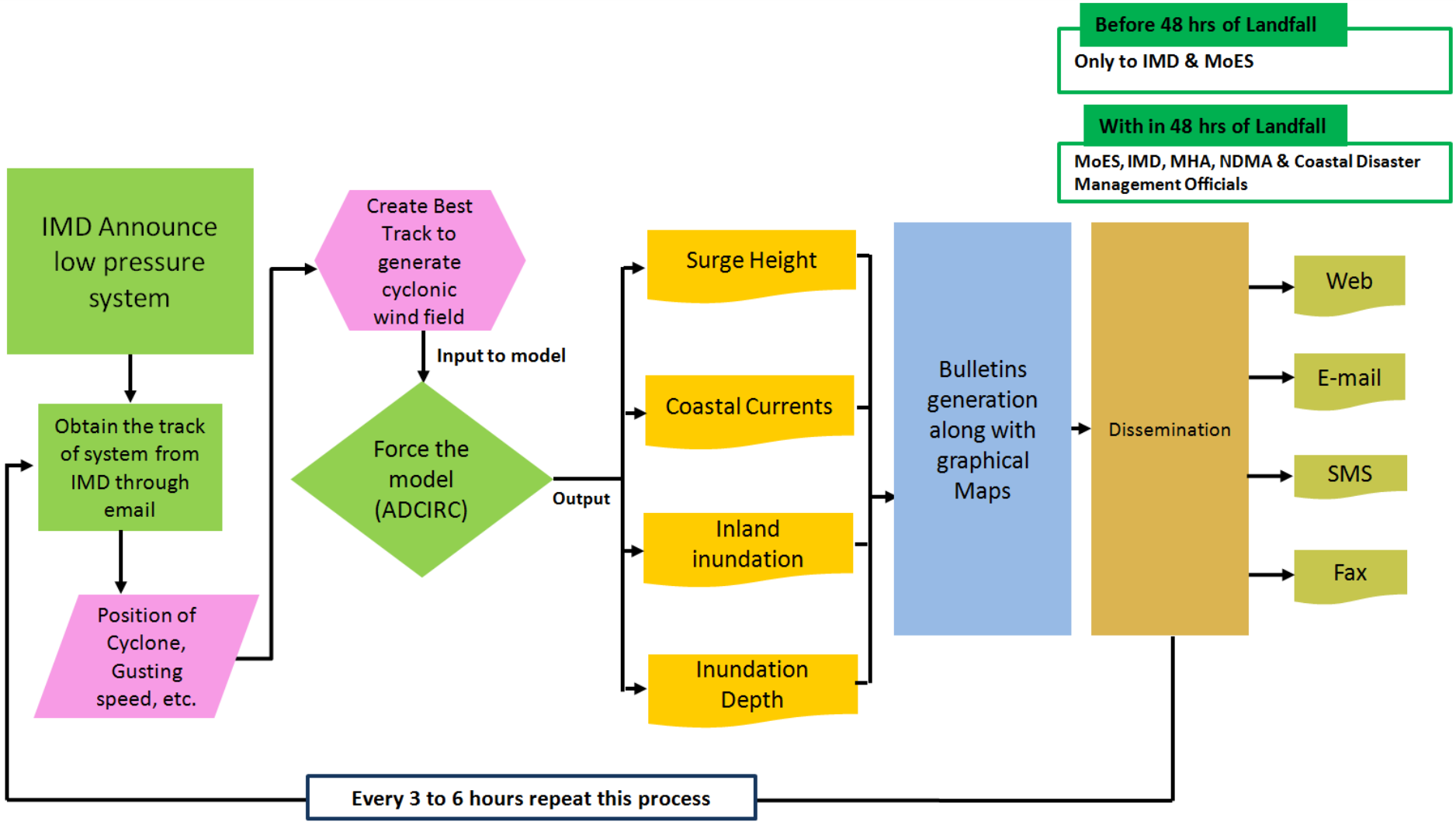
Website

Email

SMS

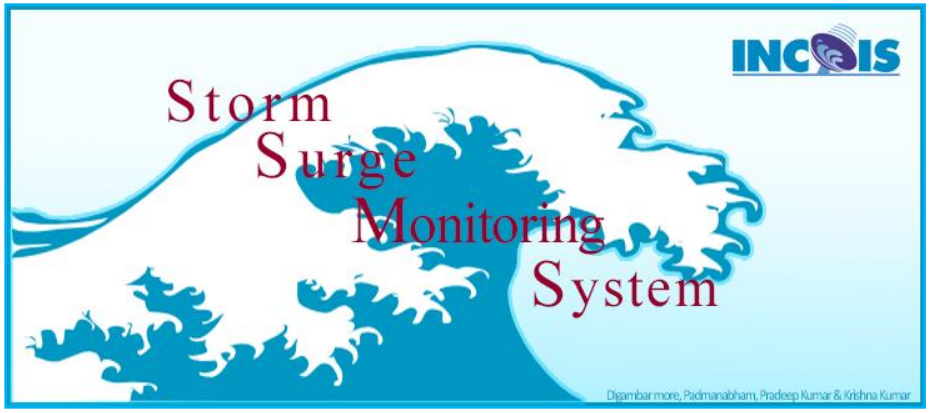
FAX

Standard Operating Procedure (SOP)



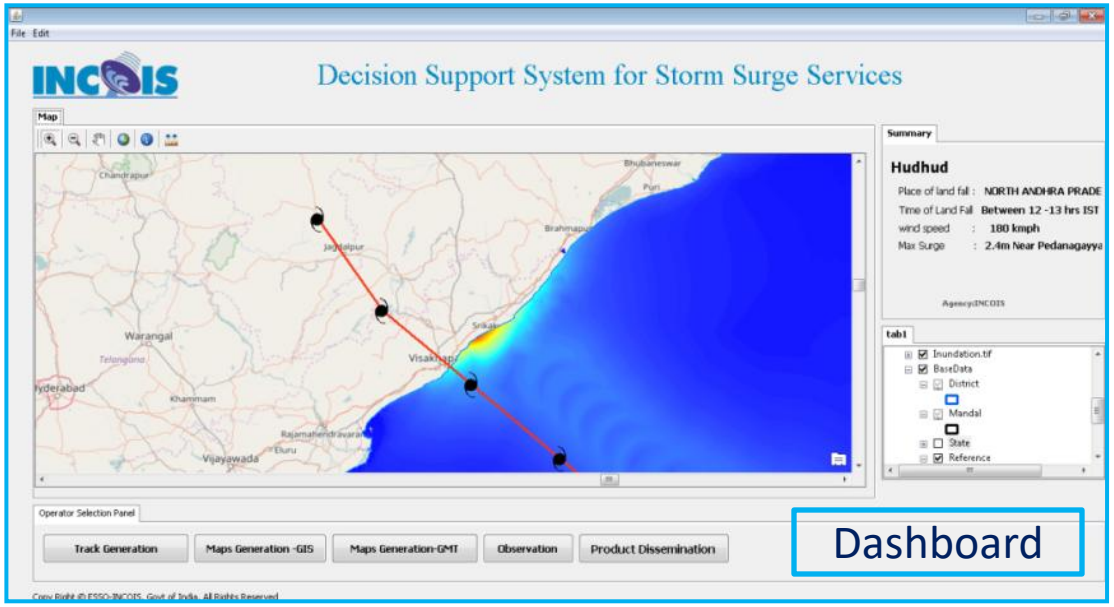
Decision support System

DSS provides **data processing**, launching of model in real time, **assessment**, **visualization**, **decision support**, analysis, **bulletin generation** , **web publish** and **dissemination** to the disaster management officials, MoES, IMD and other stakeholders

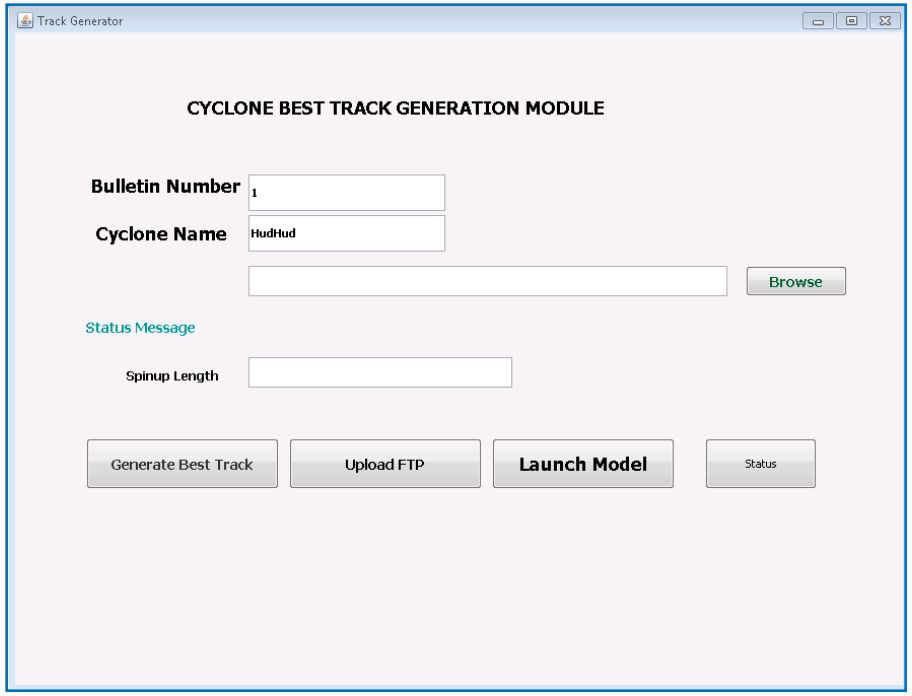


Modules:

- **Track Generator**
- **Model Launch**
- **Spatial visualization and mapping tool**
- **Bulletin Generation**
- **Dissemination**



Track Generator & Model launch



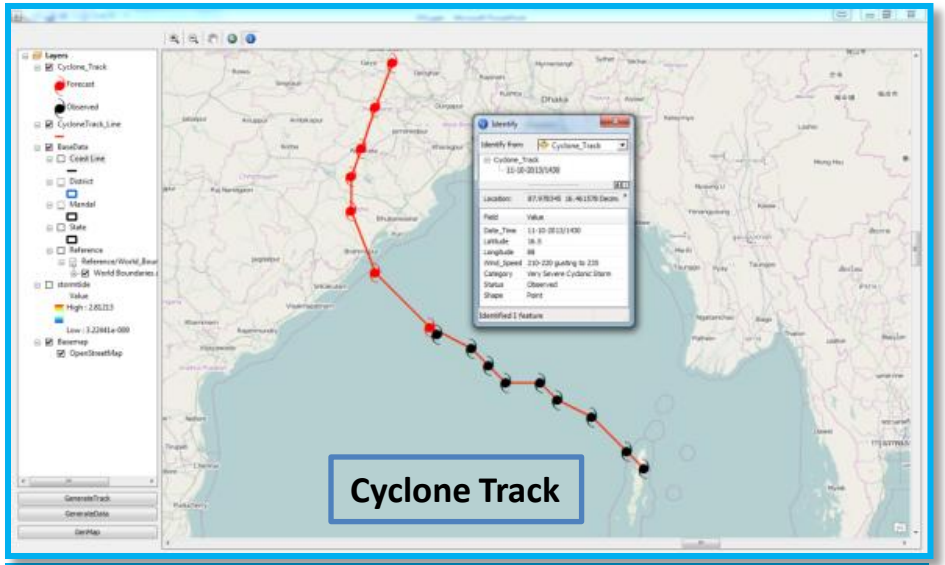
❑ **Track Generator**: **Based on the IMD bulletin** received over E-mail, data will be derived from the document and converted into **standardized global tropical cyclone best track data format** and prepare the model inputs for launching of the ADCIRC model.

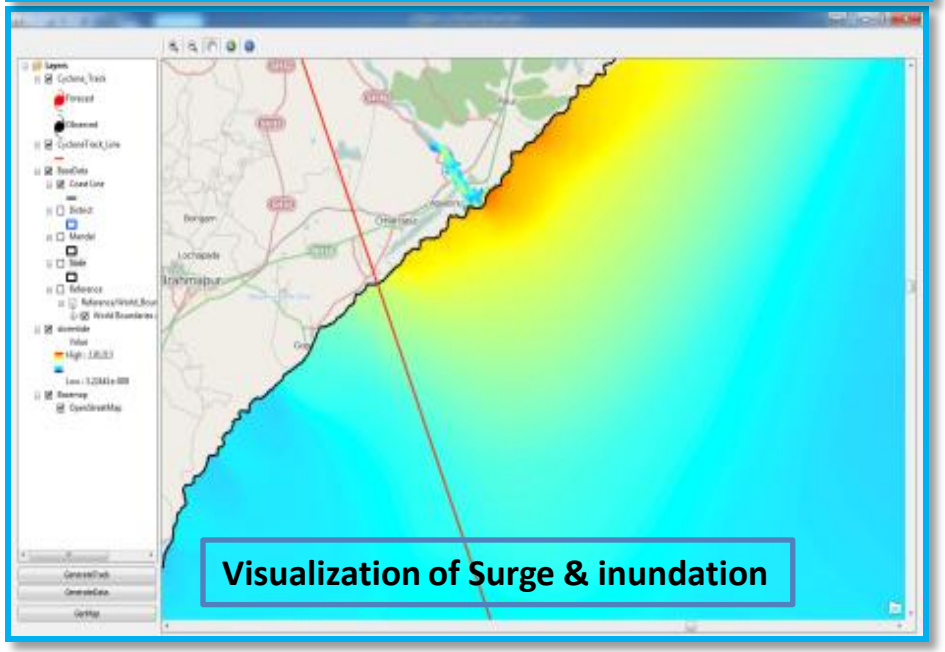
❑ **Model launcher**: It is a GUI component for automating the execution of ADCIRC model in real time on the available HPC facility at ESSO-INCOIS.

❑It allows read and develop information between geospatial databases and ADCIRC files or creating new input files for storm surge simulations.

❑ Here , the operator can provide the spin up value as input and click on the model launch button for data preparation, ftp and launching in HPC.

Spatial visualization and mapping tool





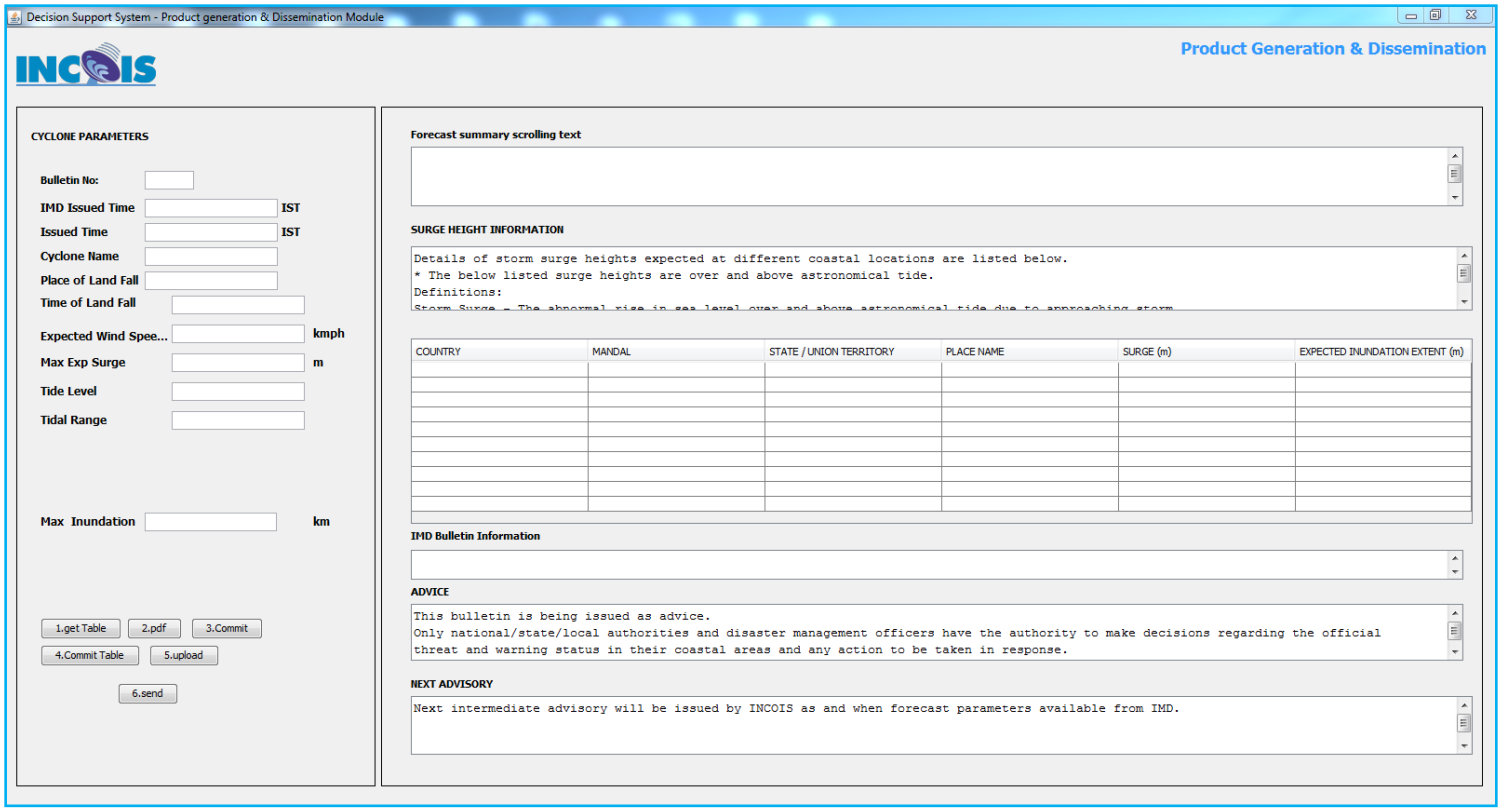
❑ A **data model Schema** that **integrates Geographic Information Systems (GIS)** and the **surge model ADCIRC**

❑ In addition to the data model schema, this module includes a **number of pre and post-processing tools** that help integrate spatial data and numerical modeling.

❑ A customizable geodatabase to accommodate model input and output and a set of **Arcpy tools designed** to:

1) pre-process input data (finite element grid editing);
2) post-process model outputs from ADCIRC simulations ;
3) The model outputs are also converted to GIS for use in coastal flood mapping, inundation extent or to be published using web services.

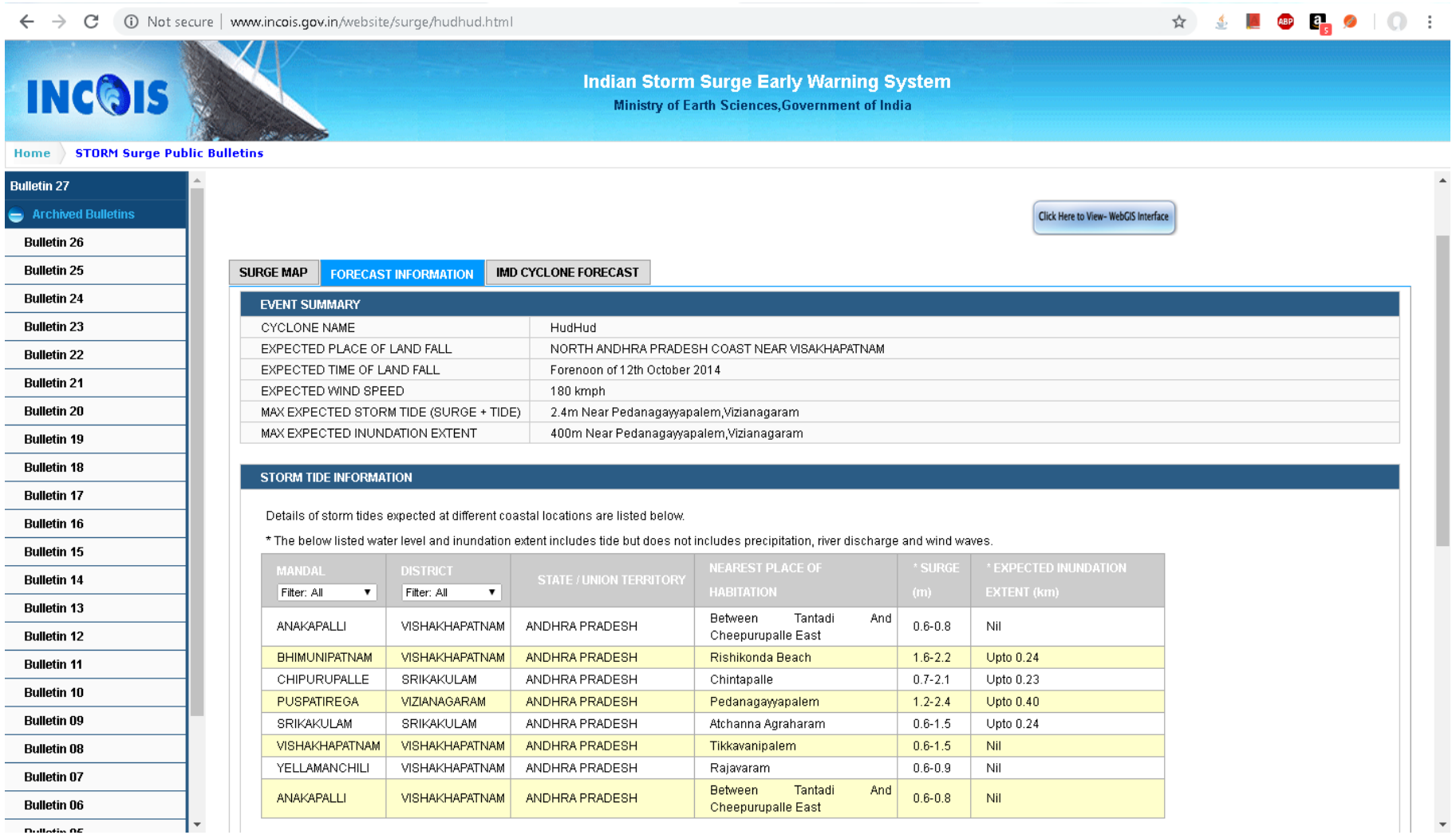
Product Generation & Dissemination



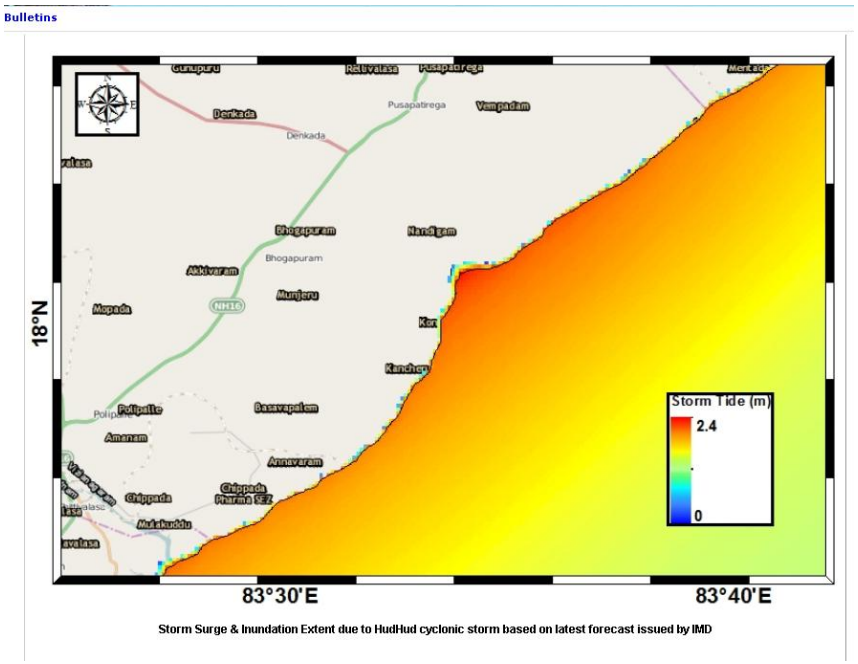
Responsible for

- ✓**Generation** of storm surge advisory **bulletins**
- ✓Bulletin **notifications**
- ✓**Dissemination**
- ✓Notification messages are sent to respective coastal disaster management officials through **email** with bulletin pdf as attachment, **SMS** and **Fax**.
- ✓Auto Publish to Website for access to the DMOs.

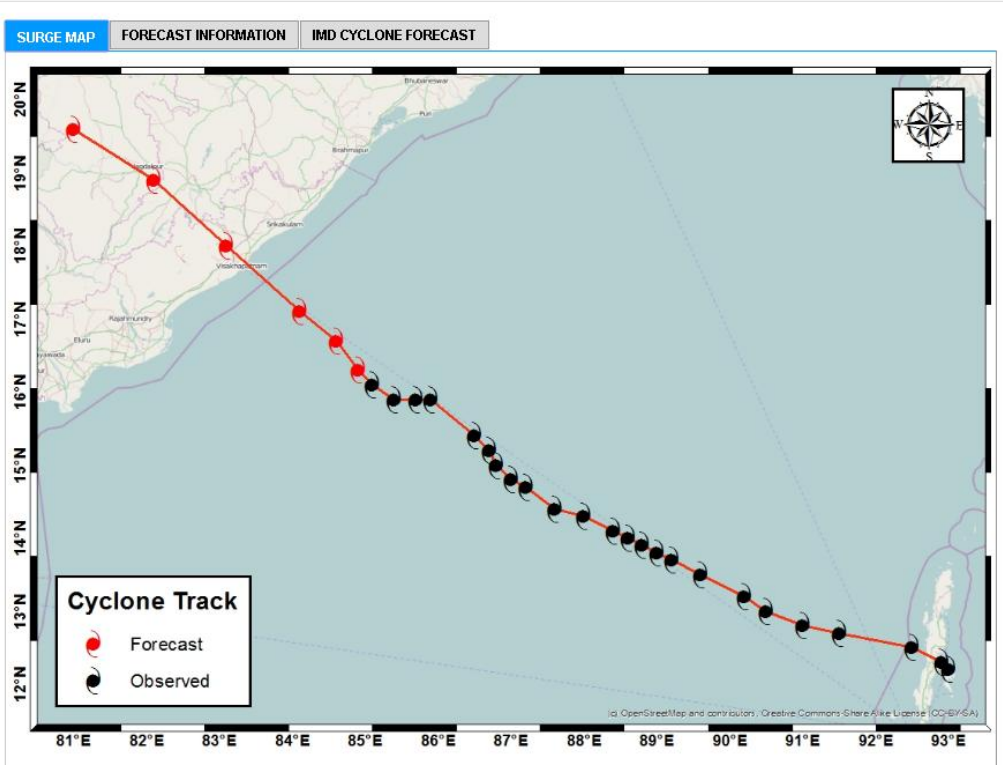
Web Bulletins



Graphic Products

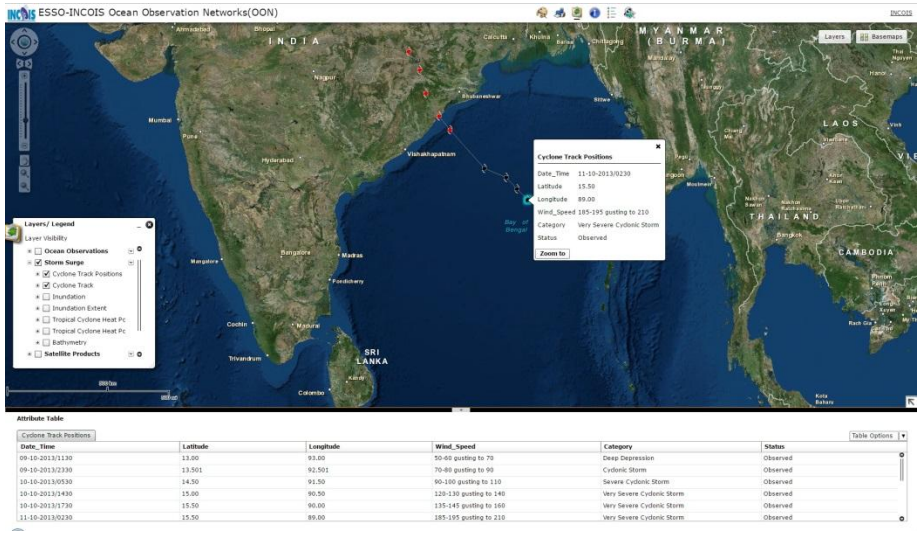


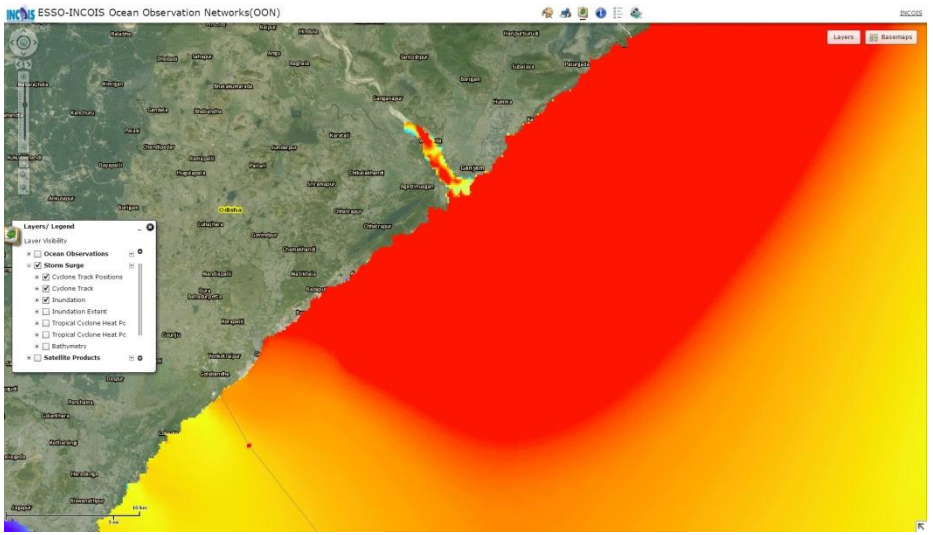
Surge Guidance

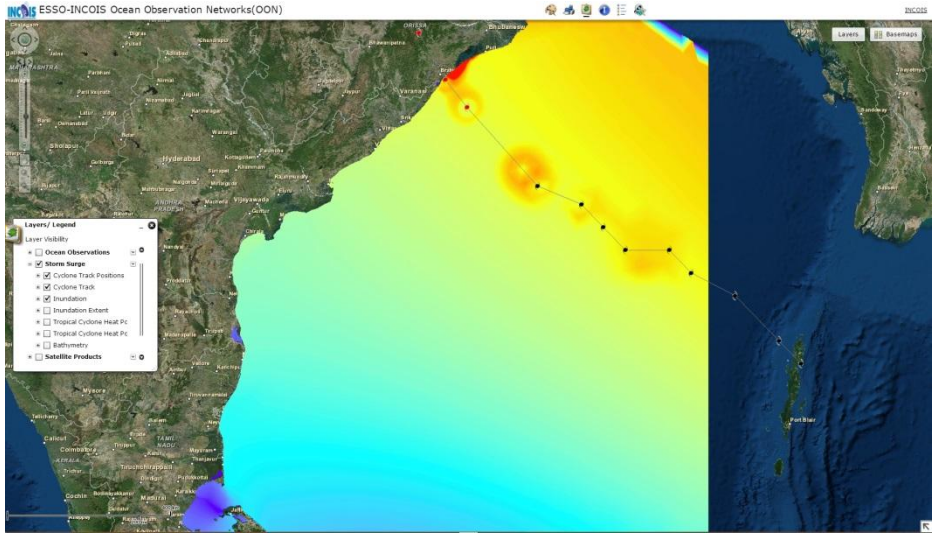


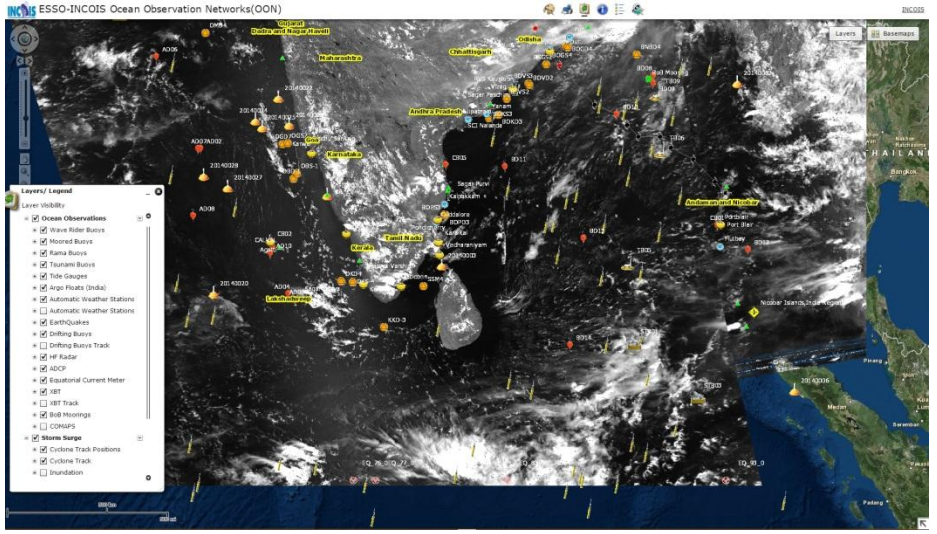
Cyclone Track

WebGIS Application for Storm Surge warning system



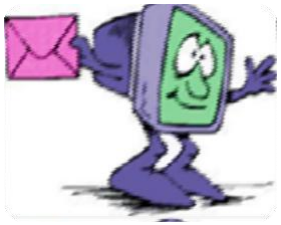






Dissemination Modes

Fax



Email

SMS

Web

National Level

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

State Level

Principal Secretaries (Revenue) of coastal states

District Level

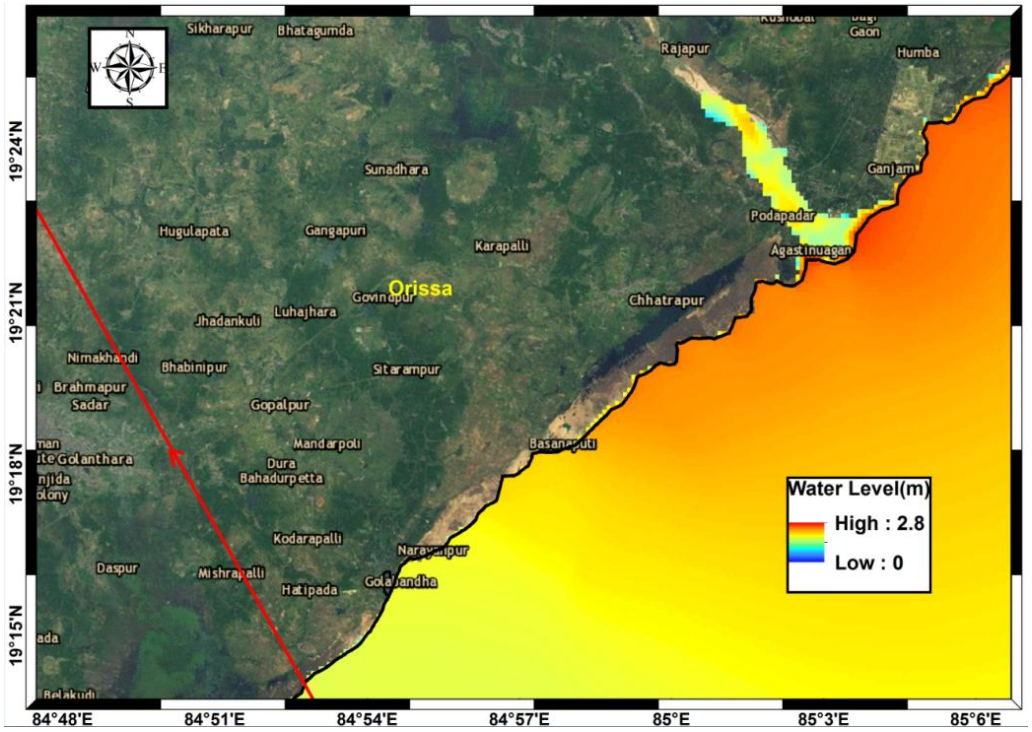
District Collectors, District EOCs, DROs, others

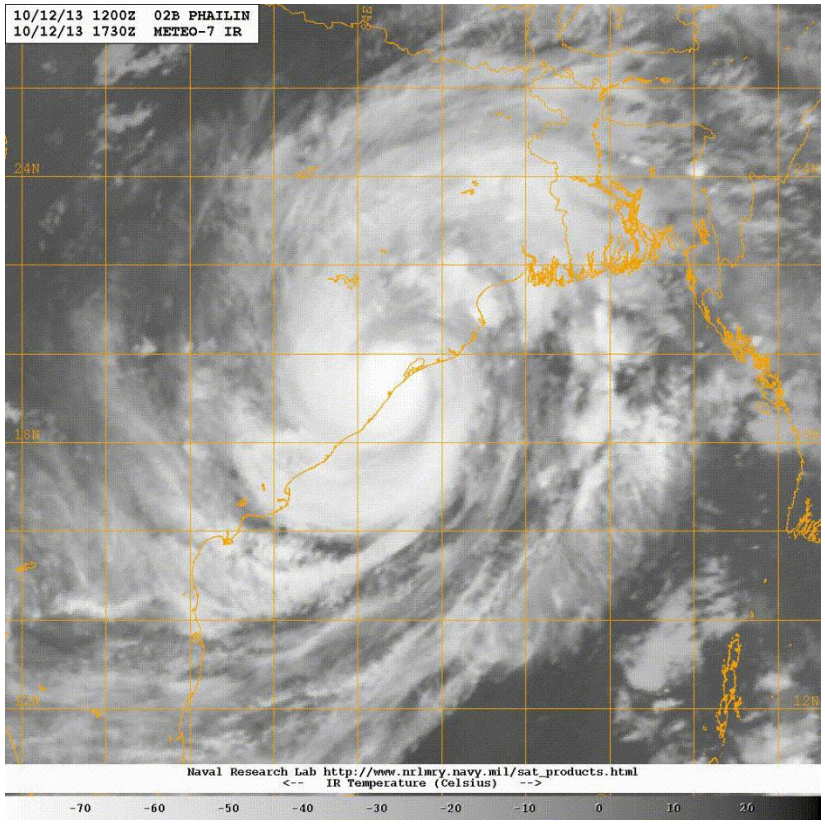
http://www.incois.gov.in/portal/stormsurge

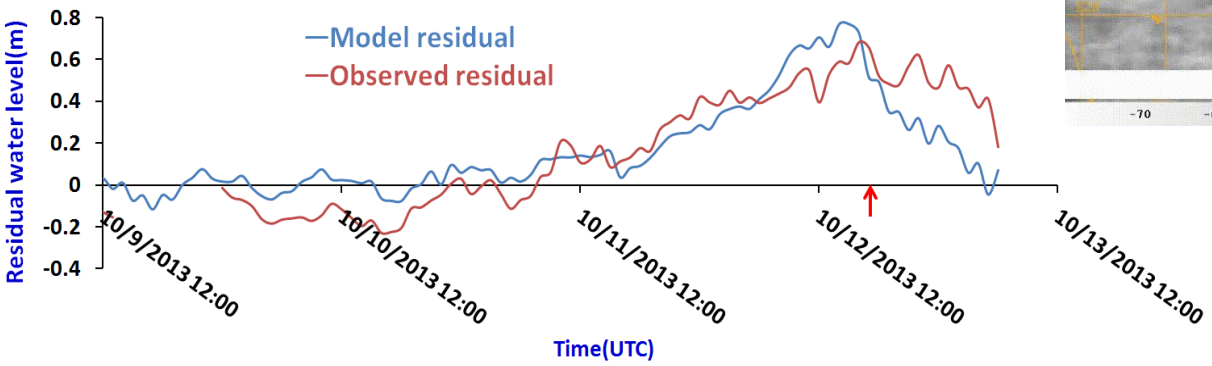
Real Time Simulation of Cyclone PHAILIN at INCOIS

FORECAST SUMMARY	
First Simulation	0530 IST of 09-10-2013
Last Simulation	0130 IST of 13-10-2013
Number of Computational Grid Points in the Inundation Model Domain	0.5 Million
Model Integration	4.5 Days
Time Taken for Each Simulation on HPC	45 Minutes using 256 Processors
Total number of bulletins issued	12
Maximum surge simulated for the entire duration of the event	2.6m near Ganjam, Orissa based on track forecast issued by IMD at 1500 IST of 12th October
Maximum inundation extent simulated for the entire duration of the event	3km through river near Ganjam, Orissa based on track forecast issued by IMD at 1500 IST of 12th October

Storm Surge model simulated water levels and inland inundation based on forecasted track issued by IMD







(a) Model estimated water levels and inundation extent using forecasted track (Precipitation is not included in the model)

(b) Comparison of model simulated residual water level to that of observed at Paradeep tide gauge (nearest tide gauge available about 202 km from the landfall point)

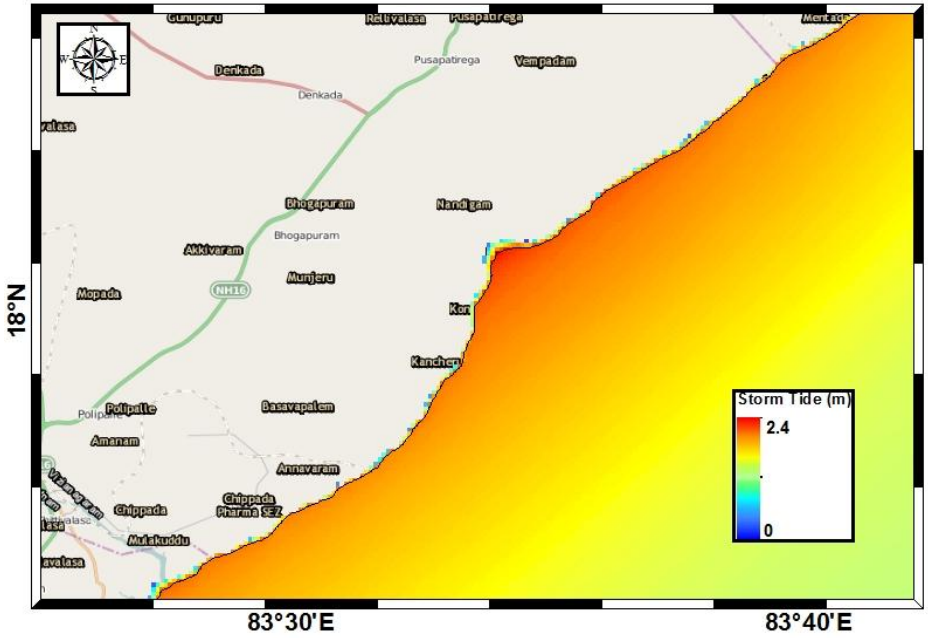
Comparison of model estimated inland inundation with post storm field measurements (Precipitation is not included in the model)

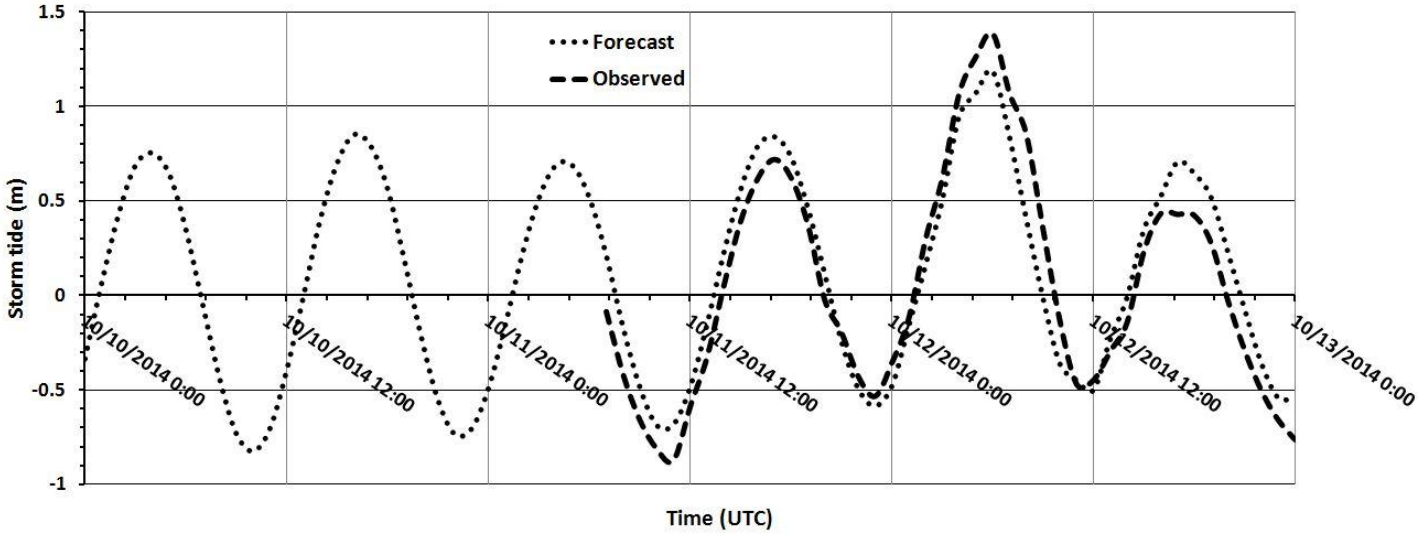
Locations along Odisha Coast	Model estimated inland extent of inundation (m)	Observed inland extent of inundation based on field measurement (m)
Dhepanuapada	-	23
Lohadigam	-	35
Humirbana	120	101
Humirbana	100	11
Podapadar	150	120
Podapadar	100	106
Agasti Naugam	250	173
Agasti Naugam	800	110
Ganjam	300	670
Mayarpada	150	160
Mayarpada	200	67
Jayamangalhil	300	65
Bhramarakudi	-	35
Bhramarakudi	-	44

Real time storm surge warning for the very severe cyclonic storm 'Hudhud'

FORECAST SUMMARY	
First Simulation	0530 IST of 08-10-2014
Last Simulation	1730 IST of 12-10-2014
Number of Computational Grid Points in the Inundation Model Domain	0.5 Million
Model Integration	5 Days
Time Taken for Each Simulation on HPC	45 Minutes using 256 Processors
Total number of bulletins issued	29
Maximum surge simulated for the entire duration of the event	2.4m near Pedanagayyapalem, Puspatirega mandal, Andhra Pradesh based on track forecast issued by IMD at 1430 IST of 11th October
Maximum inundation extent simulated for the entire duration of the event	400 m near Pedanagayyapalem, Puspatirega mandal, Andhra Pradesh

Real time storm surge warning for the very severe cyclonic storm ‘Hudhud’





Real time validation of surge levels with observed tide gauge records.
(Tide gauge station: Visakhapattanam)

Validation of inundation extent forecast for 'Hudhud' event

(Observed values were obtained by GPS survey soon after the cyclone landfall)

Place	Mandal	District, State	Inundation extent	
			Forecasted (m)	Observed (m)
Konada	Puspatirega	Vijayanagaram, AP	300	400
Kollayavalasa	Puspatirega	Vijayanagaram, AP	100	90
Pathiwada	Puspatirega	Vijayanagaram, AP	200	150
Kancheru	Puspatirega	Vijayanagaram, AP	160	150
Pedanagayyapalem	Bhimunipattanam	Visakhapattanam, AP	100	50
Chintapalle	Puspatirega	Vijayanagaram, AP	200	80
Mentada	Chipurupalle	Srikakulam, AP	150	110
Kancherupalem	Puspatirega	Vijayanagaram, AP	nil	nil
Ramachandrapuram	Chipurupalle	Srikakulam, AP	180	120
Nerellavalasa Rural	Bhimunipattanam	Visakhapattanam, AP	nil	60
Kothuru	Bhimunipattanam	Visakhapattanam, AP	100	70
Kolli Bheemavaram	Chipurupalle	Srikakulam, AP	140	140
Rishikonda beach	Bhimunipattanam	Visakhapattanam, AP	nil	60
Thimmapuram	Bhimunipattanam	Visakhapattanam, AP	100	100
Kottapalem	Chipurupalle	Srikakulam, AP	150	160
Yethapeta	Chipurupalle	Srikakulam, AP	100	80
Atchanna Agraharam	Chipurupalle	Srikakulam, AP	nil	60
Bontalakoduru	Srikakulam	Srikakulam, AP	150	190
MVP Colony	Visakhapattanam	Visakhapattanam	nil	20
Rama Krishna Beach	Visakhapattanam	Visakhapattanam	nil	50
Galla Peta	Srikakulam	Srikakulam, AP	200	150
Pathiwada	Puspatirega	Vijayanagaram, AP	200	180
Kuppili	Chipurupalle	Srikakulam, AP	200	180
Tekkali	Chipurupalle	Srikakulam, AP	100	100

Storm Surge Advisory was provided in collaboration with IMD for the following cyclonic storms:

Provided experimental forecast using DSS

- ❑Phailin (Oct, 2013)
- ❑Helen (Nov, 2013)
- ❑Lehar (Nov, 2013)
- ❑Madi (Dec, 2013)
- ❑Nanauk (Jun, 2014)

DSS made operational during VSCS- HudHud

- ❖Hudhud (Oct, 2014)
- ❖Nilofar (Oct,2014)
- ❖Ashobaa(Jun,2015)
- ❖Roanu (May, 2016)
- ❖Kyant (Oct, 2016)
- ❖Nada (Nov, 2016)
- ❖Vardah (Dec, 2016)
- ❖Maarutha (Apr, 2017)
- ❖TITLI , Luban(Oct,2018)
- ❖Gaja(Nov,2018)
- ❖Phethai(Dec,2018)
- ❖Pabuk(Jan,2019)

Thank You

ESSO-Indian National Centre for Ocean Information Services
(Ministry of Earth Sciences, Government of India), "Ocean Valley",
Pragathi Nagar (B.O.), Nizampet (S.O.),
Hyderabad-500 090
Email: stormsurge@incois.gov.in
Website:http://www.incois.gov.in/portal/stormsurge