OceanTeacher Global Academy

# Role of Ocean observations in storm surges computations

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**Training Program**

**on**

**Discovery and Use of Operational Ocean Data Products and Services" scheduled to be held from 25th Oct – 29th Oct 2021**

**ITCOocean, INCOIS, Hyderabad**

# The Mission of INCOIS

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

# Ocean Observing System in India

The following observation systems have been deployed and maintaining by MoES in and around Indian seas

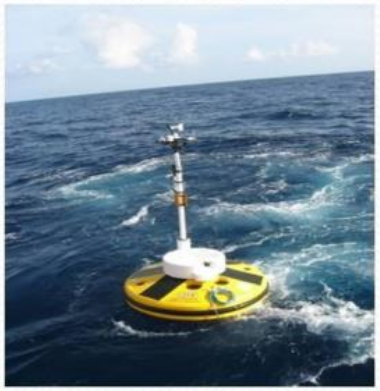
- Moored buoys (offshore)
- Argo profiling floats (one float per $3^{o}$x$3^{o}$ box in North Indian Ocean)
- Drifters (one drifter per $5^{o}$x$5^{o}$ box in North Indian Ocean)
- XBT/XCTD
- Current meter moorings
- ADCP moorings (coastal)
- Wave rider buoys (coastal)
- AWS (on board ships)
- HF radar
- Tsunami Buoys
- Tide gauges

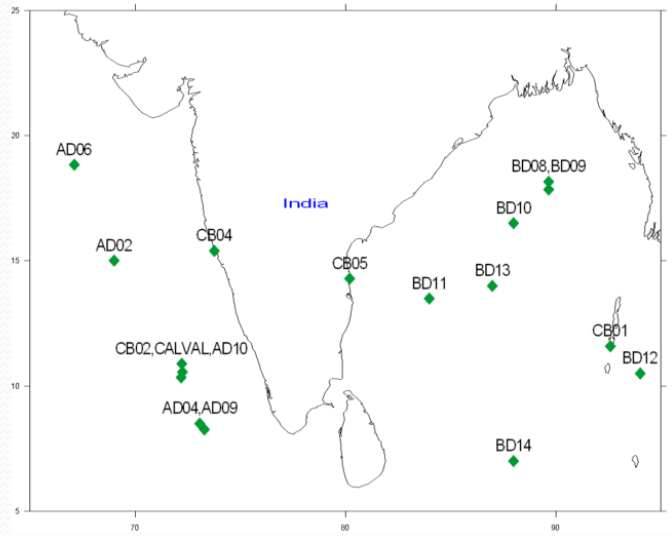
# OOSs useful for storm surge forecasting

1. **Moored buoys:** To validate the input wind forcing.
2. **Tide gauges:** To validate modeled surge heights.
3. **Tsunami Buoys:** Off-shore water levels can be validated.
4. **Post storm field survey:** To validate model predicted inland inundation extent.
5. **Automatic Weather Stations onboard Research Vessels:** Can be useful to validate input wind forcing.
6. **HF-Radar:** Can be useful to validate modeled near shore currents, wave heights etc.
7. **Wave rider buoy:** To validate model (coupled surge + wave) predicted wave.
8. **Satellite imagery:** Bathymetry / shoreline / in land topography
9. **Satellite imagery (CTT)**: To retrieval of $R_{max}$ of a cyclone.
10. **Argo:** This data can be indirectly useful for real time surge modeling. IMD utilizing the available real time products and assimilating in the atmospheric models. Accurate track and intensity prediction by IMD is however useful for surge modeling.

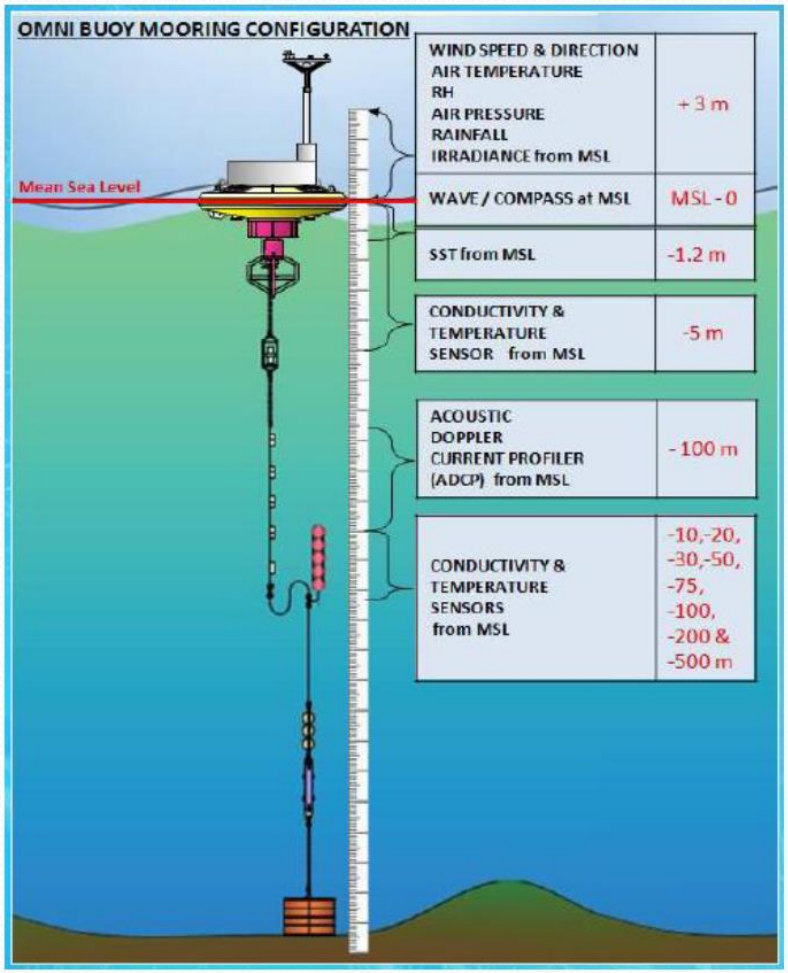
# Application of Moored Buoy data

# National Data Buoy Program





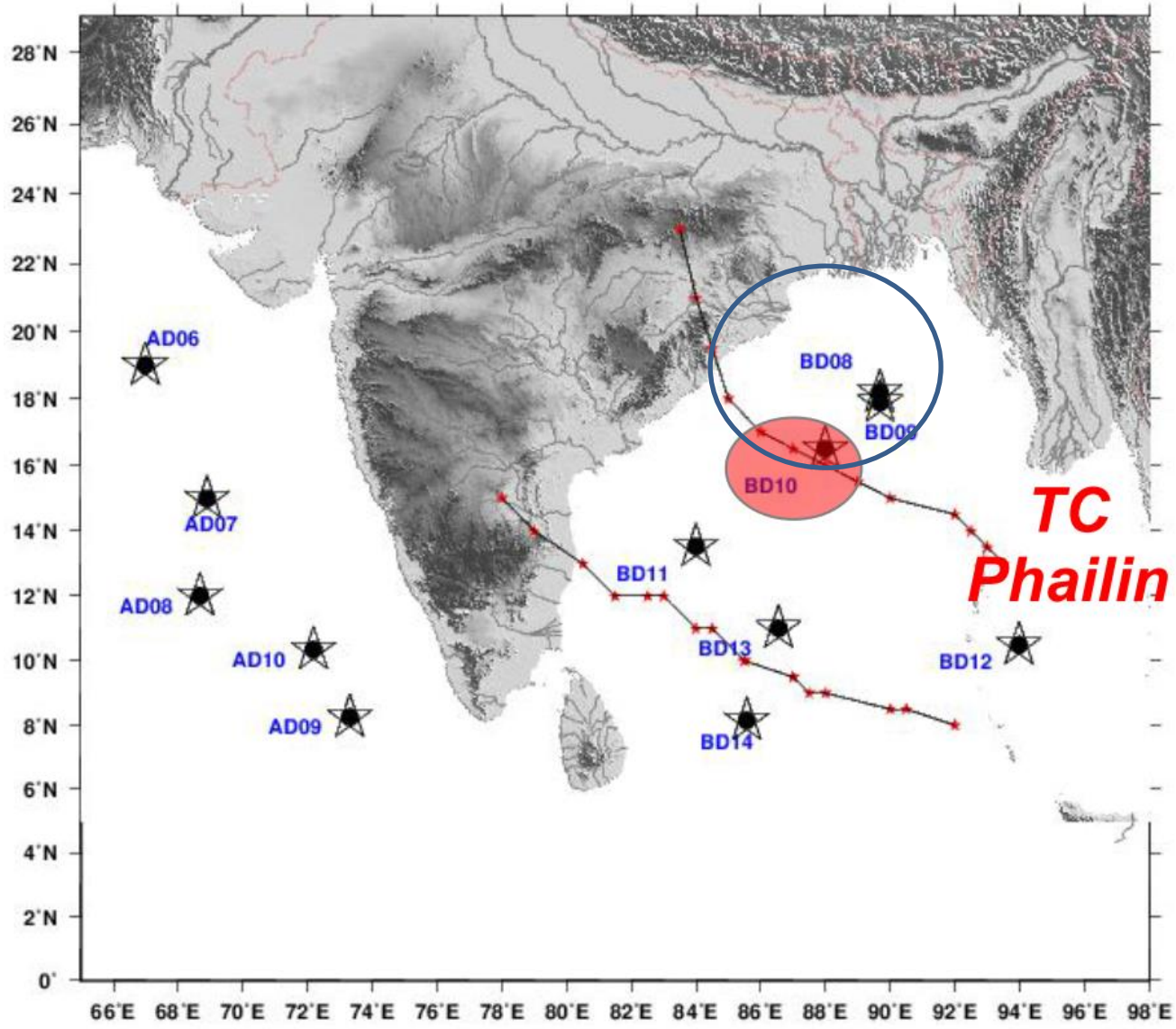

•Moored Buoys (Surface Met-Ocean, Sub-surface, Currents, T&S, Radiation, Rain gauges)
• Coastal Buoys



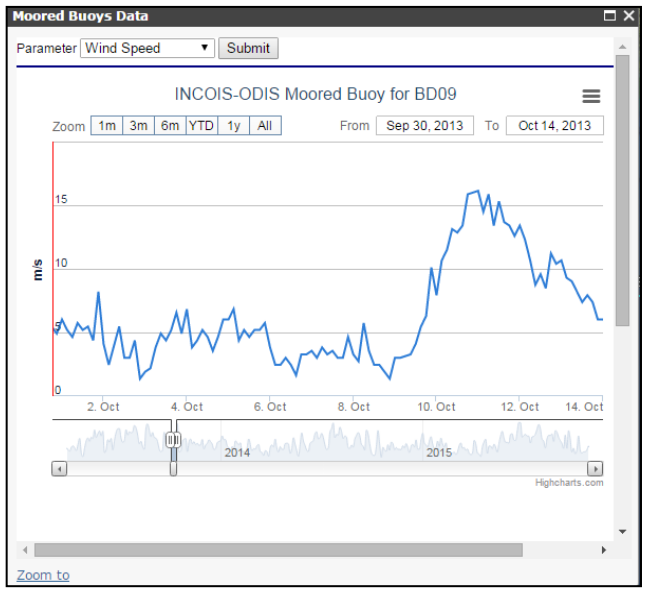
# Applications

- Weather Prediction and Early Cyclone Warning
- Calibration and validation of Satellite Sensors
- Validation of Ocean State Models
- Climate Research
- Engineering and Offshore Projects
- **Validation of model wind forcing.**

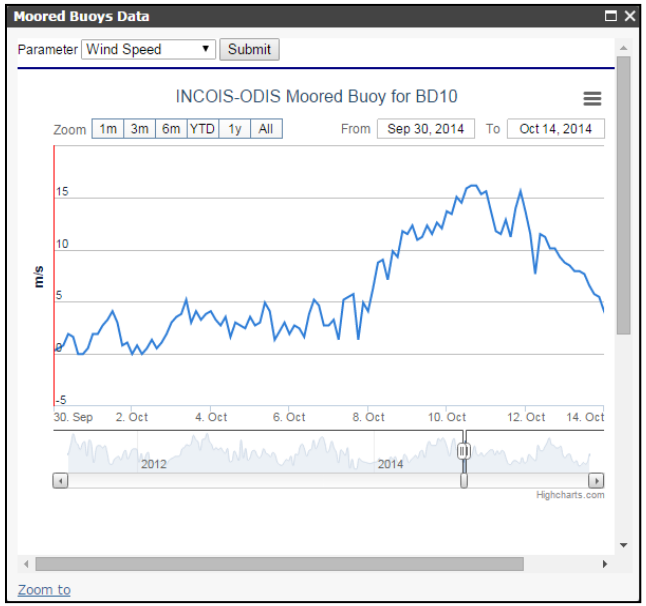
# Monitoring Cyclones

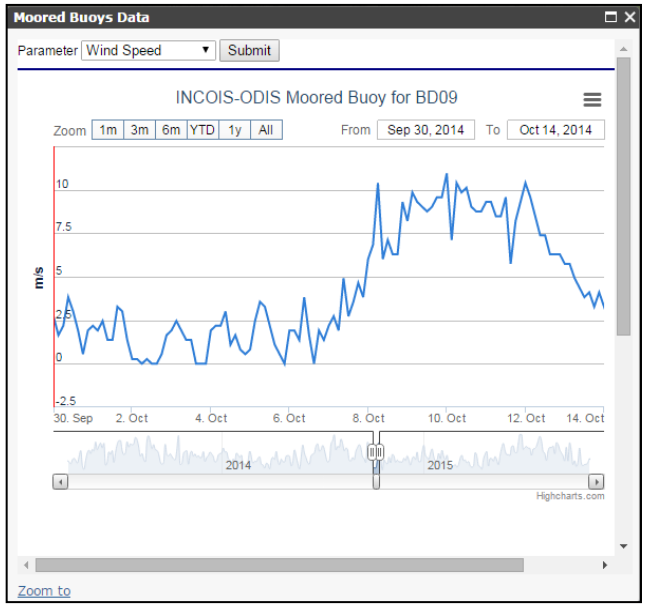


# Buoy recording wind speeds

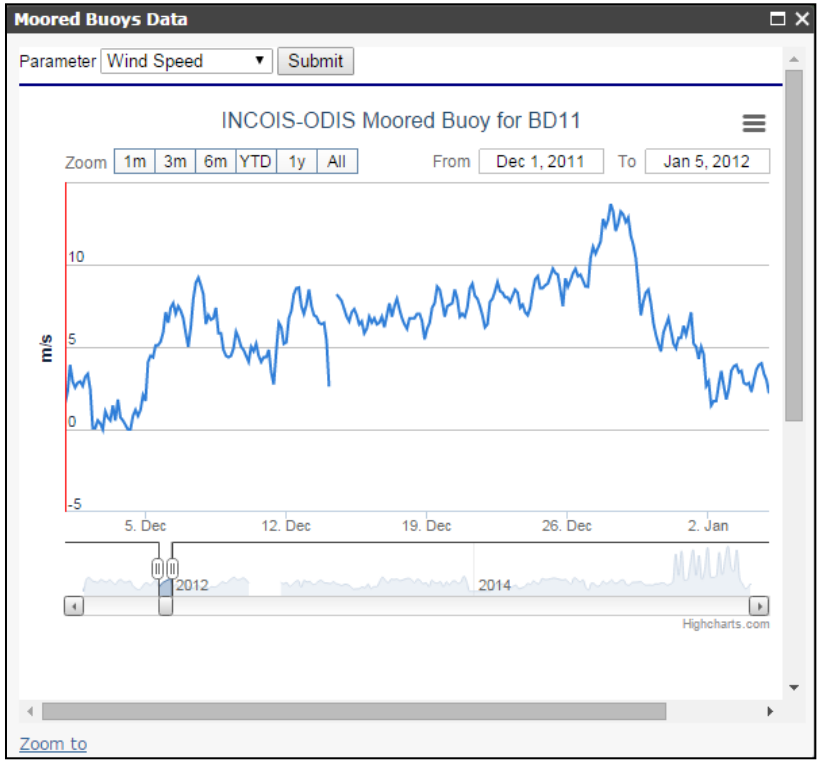

**Phailin event**




**Hudhud event**

# Buoy recorded wind speeds


**Thane event**

# Buoys 400km away helped track Phailin

TIMES NEWS NETWORK

**New Delhi:** Strategically located buoys, some as far as 400km from India's coastline, telegraphed via satellite vital data on sea pressure, surface temperature and wind speeds that helped Indian scientists read Cyclone Phailin with unerring accuracy.

The sea-borne platforms add significant muscle to India's capacity to decipher destructive weather systems like Phailin days before they strike the Indian coast, saving thousands of lives by giving authorities crucial lead time to take pre-emptive action.

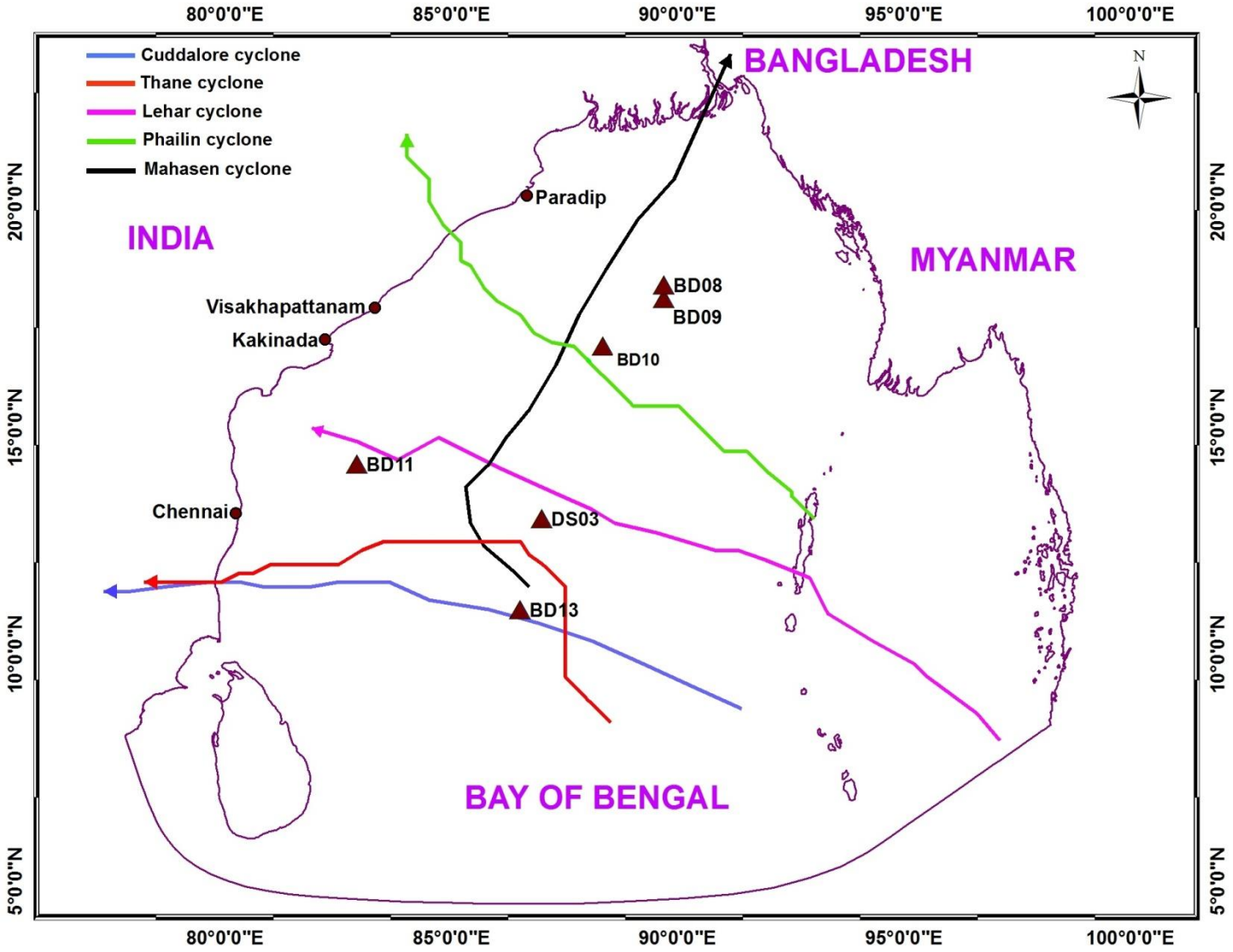
A man looks at his damaged house in Podampeta village

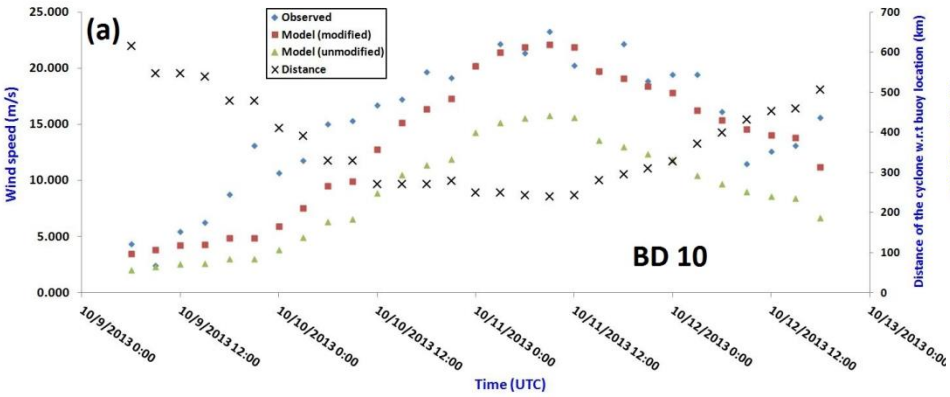
At present, there are 14 buoys in the Arabian Sea and Bay of Bengal busily supplying meteorologists, analysts, programmers and researchers a wealth of information.

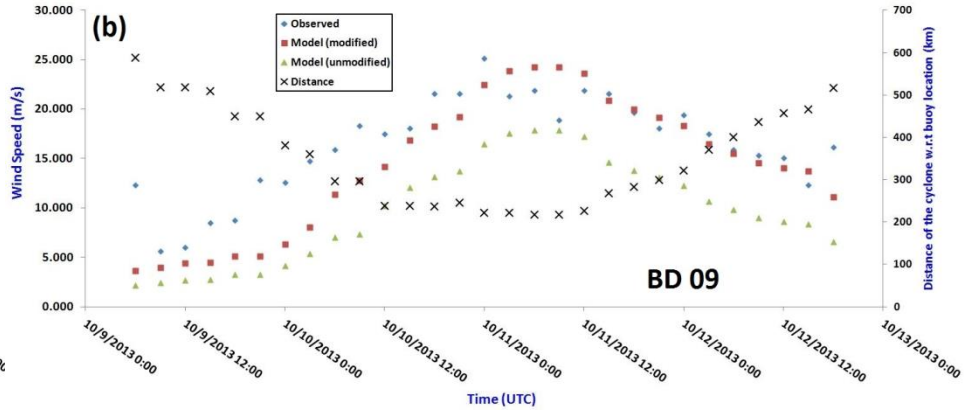
India is now looking to step up its scientific capacities by acquiring an aircraft equipped with advanced gadgetry that allows a specialist crew to take readings of clouds and atmospheric exchanges as much as 12-14 km above the earth's surface.

The fruits of a modernization programme has seen the IMD and the department of earth sciences' various facilities deliver more precise information on the monsoon and weather systems.

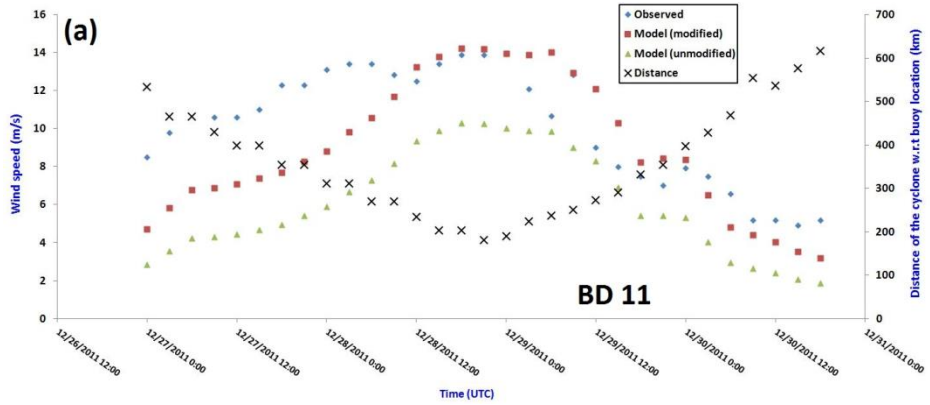
# Selection of buoys to be used based on the cyclone track

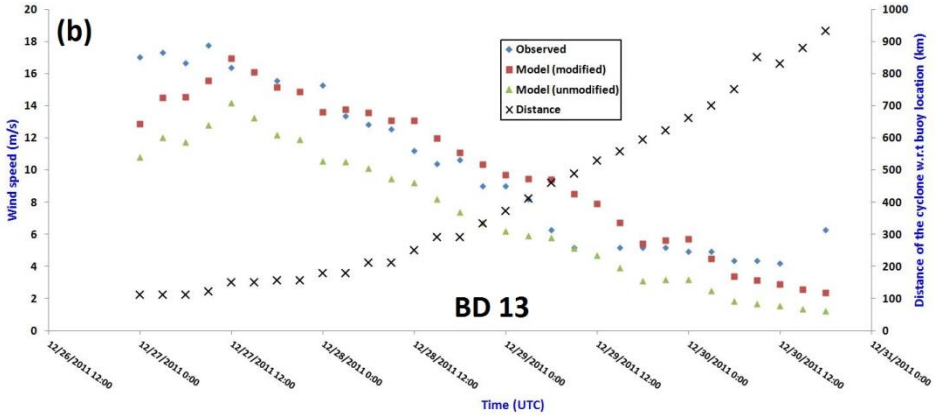




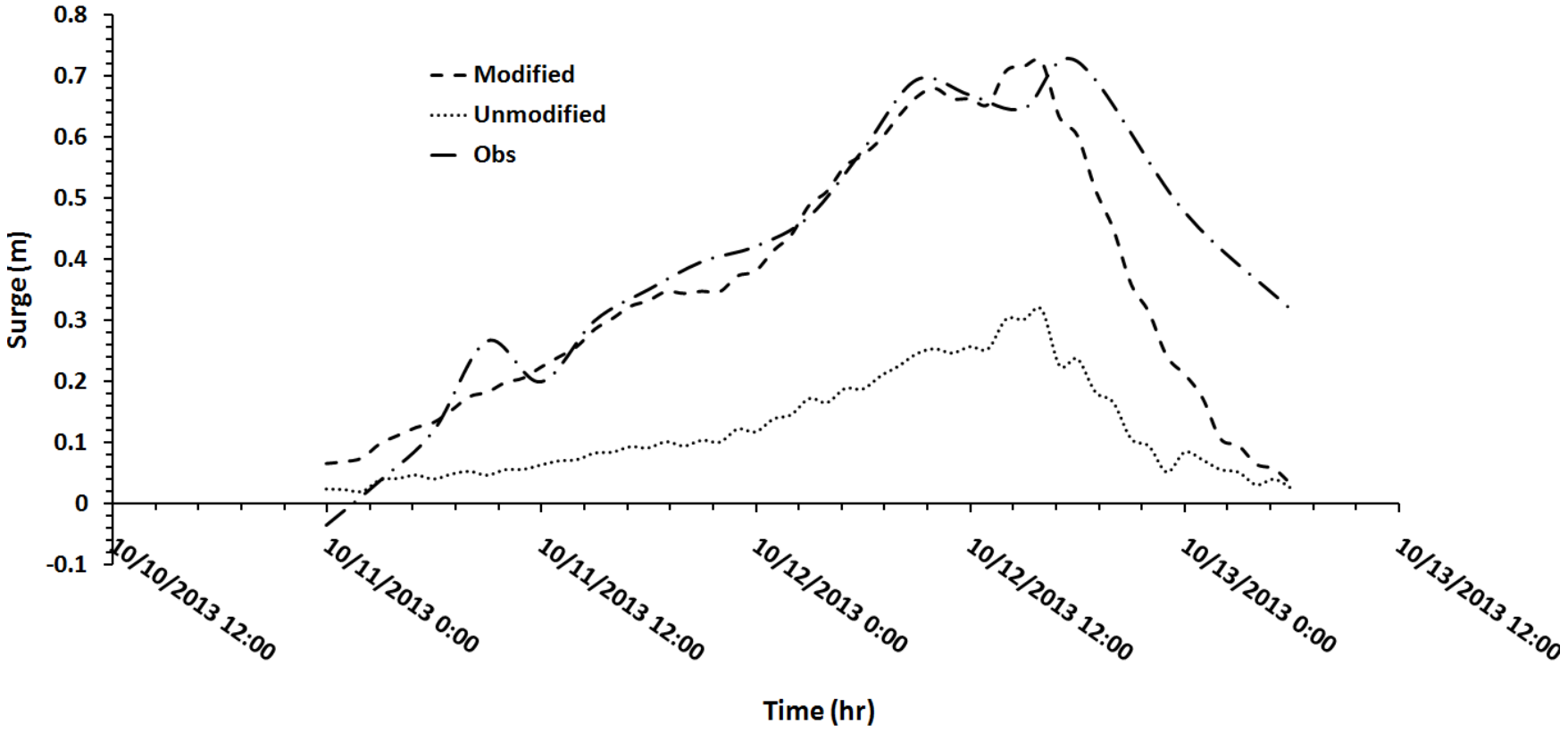

**Validation of modeled wind speed with buoy observed data during 'Phailin'**




**Validation of modeled wind speed with buoy observed data during 'Thane'**

**Murty et al., (2016).** ***Numerical study of coastal hydrodynamics using a coupled model for Hudhud cyclone in the Bay of Bengal.***




**Application of fine tuned model wind for 'Phailin' event**

# Utilization of tide gauge data

# Tide Gauge Network

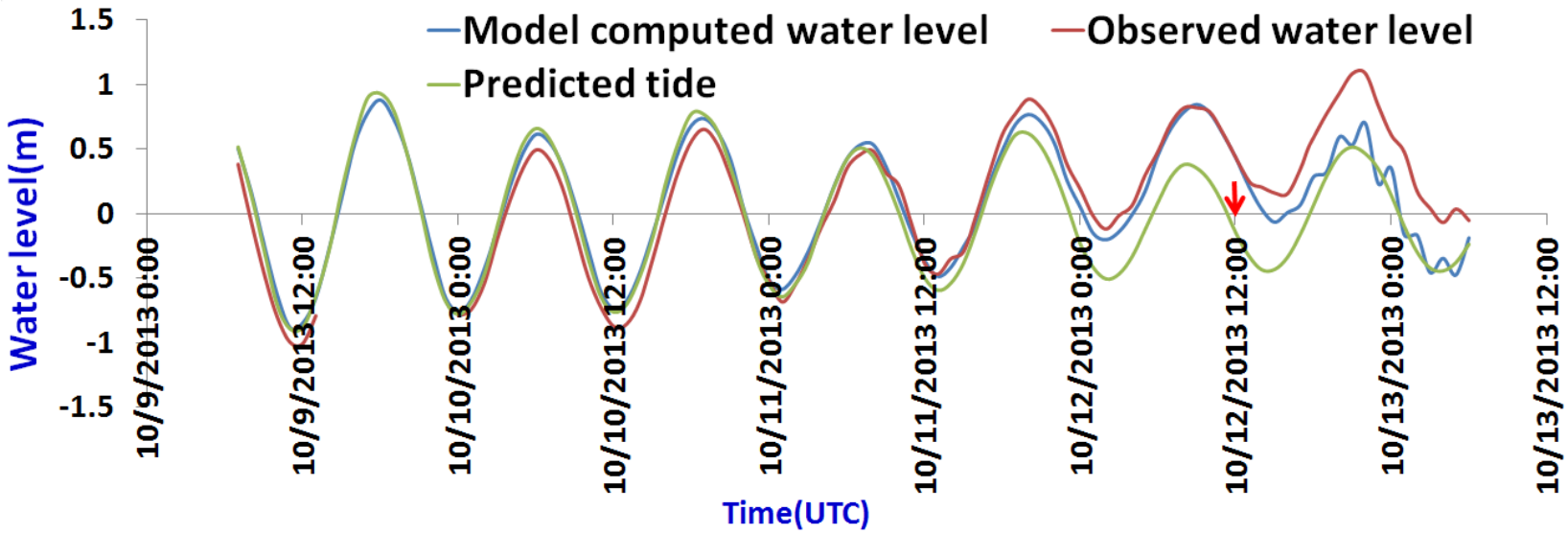

Network of 36 Tide gauges Installed and operational along the Indian Coast

1 minute averages transmitted every 5 minutes

Data come to INCOIS through VSAT and INSAT from the Tide Gauges

Real time data from 70 International tide gauges in Indian Ocean being received at INCOIS

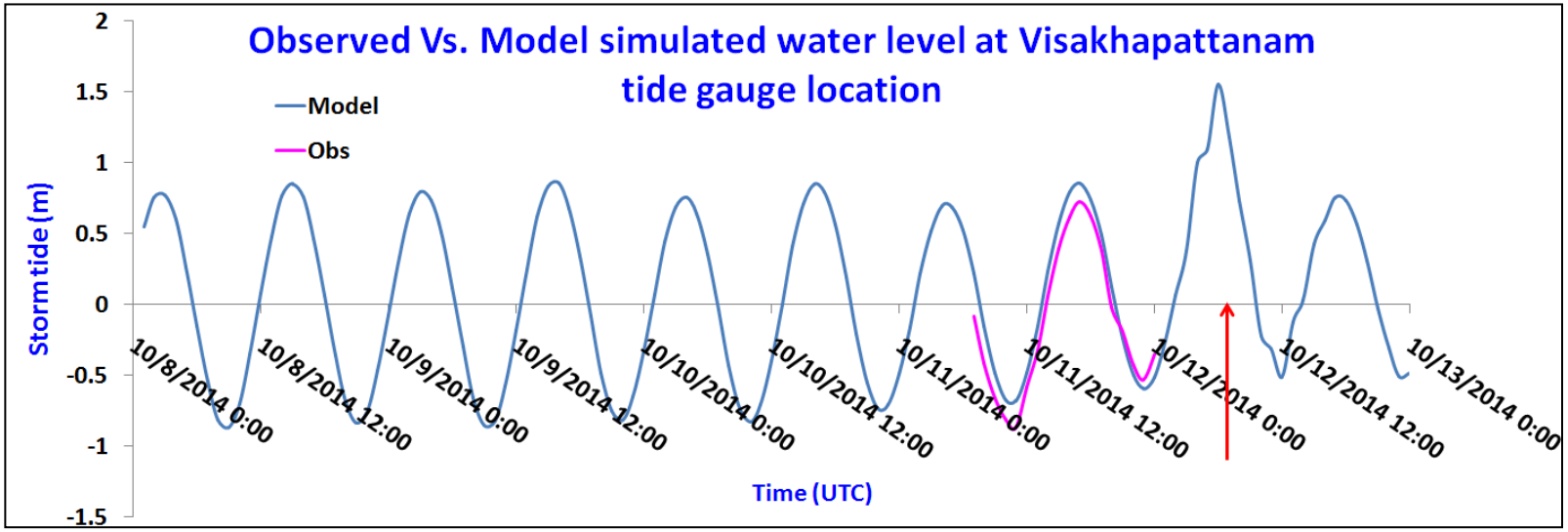
# Real time surge monitoring and validation using tide gauge records during 'Phailin'

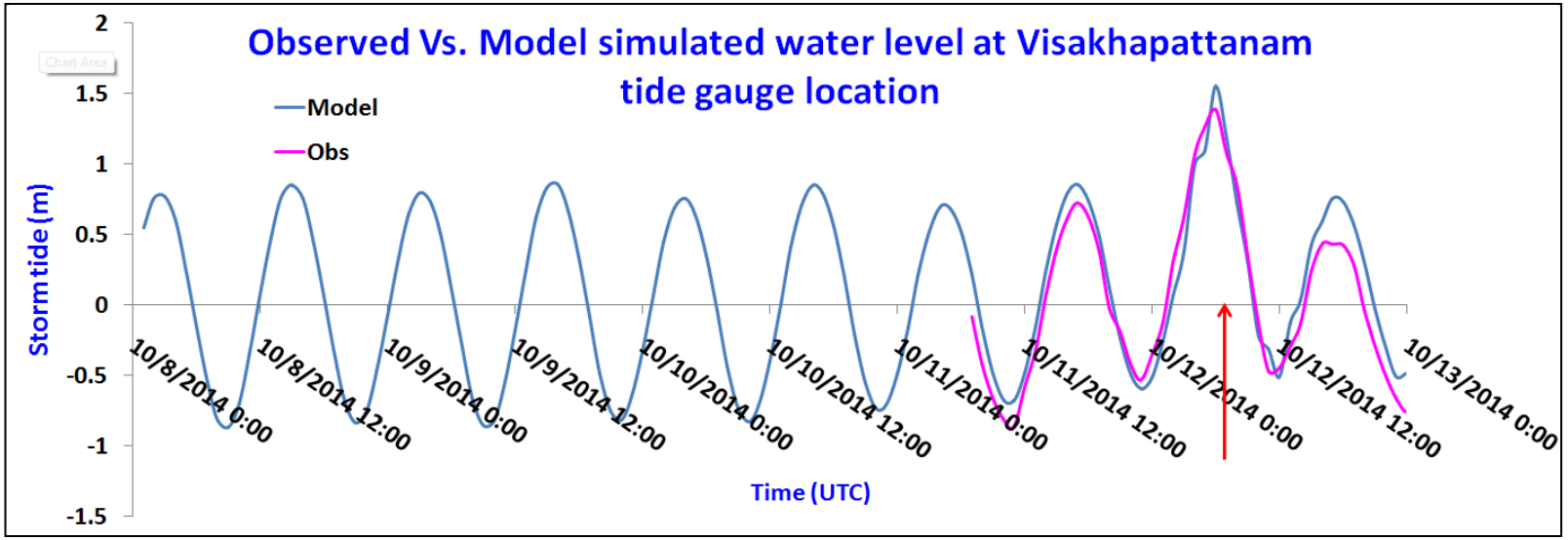



Nearest tide gauge available for validation of storm surge is at Paradip location, which is about 200 km (outer core) away from landfall point.

Underestimation in surge heights at Paradip could be due to the underestimation in outer core modeled wind.

# Real time surge monitoring and validation using tide gauge records during 'Hudhud'

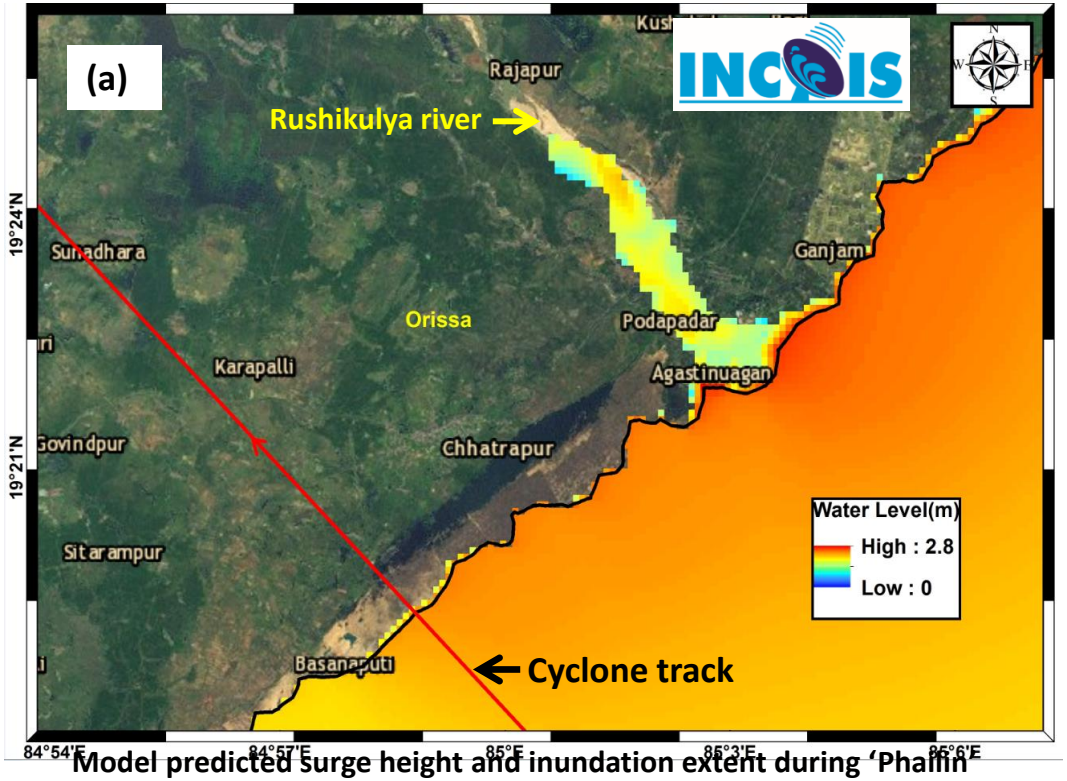


# Post storm field surveys

INCOIS conducted **post storm surveys** soon after the cyclones 'Phailin' (2013) and 'Hudhud' (2014).

These records were utilized to validate the model predicted inland inundation extents.




**Model predicted surge height and inundation extent during 'Phailin'**

| Coastal locations of Odisha | Model computed inland extent of inundation from coast line (m) | Observed inland extent of inundation from coast line based on field measurement(m) |
|---|---|---|
| Dhepanuapada | - | 23 |
| Lohadigam | 130 | 35 |
| Humirbana | 100 | 101 |
| Humirbana | 100 | 115 |
| Podapadar | 120 | 106 |
| Ganjam | 180 | 173 |
| Ganjam | 150 | 110 |
| Ganjam | 400 | 670 |
| Mayarpada | 200 | 160 |
| Jayamangalhil | 150 | 65 |
| Bhramarakudi, Ganjam | - | 35 |
| Bhramarakudi, Ganjam | - | 44 |

**Table: Comparison of model simulated inland inundation (based on observed track) with field observationsb**

**Srinivasa Kumar et al., (2015).** ***Modeling Storm Surge and its Associated Inland Inundation Extent Due to Very Severe Cyclonic Storm 'Phailin'***

# Comparison of model simulated inland inundation (based on observed track) with field observations

| 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 |

# Automatic Weather Stations onboard Research Vessels

# Automatic Weather Stations onboard Research Vessels

**Objectives**

- Validation Ocean forecast models in delayed mode and real time.
- Data assimilation in high resolution atmospheric forecast models
- Validation of satellite data.
- High Resolution coastal wind Atlas
- Real-time vessel tracking

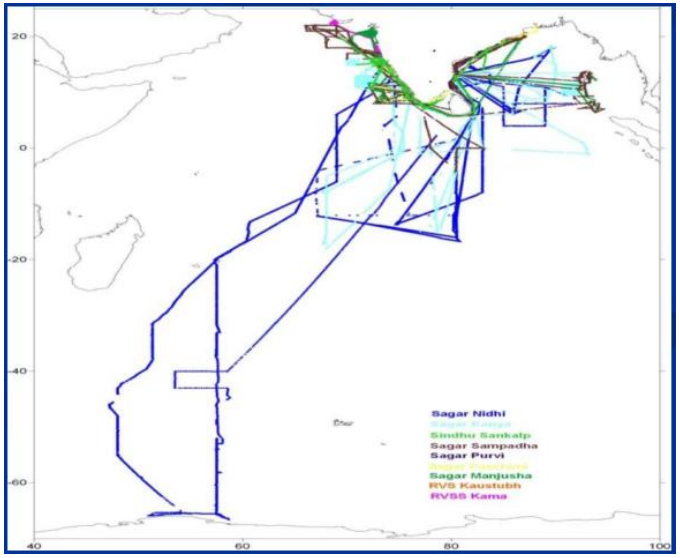
AWS onboard ORV Sagar Nidhi

**Ships**

MoES, CSIR, GSI, FSI, NHO,SCI, ONGC

**Parameters Measured**

Wind vector, Air temperature, Sea surface temperature, Relative humidity, Rainfall, Long wave radiation, Shortwave radiation

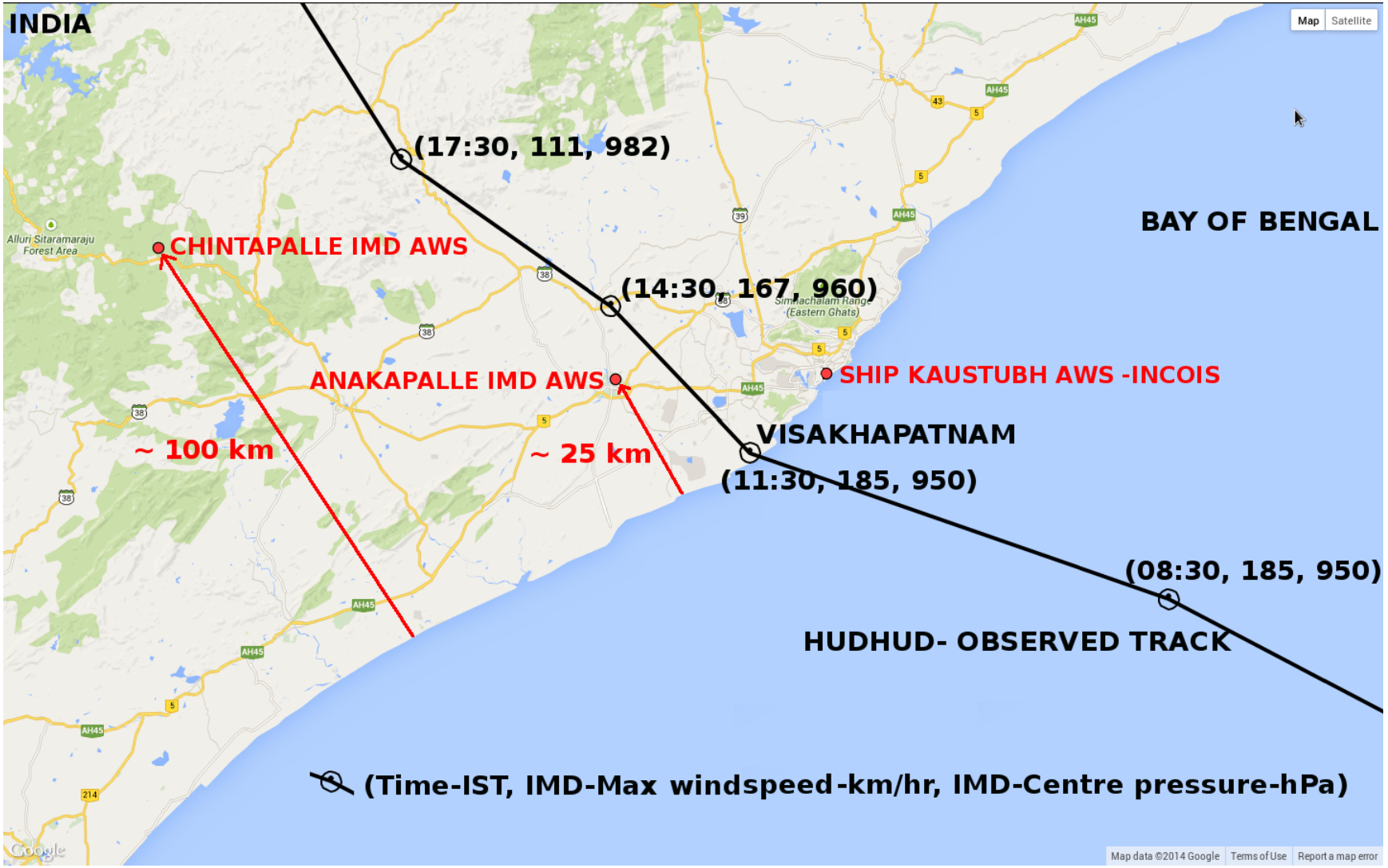



**The data is transmitted to INCOIS in real time**

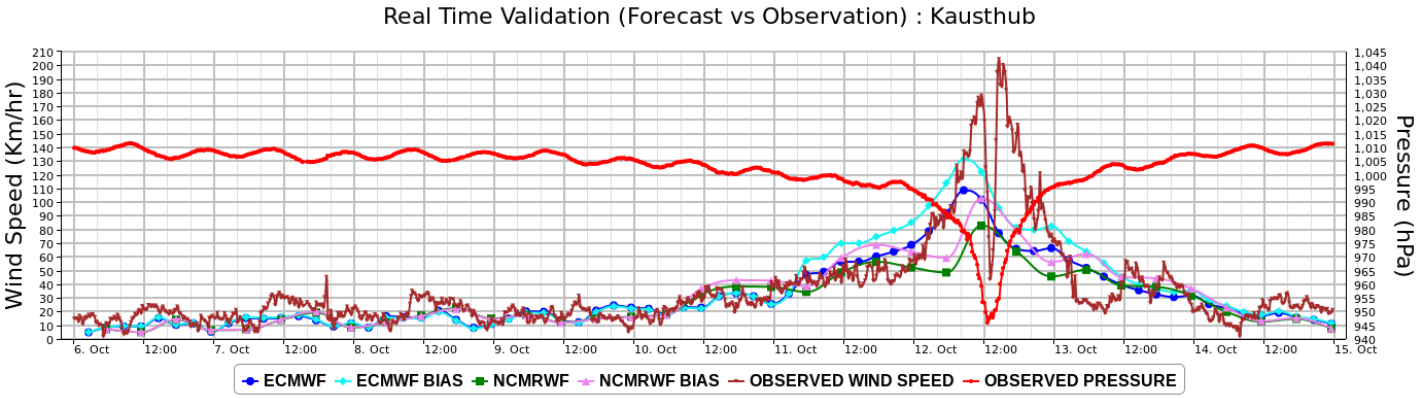
# Ocean Research Vessels

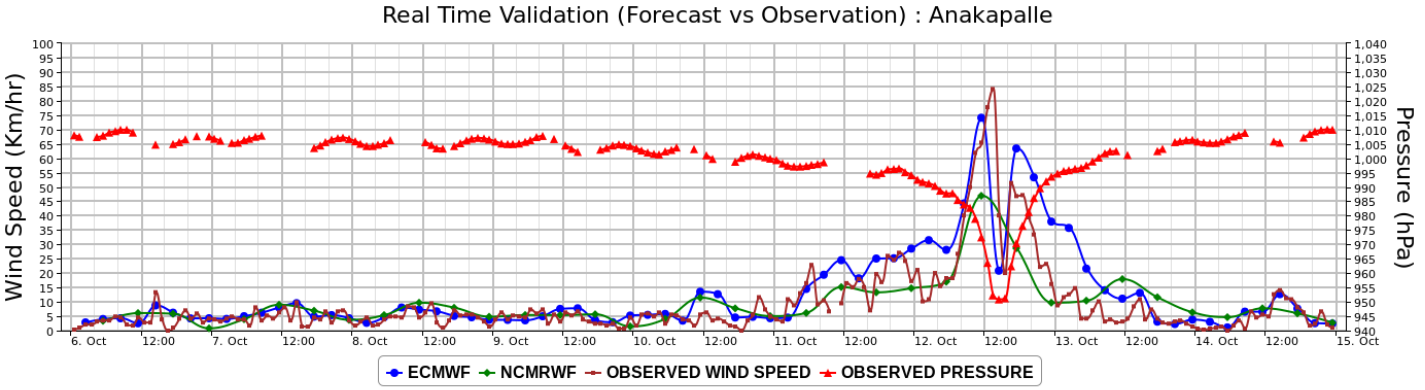
- Sagarkanya– NCAOR
- Sagar Nidhi– NIOT
- Sagar Manjusha– NIOT
- Sagar Purvi - NIOT
- Sagar Paschami– NIOT
- Sagar Sampada– CMLRE

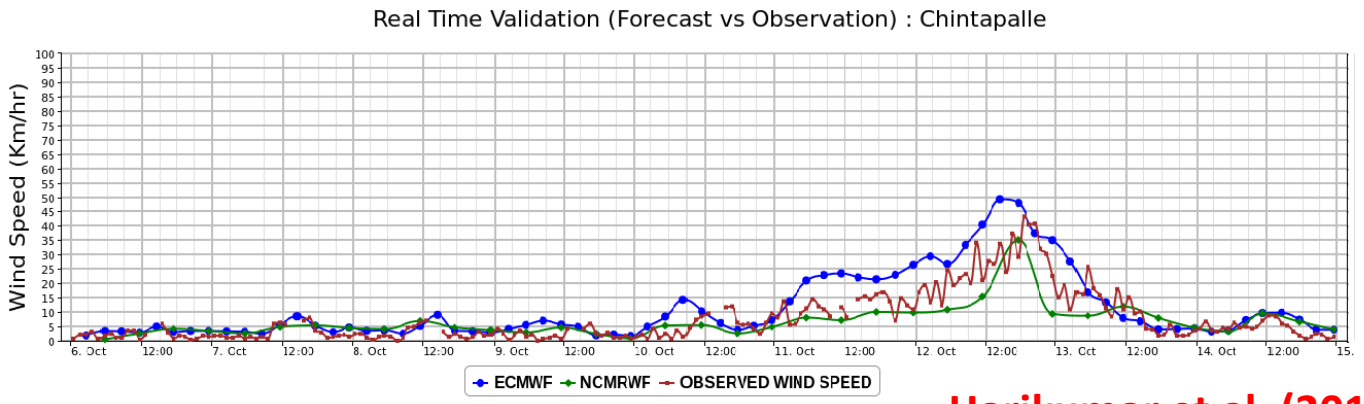
# Cyclone Hudhud - AWS observations at Visakhapatnam
# RV Kaustubh & 2 IMD AWSs inland



Surface observations at Vizag during the Hudhud landfall

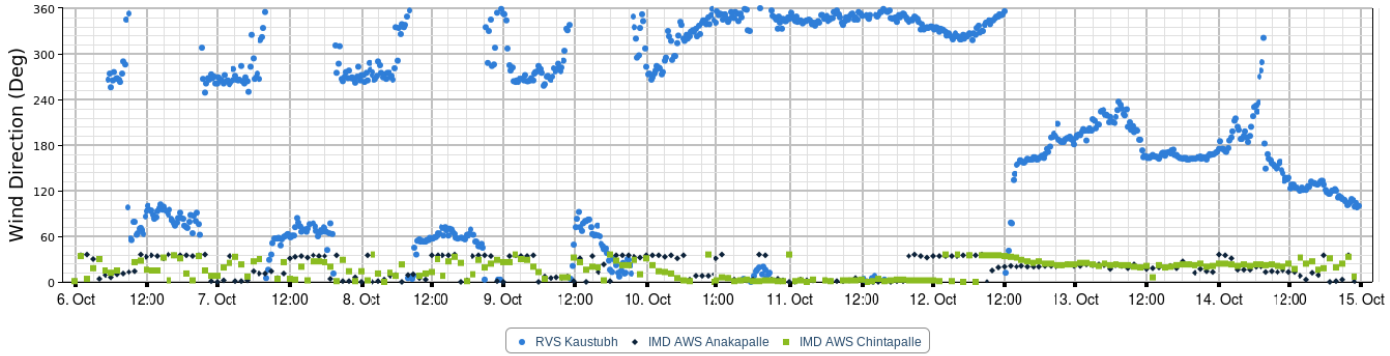


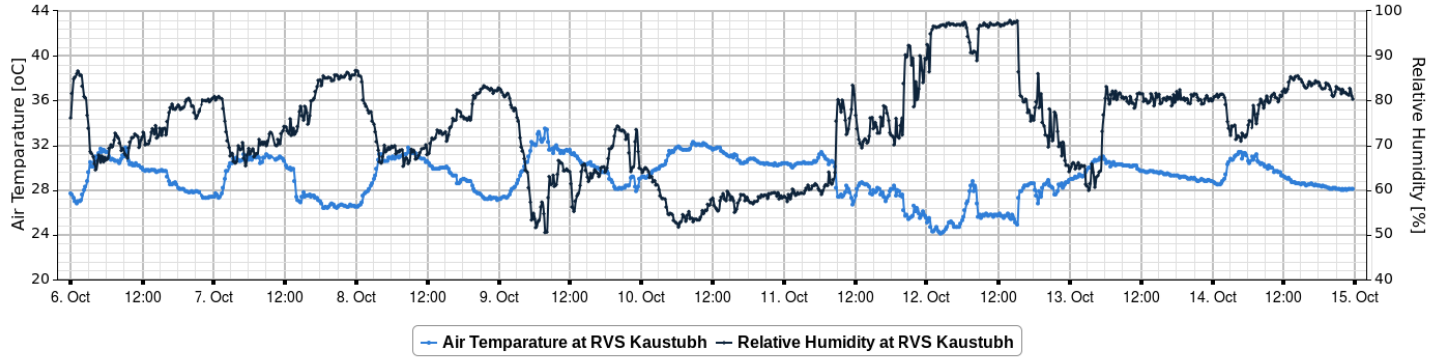




Harikumar et al. (2016)

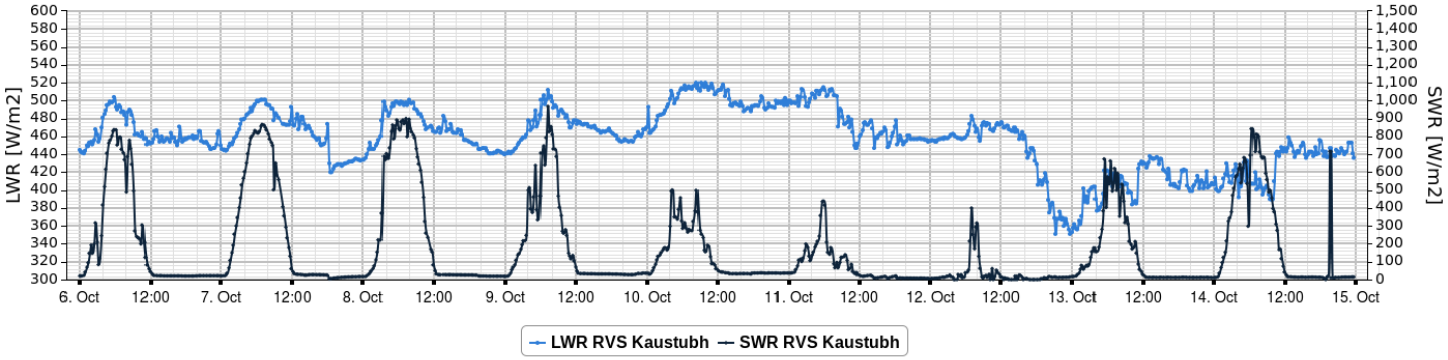
## Real Time Observation (Wind Direction)




## Real Time Observation (Air Temparature & Relative Humidity)

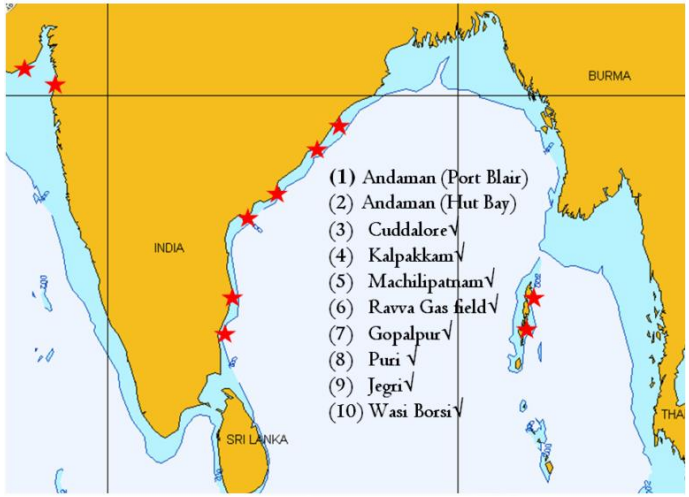



## Real Time Observation (LWR & SWR)



# Utilization of coastal HF Radar

# Coastal HF Radar Network




Enables measurement of Waves & Currents to about 200 Kms from the Coast

**Phase I ( completed by March 2008)**

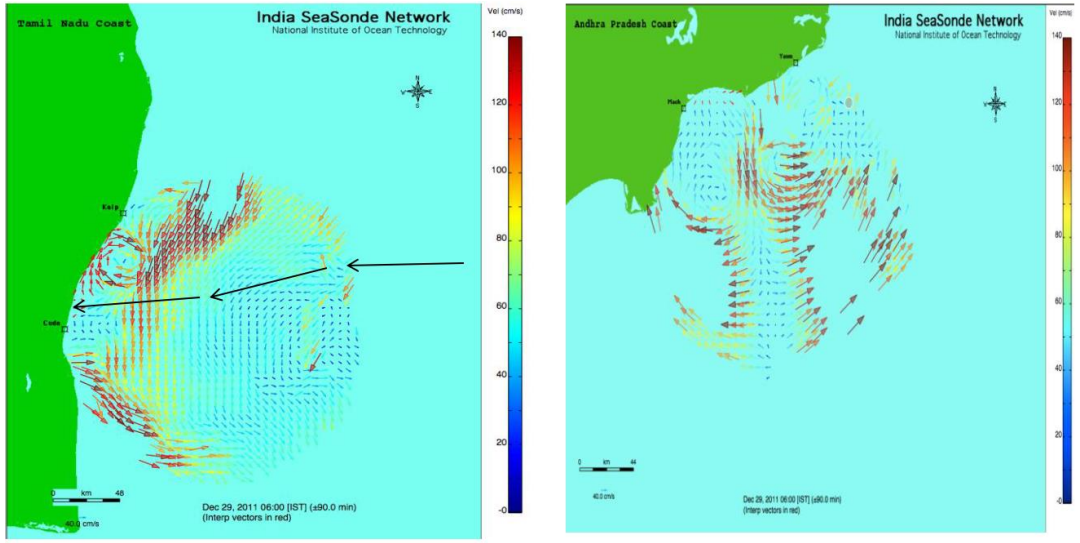
- Cudallore
- Kalpakkam
- Machilipatnam
- Yanam

**Phase II (completed by September 2009)**

- Jegri
- Wasi
- Gopalpur
- Puri

**Phase III (completed by May 2010)**

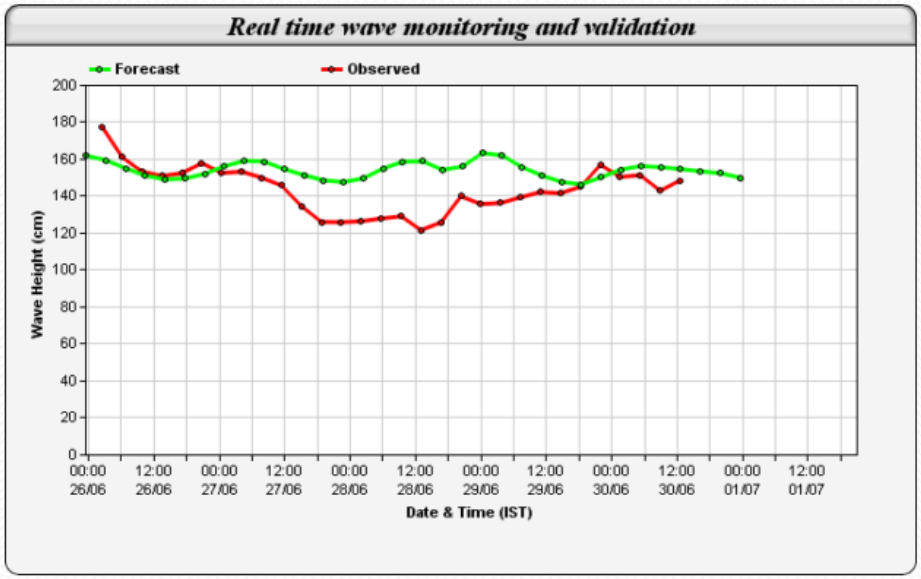
- Port-Blair
- Hut-Bay

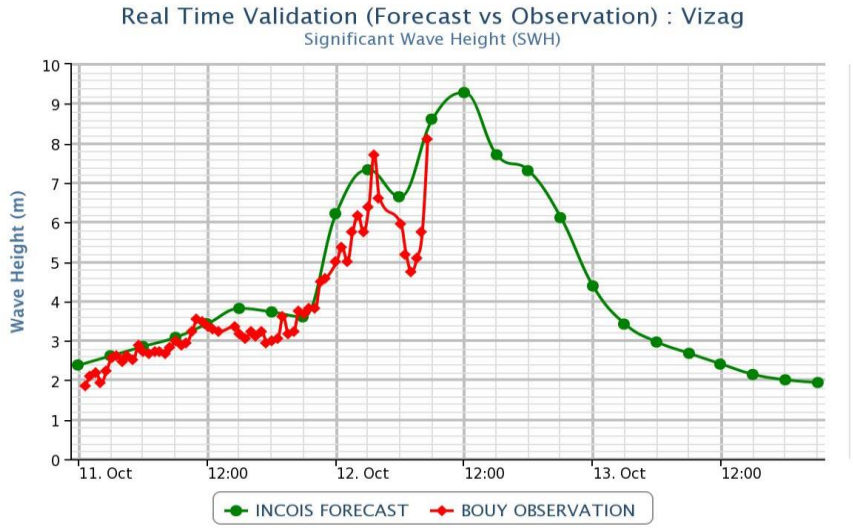



Cyclonic signatures in Surface Current

# Wave Rider buoys

# Real time monitoring of wave heights

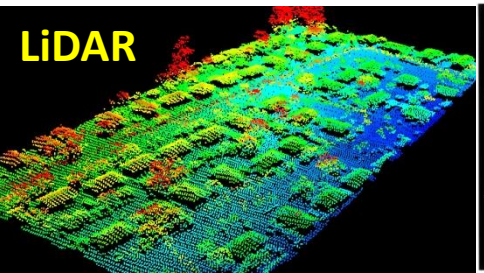


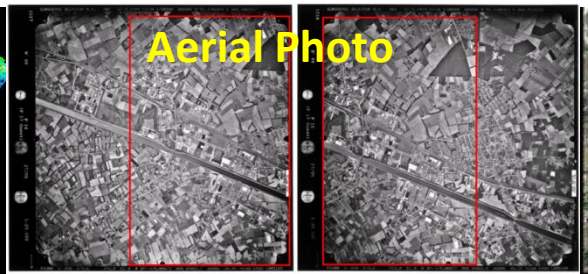



# Satellite imagery: Bathymetry / shoreline / in land topography

## High Resolution Topographic Mapping

| Platforms | Sensors/Cameras | Altitude | Ground Coverage | Details |
|---|---|---|---|---|
|   | CCD<br>RADAR | ~700km | More | Less |
|   | Camera<br>LiDAR<br>RADAR | ~2-6km | Medium | Moderate |
|   | Camera<br>LiDAR | ~100-2000m | less | More |



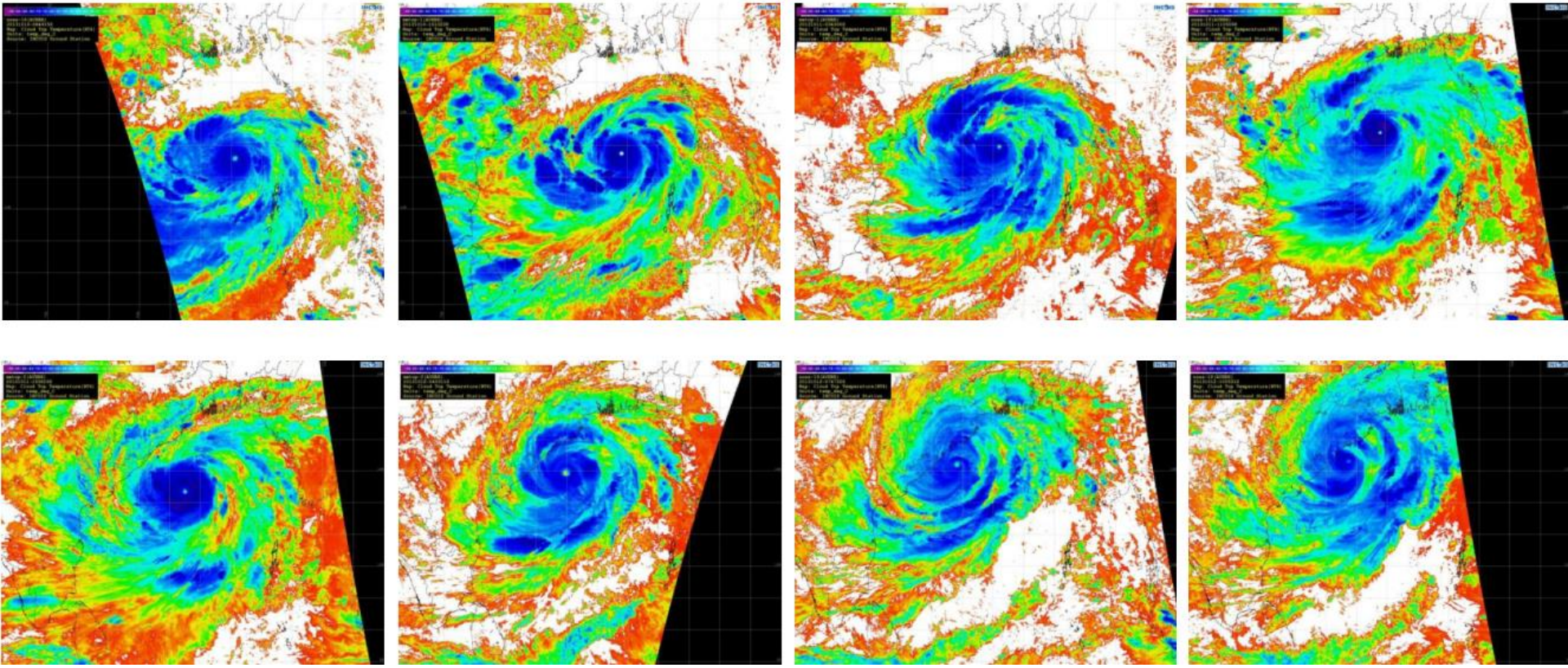





# Utilization of satellite derived CTT to retrieve Rmax of a cyclone

## Cyclone Phailin Rmax estimation from AVHRR-BT4 (10.5 – 11.5 µm)

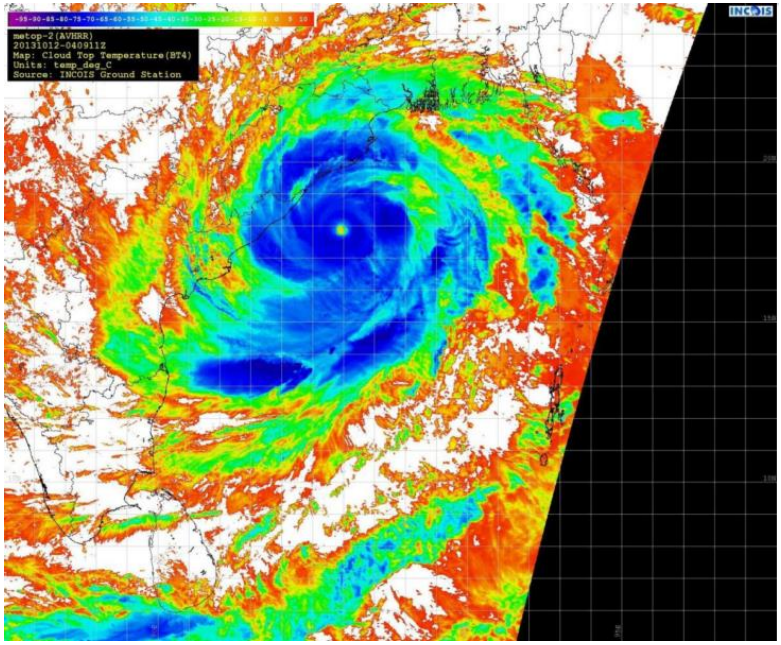
Following images shows the various stages of cyclone and it's Rmax varied from 25 to 36 Km



Satellite based determination of Rmax is a new technique based on the cloud top temperatures.

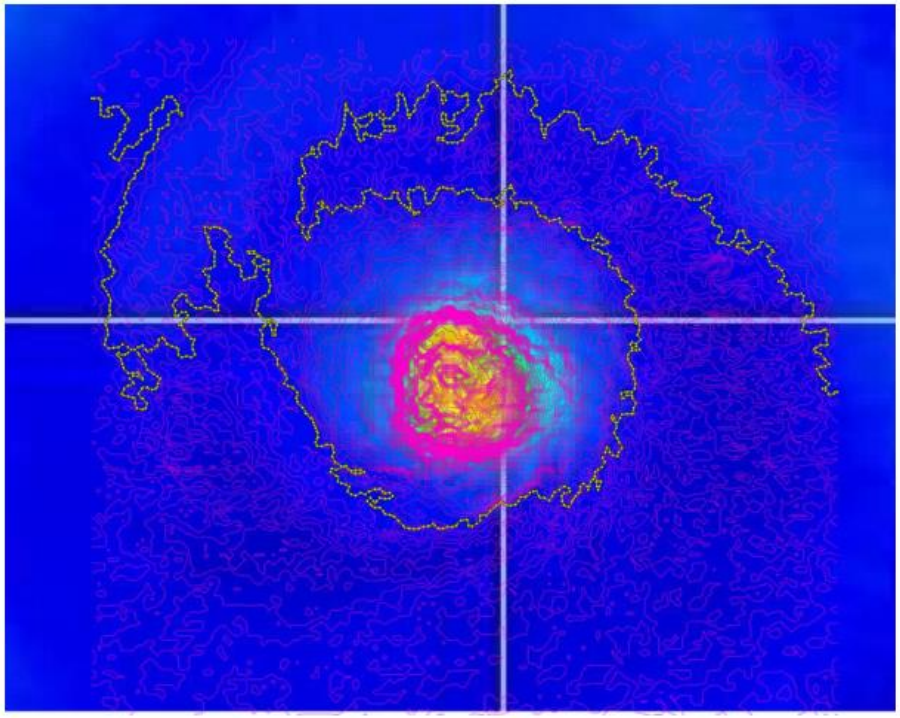
Rmax is the distance between the coldest cloud top temperature surrounding the eye and the warmest temperature within the eye of the cyclone.(S. A. Hsu & Adele Babin,2005)

Noticeable eye structure is necessary to estimate the Rmax.

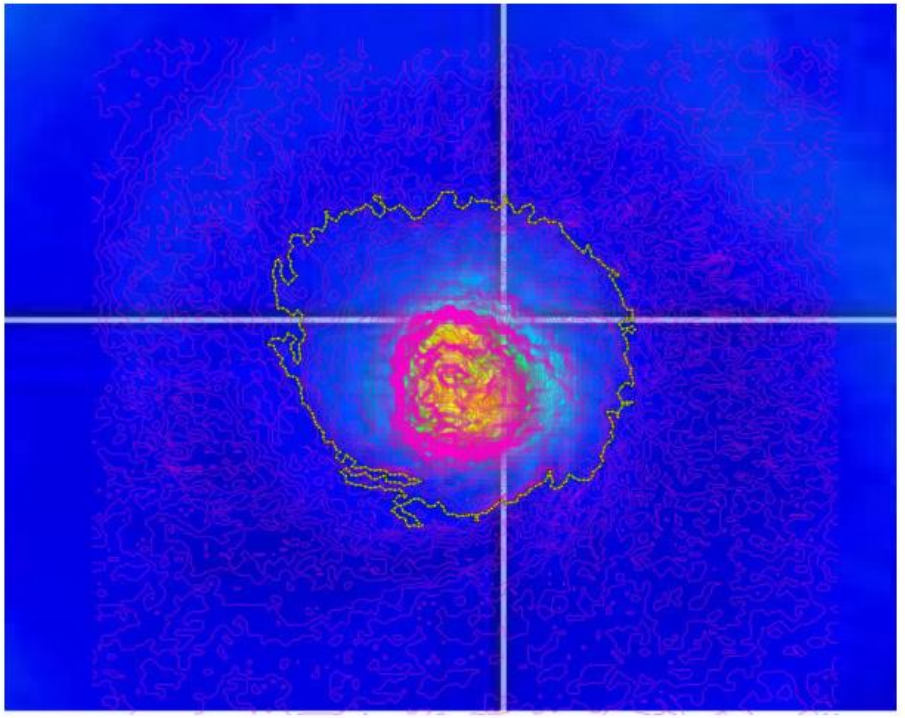


1°C contours interval, 10 Oct 2013-04:09Z

-71 °C contours

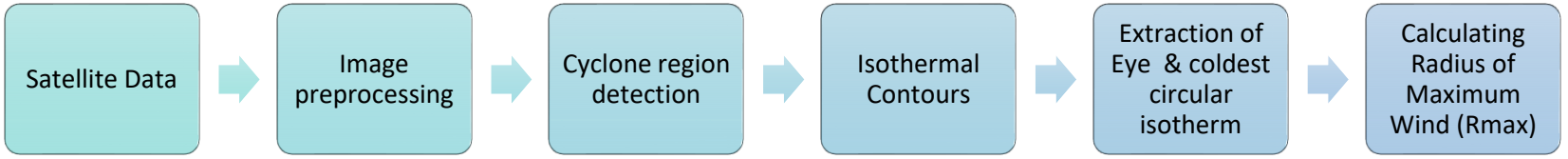


-70 °C contours



The coldest contour (-70 °C) surrounded around the eye is considered to measure Rmax, the diameter(D) of the circle is 72Km (Rmax[D/2]=36Km).

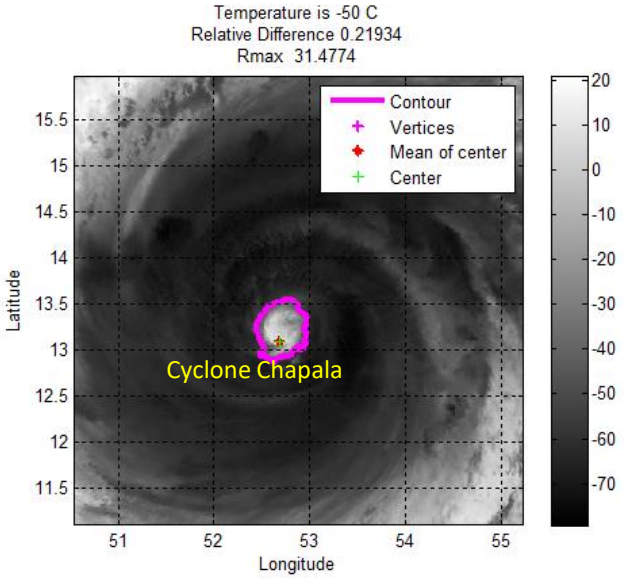
# Automatic Extraction of radius of WIND Maximum ($R_{max}$) of a tropical cyclone from IR images through image processing techniques




SOFTWARE USED: MATLAB

## Out come

- Real-time operational $R_{max}$ estimation
- Extract cyclone eye position (Lat/Long)
- Estimation of translational speed of the cyclone
- Position shift and time




France et al., 2008. A Technique to Determine the Radius of Maximum Wind of a Tropical Cyclone. (https://journals.ametsoc.org/doi/pdf/10.1175/2008WAF2007077.1)

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# Utilization of ocean observations by IMD

India Meteorological (IMD) Department is mandate for track prediction in India.

IMD makes use of observations from ships Ocean Weather Stations (OWS), Manned and Unmanned light vessels, Moored buoys, Drifting buoys, Towers, Island Automatic Weather Stations.

The observations from ocean are directly available to forecasters to evaluate the state of sea and that of atmosphere. These are also assimilated in the Numerical Weather Prediction (NWP) models to provide the forecast.

Simulation experiments with high resolution regional model show that buoy observations show significant impact on intensity and track.

A study by Osuri et al (2012), with remotely sensed satellite-derived winds over the North Indian Ocean (NIO), show that the inclusion of satellite-derived winds through a three-dimensional variational (-3DVAR) data assimilation system improves significantly the initial position, track, intensity and landfall forecast.

**The error in landfall point was reduced by 25 km by 2010 mainly due to installation of coastal AWS.**


# Thank You