Introduction to Marine Meteorology

Definition and scope of marine meteorology:

Marine meteorology is a branch of meteorology that **focuses on studying** and **understanding** the **weather and climate** patterns specific to **marine and coastal areas**. It deals with the atmospheric processes, phenomena, and interactions that occur over oceans and other bodies of water, including their influence on weather conditions and climate variability.

The **scope of marine meteorology** covers **various aspects related to weather and climate** in marine environments. Some key areas of study and investigation within marine meteorology include:

1. Marine Weather Forecasting: Marine meteorologists analyze and predict weather conditions at sea, including wind patterns, wave heights, precipitation, visibility, and temperature. These forecasts are vital for maritime operations, shipping, coastal management, and marine safety.

2. Ocean-Atmosphere Interactions: Marine meteorology explores the **interactions between the atmosphere and the underlying oceans**, which significantly influence weather and climate systems.

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3. Tropical Cyclones and Hurricanes: Understanding the **formation, intensification, and track of tropical cyclones is crucial for marine meteorology**. These severe weather systems pose significant risks to maritime activities and coastal regions, and studying their behavior helps in issuing timely warnings and mitigating potential impacts.

4. Coastal Weather and Climate: Coastal areas experience **unique weather** phenomena due to the proximity of land and the interaction between land and sea breezes. Marine meteorology investigates the specific characteristics of coastal weather patterns, including **fog, sea breezes, coastal storms, and localized climate** effects.

5. Climate Change and Sea Level Rise: Marine meteorology plays a role in studying the **impact of climate change on marine environments**. This includes analyzing changes in sea surface temperatures, ocean currents, and the potential effects of sea level rise on coastal areas and marine ecosystems.

Overall, marine meteorology seeks to deepen our understanding of the dynamic and complex interactions between the atmosphere and the ocean.

Importance of studying marine weather conditions:

Studying marine weather conditions is of crucial importance for a variety of reasons. Here are some key reasons why it is important:

1. Safety at Sea: Understanding marine weather conditions is vital for ensuring the **safety of mariners and maritime activities**. Weather conditions such as storms, high winds, heavy rainfall, fog, and rough seas can pose significant risks to ships, boats, and other vessels.

2. Navigation and Route Planning: Marine weather conditions play a critical role in **navigation and route planning**. Knowledge of wind patterns, sea currents, tides, and other weather-related factors helps sailors **determine the most efficient and safest routes for their journeys**.

3. Offshore Operations: Various **offshore activities**, such as **oil and gas exploration**, offshore **wind farms**, and marine research, heavily rely on accurate weather information. These operations often take place in challenging marine environments, where storms, hurricanes, or high waves can pose significant risks.

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4. Fisheries and Aquaculture: Marine weather conditions have a direct impact on fisheries and aquaculture industries.

5. Coastal Management and Disaster Preparedness: Coastal communities need accurate weather forecasts and data to effectively manage their coastal areas and prepare for natural disasters. Marine weather information is crucial for coastal planning, erosion control, flood management, and early warning systems for events like hurricanes, storm surges, and tsunamis.

6. Climate and Environmental Research: Studying marine weather conditions is essential for understanding climate patterns, oceanography, and the overall health of marine ecosystems. **Long-term monitoring** and analysis of marine weather data **provide insights into climate change, sea-level rise, ocean acidification, and other environmental processes**, aiding in scientific research and policymaking.

In summary, studying marine weather conditions is essential for the **safety of mariners, efficient navigation, offshore operations, fisheries management, coastal planning, disaster preparedness, and climate/environmental research**. Accurate and up-to-date knowledge of marine weather helps to mitigate risks, optimize activities, and protect both human lives and marine ecosystems.

Basic method in predicting marine weather:

1. **Observational Data**: Meteorological observations from **weather stations, buoys, ships, and other marine platforms** provide essential **real-time data** on atmospheric conditions, sea surface temperatures, wind speeds, wave heights, and other relevant parameters.

2. **Satellite Data**: Satellite imagery helps in **monitoring cloud cover, sea surface temperatures, storm systems**, and other atmospheric features over large areas.

3. **Weather Radar**: Weather radar is used to **detect precipitation, storm cells**, and other atmospheric features near the coastline or over the water.

4. **Numerical Weather Prediction (NWP) Models**: Sophisticated computer models simulate the atmosphere and oceans to forecast weather patterns. NWP models use **mathematical equations to predict future states of the atmosphere based on current conditions**. Global and regional models, such as the Global Forecast System (GFS) and the European Centre for Medium-Range Weather Forecasts (ECMWF), are commonly used for marine weather prediction.

5. **Ensemble Forecasting**: Ensemble forecasting involves running multiple NWP models with slight variations in initial conditions or model configurations.

6. **Climatology and Historical Data**: Long-term weather records and historical data help meteorologists **analyze typical weather patterns**, **seasonal variations**, and trends. Climatological information aids in understanding the expected range of weather conditions in a specific marine region, including average temperatures, prevailing winds, and storm frequency.

7. **Expert Analysis and Interpretation**: Meteorologists **with expertise in marine weather forecasting analyze the observational data, satellite imagery, NWP model outputs**, and other relevant information to interpret and synthesize the data into accurate and timely marine weather forecasts. Their **experience plays a crucial role in understanding complex interactions between the atmosphere and ocean**.

It's important to note that **marine weather prediction is a complex process** that requires continuous monitoring, analysis, and adjustment based on evolving conditions. Forecasts are subject to inherent uncertainties, particularly in regions with complex coastal topography and rapidly changing weather patterns.

Some of the Marine observations and their importance

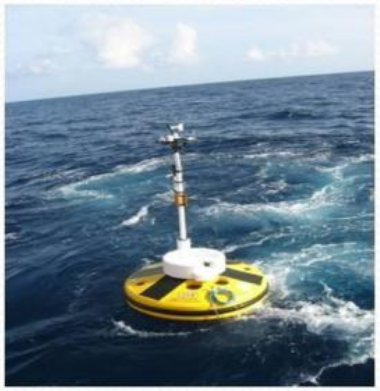
Ocean Observing System in India

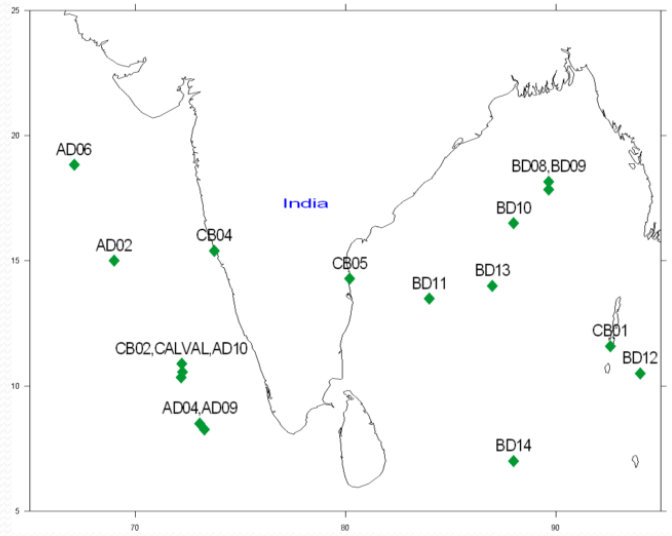
The following observation systems have been deployed and maintaining by MoES in and around Indian seas

- Moored buoys (offshore)
- Argo profiling floats (one float per 3^{o}x3^{o} box in North Indian Ocean)
- Drifters (one drifter per 5^{o}x5^{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

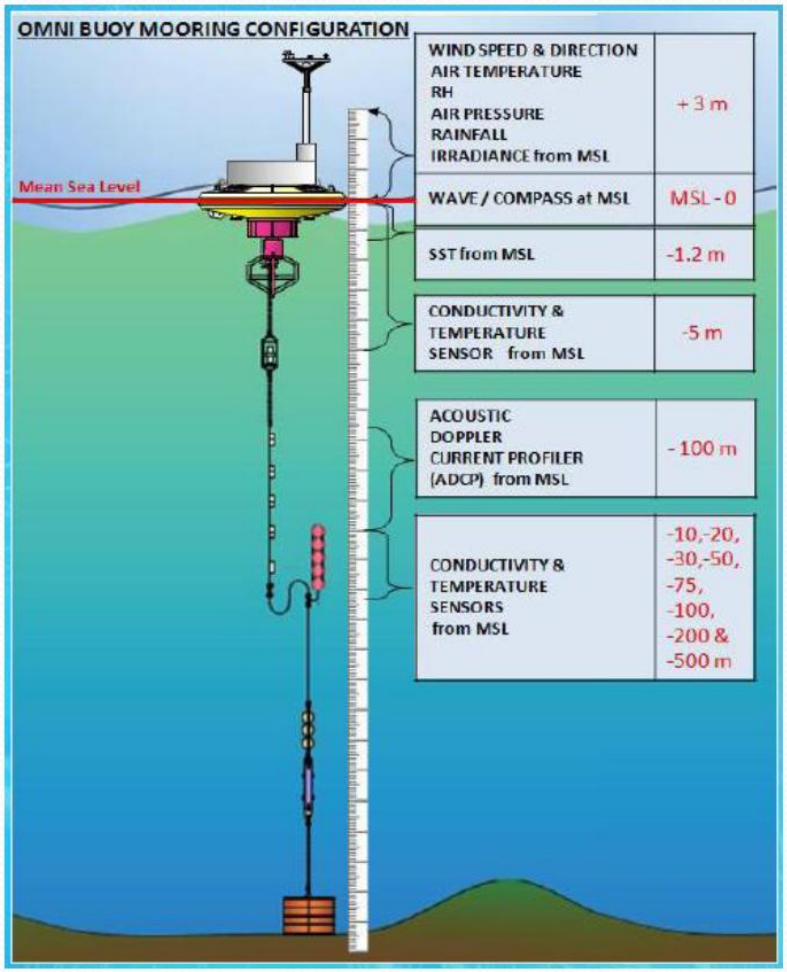
Application of Moored Buoy data

National Data Buoy Program





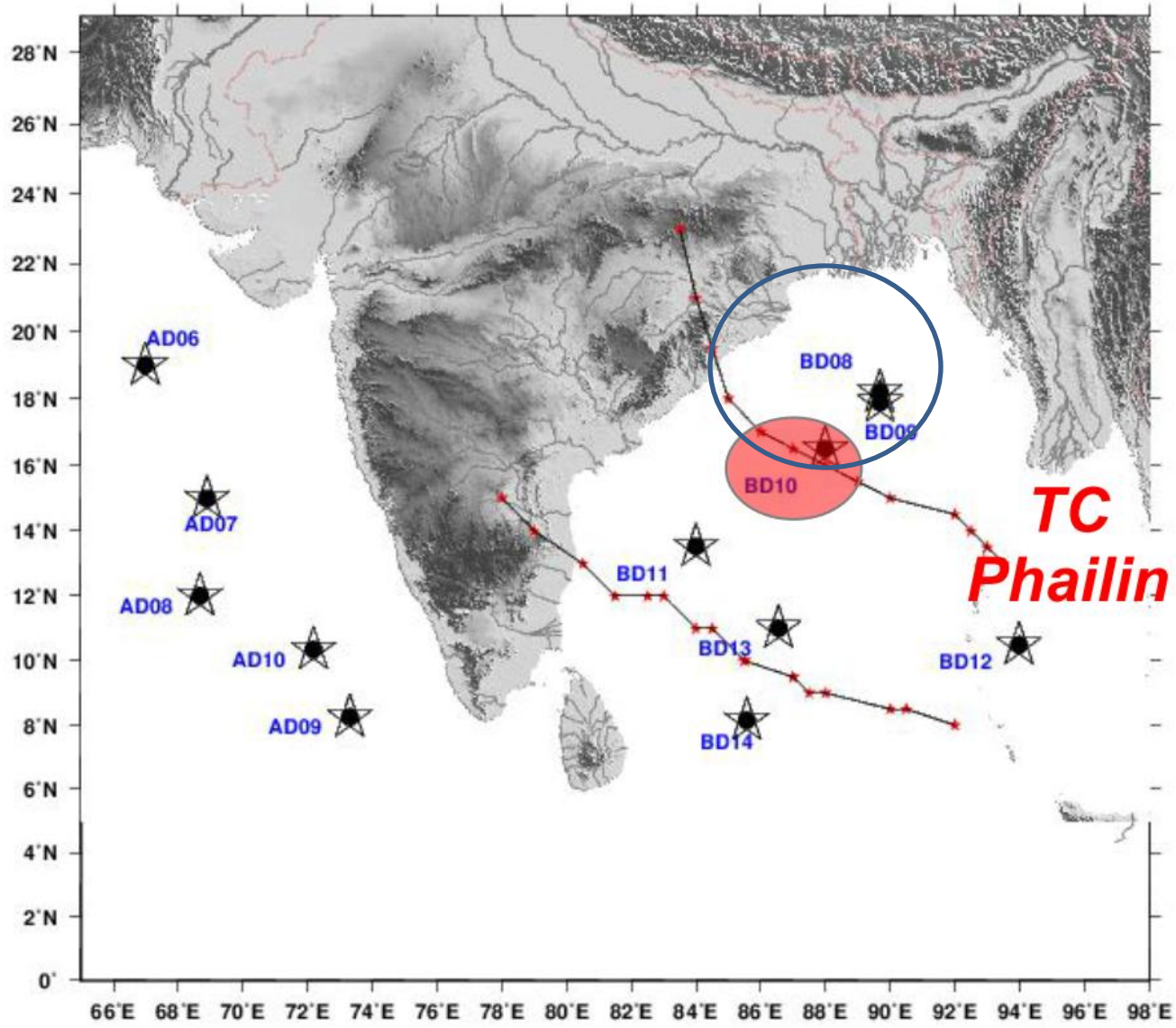
•Moored Buoys (Surface Met-Ocean, Sub-surface, Currents, T&S, Radiation, Rain gauges)
• Coastal Buoys



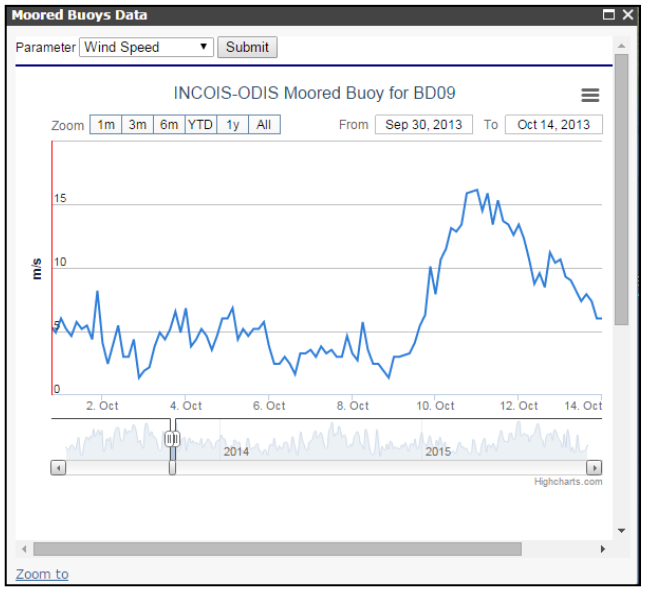
Applications

- 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.**

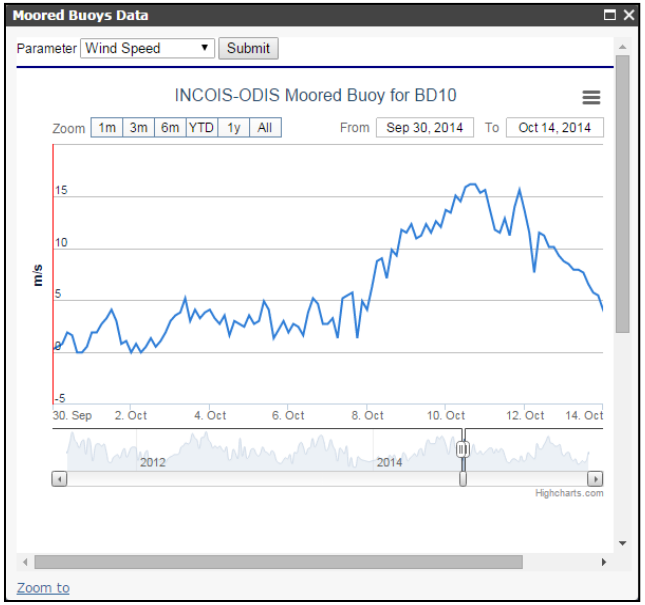
Monitoring Cyclones

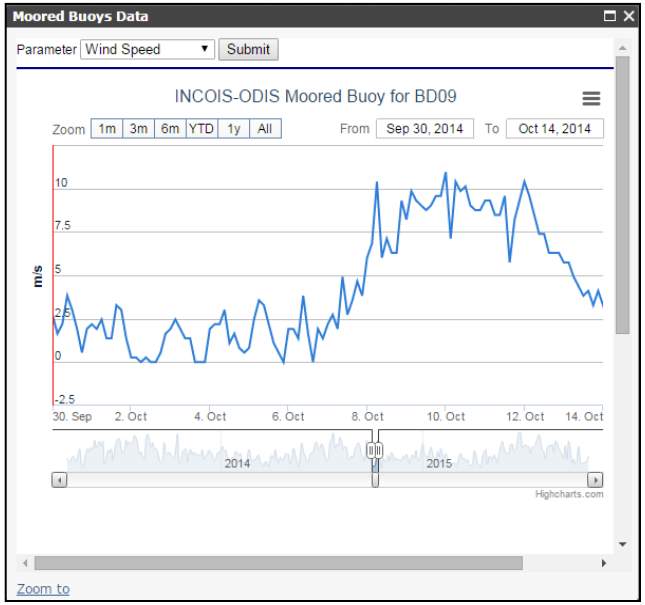


Buoy recording wind speeds



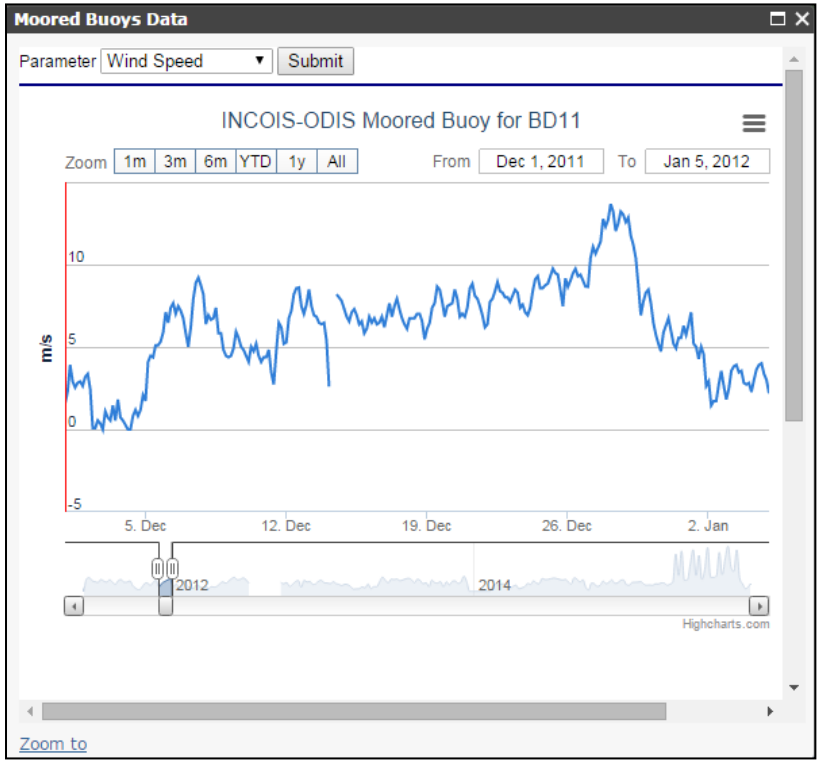
Phailin event





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.

Utilization of tide gauge data

Tide Gauge Network

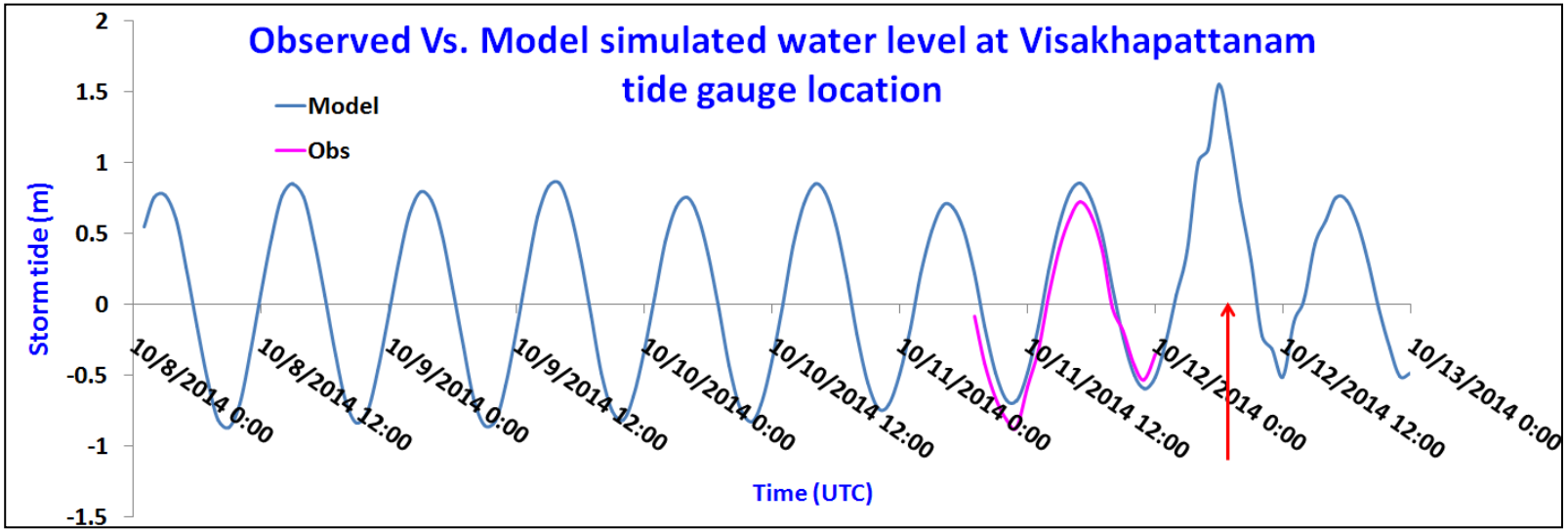
Network of 36 Tide gauges Installed and operational along the Indian Coast

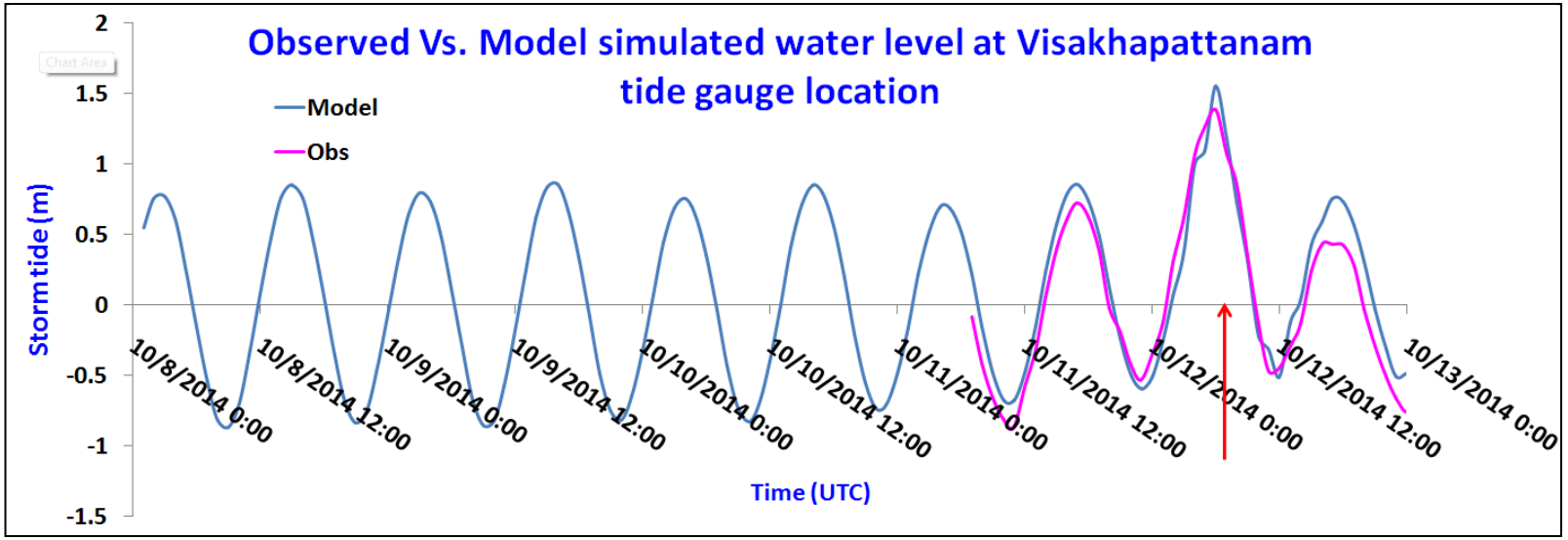
1 minute averages transmitted every 5 minutes

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

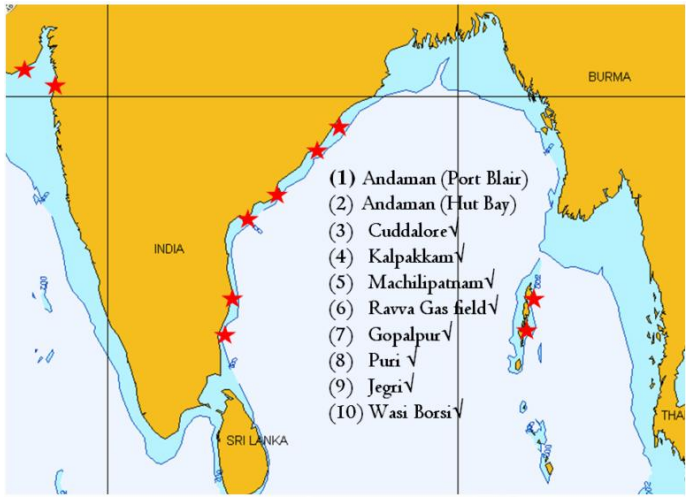
Real time surge monitoring and validation using tide gauge records during 'Hudhud'





Utilization of coastal HF Radar

Coastal HF Radar Network



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

<u>Phase</u> I (completed by March 2008)

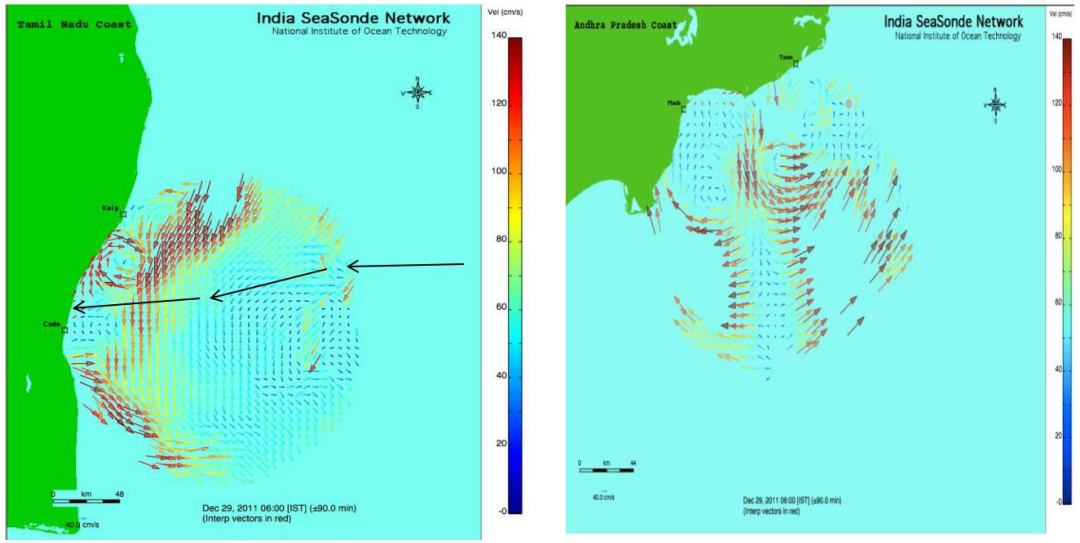
- Cudallore
- Kalpakkam
- Machilipatnam
- Yanam

<u>Phase II</u> (completed by September 2009)

- Jegri
- Wasi
- Gopalpur
- Puri

<u>Phase III</u> (completed by May 2010)

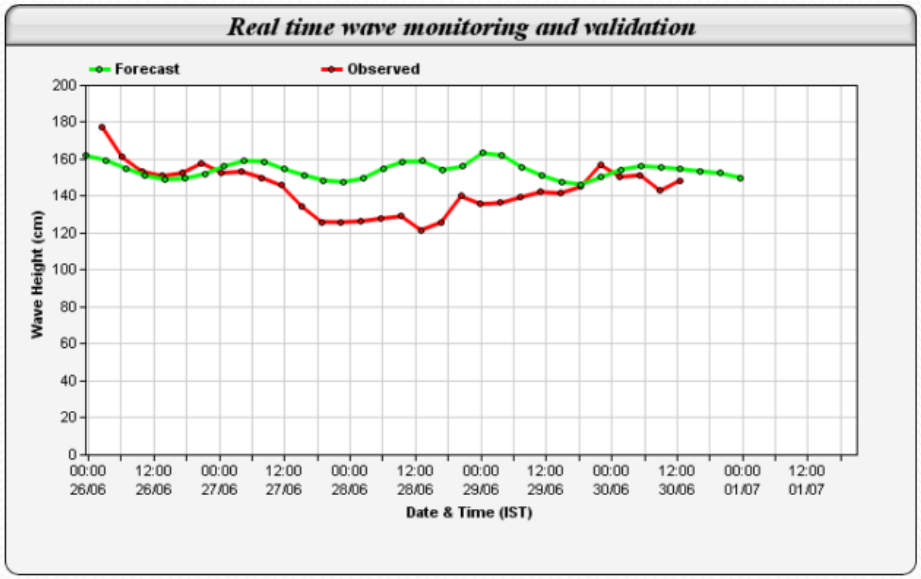
- Port-Blair
- Hut-Bay

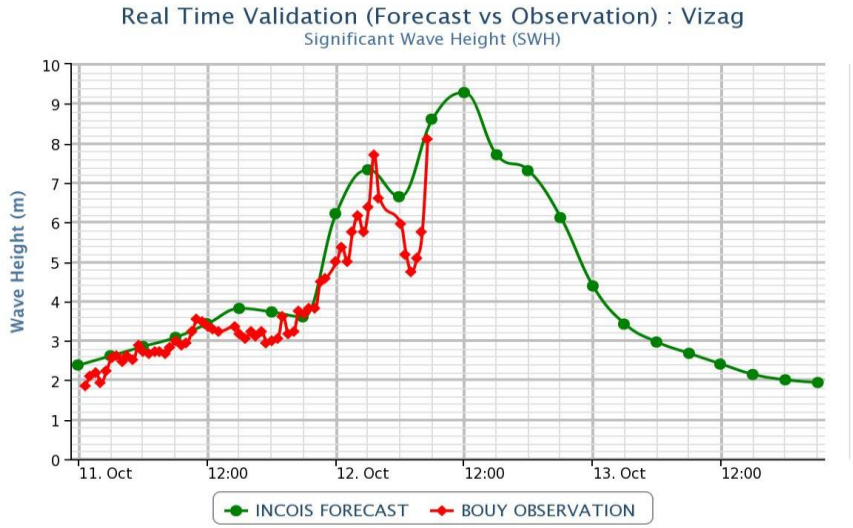


Cyclonic signatures in Surface Current

Wave Rider buoys

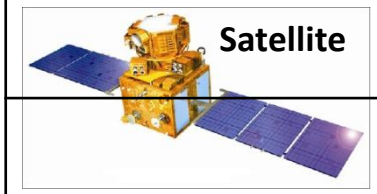
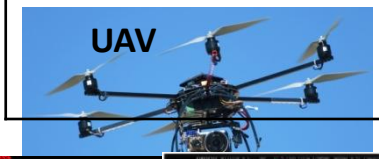
Real time monitoring of wave heights

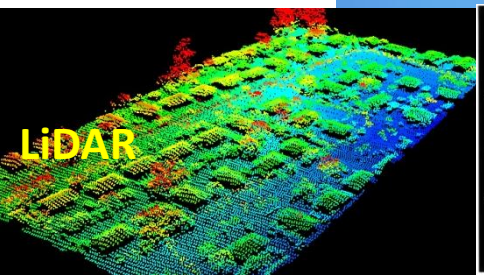


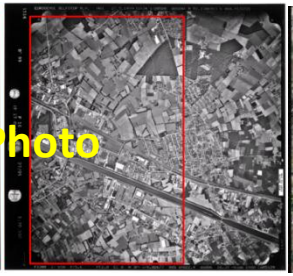


Satellite imagery: Bathymetry / shoreline / in land topography

High Resolution Topographic Mapping

Platforms	Sensors/Cameras	Altitude	Ground Coverage	Details
 Satellite	CCD RADAR	~700km	More	Less
 Aeroplane	Camera LiDAR RADAR	~2-6km	Medium	Moderate
 UAV	Camera LiDAR	~100-2000m	less	More





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.

Measurement of meteorological and oceanographic parameters

Meteorological and oceanographic parameters are essential for studying and understanding weather patterns, climate, and ocean dynamics. Here are some basic measurements for commonly observed parameters:

Meteorological Parameters:

1. Temperature: Measured in degrees Celsius (°C) or Fahrenheit (°F) using thermometers.

2. Humidity: Measured as a percentage using hygrometers.

3. Pressure: Measured in millibars (mb) or hectapascals (hPa) using barometers.

4. Wind Speed: Measured in knots, miles per hour (mph), meters per second (m/s), or kilometers per hour (km/h) using anemometers.

5. Wind Direction: Expressed in degrees or cardinal directions (north, south, east, west) using wind vanes or anemometers.

6. Precipitation: Measured in millimeters (mm) or inches using rain gauges.

7. Solar Radiation: Measured in watts per square meter (W/m^2) using pyranometers or solar radiometers.

8. Cloud Cover: Estimated as a fraction or percentage based on visual observations or using ceilometers.

Oceanographic Parameters:

1. Sea Surface Temperature (SST): Measured in degrees Celsius (°C) or Fahrenheit (°F) using satellite sensors or in situ instruments like thermometers.
2. Salinity: Measured as a dimensionless value or parts per thousand (ppt) using conductivity sensors or refractometers.
3. Sea Level: Measured in meters or feet using tide gauges or satellite altimeters.
4. Currents: Measured in centimeters per second (cm/s), meters per second (m/s), or knots using current meters or acoustic Doppler current profilers (ADCP).
5. Wave Height: Measured in meters or feet using wave buoys or wave rider buoys.
6. Dissolved Oxygen: Measured in milligrams per liter (mg/L) using oxygen sensors or titration methods.
7. Chlorophyll Concentration: Measured in micrograms per liter (μg/L) using fluorometers or spectrophotometers.
8. pH: Measured as a dimensionless value using pH meters or electrodes.

These measurements provide crucial data for meteorologists, climatologists, oceanographers, and other scientists to analyze and model weather and oceanic systems accurately.

Importance of ocean observations

Observations from the sea play a crucial role in various fields and provide valuable information for scientific research, operational forecasting, environmental monitoring, and decision-making. Here are some key importance of observations from the sea:

1. Weather Forecasting and Climate Studies: Sea observations **provide essential data** for **meteorologists and climatologists** to **analyze weather patterns**, **storm systems**, and climate trends. They **help improve** the **accuracy of weather forecasts, storm predictions**, and **long-term climate projections**.

2. Oceanography and Marine Science: Sea observations **contribute to our understanding of ocean dynamics**, currents, temperature variations, and the movement of marine organisms. They **help** scientists study ocean circulation, upwelling events, **El Niño and La Niña phenomena**, and the impacts of climate change on marine ecosystems.

3. Natural Disaster Prediction and Management: Observations from the sea, such as ocean currents, sea level, and temperature profiles, **aid in predicting and monitoring natural disasters like hurricanes, tsunamis, and storm surges**. These observations are crucial for issuing timely warnings, evacuations, and disaster response planning.

4. Maritime Operations and Safety: Sea observations **are vital for safe maritime navigation**, especially in terms of **weather conditions, wave height, currents, and visibility**. They support the planning of shipping routes, offshore operations, and the prevention of maritime accidents.

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5. Environmental Monitoring and Conservation: Sea observations help assess the health of **marine ecosystems, monitor pollution levels, track harmful algal blooms**, and study the impacts of human activities on coastal areas.

6. Climate Change Research: Sea observations provide critical data for monitoring and understanding the **impacts of climate change on the oceans**. They help track **sea surface temperature rise, sea level changes, ocean acidification, and melting ice caps**, contributing to the assessment of climate change trends and the development of mitigation strategies.

7. Fisheries and Resource Management: Sea observations aid in the study of **fish populations, migration patterns, and ecosystem dynamics**, supporting sustainable fisheries management. They also help **assess the availability of marine resources, monitor changes in fish stocks**, and guide the implementation of effective conservation measures.

In summary, observations from the sea are fundamental for advancing our knowledge of weather, climate, oceanography, and marine ecosystems. They have wide-ranging applications, from improving weather forecasts to safeguarding marine life and supporting sustainable development.

Collection of marine data from ship's log and their compilation

The collection of marine data from ship's logs and its compilation involves the systematic recording and organization of observations made onboard ships. Here are the steps involved in the process:

1. Ship's Logbook: Ship crews maintain logbooks where they **record various meteorological and oceanographic observations**. These **logbooks serve** as the **primary source of data collection**. The logbook entries typically include information such as **date, time, location, weather conditions, sea state, wind speed and direction, barometric pressure, sea surface temperature**, and any other relevant observations.

2. Data Extraction: The data from ship's logbooks **will be reviewing and extracting**, ensuring accuracy and consistency in data collection.

3. Quality Control: Extracted data **undergoes quality** control procedures **to identify** and correct **any errors or inconsistencies**.

4. Data Encoding: The extracted **data is then encoded into a standardized format** suitable **for further processing and analysis**. Common data formats used in marine data compilation include **netCDF** (Network Common Data Form) and **CSV** (Comma-Separated Values).

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5. Metadata Annotation: Metadata, includes details such as the source of the data, vessel information, data collection methods, and any relevant notes or comments.

6. Data Compilation and Integration: The compiled **data from multiple sources**, including **ship logbooks**, can be **integrated** with data **from other observation platforms** such as buoys, satellites, and coastal stations. This integration **enhances** the **comprehensiveness and spatial coverage of the dataset**, enabling a more holistic understanding of marine conditions.

7. Data Storage and Accessibility: The compiled dataset is **stored in a secure** and **accessible repository**. This could be a **centralized database or an online platform** where researchers and scientists can access and utilize the data for various applications, such as climate studies, oceanographic research, and model validations.

8. Data Sharing and Collaboration: **Sharing compiled marine data** with the **scientific community promotes collaboration and enables the broader use of the data** for research and applications.

By following these steps, the collection of marine data from ship's logbooks and its compilation helps create valuable datasets that contribute to our understanding of the oceans, climate, and marine ecosystems.

Thank You