New Moored buoy network in Northern Indian Ocean
with surface/subsurface Measurements, their analysis and applications

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The Indian Ocean is unique among the three tropical ocean basins in that it is blocked at 25°N by the Asian landmass.

Seasonal heating and cooling of the land sets the stage for dramatic monsoon wind reversals, strong ocean–atmosphere interactions, and intense seasonal rains over the Indian subcontinent, Southeast Asia, East Africa, and Australia.

Scientific need to have long term ocean observation.
Ocean Observation Systems

• Under the Ocean observation systems programme of Ministry of Earth Sciences, Gov. of India, NIOT has the mandate to establish and maintain moored buoy network in Indian seas.
• Real time data transmission to INCOIS via FTP/Email for dissemination to user agencies.
Moored Buoy network in Indian seas

12 OMNI, 6 Met Ocean & 4 Tsunami buoys
NEW OMNI BUOYS

- Surface meteorological
  - Wind speed and direction
  - Air temperature
  - Air pressure
  - Humidity
  - Short wave radiation
  - Incoming long wave radiation
  - Precipitation

- Surface Ocean parameters
  - Sea surface temperature
  - Conductivity
  - Wave
  - Current speed and direction

- Sub surface parameters
  - Temperature and salinity at depths starting from 5m, 10m, 15m, 20m, 30m, 50m, 75m, 100m, 200m and 500m
  - Currents at depth levels 10m, 20m, 30m, 50m and 100m
MOORED BUOY DATA ANALYSIS

- Response of the Bay of Bengal to Cyclone forcing
- Does cyclonic forcing warm the ocean surface in the Bay of Bengal?
- Warm pool analysis in the Arabian sea and Bay of Bengal
- Interannual variations of SST and its impact on coral reef near the Andaman Islands
- Wave Forecasting using Artificial Neural Network
- Wave data assimilation
BAY OF BENGAL AND CYCLONE

• Bay of Bengal is home to about three or four named tropical cyclones every year.
• Cyclones are formed within the lower tropospheric equatorial troughs and propagates westward.
• The strong winds associated with cyclone causes mixing of the ocean with higher rate of exchange between ocean and atmosphere.
• The ocean response is three times larger during pre-monsoon than compared to post-monsoon season.
RESPONSE OF THE BAY OF BENGAL TO CYCLONE FORCING
CYCLONES IN THE BAY OF BENGAL
during October 2010 to October 2013

- JAL CYCLONE during NOVEMBER 2010
- THANE CYCLONE during DECEMBER 2011
- NILAM CYCLONE during OCTOBER 2012
- MAHESAN CYCLONE during MAY 2013
- PHAILIN CYCLONE during OCTOBER 2013
Significant Observations during Cyclone PHAILIN

Air Pressure

WIND GUST
Significant Observations during Cyclone PHAILIN

**SST**

- Temperature (°C)
- 08 Oct 2013 to 14 Oct 2013
- SST values from 27.5 to 30.5

**SALINITY**

- Salinity (ppt)
- 08 Oct 2013 to 14 Oct 2013
- Salinity values from 30 to 33.5

**IRRADIANCE**

- Irradiance (W/m²)
- 08 Oct 2013 to 14 Oct 2013
- Irradiance values from 0 to 1200

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Buoys 400km away helped track Phailin

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.

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.
MAHESAN CYCLONE MAY 2013
RESPONSE IN THE WIND AND ATMOSPHERIC PRESSURE

WIND SPEED

ATMOSPHERIC PRESSURE
OCEANIC RESPONSE IN THE SUBSURFACE TEMPERATURE

TEMPERATURE RESPONSE

BD11_13.5N84E

BD13_11N86.5N

- temp 10m
- temp 15m

1 deg drop in the water column
2.5 deg drop
OCEANIC RESPONSE IN THE SUBSURFACE SALINITY

SALINITY RESPONSE

BD11_13.5N84E

BD13_11N86.5N

MAY

salinity 10m

red - salinity 15m

blue - salinity 20m

MAY

depth (m)

depth (m)
OCEANIC RESPONSE IN THE CURRENT SPEED

CURRENT SPEED AT 11N, 86.5E (BD13)

CURRENT SPEED AT 16.5N, 88E (BD10)

CURRENT SPEED AT 13.5N, 84E (BD11)

Legend:
- current speed 10m
- current speed 20m
- current speed 30m
THANE CYCLONE DECEMBER 2011
RESPONSE ON THE ATMOSPHERIC PARAMETERS

- Wind Speed: 22 m/s
- Air Pressure: 4.5 deg drop
1 deg rise

Increased by 2 p.s.u.
OCEANIC RESPONSE IN THE CURRENT SPEED

CURRENT SPEED AT 11N, 86E (BD13)

chart showing the current speed at 11N, 86E with data from December 2011 to January 2012. The chart includes a graph and a color-coded map indicating the speed at different depths (20m, 15m, 10m).
CONCLUSION

- Buoy data are useful to study the oceanic response to cyclonic forcing during various seasons in the bay of Bengal.

- Cyclones have resulted in cooling and entrainment of subsurface high saline waters at the buoy locations.

- The temperature inversion in the subsurface layer during December has resulted in an increase in surface temperature and salinity.

- The cyclonic forcing has resulted in inertial oscillation in the thermocline.
Warm pool studies

- Buildup and collapse of warm pool using SST data collected from the moored buoy network in the eastern Arabian Sea and the Bay of Bengal.
- To characterize the observed intraseasonal variability of SST in the deep and shallow waters of Arabian sea

ARABIAN SEA - BUILD UP OF WARM POOL

- A diurnal cycle is seen overriding in the seasonal cycle
- Similar features occurring in the DS2 location
The collapse is dramatic during 1998 due to passage of onset vortex.

The intraseasonal variability during the collapse phase is relatively weak.

Diurnal scale variability is also very small.
A comparison of SST record in the deep (11N, 72E) and shallow (13N, 75E) water region during May-September 2002

COLLAPSE OF WARM POOL

- These intraseasonal oscillation are only seen in the coastal SST record
CONCLUSIONS

- The warm pool in the Arabian Sea shows a progressive build up during February – May and collapse during summer monsoon season. The collapse is dramatic during the years of onset vortex.
- Relatively weaker amplitude intraseasonal oscillations are seen during the summer monsoon season in the deep waters of eastern Arabian Sea.
- Relatively large amplitude oscillations are seen in the coastal SST records in the Arabian Sea.
Inter-annual variations of Sea Surface Temperature and its impact on coral reef near the Andaman Island
Coral reef map of India
- Coral reefs are the most remarkable and diverse marine ecosystems on the planet
- Crucial Role in the sources of Income and resources
- Intensity and frequency of bleaching was more in Andaman Islands compared to Lakshadweep and Gulf of Mannar (KohTao 2010)
NIOT Coral Reef Data Buoy System

- Need for the continuous time series of in-situ data from the coral reef environment

- Request from Department of Environment and Forest

- NIOT developed a met data buoy called “Coral Reef Data Buoy System” and deployed at Grub Island of Mahatma Gandhi Marine National Park, Wandoor, Andaman on 23 February 2011.

- Coral Reef Buoy (11.58N&92.60) in the Andaman Island provides continuous time series measurements of Met-ocean parameters like SST, Wind speed and direction, Air pressure, Air temperature, Air humidity, current speed and direction and conductivity.
Soft corals found at the bottom of the buoy hull retrieved after one year

**Coral Reef Buoy – Andaman**

**Formation of corals under data buoy excites scientists**

They now have evidence that corals are capable of surviving global warming
Objectives

• To examine the evolution of SST near the Andaman Island by using the buoy data during March-June months of the years 2011-2012.

• To compare the differences in the thermal stress over the coral reef region during the years 2010, 2011 and 2012 by using ‘Hotspot’ analysis.
Data Sets Utilised for SST

- Daily averaged Buoy SST @ 1m depth (11.58N & 92.60E).
- Weekly and Monthly averaged AVHRR-Pathfinder V4-SST.
Monthly SST Climatology of Andaman Reef region (11.5-14N, 91.5-94E) for the period of 1985-2012 by using AVHRR.
Comparison of AVHRR SST during 2010, 2011 and 2012

Andaman Sea witnessed mass coral reef bleaching during April-May months of the year 2010 (Krishnan et al. 2010)
Evolution of Buoy SST during the warming phase of the years 2011 and 2012.
Hot Spot

• Large scale coral bleaching follows high temperature extremes when the weekly average SST values reach $1^{0}\text{C}$ above normal maximum monthly averages.

• Hot spot is the areas of the ocean with SST anomalies over $1^{0}\text{C}$ above long-term averages of monthly maximum. (‘Hot Spots’, as defined by Goreau & Hayes, 1994).

• Monthly Mean Maximum SST for the Andaman Sea (29.84$^{0}\text{C}$) is calculated by using AVHRR v4 (9x9km) SST data for the period of 1985-2012.

• In Andaman, the region where the SST crossed the value of 30.84$^{0}\text{C}$ can be considered as Hot spot region.
Hot Spot Around Andaman Islands: March – May, 2010
Hot Spot Around Andaman Islands: March – May, 2011
Hot Spot Around Andaman Islands: March – May, 2012
Conclusions

- Based on the buoy data and satellite data, it has become clear that the year 2011 was a cooling phase for the Andaman reef region.

- Hotspot shows interannual variability with maximum duration (6 weeks) in the year 2010.

- Co-occurrence of SST anomaly maxima and the climatological maxima and the resultant development of Hot spot pattern may be the probable causes for the mass bleaching happened during the year 2010.
Wave data analysis and applications
• Six Buoys have been deployed in the Arabian Sea and the Bay Bengal for wave measurement
Wave Forecasting using Artificial Neural Network

- To develop a model for wave forecasting using soft computing techniques such as Artificial Neural Networks (ANN)
Study Parameters

Wind data input To Forecasting Significant Wave Height

An attempt to made use wind data to predict SWH since maintenance of wave buoy is very difficult

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<th>Buoy Details</th>
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<tr>
<td>Buoy Id</td>
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<td>Lat</td>
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<td>Long</td>
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<tr>
<td>Depth</td>
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Training – 70% data (Jan 2003-Dec 2003)

Time series plot for Significant wave height

Correlation Coefficient: 0.9

24th Hour Forecasting at DS3

Wind data input

Correlation Coefficient: 0.9
Time series plot for Significant wave height at Station DS3 with input wind speed – Prediction by ANN
Real time wave forecasting using ANN

Study Period:

**DS5 – September 2007 – December 2007**

Buoy Details

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<tr>
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<tr>
<td>Long</td>
<td>83 E</td>
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<td>Depth</td>
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12th and 24th hrs Real time forecasting Significant Wave Height Forecasting – DS5

Error Statistics

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<tr>
<td>DS5</td>
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<td>0.91</td>
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Wave data assimilation
**Buoy Data Assimilation into Wave Model**

**Objective:** Improvement of wave model prediction using multiple buoy data assimilation

- Data Assimilation using Buoy data efficiently improves the model prediction and steers the model towards the measurements (Significant wave height).

- In India, buoy data assimilation studies for wave model has been carried out availing single buoy data only (Sannasiraj et al, Natural hazards, 2009).
Numerical Frame Work

Wave Model: WAM III Cycle 4
Wave Parameter: Significant wave height

Wind forcing
- ECMWF wind data: $1^\circ \times 1.25^\circ$ (Old buoy network)
- ECMWF wind data: $0.5^\circ \times 0.5^\circ$ (New buoy network)

Bathymetry: Etopo2
Model Grid resolution: $0.5^\circ \times 0.5^\circ$
Model domain: Easting: 30-120; Northing: -50S – 30N

Observed data: NIOT Moored buoy network program

Data Assimilation technique:
- Optimum Interpolation (correction to the output)
Multiple buoy data assimilation

- Improvement in Wave height prediction in Model Domain

  Effectively fixing the influence area of given buoy in the model domain

  Gain:

  Weightage factor to correct and distribute the error (obs-model) at any buoy location; based on the co-variance of Hs between the buoy location and at each grid in the model domain.
Reason for performing Multiple Buoy Assimilation Case: Buoy off MB12 - Gain Distribution

MB12-Single Buoy

MB12-Three Buoys (mb12+mb11+ds4)

MB12-Four Buoys (mb12+mb11+ds4+ds3)

MB12-Five Buoys (mb12+mb11+ds4+ds3+ob8)
Comparison of Buoy Observations with WAM Wave Model Predictions Before and After Buoy Data Assimilation

- **MB12**: Observation, MB12-WAM model, MB12-WAM after Assimilation

- **MB11**: Observations, MB11-WAM model, MB11-WAM after Assimilation

- **DS4**: Observations, DS4-WAM model, DS4-WAM after Assimilation

SW monsoon
Effect of Neighboring Buoys Assimilation on MB12

Improvement in MAE at MB12 due to neighboring buoy assimilation

Improvement in RMSE at MB12 due to neighboring buoy assimilation

RMSE & MAE statistics at buoy location MB12 showing the influence of neighbouring buoys.
Influence of Neighbouring Buoys (MB11 & DS4) on MB12

**MB11-assimilated - Improvement at MB12**
- MB12-Obs
- MB12-WAM model
- Mb12-(MB11-assm)

**DS4-assimilated - Improvement at MB12**
- MB12-Observations
- MB12-WAM model
- Mb12-(DS4-assm)

**(MB11+DS4) Assimilated-Improvement at MB12**
- MB12-Observations
- MB12-WAM model
- Mb12-2B(mb11+ds4)
Capacity Building

Sensors and Buoy system

1. Regional Workshop on Best Practices for instruments and Methods of Ocean Observation from 19th – 21st November 2012
2. National Training for Data Collection in the Ocean by Seabird Electronics and WET Labs from 22nd – 27th November 2012
3. 2011 Regional workshop on awareness on protection of buoys
4. Prof Eric & Prof Craig Lee on Oceanographic Glider and Floats University of Washington February 2013
5. Training on OMNI buoy systems at NIOT by Fugro Oceanor Norway October 2012.
6. Training by Pacific Marine Environmental Laborato

Data Quality

1. Training by National Data Buoy Center USA at NIOT
2. Technical challenges on Oceanographic sensors by Dr. Paul Freitag of NOAA-PMEL during November 2012.
3. Training planned for 3 staff at PMEL and NDBC from 4 August to 14 August 2013
4. ADCP DATA NIO GOA

Calibration

1. WMO training 2013, July 2013 FIO China
2. NOAA PMEL

New observation tools

1. Dr Vembu US Ocean Observation network SECOORA
Regional Workshop on Best Practices for instruments and Methods of Ocean Observation

Objective: Capacity building of scientists, researchers, engineers and managers on best of practices on calibration and testing instruments for ocean observation systems

Date: 19th–21st November 2012.

Participant Countries: 19
Number of Industries: 26
Number of presentations: 33

Release of Training manual and Foot Print

Number of attendees: 120
National Training for Data Collection in the Ocean by Seabird Electronics, WET Labs USA

Objective: To provide knowledge on the advanced observational techniques with sensors and use different standards and protocols for collecting, archiving, and assimilating high quality data and thus monitoring and processing the collected data of the global oceans

Date: 22nd - 27th November 2012

Lecture & Practical training by Science Director, Seabird electronics Inc.

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<td>NIOT (OOS, OA, OE, CEE, MBT &amp; ROSUB)</td>
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Thank You