Future Plans

DBCP 31 SCIENTIFIC AND TECHNICAL WORKSHOP

STUDY ON PERFORMANCE OF SENSORS IN INDIAN MOORED BUOYS

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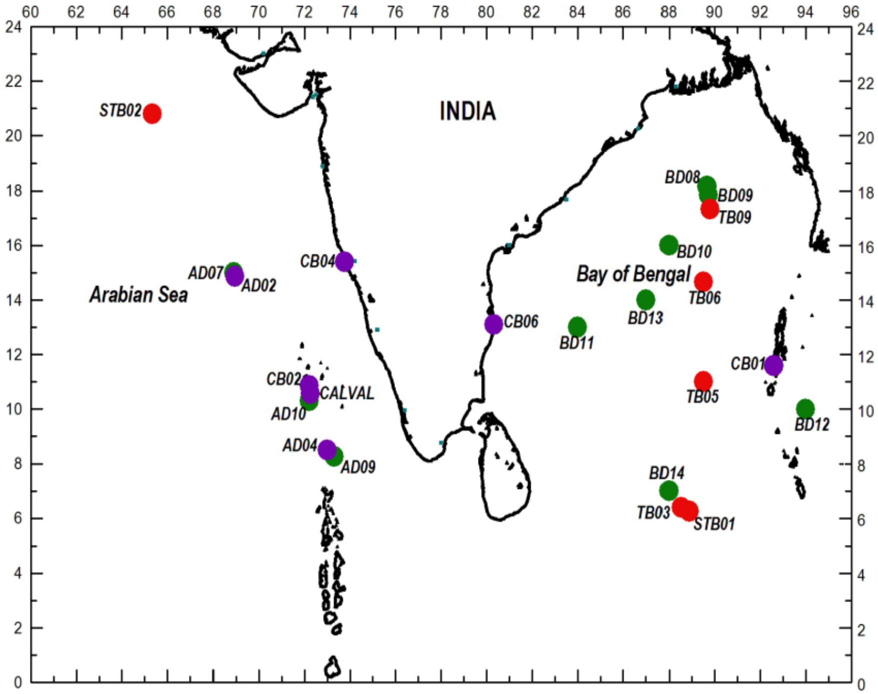
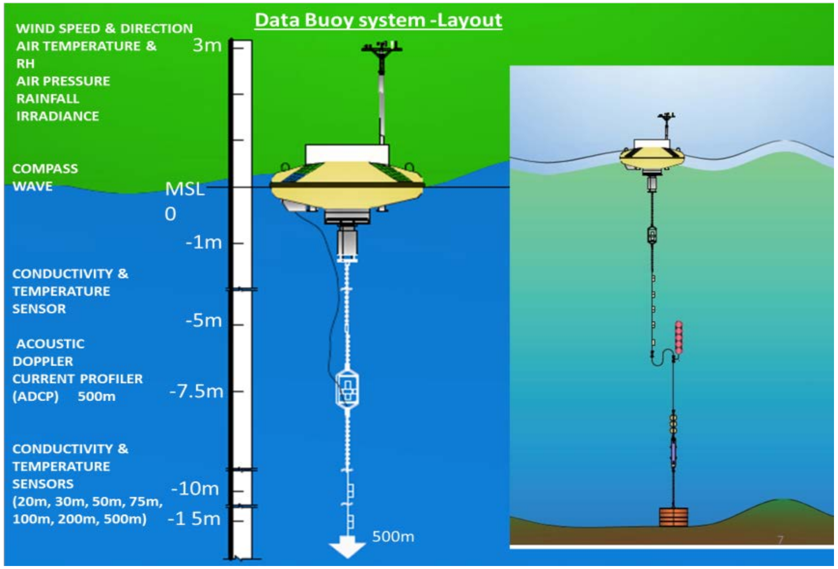
Outline

- Indian Buoy Network
- Significance of Buoy System
- Factors Influencing Data Acquisition
    - Sensors
    - Electronics

INDIAN MOORED BUOY SYSTEM AND NETWORK 1997 to till date





Meteorological

Air temperature

Air pressure

Air Humidity

Wind speed and Direction

Rainfall

Radiation(Short and Long)

Ocean Surface

Sea surface temperature

Sea Surface salinity (Conductivity)

Current speed and direction

Wave

Ocean Sub-surface

Temperature

Salinity (Conductivity)

Nutrients

Ocean current

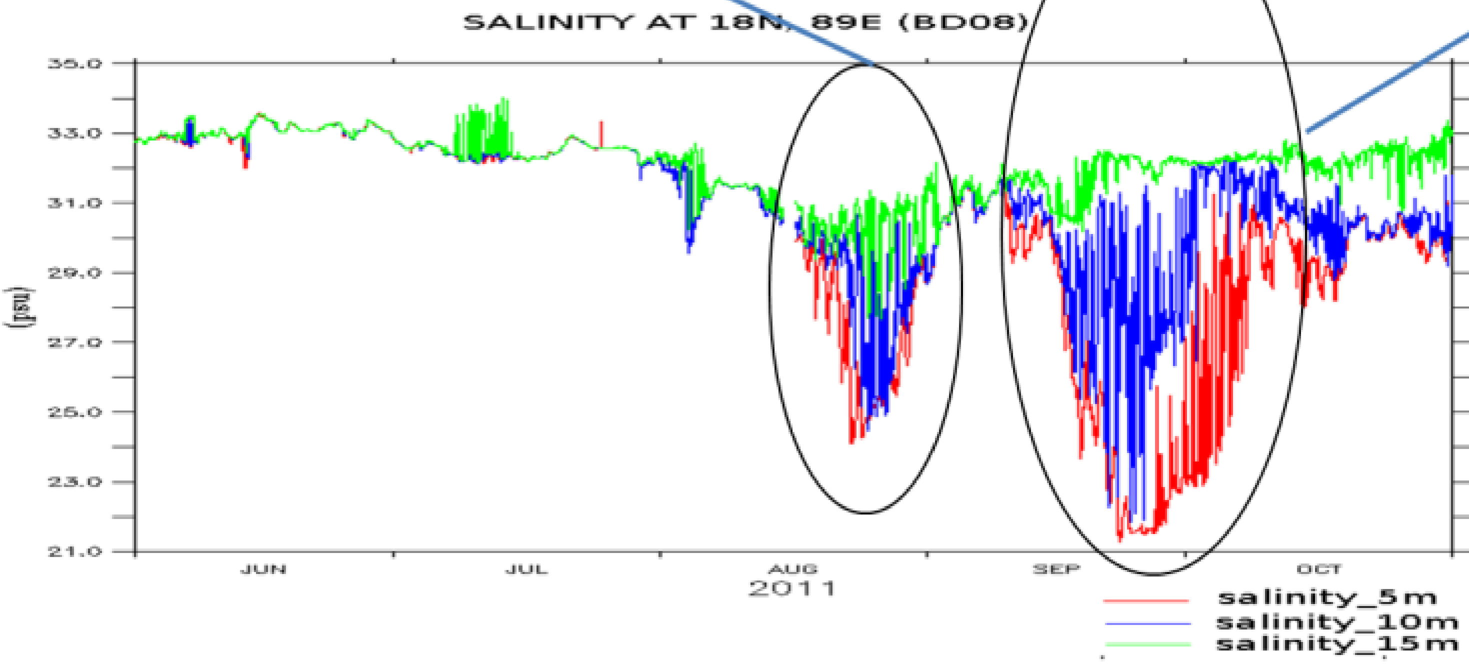
Bay of Bengal

FRESHENING EPISODES IN THE HEAD BAY -2011 (18N, 89E)

- The Bay of Bengal is characterized by a strong ocean salinity stratification resulting from an excess of freshwater supply over evaporation.
- Fresher surface water increases the vertical stability of the water column thereby heat gets trapped in the upper layer.

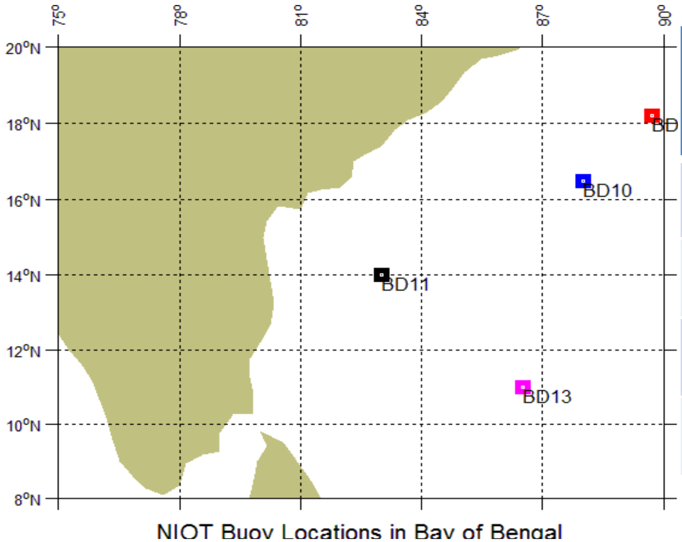
1ST EPISODE

2ND EPISODE



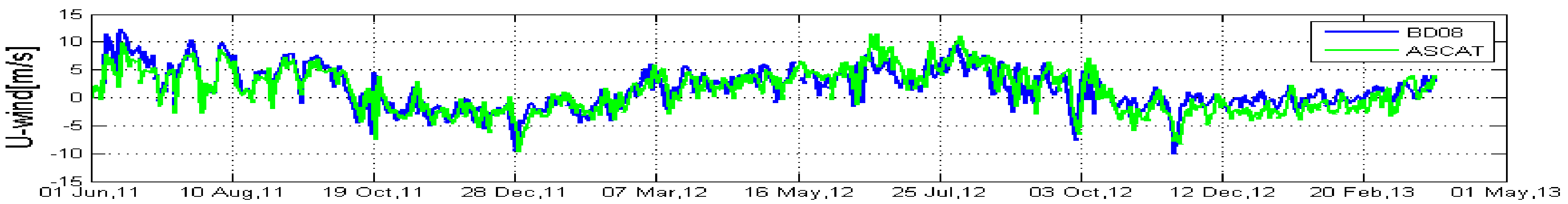
Current

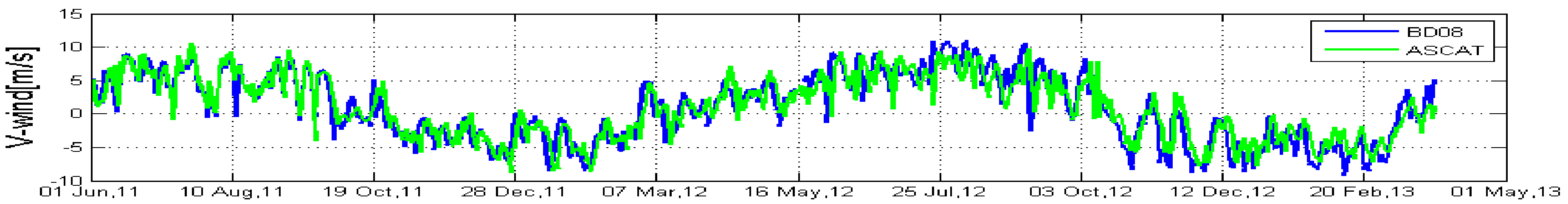
Validation of surface current data from the OMNI buoys were validated using OSCAR and GEKCO products



Correlation between ASCAT & Buoy wind sensor	Zonal	Meridional
BD08	0.7890	0.8748
BD10	0.8960	0.8517
BD11	0.9546	0.9244
BD13	0.8624	0.8349

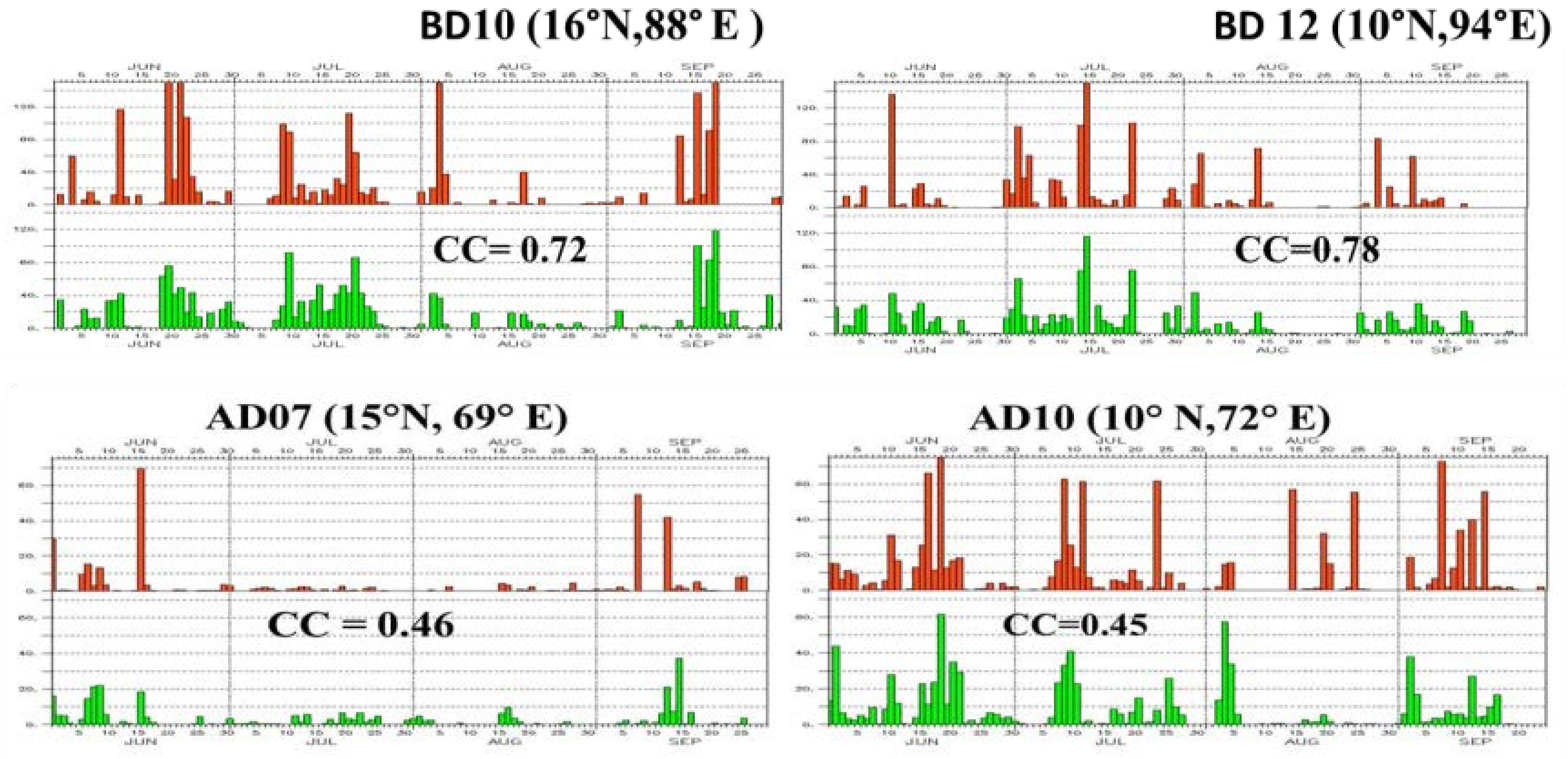
- GEKCO Current(CTOH, France)
- OSCAR current (NOAA)





Precipitation

Validation of TRMM-3B42 precipitation product



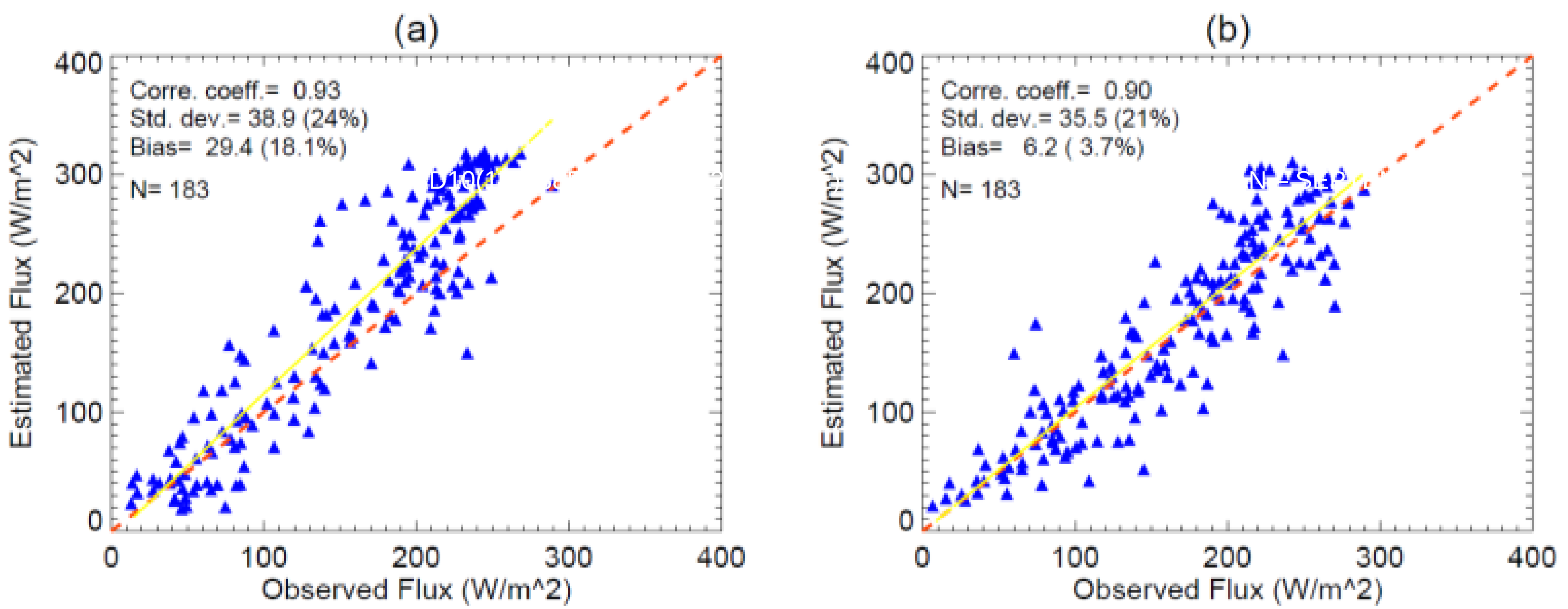
- Both the precipitation estimates show similar variability.
- The precipitation and CC is less over AS compared to BOB.
- However TMPA systematically underestimates very high precipitation events.

Time series of OMNI (red) and TMPA (green) daily precipitation over BOB

IRRADIANCE

VALIDATION OF CERES IRRADIANCE DATA

- **Source**: http://ceres.larc.nasa.gov/
- The CERES instruments measure the Solar reflected radiation and Earth emitted radiation from the top of the atmosphere to the Earth's surface. The surface fluxes of Level-3 SYN1deg-M3Hour are computed using Langley Fu-Liou radiative transfer model.

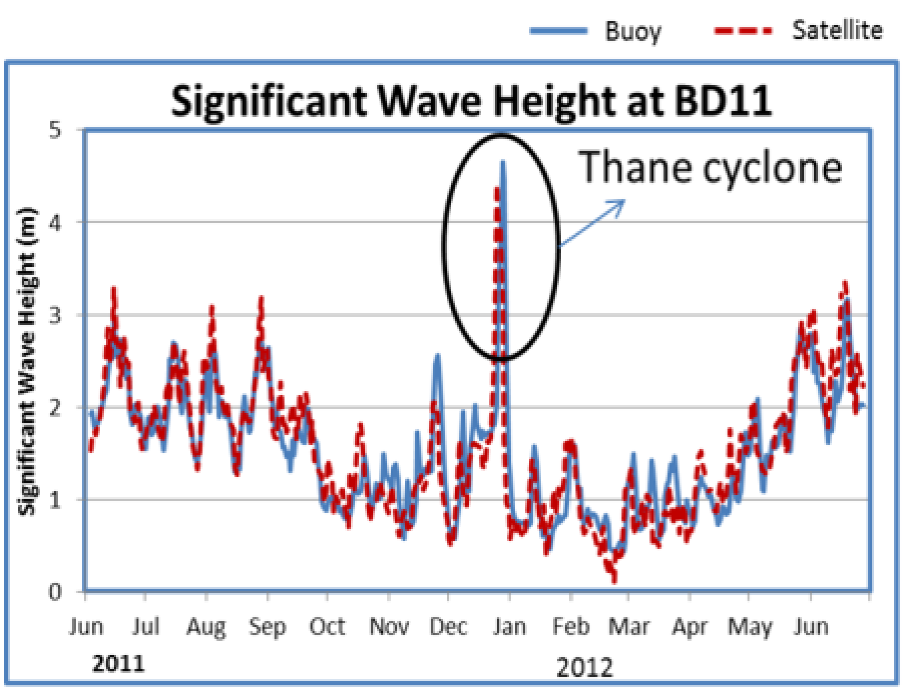


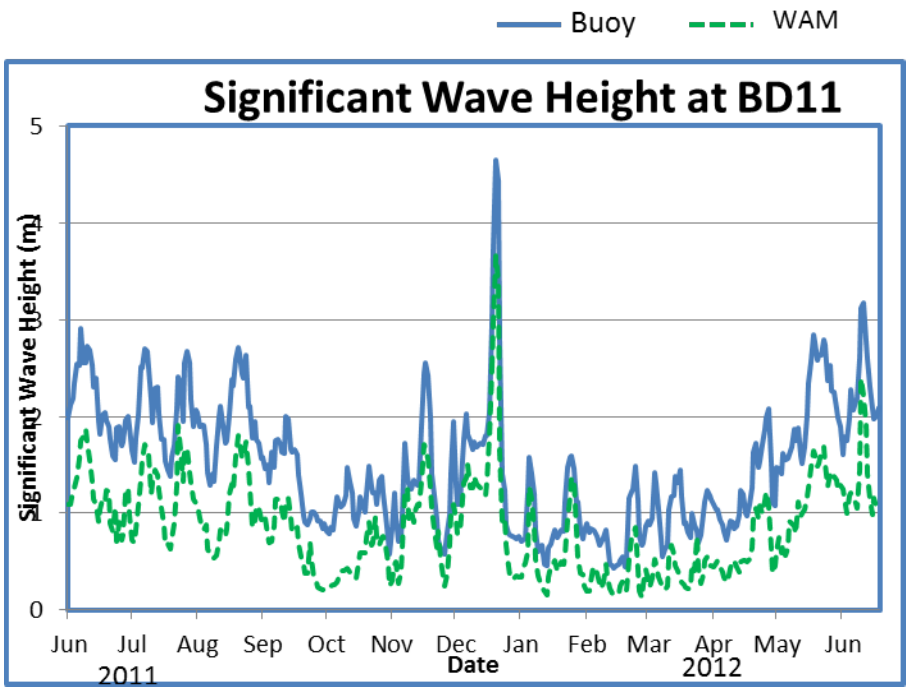
Reference: Wielicki, B.A.et al1996: Bull. Amer. Meteor. Soc., 77, 853-868

WAVE SPECTRUM ANALYSIS

- To analyze wave spectrum over the northern Indian Ocean using observations from moored buoy.
- Comparison of observed spectrum with the theoretical spectrum
- Validation of WAM model spectrum with help of the observed spectrum.
- Simulation of significant wave height for cyclones in the Northern Indian Ocean during 2010-2014 using wave model WAM

Validating satellite data (JASON-2) and WAM output using NIOT OMNI buoy data at 14N/84E (BD11) during extreme events

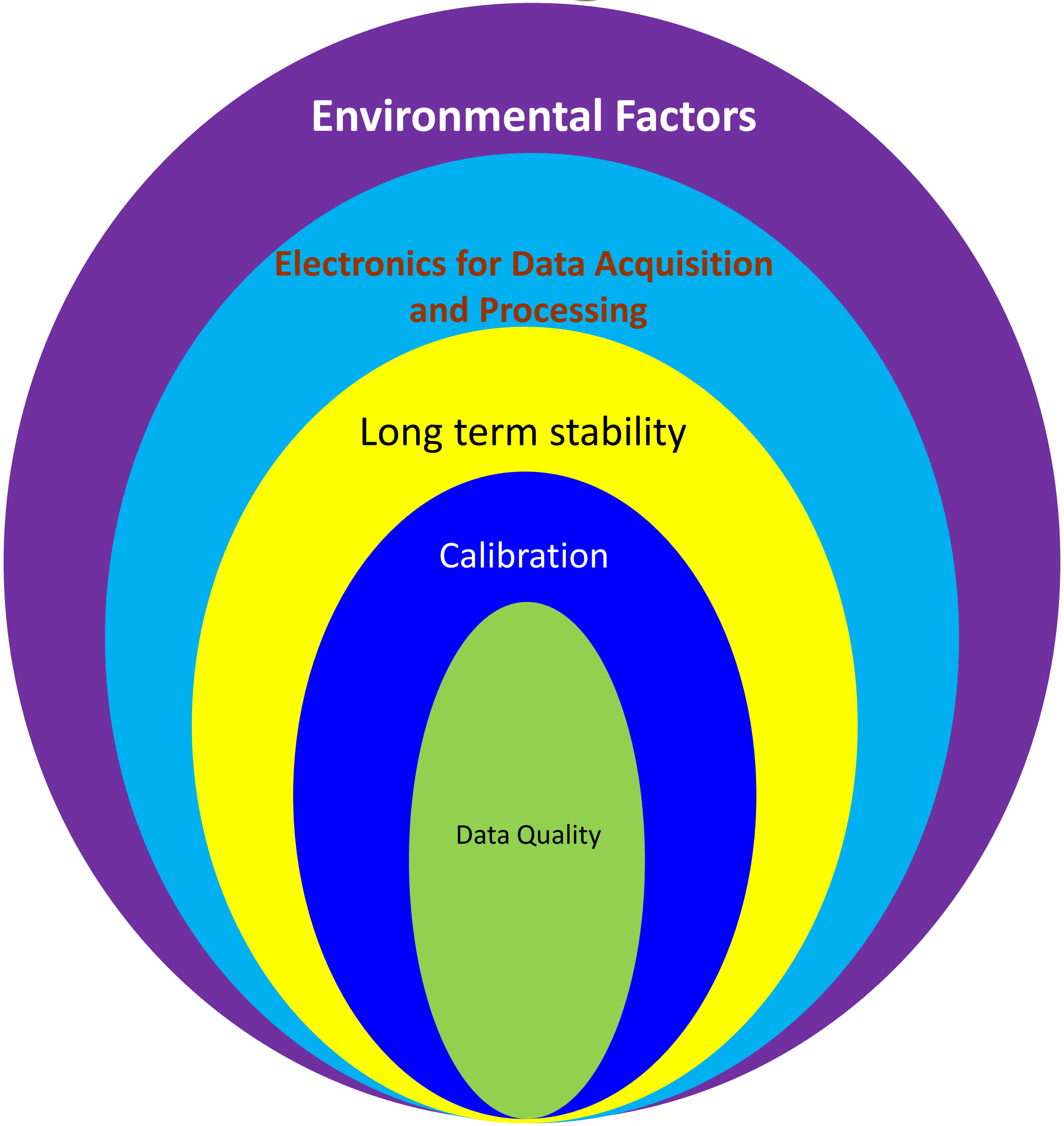




- Thane cyclone (December 2011) has been well captured by the WAM model simulations and satellite records
- The WAM model underestimated the significant wave heights recorded by both buoys and satellite
- The 'Jason-2' satellite data matched well with the in-situ observations of the significant wave heights in deep water around the Indian coastline.

International Journal of Ocean and Climate Systems ,"Analysis of Significant wave heights from ANN, WAM and Satellite using Moored Buoy Observations in Indian seas" - Vimala J, Latha G and Venkatesan R

Factors influencing data collection



Challenges experienced in Indian moored buoys

Sensor	Challenges	Remedial measures
Conductivity Temperature) ADCP DVS	Degraded performance of sensors due to Bio-fouling Connector pin damage	Continuous and effective anti-fouling measures Experience based measures to improve performance
Relative Humidity	Saturated RH sensor even after rainfall (100% RH saturated)	Modified placement of the RH sensor in the shield increase the surface evaporation phenomenon
Radiation(Short and Long)	Inconsistent Performance due to drift in the sensor	Standard calibration and periodic inter-comparisons with other standard sensor
Wind speed	Observed differences in the velocity measurements of Cup anemometer to the new GILL Sonic anemometer	Standard calibration and periodic inter-comparisons with other standard sensor
Position transmitter	Inconsistent Performance of Argos Transmitters in buoy system	Redundant indigenous INSAT Transmitters in buoy system

INDARC

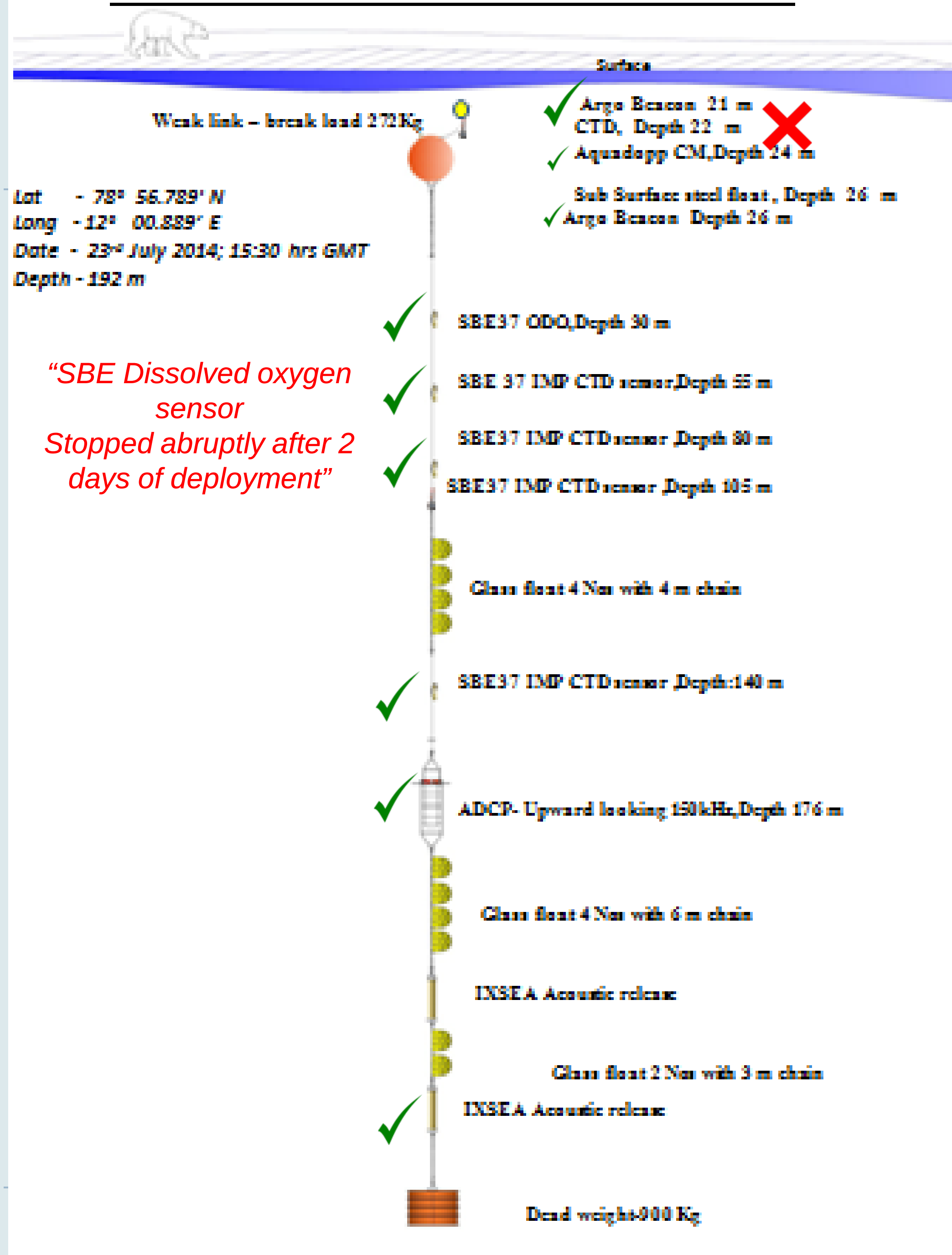
357 Days of Continuous data captured.
>10Lakh Data points

India's First Long Term Observatory in Arctic

Provides critical winter time data

Proves India's Technical Capability to design and maintain long term underwater observatory in International Scientific Community

MOORING LAYOUT FOR IndARC-JULY 2014



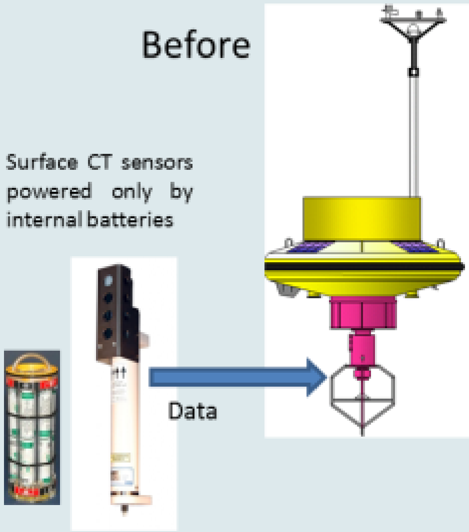
Seabird CT Sensor

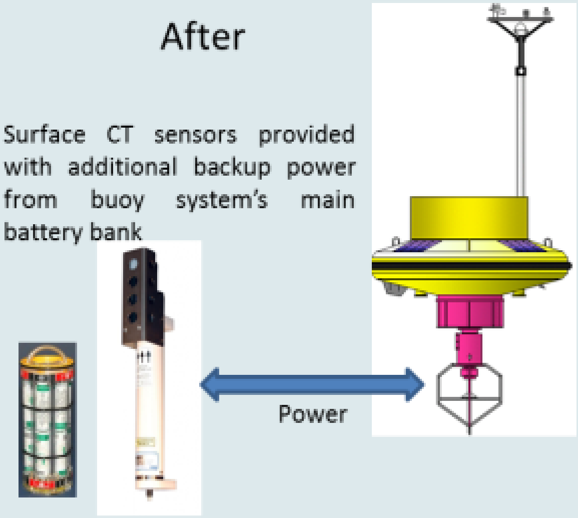
Effect of additional backup power from buoy system on the sensor performance

```
IMM>
<Executed
<RemoteReply>SBE37-IM v4.3  SERIAL NO. 13089  01 Oct 2015
14:09:44
vMain = 13.92, vLith =  3.06
samplenumber = 119, free = 559121
not logging, low battery
sample interval = 3600 seconds
data format = converted engineering
compatible mode enabled
transmit sample number
do not transmit sample HEX time
pump installed = yes, minimum conductivity frequency = 3233.9
PC baud rate = 9600
<Executed/>
</RemoteReply>
<Executed/>
```

Brand New CT sensor with new battery pack Flags a low battery error!

Modification of the connector pins to improve the handling capabilities

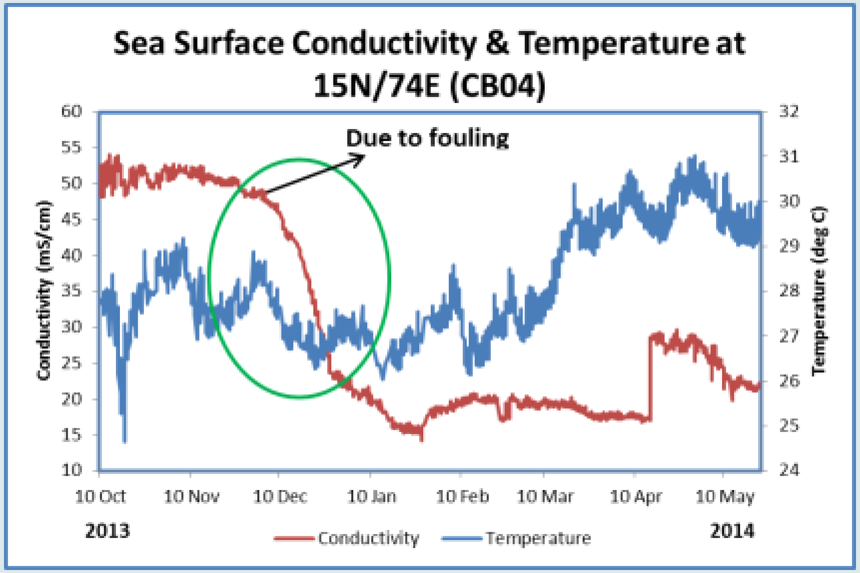


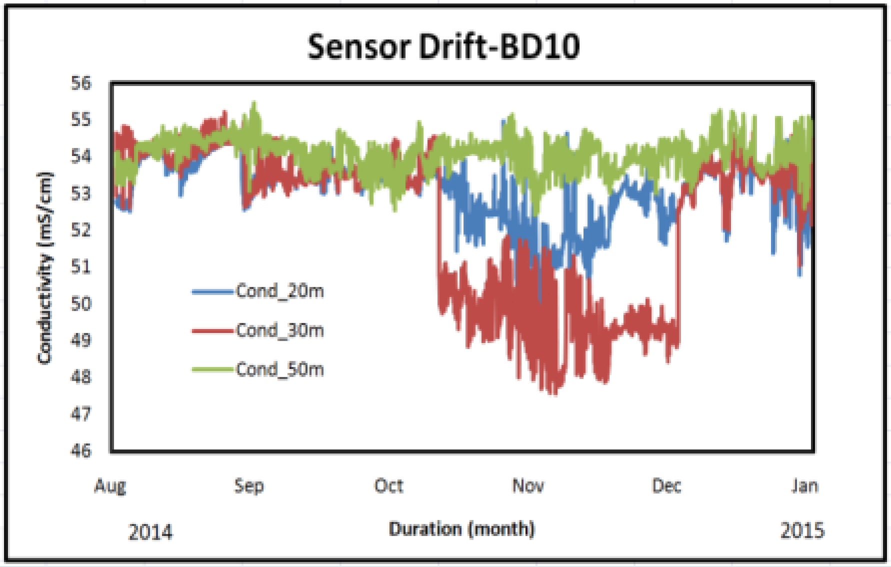


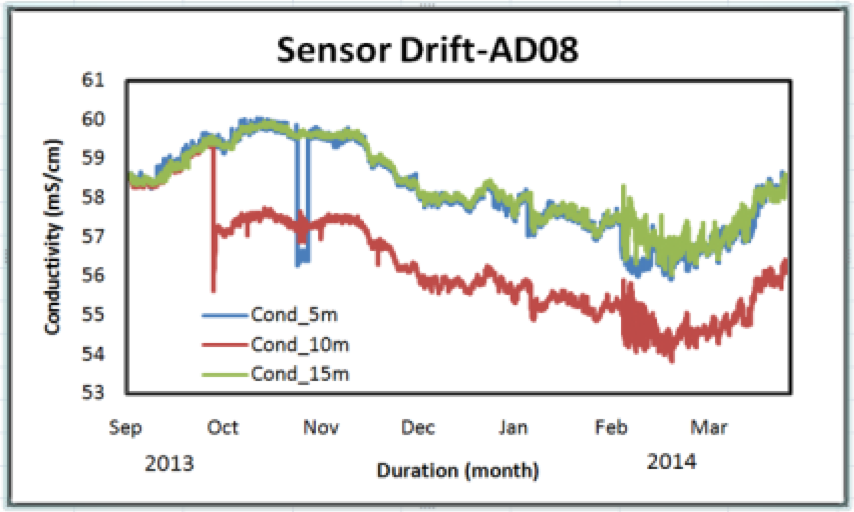
The male end connectors of SBE 37 SMP's were found to be too weak in the field as even a mild mishandling result in breakage.

Thus it was communicated to the OEM (SBE) regarding this issue and changes were made in the connector for stiffening the copper pins.

Effect of bio-fouling on the sensor performance





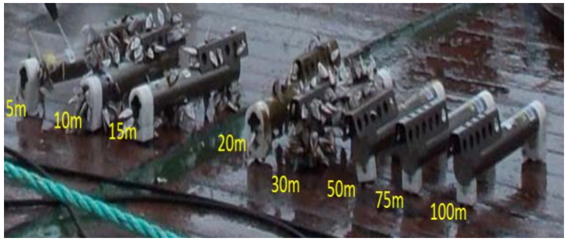


Fouled CT sensor

Statistics of bio-fouling on the sensors in different depths at different locations

- In all the retrieved sensors, irrespective of the buoy location the fouling growth is observed till ***50 m depth***, *seldom seaweeds growth* are found till ***75 m depth***.
- All the sensors are retrieved with ***Lepasanatifera***, commonly known as the pelagic gooseneck barnacle or smooth gooseneck barnacle from the family ***Lepadidae***.

AD09



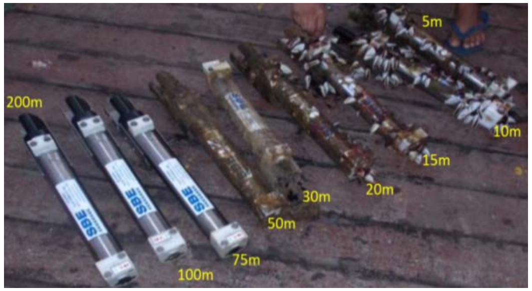
- Sensors retrieved from 08°15.828' N/73°18.088' E

which is **16 Nm** away from Island

(**225 Nm from Shore**)

- Sensors was in the deployed location for 288days
- Station depth – 2000 m

AD10



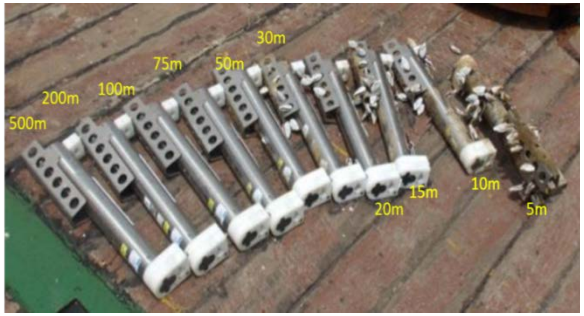
- Sensors retrieved from 08° 28.7 ' N/73° 05.93' E

which is **12 Nm** away from Island

(**207 Nm from Shore**)

- Sensors was in the deployed location for 289days
- Station depth – 1925 m

AD04



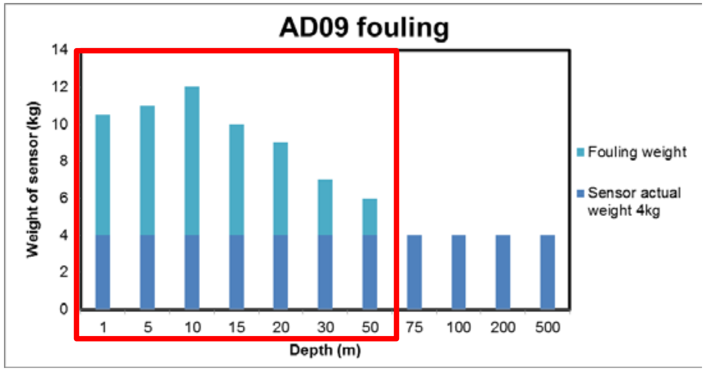
- Sensors retrieved from 10° 20.15' N/73° 11.378' E

which is **13 Nm** away from Island

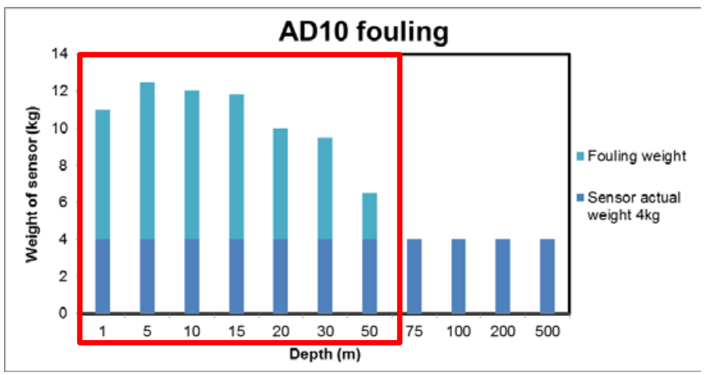
(**223 Nm from Shore**)

- Sensors was in the deployed location for 294days
- Station depth – 1925m

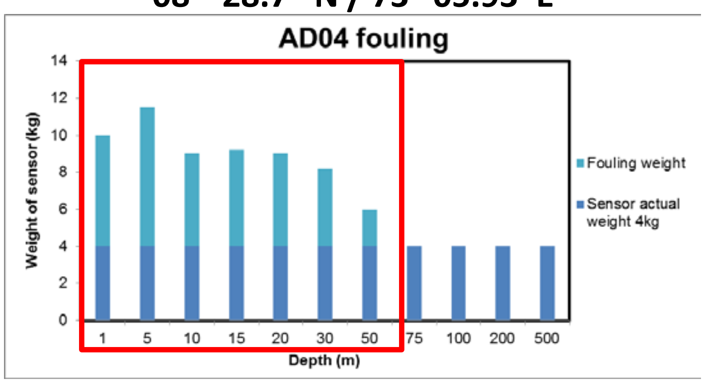
08°15.828' N/73°18.088' E

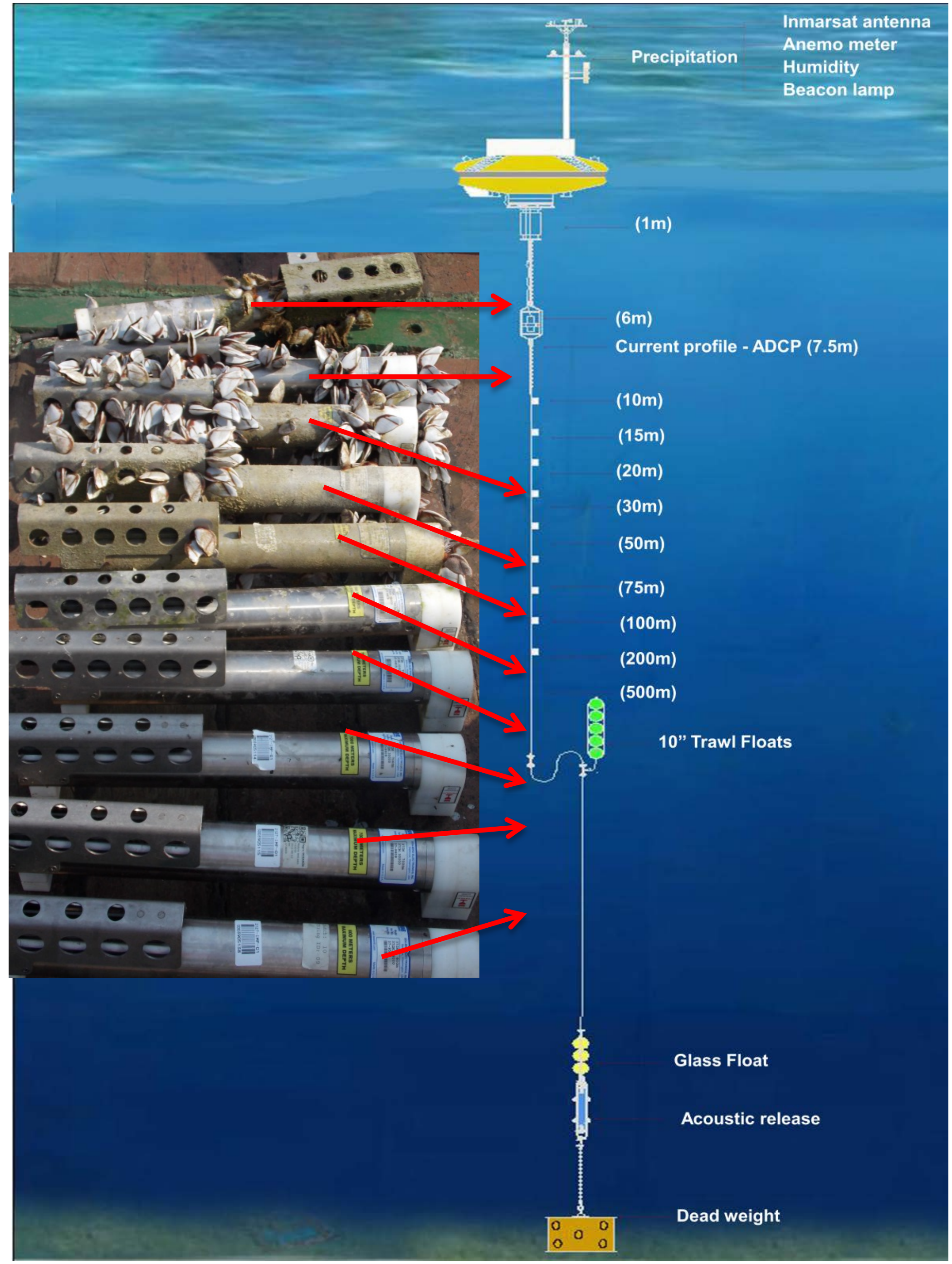


10° 20.15' N/73° 11.378' E



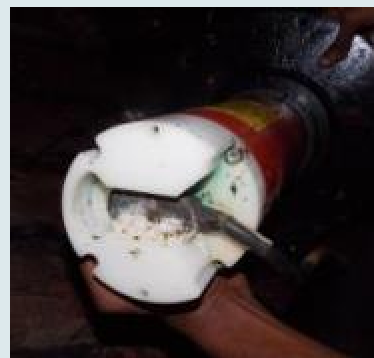
08° 28.7 ' N / 73° 05.93' E





Biofouling – Connector Damage

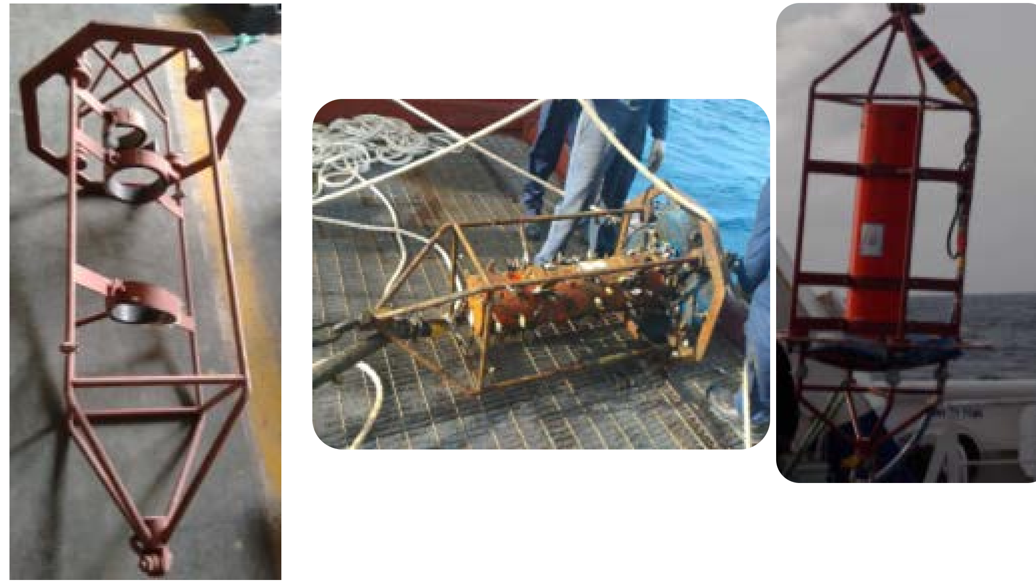
Deployed Location : 12N/69E
Worked duration : 202 days
Observation :Marine growth over ADCP connector, Connector damaged.



Deployed Location : 12N/69E
Worked duration : 202 days
Observation : DVS Connector damaged.

Recommended anti-fouling measures taken in moored buoy systems

- Anti-fouling wipers
- 2” wide copper tape
- Plastic anti-fouling sleeves
- Copper-alloy sensor guard
- Copper-alloy screen
- C-Spray protective probe solution
- Clear packing tape
- High-visibility duct tape
- Plastic cling wrap
- Anti-fouling paint



SS ADCP frame was painted with anti fouling paint

Applying anti-fouling paint in buoy components

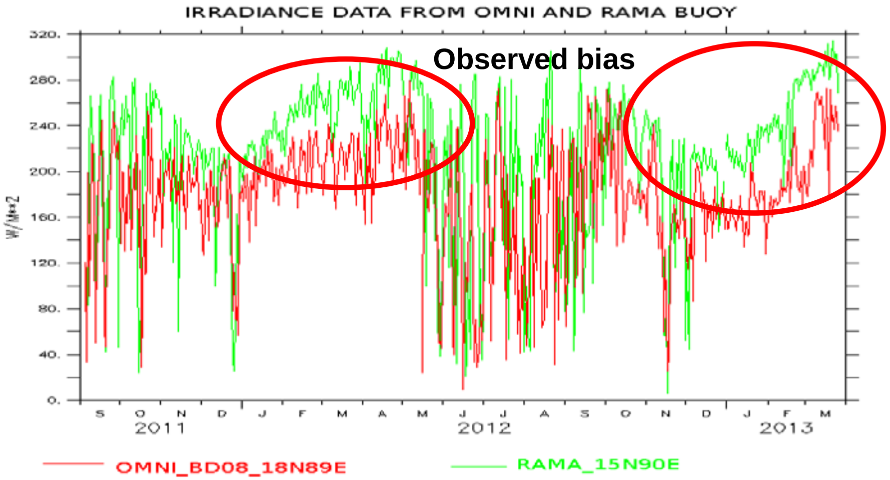
Installation of anti-foulant device

A White plastic cylinder (0.68 inches diameter and 0.68 inches tall).The plastic is impregnated with bis(tributyltin) oxide(53% by weight). This device will be installed in the anti-foulant device caps to avoid fouling in CT sensors.

Radiation sensors

Observation OMNI BUOY with RAMA buoy:

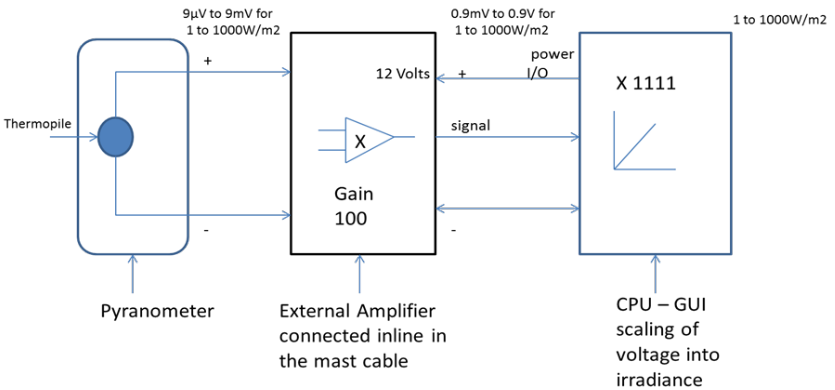
OMNI (18N,89E) buoy is compared with RAMA (15N,90E) and it is observed that short wave radiation measured in this buoy has some bias compared to RAMA buoy.



Comparison of shortwave radiation (OMNI-RAMA)

Description of the signal conditioning, data sampling and processing:

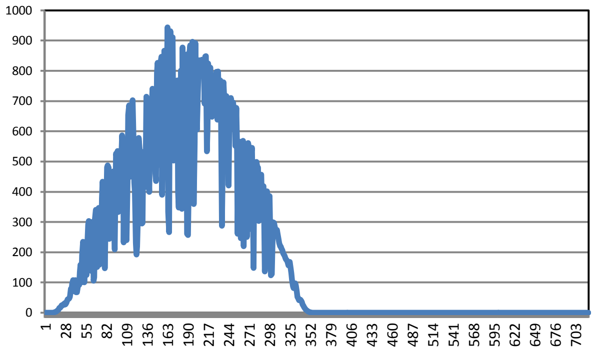
Short wave radiation is the incoming radiation from the direct sun light; it is measured by the pyranometer sensor which is supplied by M/s Eppley Laboratory, USA. This sensor has an output of 9 micro volts /Watts meter^2 and has the range of 0-1400 Watts meter^2.



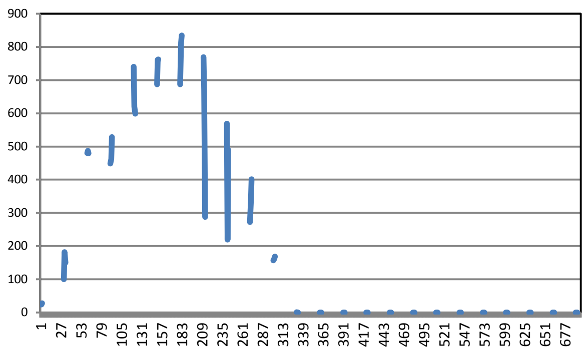
Block diagram of signal flow

- This sensors doesn't have inbuilt **signal conditioning circuit**, so, it is designed an external amplifier with a gain of 100
- **CPU has a scaling factor** in the Graphical User Interface (GUI configuration) and it is scaled as 1111 for the sensor sensitivity of 9µV. This scaling factor will vary depends on the sensitivity of the sensor.
- For the sampling of data, end of the every hour, the CPU provide the power to the amplifier via I/O line and sensor is sampled 2minute @0.5 Hz (60 sample) and it is averaged for the real time data transmission.

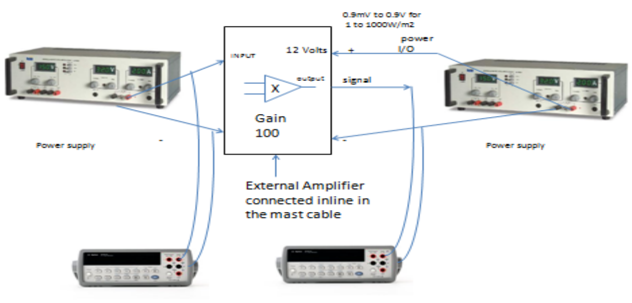
Validations studies on Radiation sensors



Irradiance sampled in RAMA



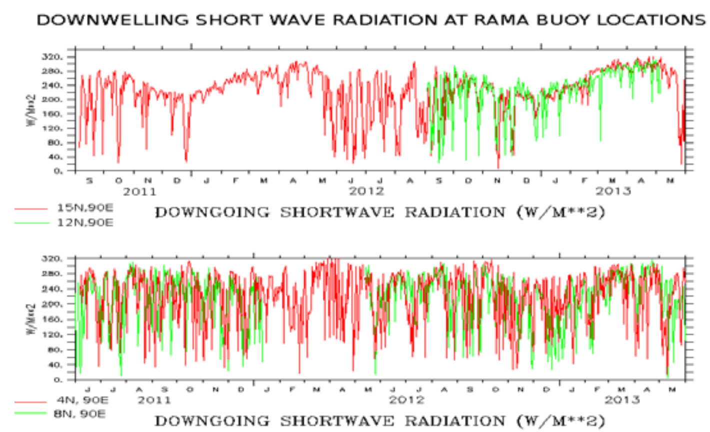
Irradiance sampled in OMNI



Block diagram of the testing of the amplifier

- **Whether Difference in the Sampling frequency and sample interval make this bias?**

1. Irradiance in the RAMA buoy are sampled continuously @ 1 Hz and averaged at every 2 minute.
2. Irradiance of OMNI is at end of the every hour, sensor is sampled 2minute @0.5 Hz (60 sample) and it is averaged for the real time data transmission.
3. To address this, sampling method of OMNI is applied in reading collected in RAMA buoy (clear sky condition since the irradiance measure in rough weather condition may lead offset due tilt of sensor). It is observed variation is around only on $8W/m^2$.

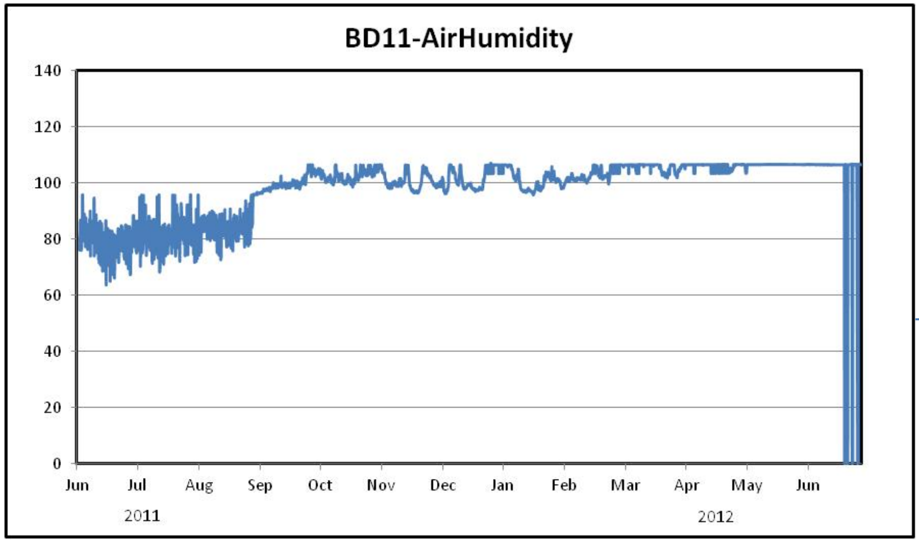


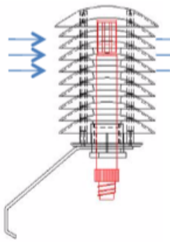
Irradiance comparison between RAMA buoys

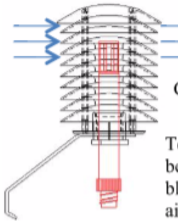
It is tested with the following method. Potential divider is used to reduce the voltage to input of amplifier. Amplifier gain is almost around 100 and correction factor is very less and still bias exists.

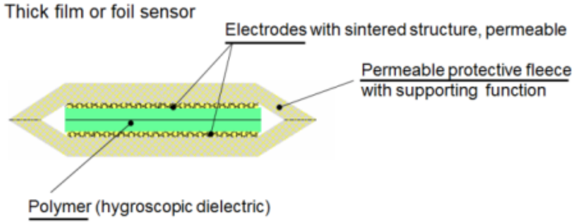
Humidity

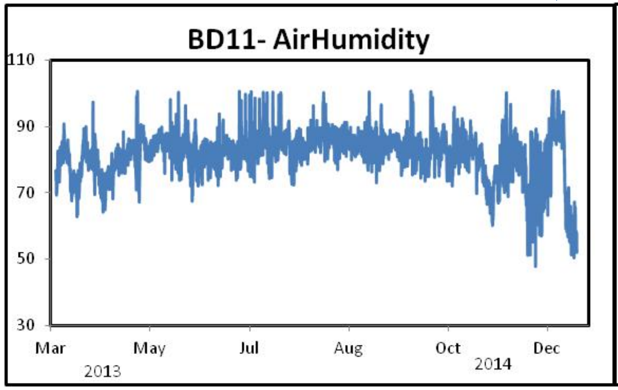
Rotronic

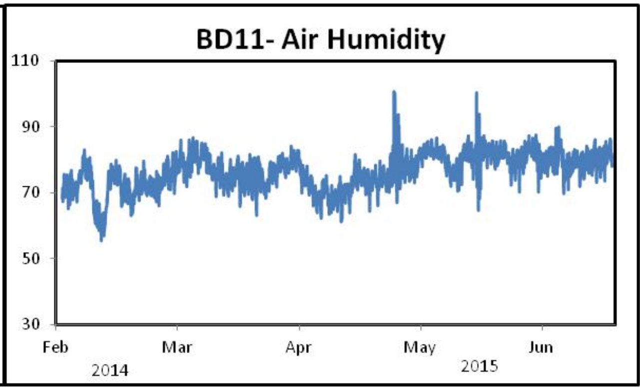






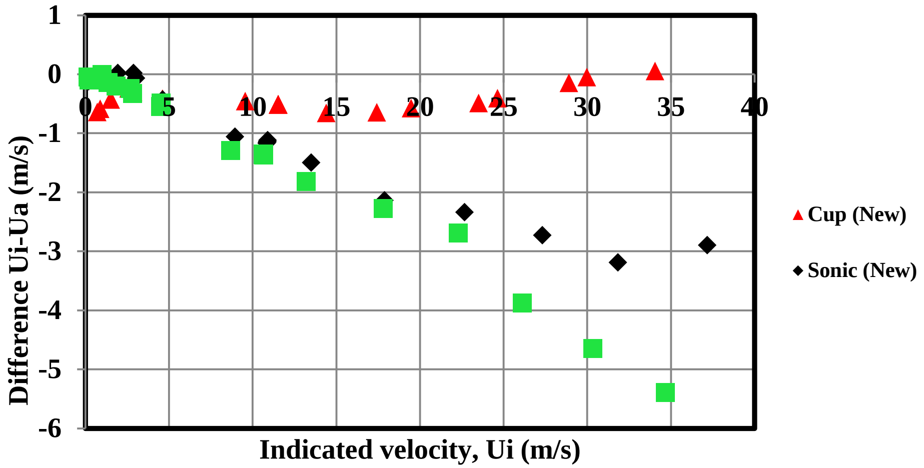




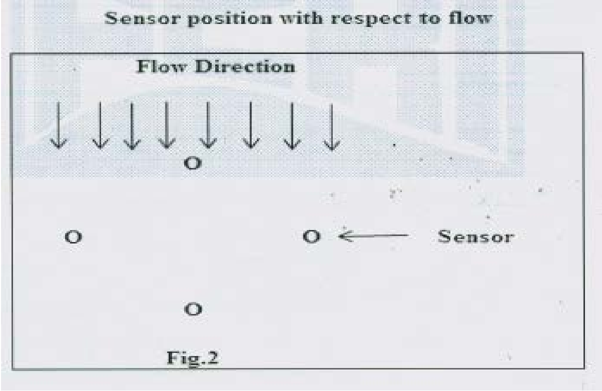


Ratio of partial water vapour pressure over saturation vapour pressure at a given temperature

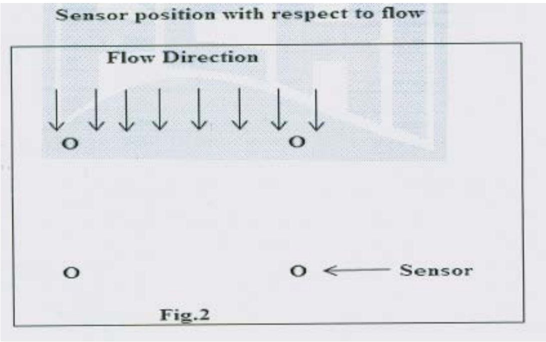
Wind Speed
Comparison of the wind speed error for three anemometers up to 40 m/s



- **Cup type anemometer performs consistently (within ≤ 2% of FS reading) with in the speed range of 0-35 m/s as specified by OEM, where the initial/starting threshold is nearly 0.8 m/s.**
- **Sonic anemometer captured accurately the velocities below 4 m/s, but the performance/accuracy reduced with increase in velocity.**
- **With increase in velocity the % error of accuracy of sonic anemometer has degraded to >8% of FS reading.**
- **Orientation of sonic anemometer also effects the speed measurement**



Bad performance



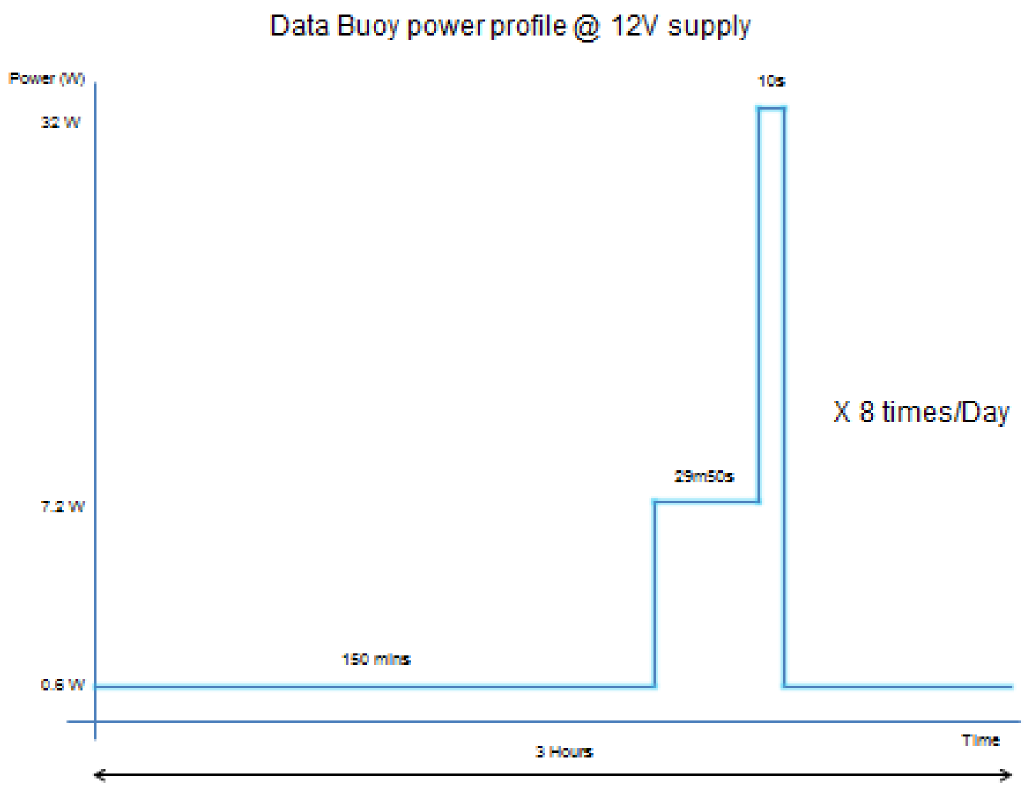
Good performance

ENERGY DEMAND
Sampling Interval vs Energy Demand

Parameter	Sensor type	Make/model	Resolution	Accuracy	Range	Sample rate	Sampling period	Data recorded
Wind speed	Cup anemometer	Lambrecht/1453	0.1 m/s	± 2%	0–35 m/s	1 Hz	10 min	1 h
Wind direction	Vane + fluxgate compass	Lambrecht/1453	0.1°	1.5– 4°	0–359°	1 Hz	10 min	1 h
Air temperature	Pt/100 RTD	Rotronic/MP 102A	0.0015°C	± 0.3°C	–30–70°C	1 Hz	1 min	1 h
Relative humidity	Capacitance		0.47	± 1%	0–100% RH	1 Hz	1 min	1 h
Air pressure	Pressure transducer	Vaisala/PTB 330	0.01 hPa	± 0.15 hPa	500–1100 hPa	1 sample/h	Instantaneous	1 h
Rainfall	Capacitance	RM Young:/50202	0.058	± 1 mm	0–50 mm	1 Hz	1 min	2 min
Downwelling long-wave radiation	Pyrgeometer	Eppley/PIR	1.27 W/m^2	5%	0–700 W/m^2	1 Hz	1 min	1 h
Downwelling short-wave radiation	Pyranometer	Eppley/PSP	0.488 W/m^2	3%	0–2800 W/m^2	1 Hz	1 min	1 h
Water temperature	Thermistor	Seabird/Micro-CAT SBE37	T: 0.0001°C	0.002°C	–5–35°C	1 sample/h	Instantaneous	1 h
Conductivity	Conductivity cell	Seabird/Micro-CAT SBE37	C: 0.0001 mS/cm	0.003 mS/cm	0–70 mS/cm	1 sample/h	Instantaneous	1 h
Water pressure	Strain gauge	Seabird/Micro-CAT SBE37	P: 0.002%	0.1%	0–100 bar	1 sample/h	Instantaneous	1 h
Directional wave spectra	Accelerometer, angular rate sensor, magnetometer	Kongsberg/ Seatex MRU 4	Pitch and roll: < 0.001°	Heave: 5 cm pitch and roll: 0.05° Heading: 1.2°	Heave: ± 50 m Heading: ± 180°	1 Hz	17.5 min	1 h
Ocean current profile	Accoustic Doppler current profiler	Teledyne RD Instrument 150 kHz	Velocity: 0.1 cm/s Dir: 0.01°	Velocity: ± 5 mm/s Dir: ± 2°	0–256 cm/s	1 sample/h	Instantaneous	1 h
Single point	Doppler volume sampler	Teledyne RD Instrument 150 kHz	Velocity: 0.1 cm/s Dir: 0.01°	Velocity: 1% Dir: ± 2°	0–600 cm/s	1 sample/h	Instantaneous	1 h

Energy demand trend of buoy system

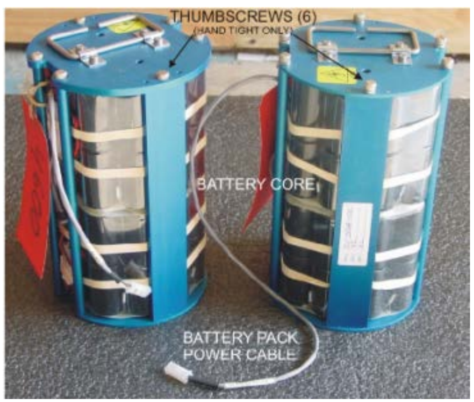
Per Day requirement of 12V/14.4V loads of Buoy Systems		
Met-Ocean Buoy System	Tsunami buoy System	OMNI Buoy System
4.5Ah	5Ah	6.5Ah



Met and OMNI buoy system

Different types of batteries

Primary Lithium Metal Batteries

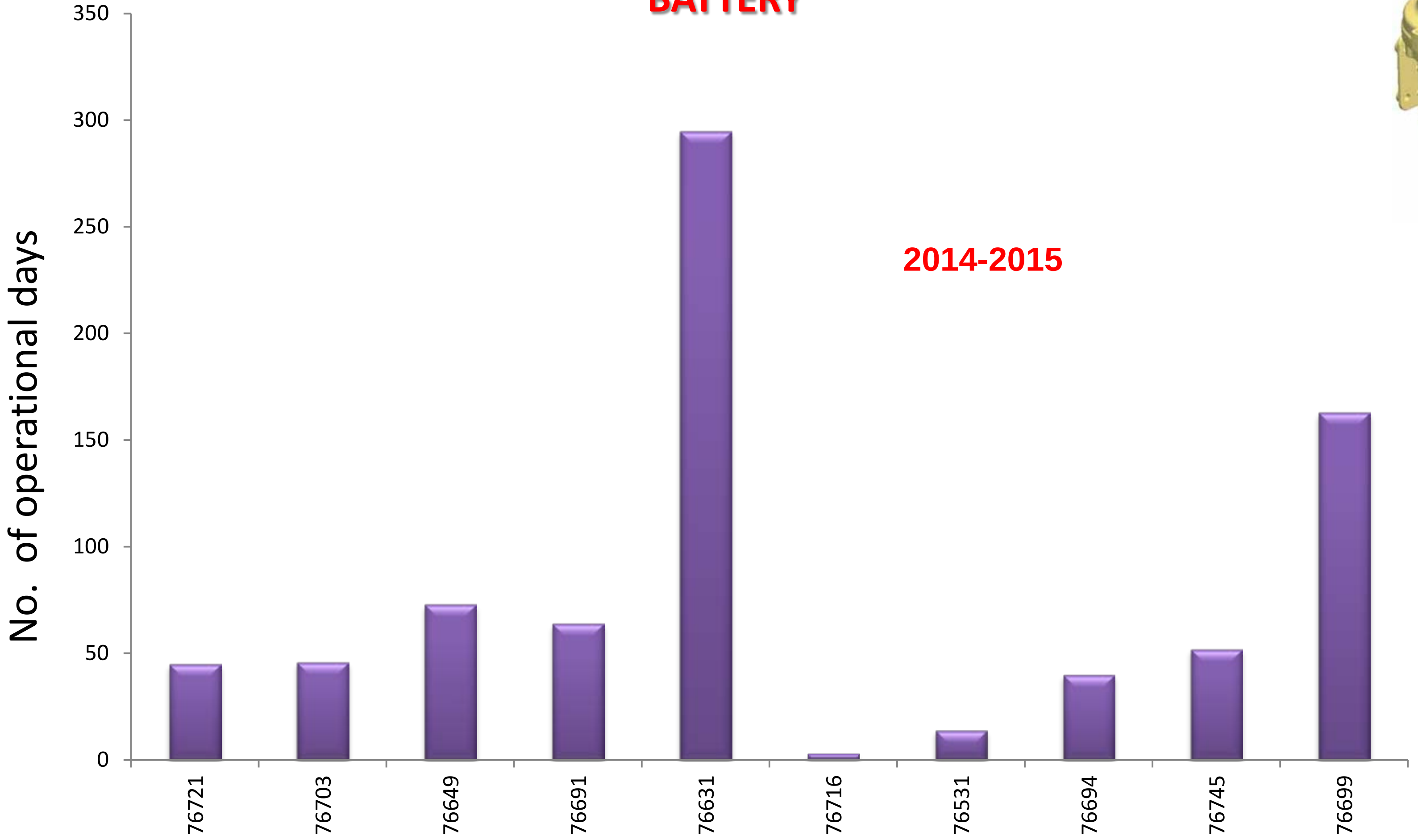


Alkaline

Alkaline

Lead Acid Battery

ARGOS TRANSMITTER BATTERY



Make: CLS
Transmitter Model: WildCAT PTT
Battery : 7.2V, 26Ah Primary Lithium Thionyl Chloride
Life of Operation : >1 Year.

Data Acquisition System - Electronics

The Analog to Digital Converters used in Data Acquisition systems are prone to generate Error in data due to following factors

Drift

- Integral Non Linearity
- Differential Non-Linearity
- Zero Error
- Zero Error Drift
- Gain Error
- Gain Error Drift
- Total Harmonic Distortion

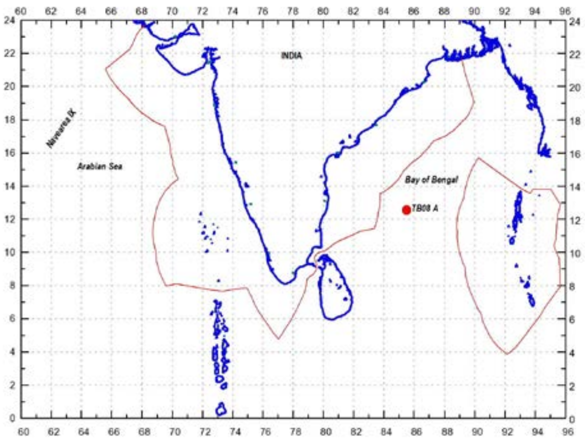
Indigenised Data Acquisition System-Hridaya

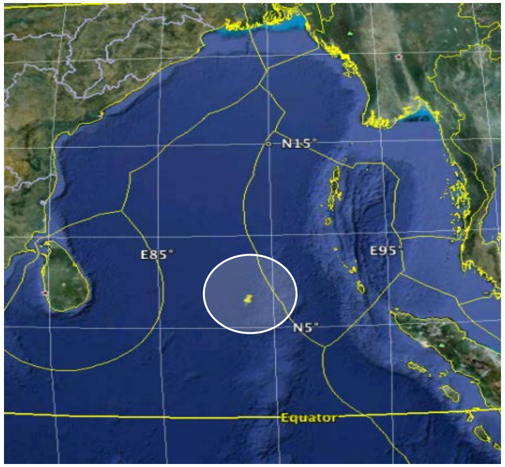
In-House Data Validation and correction helps in minization of errors

Usage of Precision in house Voltage and Current Source, Computation systems for Regular validation of Electronic system used for Ocean Data Acquisition System

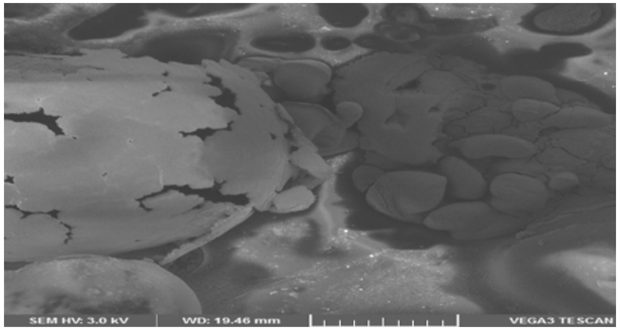
Unusual corrosion and deposit of unknown material on deep sea instrument at 3700m depth from 29-08-2011 to 02-04-2013

Lat 12° 32.93’ N, Long 85° 31.38’E





Hydrothermal Vent ????



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Conclusion

- Most expensive oceanographic data collection Ship time , Man hours, accessibility in deep ocean, skilled manpower, re installation cost etc.
- Major concern is unaccountable loss of data
- Need for International Standards on marine oceanographic sensor - WMO Standard on Marine Meteorological Sensors
- Share our unique experience among users Interface of sensors

GUIDE TO MOORED BUOYS AND OTHER OCEAN DATA ACQUISITION SYSTEMS
by A. Meindl
DBCP Technical document no 8   1996