WMO-IOC Regional Marine Instrument Centre for Asia-Pacific RMIC-RA-II (AP)

Sixth Marine Instrumentation Workshop for Asia-Pacific Region

"Ensure high quality procedure we take, deliver the ocean data we need"

13-17 December 2021

"Ensure high quality procedure we take, deliver the ocean data we need"

Calibration of Sensors for Moored Buoys

Dr.R.Venkatesan

PhD. DSc ,CMarTech, Fellow-MTS, Fellow-NACE,SMIEEE FIE,PGDML,PGDMPM,

Fulbright Awardee, Honorific Scholar- University of Massachusetts, Dartmouth,USA

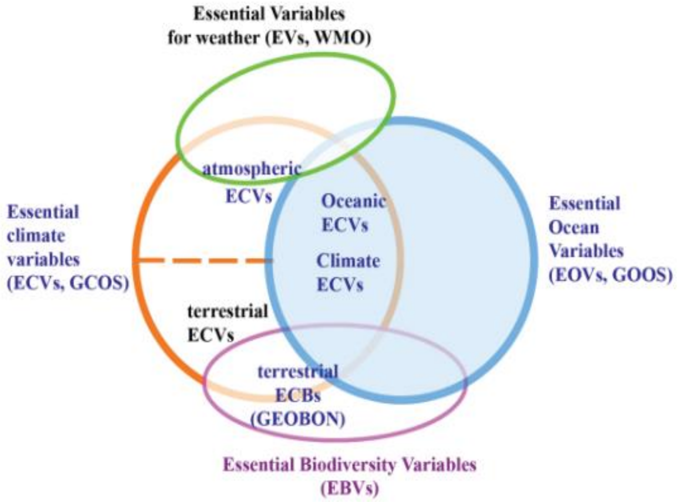
Chair GRA Intergovernmental Oceanographic Commission IOC of UNESCO Paris

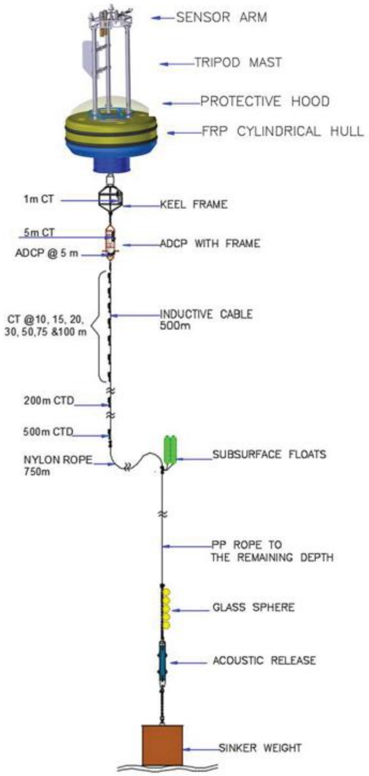
Vice-Chair of SG-OOIS of World Meteorological Organisation, WMO, Geneva

Scientist G & Head Ocean Observation, National Institute of Ocean Technology Ministry of Earth Sciences Chennai

EOV

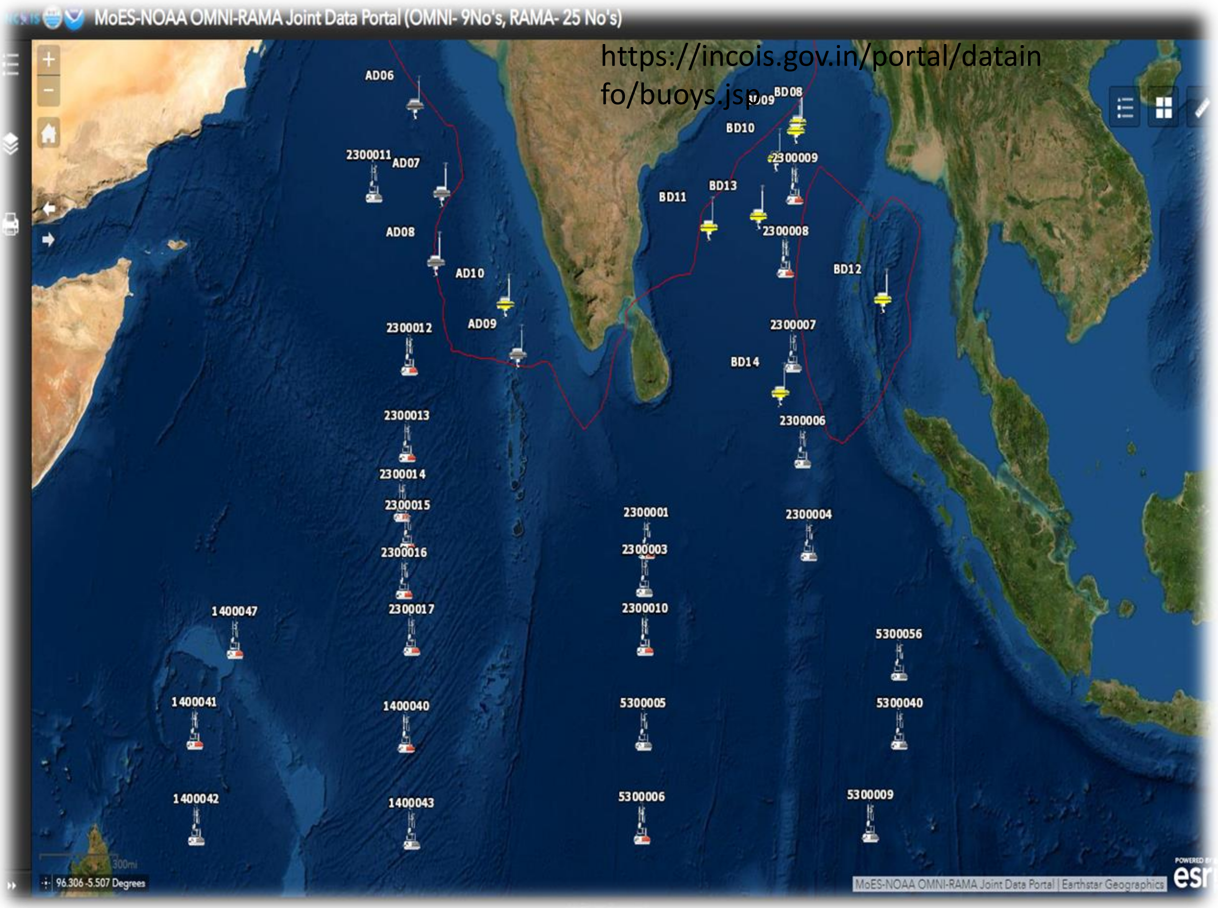
EOV	Observing platforms
Sea State	MBuoy, Drifter, HFRadar Satellite altimeter
Sea Surface Height (SSH)	Tsunami Buoy Tide gauges
Sea Surface Temperature (SST)	MBuoys, Drifter, Ship Satellite (IR/MW)
Subsurface Temperature	MBuoy, Argo float, Gliders, Ship CTD
Surface Current	MBuoy, HFRadar, Argo float, Satellite altimetry
Subsurface Current	MBuoys, Argo float, Glider, ADCP
Sea Surface Salinity	MBuoy, Drifter, Ship
Sub Surface Salinity	MBuoy, Argo float, Glider Ship CTD
Oxygen	MBuoy, Argo float, Glider, Ship
Nutrients	Ship
Inorganic carbon	Moored data buoys, Drifter, Ship
Suspended particulates	MBuoy, Ship, Argo float
Transient tracers	Ship

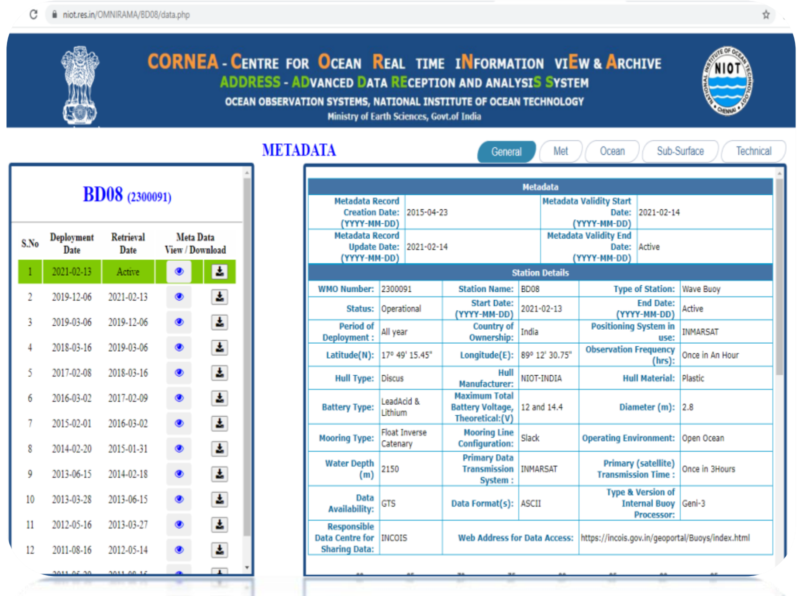


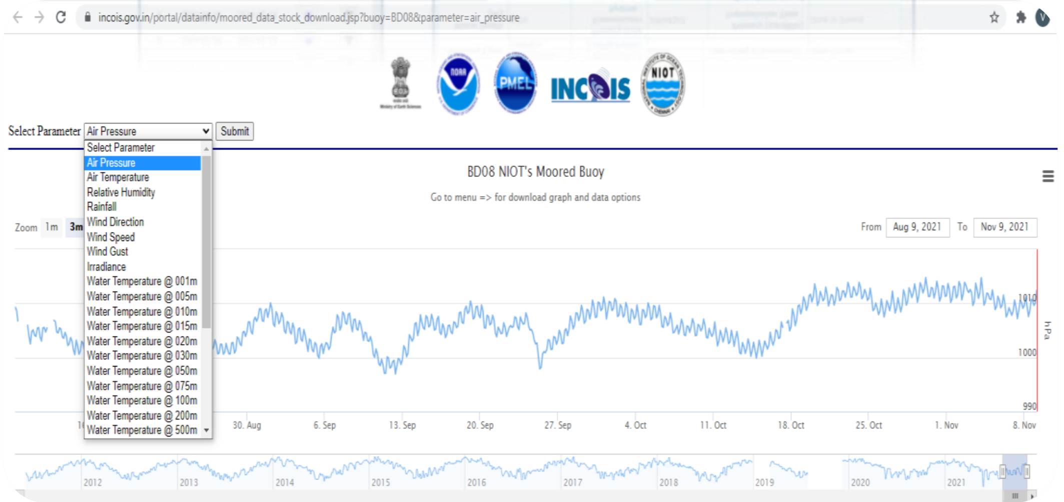


Venkatesan, R. et al. Technological Trends and Significance of the Essential Ocean Variables by the Indian Mo
Observatories: Relevance to UN Decade of Ocean Sciences. *Marine Technology Society Journal*, *55*(3), 2020

MoES-NOAA OMNI-RAMA Joint Data Portal

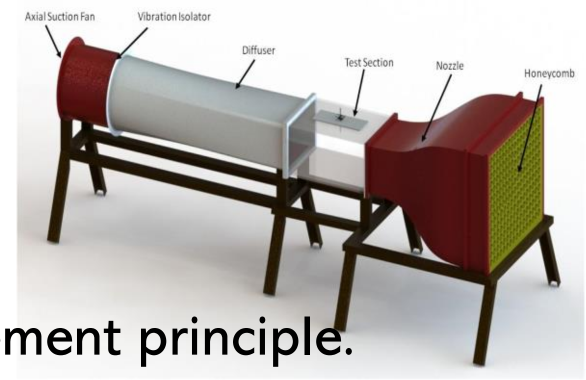






25 RAMA Buoy
9 OMNI Buoy
Detailed Metadata
Data Download and
Data Visualization

Wind speed – Calibration and standards



✓Reference wind speed - Pitot-static tube with differential pressure measurement principle.

✓local conditions inside the wind tunnel test section monitored as per the MEASNET guidelines

✓ Calibration procedure as per ASTM, IEC and ISO standards.

✓Reference sensors must be traceable to a standard authority.

Comparison with satellite data

- SSW SST of AMSR-2 satellite are compared with moored buoy

- Two year-long (2013–2014) comparison RMSE of AMSR-2 SST and SSW is $<0.4^{\circ}C$ *and* $<1.5\ ms^{-1}$, respectively

Reddy, B.N.K., Venkatesan, R., et al., 2018. Comparison of AMSR-2 wind speed and sea surface temperature with moored buoy observations over the Northern Indian Ocean. *Journal of Earth System Science*, *127*(1)

Atmospheric Pressure – Estimation of uncertainty measurement

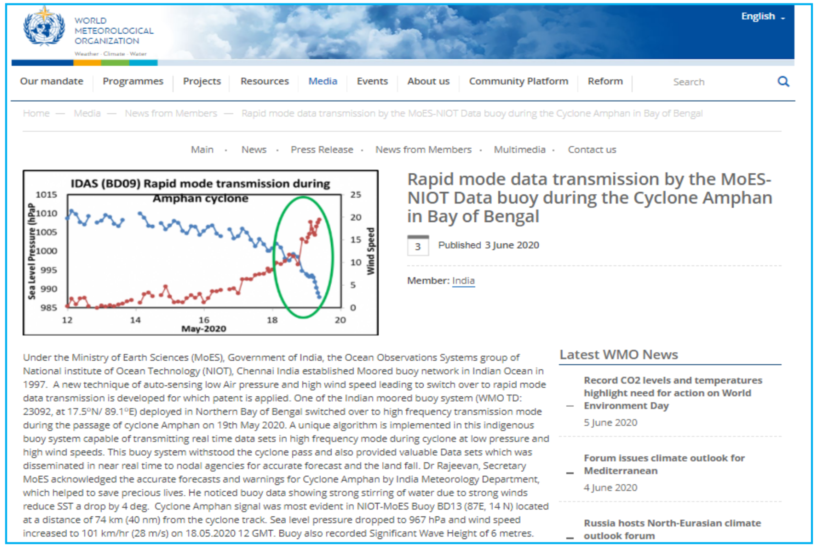
✓Primary calibration of pressure sensors, is the deadweight tester that produces calibrated pressure related to the precision weights used and the local gravity field.

✓ WMO - Accuracy should be ± 0.3hPa

✓ Uncertainty budget is calculated based on Guide to Expression of Uncertainty in Measurement (GUM).

✓**Sensor accuracy, drift, Static pressure head, Telemetry resolution, Repeatability Hysteresis** are considered to account the overall uncertainty and Estimated as ± 0.13hPa, within WMO recommended value

Rapid mode transmission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Rapid mode data transmission by the MoES-NIOT Data buoy during the Cyclone Amphan in Bay of Bengal

3 Published 3 June 2020

Member: India

Under the Ministry of Earth Sciences (MoES), Government of India, the Ocean Observations Systems group of National institute of Ocean Technology (NIOT), Chennai India established Moored buoy network in Indian Ocean in 1997. A new technique of auto-sensing low Air pressure and high wind speed leading to switch over to rapid mode data transmission is developed for which patent is applied. One of the Indian moored buoy system (WMO TD: 23092, at 17.5ºN/ 89.1ºE) deployed in Northern Bay of Bengal switched over to high frequency transmission mode during the passage of cyclone Amphan on 19th May 2020. A unique algorithm is implemented in this indigenous buoy system capable of transmitting real time data sets in high frequency mode during cyclone at low pressure and high wind speeds. This buoy system withstood the cyclone pass and also provided valuable Data sets which was disseminated in near real time to nodal agencies for accurate forecast and the land fall. Dr Rajeevan, Secretary MoES acknowledged the accurate forecasts and warnings for Cyclone Amphan by India Meteorology Department, which helped to save precious lives. He noticed buoy data showing strong stirring of water due to strong winds reduce SST a drop by 4 deg. Cyclone Amphan signal was most evident in NIOT-MoES Buoy BD13 (87E, 14 N) located at a distance of 74 km (40 nm) from the cyclone track. Sea level pressure dropped to 967 hPa and wind speed increased to 101 km/hr (28 m/s) on 18.05.2020 12 GMT. Buoy also recorded Significant Wave Height of 6 metres.

Latest WMO News

– Record CO2 levels and temperatures highlight need for action on World Environment Day
5 June 2020

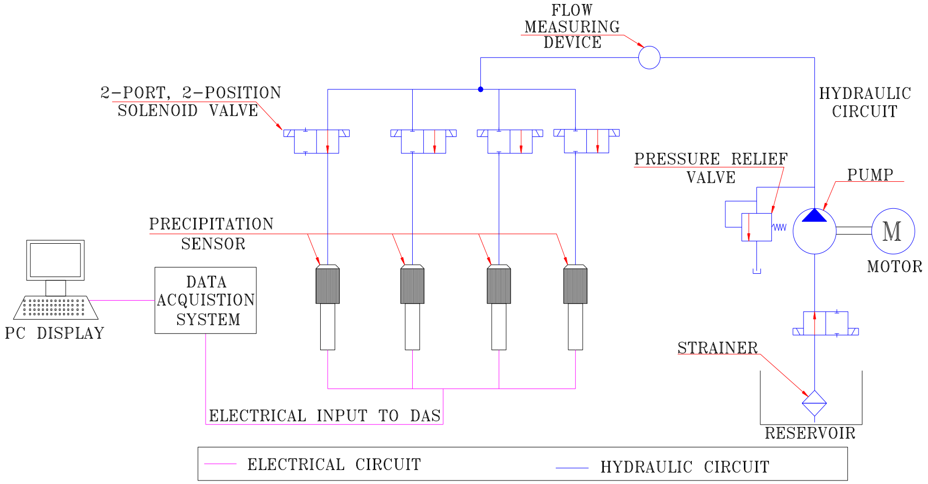
– Forum issues climate outlook for Mediterranean
4 June 2020

– Russia hosts North-Eurasian climate outlook forum

Venkatesan, R., et al, 2021. Estimation of Uncertainty in the Atmospheric Pressure Measurement From the Indian Ocean Moored Buoy Systems. *Marine Technology Society Journal*, *55*(1),

Precipitation – Calibration and validation

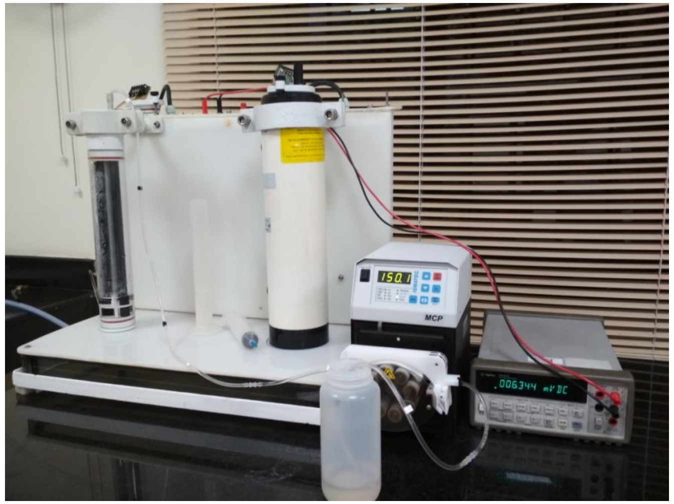
✓Calibration is carried out using a flow bench, known quantity of water is pumped from the reservoir to Sensor.
✓Post calibration is performed without cleaning the measuring tube as received from the field.



Comparison with Satellite data

- Integrated Multi-satellitE Retrievals for GPM (IMERG) precipitation is evaluated against moored buoy observations over Indian Ocean March 2014 to Dec 2015.

- IMERG precipitation performs considerably better over the Bay of Bengal than the Arabian Sea in both detection and estimation.



Prakash, S., Kumar, M.R., Mathew, S. Venkatesan, R., 2018. How accurate are satellite estimates of precipitation over the north Indian Ocean?. *Theoretical and Applied Climatology*, *134*(1),

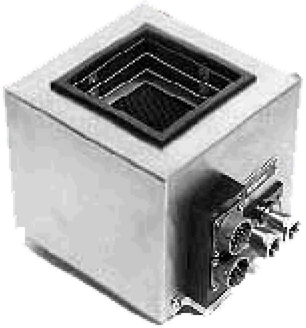
Solar Radiation sensor – Calibration and validation

✓Absolute Cavity Pyrheliometer sensor
✓Reference sensors -International Pyrheliometric Comparison (IPC)
✓Traceable to the World Radiometric Reference **(WRR).**
✓Blackened cavity array radiator is used for long wave radiation sensor calibration


Absolute Cavity Radiometer

Comparison with satellite data

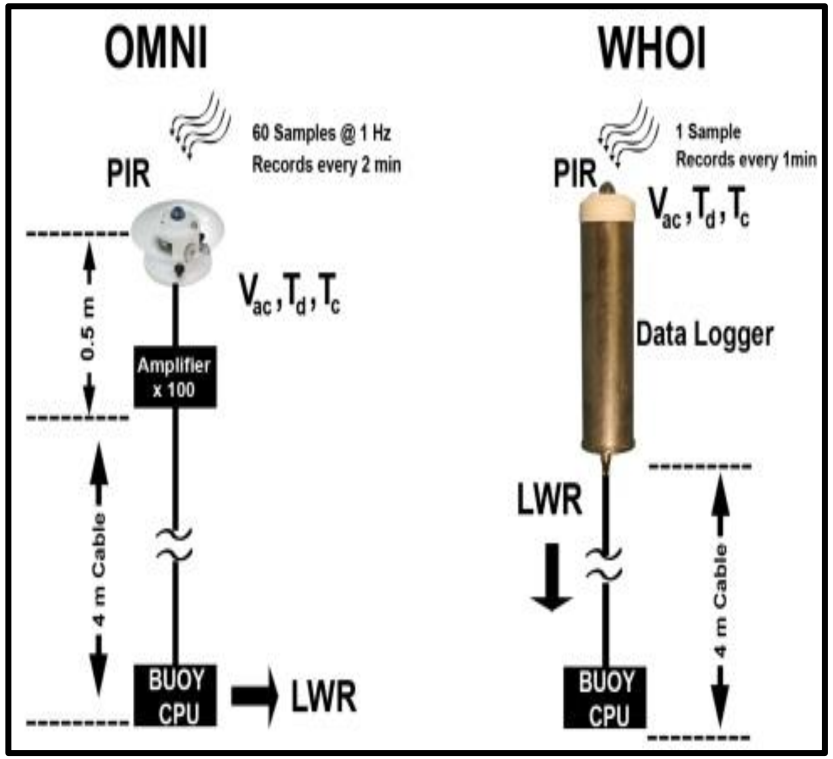
- Moderate Resolution Imaging Spectroradiometer (MODIS) sensor onboard the NASA AQUA and TERRA satellites over the north Indian Ocean.
- Evaluations of MODIS-based SW↓ fluxes as a reference for the evaluation of OMNI Buoy observations.


Infrared Calibration Source

Kumar, M.R., Pinker, R.T., Mathew, S., Venkatesan, R. Chen, W., 2018. Evaluation of radiative fluxes over the north Indian Ocean. *Theoretical and Applied Climatology*, *132*(3),

Correction of LWR in Field Data

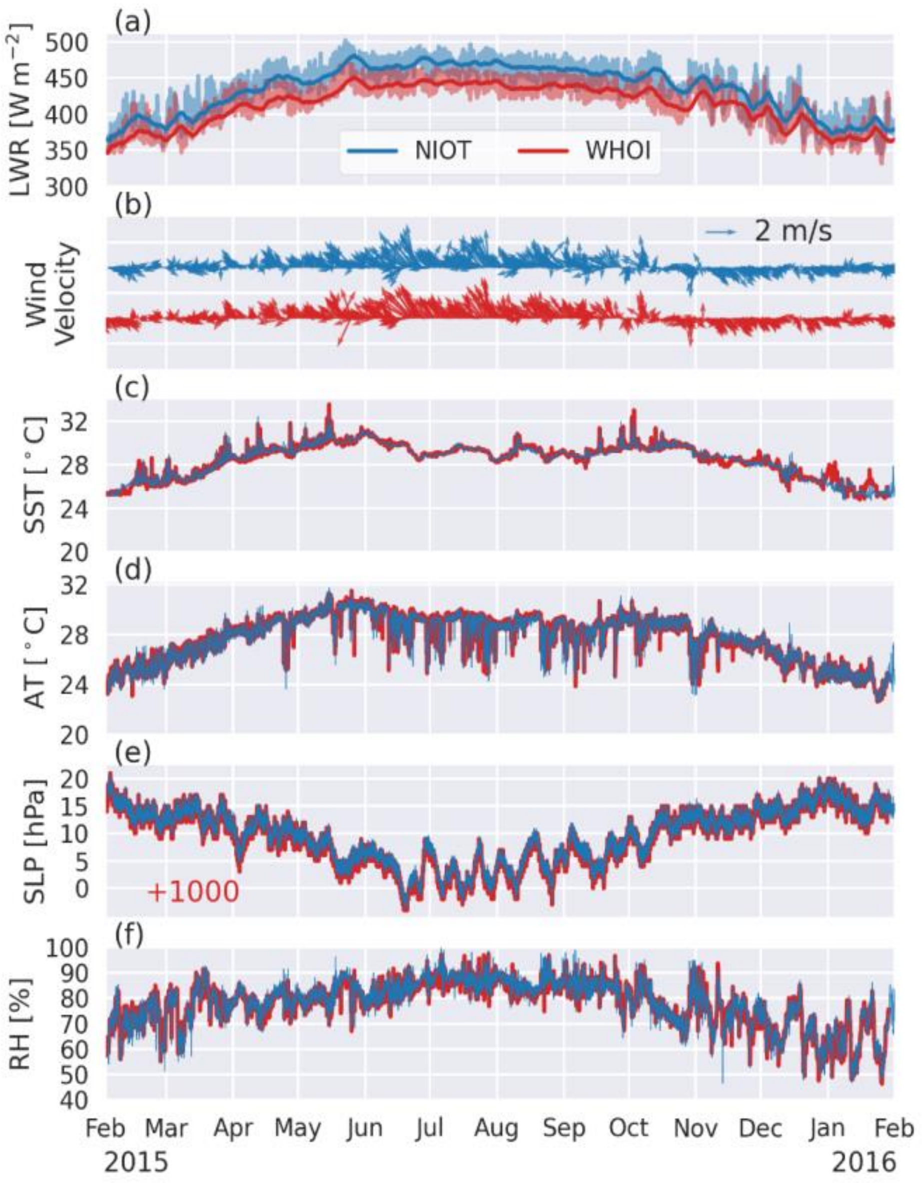
- Pyrgeometers measure the LWR↓ with thermopile voltage, case temperature and dome temperature.
- OMNI and WHOI buoys are fitted with Precision Infrared Radiometer (PIR) for LWR↓ Eppley Laboratory, Inc.
- WHOI a single snapshot at the end of each minute; OMNI buoy averages 60 samples collected at 1 Hz at 2 minutes interval.

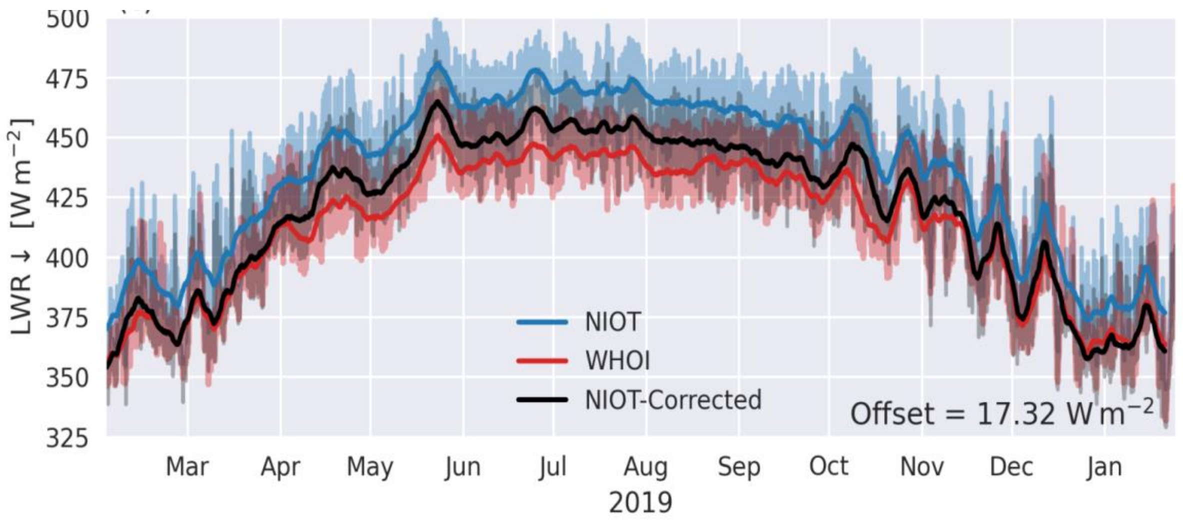


$$R_{in} = V_{ac} / S + \sigma T_c^4 - k\sigma(T_d^4 - T_c^4)$$

- ❖ **WHOI's standalone unit with dedicated data logger processes the PIR signal and sends the computed LWR↓ to buoy CPU**
- ❖ **OMNI setup uses an amplifier and sends the signal to CPU which computes the LWR↓**

Correction of LWR in Field Data





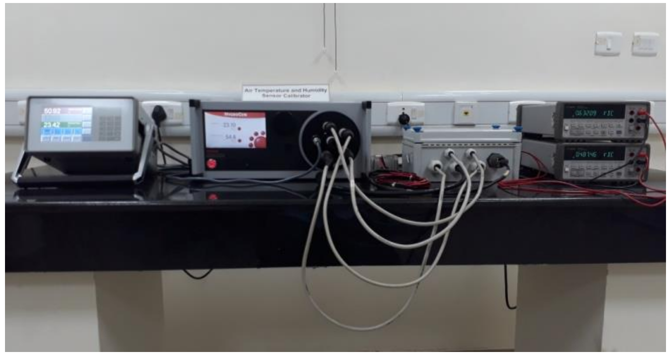
- Offset between LWR↓$_{cl}$ with corresponding LWR↓ is estimated as 17.32 W/m^2 and is applied in the LWR↓ measurements.
- The corrected NIOT-LWR↓ with that of nearby WHOI measurements in northern BoB exhibited good correlation of 0.95 with a standard deviation of 10.85 W/m^2.

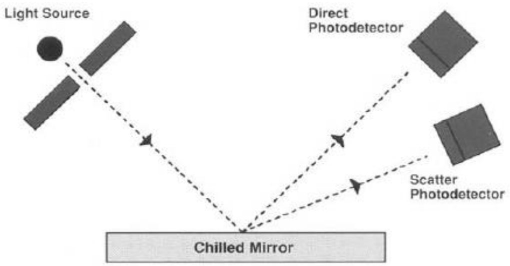
Buoy-CPU

✓The analog signal channels in the DAS need to be calibrated to acquire high quality data.
✓calibrated to the voltage range which corresponds to the sensor's output range, using the standard digital DC source, digital multimeter.

Air temperature and humidity – calibration

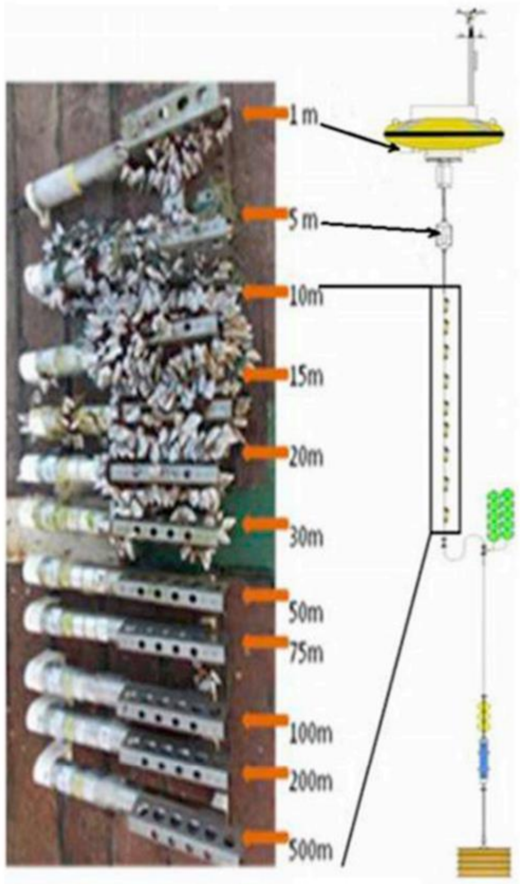
✓Hygrogen is a portable humidity and temperature generator, which is used to generate a range of temperatures and humidity.
✓A chilled mirror and a platinum resistance thermometer is used as a reference sensor to calibrate the air humidity sensor and air temperature sensor, respectively.

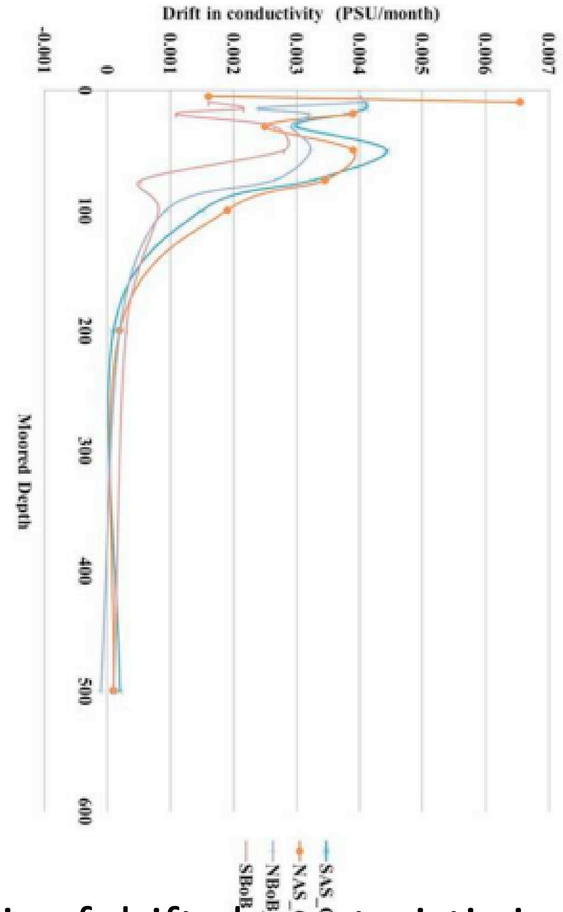


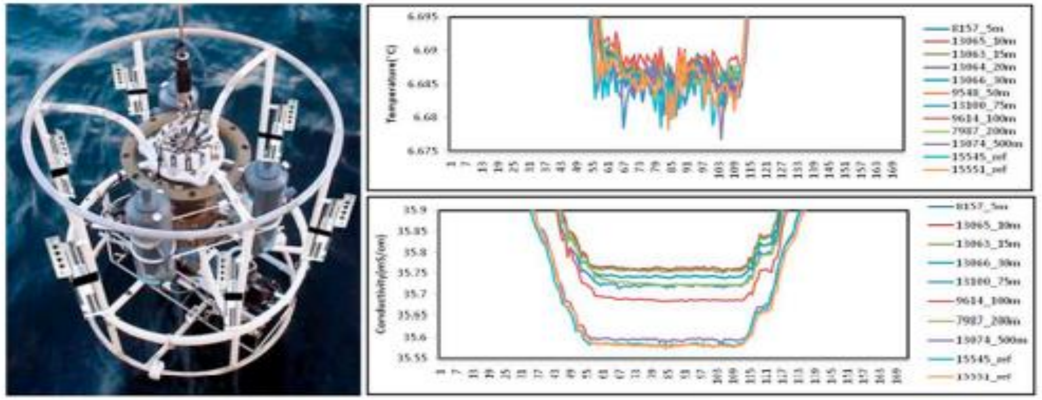


Analysis of drift characteristic in CT sensors Moored buoy system

✓Drift in temperature sensor was very minimal and well within the accuracy limit.
✓Drift in the conductivity sensors was more significant.
✓Drift in the conductivity sensor decreases as the deployment depth of the sensor increases







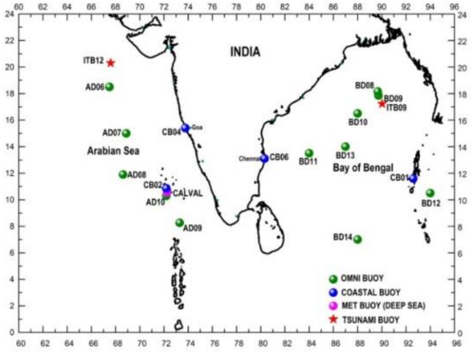
Field calibration setup a) temperature reading b)conductivity reading from all sensors at 1000m

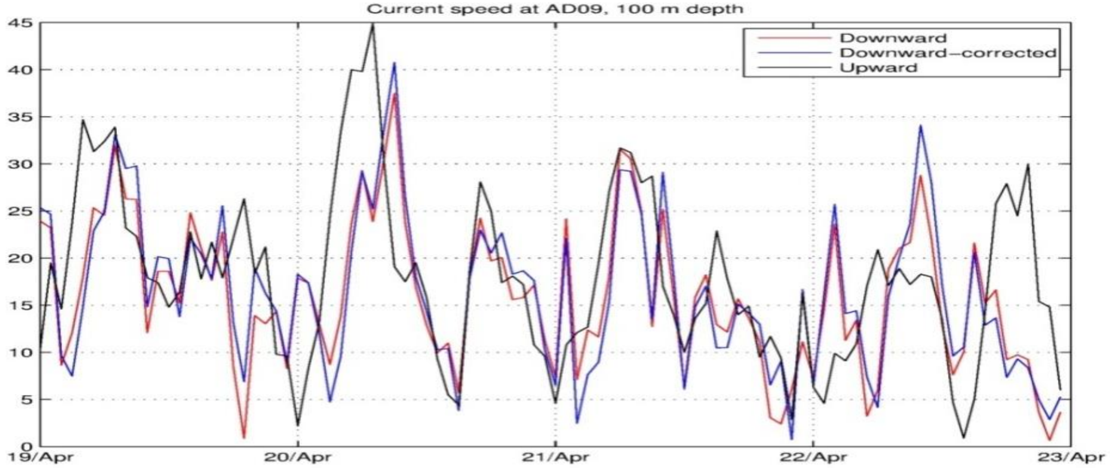
Drift of conductivity sensor in PSU/month.

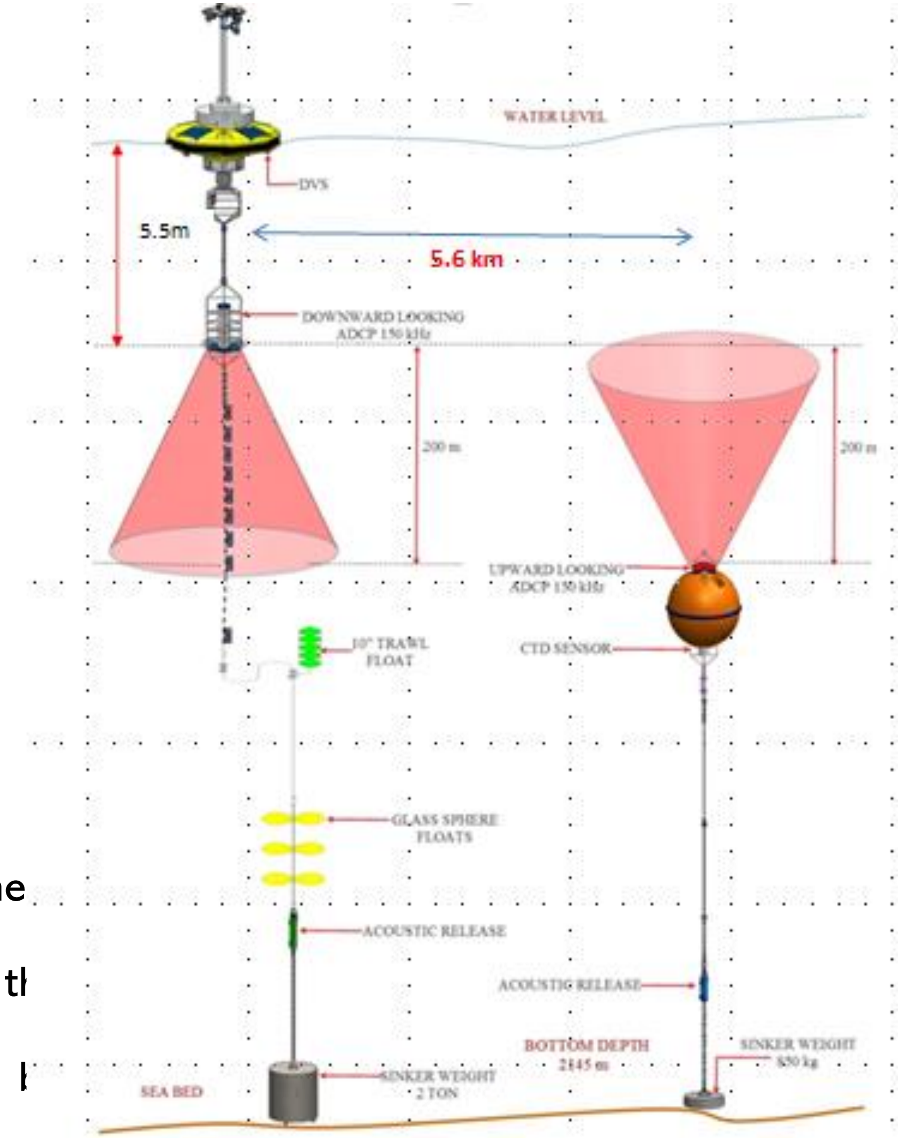
Location		Arabian Sea	BOB
Surface Layer(above 30m)	Average	0.00335	0.00275
	Std Dev	0.01183	0.00139
	Data Points	12	21
Subsurface Layer(50–100m)	Average	0.00318	0.00196
	Std Dev	0.00154	0.00121
	Data Points	14	13
Deep Layer(200–500m)	Average	0.00014	0.00013
	Std Dev	0.00121	0.00007
	Data Points	5	4

Venkatesan, R., et al 2019. Analysis of drift characteristic in conductivity and temperature sensors used in moored buoy system. Ocean Engineering

Comparison of current profile
Surface buoy mounted ADCP and Subsurface ADCP mooring



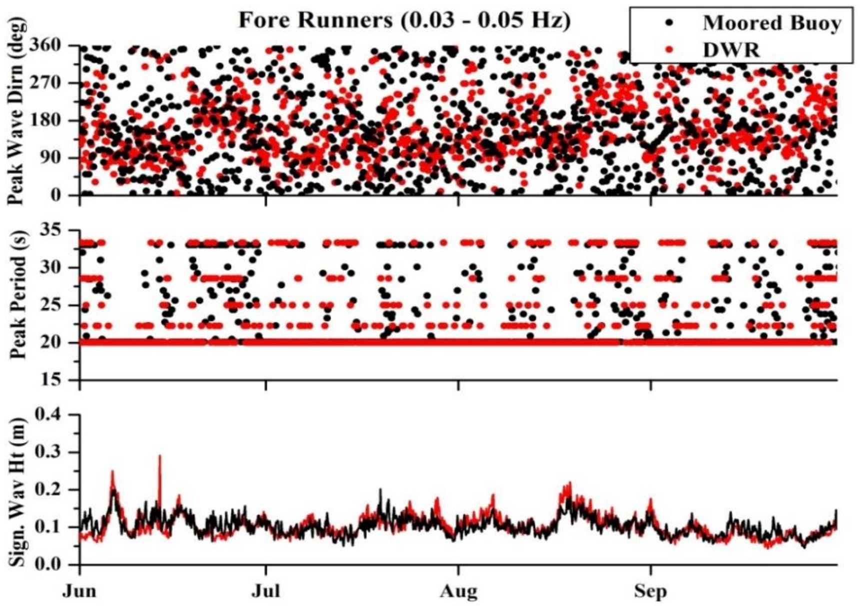


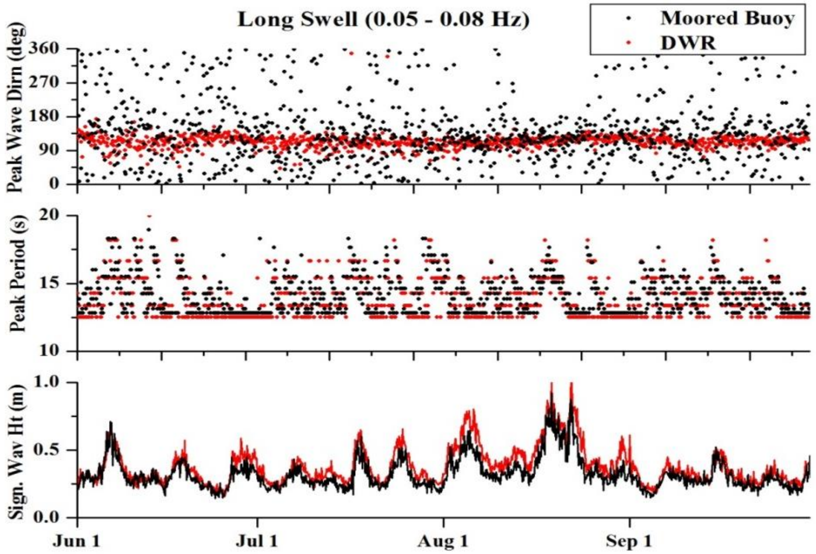


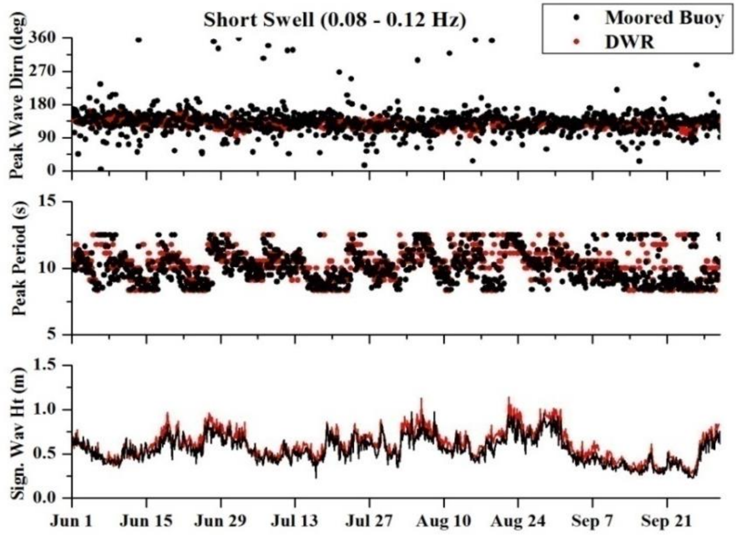
- Crrent speed measured by upward looking ADCP is generally in good agreeme with that measured by downward looking ADCP
- Deviations observed in the data are mainly attributed to distance between tl moorings (5.6 km) and tidal currents
- Data designed depth (250 m) was achieved (248 m) after deployment l precise mooring calculations.

Wave- PPWET

- To carry out wave measurement consistently across various global networks, even though the hull, sensors and processing systems, payload, mooring, sampling frequency, and period vary,
- JCOMM / DBCP are taking necessary steps to establish required guidelines of best practices for wave measurements.

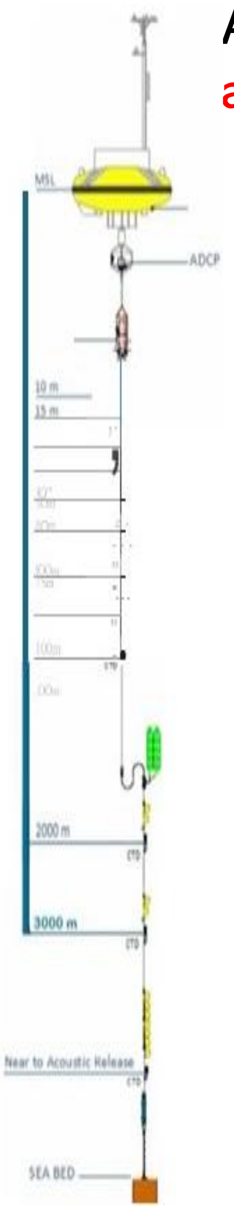




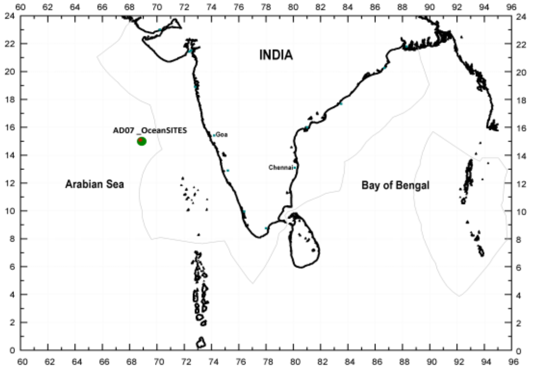


Venkatesan, R., et al 2019. Data Returns and Reliability Metrics From the Indian Deep Ocean Wave Measurement Buoys. *Marine Technology Society Journal*, *53*(6).

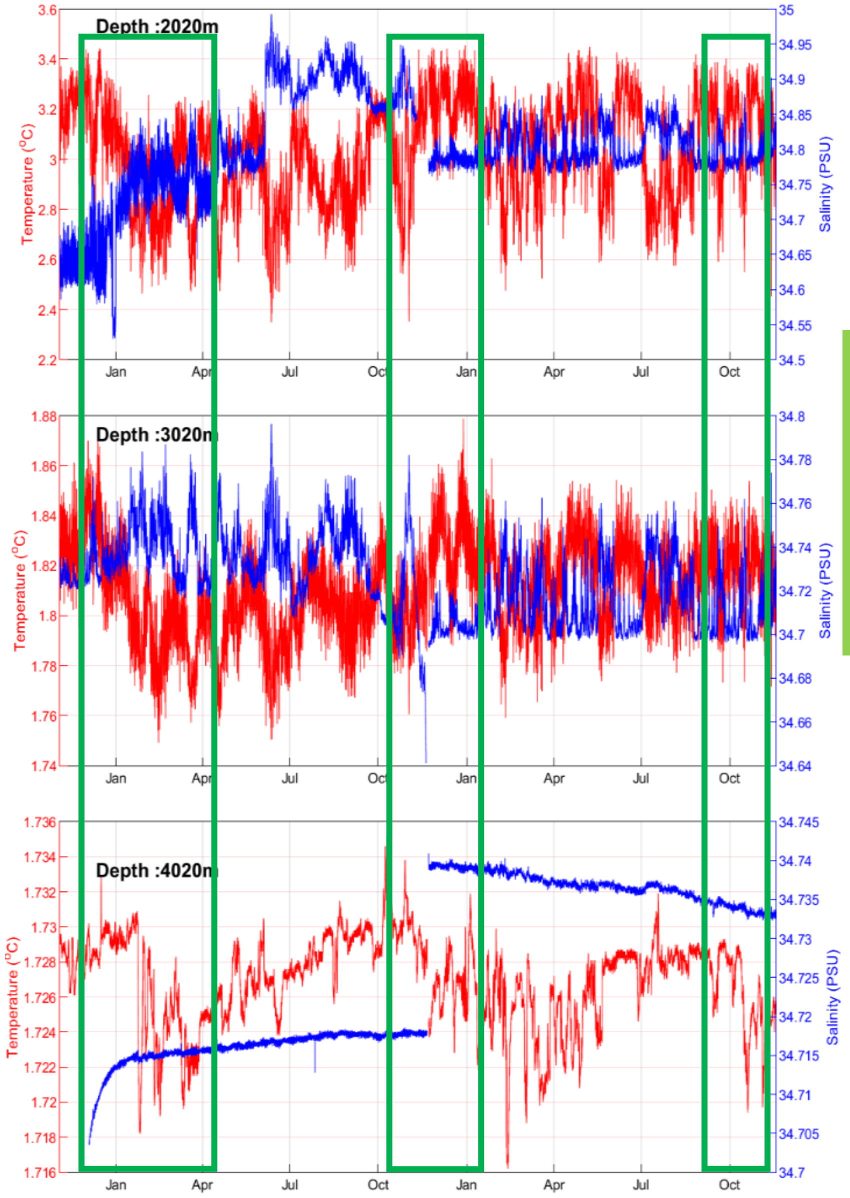
OceanSITES:
Seasonal cooling observed near seabed (4020 m) in Central Arabian Sea



Abyssal Temperature and salinity time series at 14.9N, 68.99E Nov 2018 to Nov 2020



- **Temperature : Two-year time series near seabed (4020 m) show a seasonal variation of temperature with warming phase peaking during October to January followed by a cooling event.**
- **Salinity near seabed (blue line in bottom right panel) recorded by SBE 37-IM MicroCAT sensors were erroneous during two consecutive deployments.**



2020 m

3020 m 1015 m above seabed

4020 m, 15 m above seabed

Thank you