INTERNATIONAL INDIAN OCEAN EXPEDITION

INCOIS

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INTERNATIONAL INDIAN OCEAN EXPEDITION - II

The Indian Ocean Bubble 2

EDITORIAL

Dear IIOE-2 member,

Greetings from the Indian Ocean region!

We are happy to bring you the latest issue of the IO-Bubble.

In this issue, Indian Ocean science uncovered with a set of articles on ocean data, followed by those on ocean circulation and modelling. Fisheries have been a staple in most of our past issues, so is here. We also feature an EC article contribution to her inspiration. As we strive to keep you updated on important events, we bring you reports of the event from within and beyond Indian Ocean. Not the least, at last we seek your attention to upcoming workshops/conferences that you may not want to miss.

The elevation of IOCINDIO as the newest IOC-UNESCO sub-commission (at par with IOCARRIBE, IOCAFRICA and IOC-WESTPAC) is a major event pertaining to the IO region and also opens the doors for major collaborations and initiatives.

At the risk of reiterating, we once again strongly believe that these initiatives will synergise and flourish during the Ocean Decade under various frameworks, paving way for better Indian Ocean science.

On behalf of the IIOE-2 PO team,
N. Kiran Kumar, Nimit Kumar and Aneesh Lotliker

IN THIS ISSUE

Ocean Data

Quality Control Procedures and Analysis for INCOIS Wave Rider Buoy Observations in the Indian Ocean

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Introduction

The quality of wave measurements is crucial for validating wave forecasting models, calibrating, and validating satellite wave sensors, comprehending wave physics, monitoring climate conditions, designing ships and offshore installations, conducting effective sea operations, and conducting studies on climate trends and variability (Magnusson et al 2021). The Wave Rider Buoys (WRB) are designed to measure essential wave parameters, including Significant Wave Height (SWH), wave period, and wave direction. The buoy computes spectra using Fast Fourier Transforms (FFT), with a high-frequency cut-off at 0.58 Hz (Balakrishna Nair et al., 2013, Sirisha et al., 2023). The WRB in the coastal waters of India are maintained by Earth System Science Organisation – Indian National Centre for Ocean Information Services (ESSO-INCOIS). The network of WRB, deployed both in east and west coasts of India during 2007 – 2020 is shown in Figure-1. The WRB comprise two types Mk3 and Mk4 provided from Data well company.

Figure-1: Network of WRB locations in Indian Ocean

Among the 16 WRBs, the Gopalpur, Vizag, Krishnapatnam, Karwar, Kollam and Kanyakumari are MK4 buoys and the Digha, Pondicherry, Tuticorin, Veraval, Versova, Ratnagiri, Agati, Port Blair and Seychelles buoys are Mk3 Buoys. The Mk3 buoys measure wave height, direction, and water temperature, whereas the Mk4 buoys offer additional capabilities, including the measurement of ocean currents along with wave height, direction, and water temperature (Peach et al, 2017). Additional information about buoy measurements can be found in (Sanil Kumar et al., 2013).

Results and Discussion

The primary aim of this work is to explain the quality control procedure applied upon the data from WRB data in delayed mode. For the same, the data during 2009 to 2023 at 30 minutes interval is considered and the time series of significant wave height (m) at Vizag location is shown in Figure-2. The time series of SWH data shows the many spikes ranging upto 40 m, which shows the need for the quality control of the data before the qualitative utility of the data.

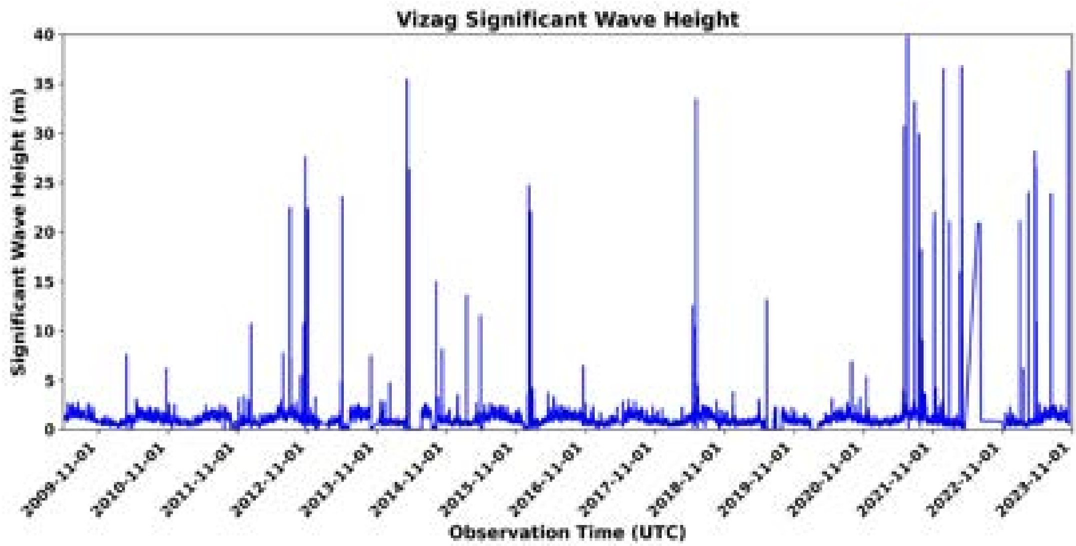

Figure-2: Time series of significant wave height (m) from Vizag WRB during 2009 – 2023

The steps involved in the quality control check of the WRB dataset are outlined below.

1. Impossible Location and Time Test

The Impossible Location and Time Test is applied to check that the recorded values are within reasonable geographic and time boundaries. In the case of time, years (2009-2023), month (1-12), date (1-31), hour (0-24), minutes (1-60) and seconds (1-60) are checked whether they are in range. In the case of location, half degree plus and minus of the buoy location (latitude, longitude) is checked. If the observation time or location is in permissible range, then the QC flag as assigned '1' otherwise '2'.

2. Spike Test

Spikes are defined as points more than 4 times the standard deviation (std) away from the series mean (SWH >= mean + 4*std). The spike test employed here is three observations made before and after the observation in query are considered along with the one in query, if the value under query is greater than mean plus 4 * std and the three observations before and after the query is less than mean plus 4 * std then the query is flagged as Spike flag assigned as 4.

3. Range Test

The variables are checked whether their value is within the permissible limit. Table-1 gives the details of permissible ranges and units of the variables. If the parameter values in the records are not within the permissible range, then the QC flag assigned as '3'.

Sl.No	Parameter	Range	Units
1	Significant Wave Height	0.1 - 16	meters
2	Wave Direction	0 - 360	deg
3	Wave Period	1.7 - 30	seconds
4	Sea Surface Temperature	0 – 35	centigrade
5	Current Speed	0 - 4.1	meter/ second

Table-1: Details of upper and lower limits of WRB data variables used in QC - Range check

4. Struck Value Test

This test checks if a value has remained the same for an excessive period. The number of repetitions of the parameter value allowed depends on the parameter and the frequency of observation. The struck values which repeat continuously more than six times are flagged. The QC flag of all such observations is assigned as '5'.

5. Missing Value Test

This test checks the time series for gaps by checking the date and time tags. If the gaps are identified, the missing date stamps rows are created with the variable values as NAN and the QC flag is assigned as '9. This approach allows us to easily identify and handle missing data in variables.

6. Maximum Wave Height Test

The time series is rejected and flagged as 6 if the significant wave height (calculated as 4 times the series standard deviation) is greater than the maximum allowable wave height value (16 m).

Table-2 shows the final QC flags assigned as, if the data passes all the QC tests are assigned with the quality flag as 1, if any one of the QC tests is failed the QC flag is given as 4 and for the Missing data quality flag 9 is assigned.

Flag Value	Meaning
1	Good data
9	Missing values
4	QC failed
3	Suspected

Table-2: Binary numbers used in defining the secondary QC

Implemented quality control methods to the Significant wave height data from the Vizag WRB for period 2009 to 2023. Illustrated the procedures before and after quality control. Initially the Vizag wave rider buoy significant wave height data is organised in 1 m bin wise to check the number of data points in each 1 m bin. Figure-3 shows the histogram of Significant wave height (m) which ranges from 0 – 37 m in x-axis and y-axis shows the number of data points. Most of the data is in the range of 0 – 3 m. In the total data points of 2,14,950 most of the data is in 0-1 m range with the number of data points of 1,22,045, in the range of 1-2 m the number of data points are 86,674, and in the 2 - 3 m range the number of records are 6012 from there the number of data points are decreased drastically from 3 – 38 m range.

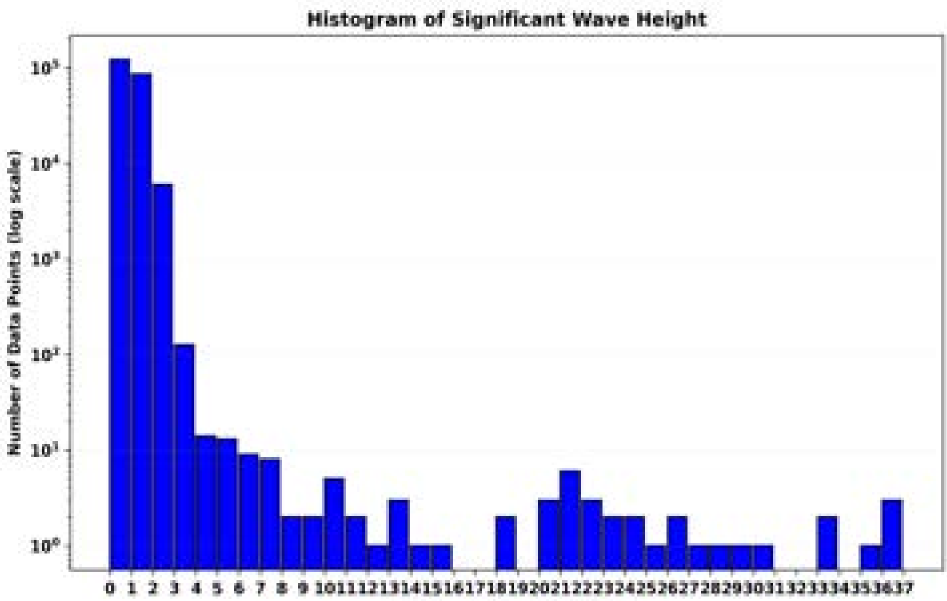

Figure-3: Histogram of Significant wave Height data with 1 m bin

One of the more perplexing challenges has been differentiating between the occurrence of spikes, instances in which individual data points unreasonably different from surrounding values. In most cases, spikes are indicators of physical impact on the buoy or a malfunctioning sensor. The spike test is performed for the SWH data for the period of 2009 to 2023 for Vizag WRB. Figure-4 shows the time series of SWH, with red dots as spikes.

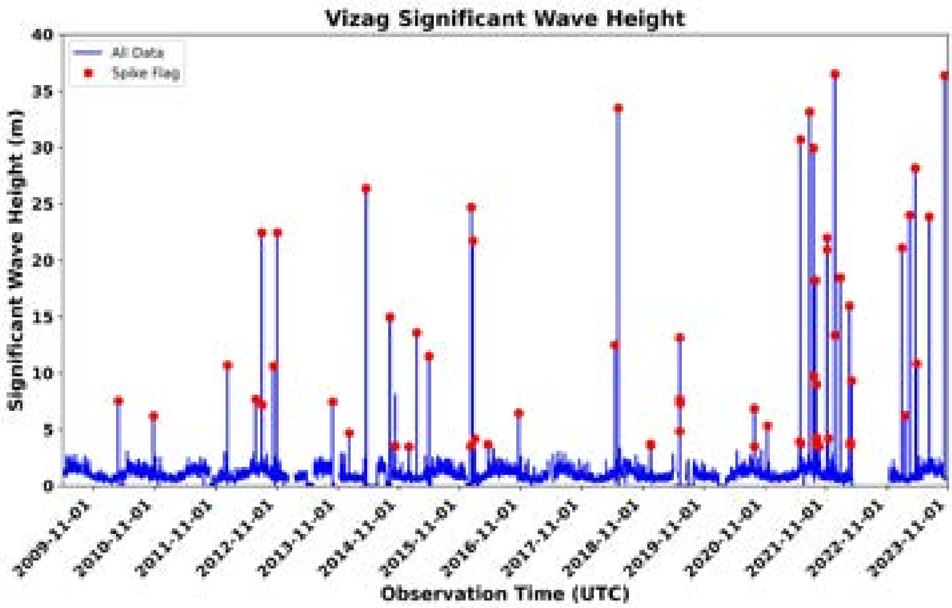

Figure-4: Time series of significant wave height (m) (blue line) and the red dots (spikes) from Vizag WRB during 2009 – 2023

In the range test, the ranges defined are appropriate to the Indian Ocean basin and the limits are set in such a way where extreme events data is also considered. As the SWH range, less than 0.1m and more than 16 m are flagged in the range test and assigned flag as '3'. The data points which repeat continuously more than six times are identified, the QC flags of all such data are flagged and assigned the flag as '5' . It determines if the instrument is transmitting a constant value without any change.

The data points which fail in the Impossible Date and Location test are identified, the QC flags of all such data are flagged and assigned the flag as '2'. In the Missing value test or gap test, identified the time series by checking the date and time tags. If the gaps are identified, the missing date stamps rows are created with the variable values as NAN and the QC flag is assigned as '9. This approach allows us to easily identify and handle missing data in variables. The Maximum wave height is performed by identifying the significant wave height (calculated as 4 times the series standard deviation) is greater than the maximum allowable wave height value (16 m). If the test passes, the time series is rejected and flagged as 6. In the Vizag WRB SWH data is not identified the series (4*std) greater than maximum allowable wave height (16 m). So, the time series is flagged as good data with assigned flag 1. Figure-5 is the timeseries of Vizag WRB significant wave height, will all the QC flags.

Figure-6 shows timeseries of Vizag WRB significant wave height, after removing all the QC flagged data. QC flag with 1, good SWH data is plotted against time. The time series data ranges between 0 to 9 m, which is reliable. The good data also includes the data during cyclone period specially during super cyclone Hudhud, the significant wave height data recorded is about 8 m which is clearly seen in Figure-8. The good data is 1,93,440 from the total data of 2,14,950 points.

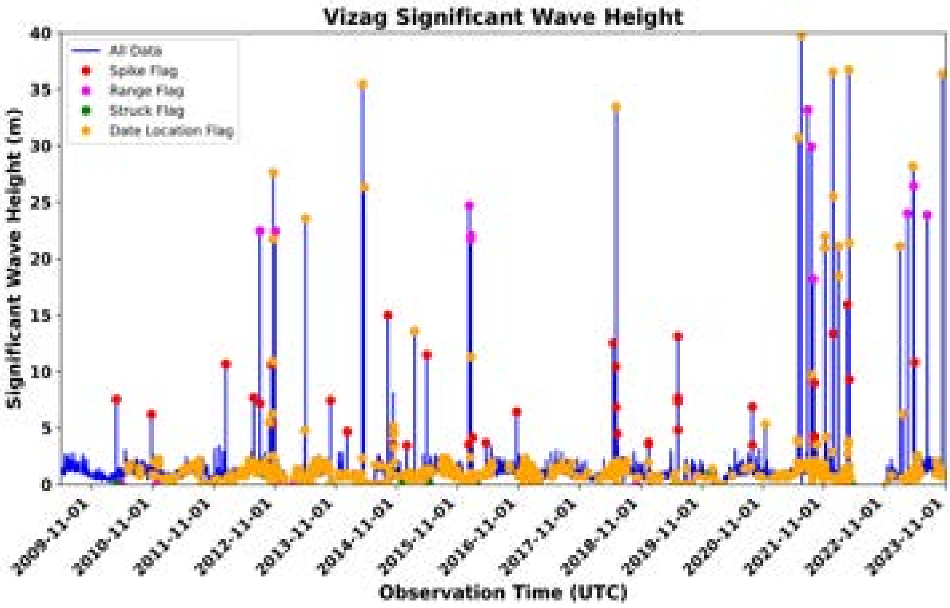

Figure-5: Time series of significant wave height (m) (blue line) for Vizag WRB during 2009 – 2023, observations failed in all the QC tests are flagged in distinct colors.

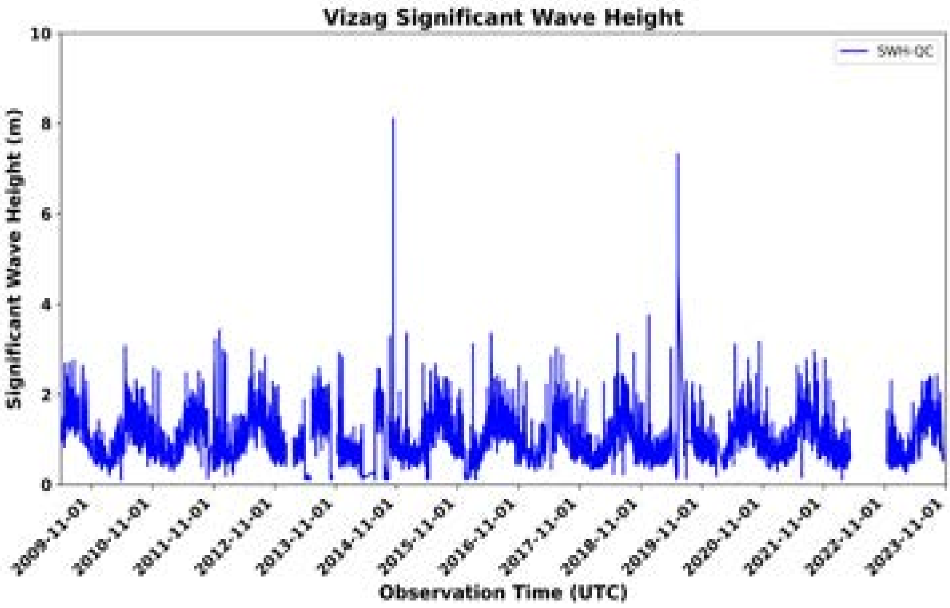

Figure-6: Time series of significant wave height (m) (blue line) for Vizag WRB during 2009 – 2023 after removing all the QC flagged data

The average number of observations that passed the QC procedure is 1,93,440 records from the total data of 2,14,950. On average the QC pass percentage of SWH is about 90%. In the total data, 10 percent of the data is flagged as bad data due to quality control. Among the 14 years (2009-2023), 30 min interval data, the missing data is about 18 % (38,379 points) of the total data. The same QC methods are applied to the wave rider buoys (Kollam, Gopalpur, Krishnapatnam, Pondicherry). Table-3 shows the details of each buoy, good data, QC failed (bad) data, Suspected data, and Missing data with assigned flags. The suspected data is mostly coming under good data as only Location (Lat, Lon) is missing in the data, rest of the data is good.

Station Name (data from year)	Total Data	Good Data QC Flag – 1	QC Failed (bad) Data (%) QC Flag - 4	Suspected Data QC Flag - 3	Missing Data QC Flag - 9
Vizag (2009)	2,14,950	1,93,440	14,057 (6.5 %)	7,453	38,379
Kollam (2012)	1,21,648	1,04,593	8,724 (7.2 %)	8,331	83,310
Krishnapatnam (2015)	93,461	83,421	8,231 (8.8 %)	1,809	46,877
Gopalpur (2008)	1,77,868	1,66,351	11,421 (6.4 %)	96	96,284
Pondicherry (2007)	2,36,886	1,90,575	3,491 (1.4 %)	42,820	53,968

Table-2: Final Quality Flags

Conclusions

The INCOIS Wave rider Buoy data sets during 2009 to 2023 is extracted, processed, quality controlled. As the quality of dataset is found to be reliable, the WRB data can be utilised in validating wave forecasting models, calibrating and validating satellite wave sensors, comprehending wave physics, monitoring climate conditions, designing ships and offshore installations, conducting effective sea operations etc.

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Tide Gauge Data Processing and Quality Control Methods

P Suneeta, TVS Udaya Bhaskar, E Pattabhi Rama Rao

Introduction

Tide gauges are vital instruments for monitoring sea level changes and detecting tsunamis, storm surges and swells. INCOIS has installed three types of tide gauge sensors (Radar gauge (RAD), Pressure gauge (PRS), Shaft encoder (ENC) at 21 locations since 2010-11, along with RAD sensors at 15 additional locations since 2015-16. These sensors measure water level heights with respect to a reference level. Figure-1 illustrates the network of tide gauge locations maintained by the INCOIS. Based on the delivery timelines, each associated with a different level of quality control and / or data processing, and related to different applications, data processing can be applied to: real time data (RT), near-real time data (NRT) and delayed mode data (DM) (Pouliquen et al. 2011).

Figure-1: Network of Tide gauges locations in Indian Ocean

The entire Quality Control (QC) technique is separated into two parts: a primary QC procedure and a secondary QC procedure with more complexity. Table-2 shows the lists the various QC procedures under both the categories. We assign the QC flags, QC flag which provides the details of the result of each QC test that the datum has undergone. The primary QC flag takes only three QC flags, where '1' denotes that all QC tests are passed by the datum, and it is good data. '9' denotes that the datum has failed in missing values. Table-3 provides the details of the same. Table-3 lists the QC tests that are included in the primary QC flag. The starred ones are those which give a QC flag '2' when passed outliers, The remaining primary QC tests result in QC flags '3' and '4' when QC test is passed spike and out of range, respectively. Finally, the QC tests of time of observation, location, and time sequence will be directly assigned to the primary QC flag, I.e., if any of the four tests pass, then the primary QC flag is assigned '1'.

Primary QC Tests
Range Check
Spike Test
Outliers Check
Out of Range
Missing Values Check Buddy or Neighbor Test
Time Sequence Check

Table-1: Primary QC procedures

Binary number	Detail
1	Good data
9	Missing values
2	Outliers
3	Spikes
4	Out of control

Table-2: Binary numbers used in defining the secondary QC

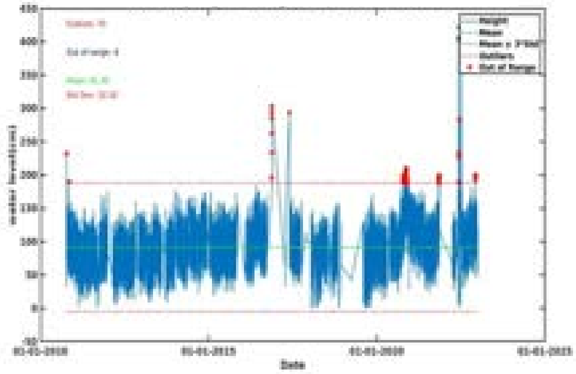
Results and Discussion

The dataset used for analysis comprises of a time series dataset with variable frequency, wherein 1-minute observations were aggregated into 1-hour observations. This investigation specifically targets five tide gauge stations situated in the Indian Ocean, serving as an initial exploration into tide gauge data processing and quality control. Spanning from 2011 to 2023, observations were showed at the covering a comprehensive 14-year period. Figure-2 illustrates the data processing and quality control flags for the five tide gauge stations. From the figure, blue lines depict the time series data of water level, green dotted lines indicate mean spikes, red dots represent outliers, and black dots signify data out of range. Detailed insights into the quality and quantity of flagged data for the five stations are provided in Table-3. Chennai station has 214 flagged data points, constituting 0.2% of its total data. Cochin station has 382 flagged data points, accounting for 0.4% of its total data. Nagapattnam has 451 flagged data points, also making up 0.4% of its total data. Kakinada station has 42 flagged data points, representing 0.04% of its total data. Lastly, Visakhapatnam has 140 flagged data points, making up 0.1% of its total data.

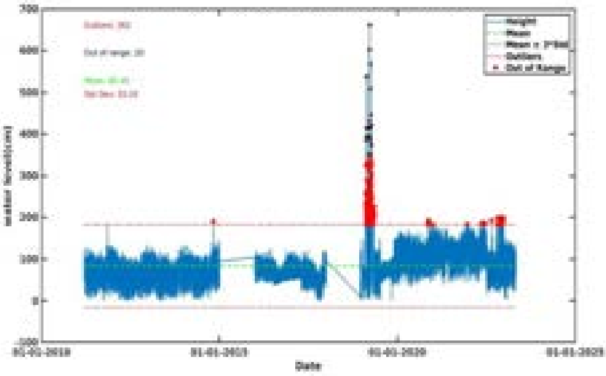
Station Name	Out of Control Flag (4)	Outliers Flag (2)	Quality Data Flag (1)	Total Flagged Data	Missing Data Flag (9)	Percentage of Flagged Data
Chennai	4	70	74,539	214	48,173	0.2 %
Cochin	20	362	85,799	382	28,153	0.4 %
Nagapattnam	17	434	99,317	451	14,635	0.4 %
Visakhapatnam	13	127	97,247	140	16,705	0.1 %
Kakinada	10	32	87,273	42	26,673	0.04 %

Table-3: Details of the number of quality and flagged based on the QC procedure.

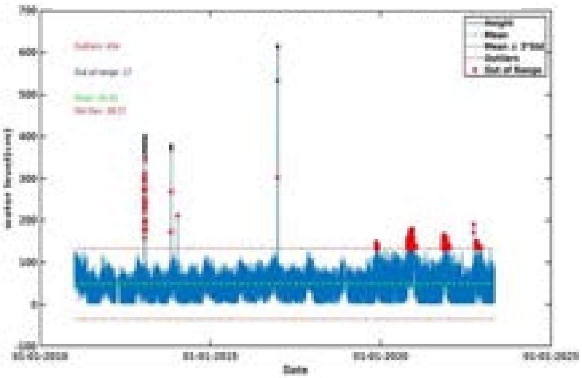
Data with Quality Control Flags, Mean, and Standard Deviation



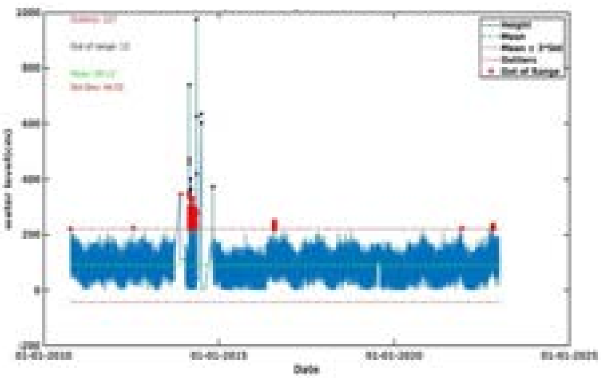
Data with Quality Control Flags, Mean, and Standard Deviation



Data with Quality Control Flags, Mean, and Standard Deviation



Data with Quality Control Flags, Mean, and Standard Deviation



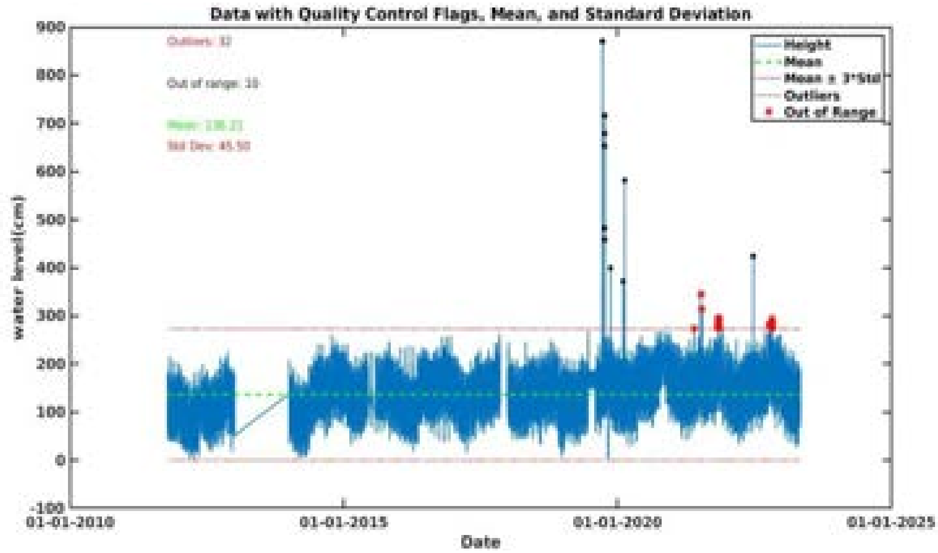


Figure-2: Quality Control flags for Chennai, Cochin, Nagapattnam, Visakhapatnam and Kakinada stations from the period 2011-2023.

Conclusions and Future Scope

As part of quality control, predicted tide data was utilized and various validation steps were conducted, including Demean, Detide, assessing residuals, calculating RMSE, and standard deviation. These validation steps demonstrated a strong agreement between observed and modeled data. Tidal analysis, prediction, identification of tidal constituents, and gap filling were performed during data processing. This process has been automated for other stations within the tidal gauge network.

However, for the overall improvement of the network, proper monitoring of water levels is essential. Enhancing water level monitoring would not only increase scientific applicability but also provide a more accurate representation of the environment. Additionally, implementing features such as a tsunami/seiches detection algorithm and basic data analysis would enable immediate utilization of tide gauge data in operational oceanography and facilitating a better understanding of higher frequency variations.

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Quality Control Tests on the Sub-Surface CTD Data from the Omni-Buoys across Indian Ocean

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The Indian moored buoy network currently consists of 12 OMNI (Ocean Moored buoy Network for Northern Indian) buoys and 4 MET-buoys. They produce real-time time-series of meteorological, oceanographic and wave parameters at 3-hours interval at several point locations across the Arabian Sea and Bay of Bengal. In the offline log data, the same parameters at some additional depths and higher temporal resolution are present. Table-1 below shows the total list of variables obtained from OMNI buoys and MET buoys. Figure-1 shows the positions of OMNI buoys and MET buoys with detailed structure of a OMNI buoy in the inset image.

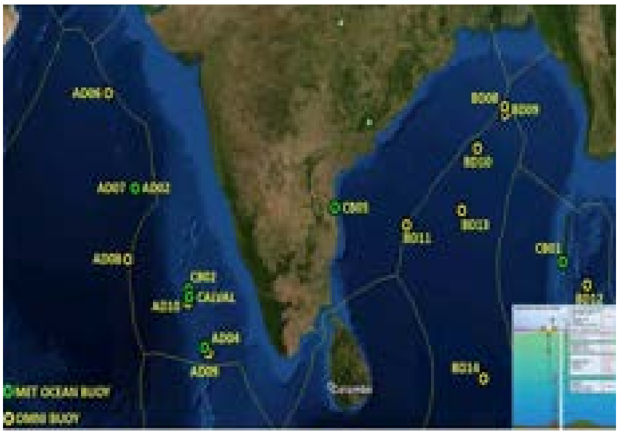

Figure-1: Position of OMNI and MET buoys across Indian Ocean with the OMNI buoy mooring configuration in the inset image

Meteorological Parameters	Sub-surface Oceanographic Parameters	Wave Parameters
Wind speed	Current speed	Significant wave height
Air temperature	Current direction	Wave period and direction
Humidity	Water temperature	Swell wave
Sea level pressure	Water salinity	Wind wave
Rainfall		
Shortwave radiation		
Longwave radiation		

Table-1: List of variables measured onboard the OMNI and MET buoys.

The subsurface parameters measured in a MET buoy are usually only at 1.25m and maximum up to 5m in some buoys. For most of the OMNI buoys, measurements are up to 500m and up to 3.5km in few buoys for some deployments. This metadata can be obtained from 'CORNEA' webpage from NIOT (https://www.niot.res.in/OMNIRAMA/AD08/data.php).

The subsurface water temperature is measured by the CTD instrument. These instruments measure conductivity, temperature of water; and salinity, density of water are derived. The CTD sensor comes with a depth pressure sensor to observe the amount of pressure exerted by the fluid column of water above. For the OMNI buoys the depth of the CTD observations is measured only at few specific depths. In this study, we discuss the statistics resulted by the application of different quality control procedures.

The first step of QC check would be the removal of unrealistic out of range values specified by the sensor manual. However, this wouldn't be sufficient, as the so-called range specified includes all the ranges of value that could be measured anywhere globally and anytime temporally. This is because the instruments used to measure are not region-specific, but the variability of the thermodynamic properties of sea water is regional. Hence several steps of quality control procedures have to be applied to ensure a good data quality. The other QC checks include climatology based standard-deviation trimming test, spike test, persistence check, etc. This article specifically focuses on the variations brought by the standard-deviation trimming tests.

The standard deviation trimming test is a parametric statistical test. Since the observation value is compared to a long-term mean value which is region specific, values though existing in the standard range would be marked as outliers, if they are deviated from the long-term mean. The resultant QC flags of this test are usually acceptable with some precautions, as follows,

1. Lack of consistency in the number of observations used in the construction of climatology fields. Since these are long term gridded fields, any data gaps spatially or temporally will be replaced by the nearby buddies mean. Hence, these fields are spatially smoothened and do not reflect the actual characteristics at those grid points with few observations used in the climatology construction.
2. Dependency on predefined thresholds. Since the thresholds are defined based on long-term statistics, any local variability of any scale, will result in the observations marked as outliers.

Having the constraints in the usage of climatology-based standard-deviation trimming QC check, a local standard-deviation trimming QC check has been adopted in this study and the same is discussed further.

For the demonstration of the QC procedures applied upon the subsurface observations of the moored buoys, a sample of water temperature data at 200 m from the buoy BD08 (17.82 ° N, 89.24 ° E), is considered. When compared to the existing quality control procedures, new sub-surface-specific QC procedures have been developed and applied to the data, and the same is discussed. Following are the QC procedures applied to sub-surface CTD data:

1. Standard-deviation based Trimming QC Check

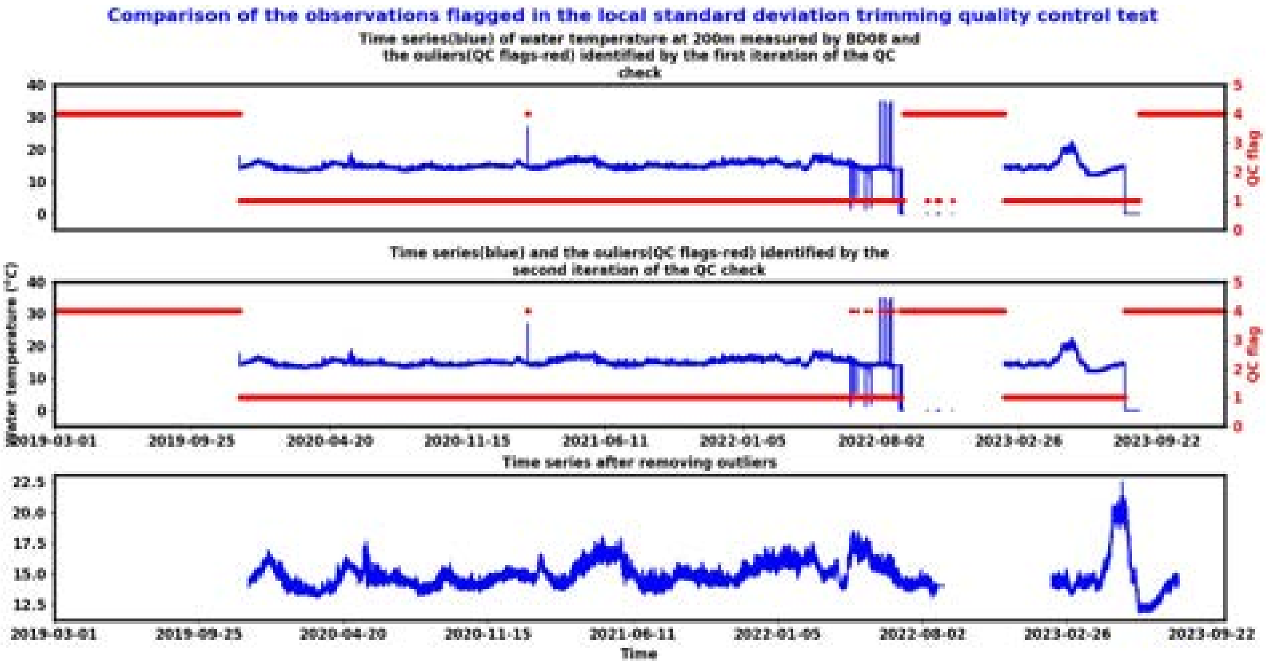

Figure-2: Comparison of the observations before and after applying local standard-deviation trimming test

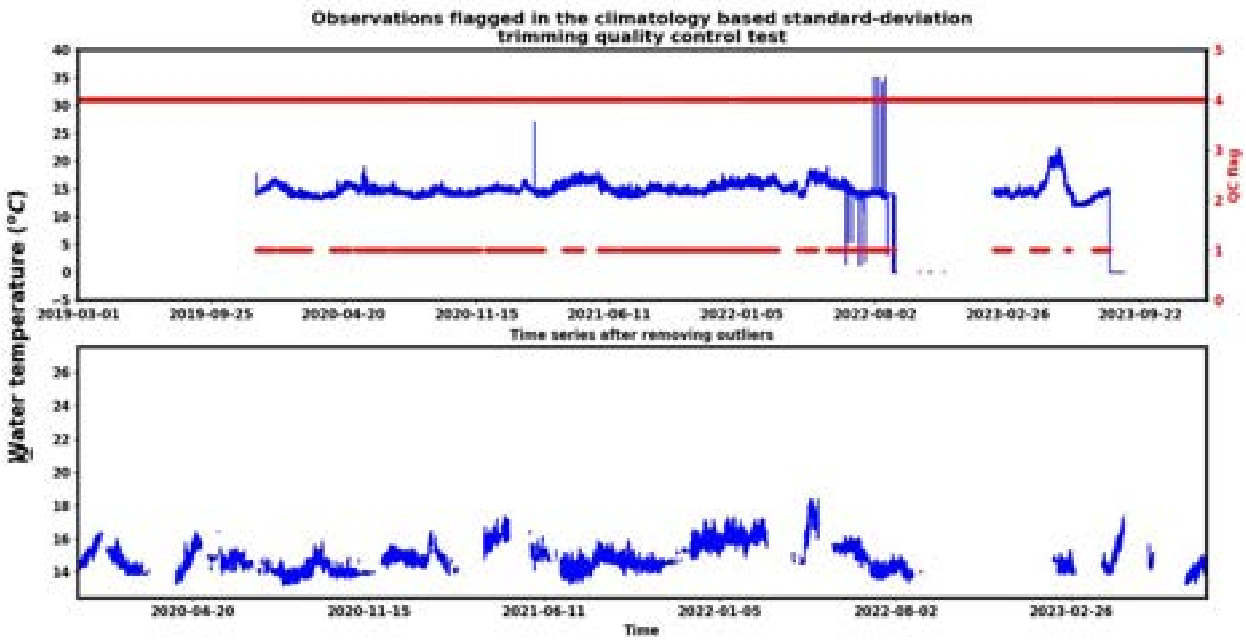

Figure-3: Comparison of the observations before and after applying climatology based standard-deviation trimming test

This test can be of two ways, where the 'mean statistic' required to calculate the standard deviation could be obtained from an existing long-term climatology or from the existing dataset which is being quality checked. The first two figures in the Figure-2 shows the outliers picked in the time-series of water temperature measured at 200 m by two iterations of local standard-deviation trimming. Here, the word 'local' refers to the data which is being checked. We are applying the test in two iterations as it ensures the removal of outliers which are of both high magnitude (first iteration) and of moderate magnitude (second iteration). Both kind of outliers cannot be removed in a single iteration as the 'mean statistic' calculated is influenced by the extreme outliers. The third plot in the Figure-2 shows the time-series after all the outliers removed. Figure-3 shows the observations flagged by the climatology based standard deviation trimming test. It can be observed that there is a huge data loss. Hence, after thorough analysis, the local standard-deviation trimming test will be used instead of climatology-based check. This decision has been obtained as evidently, the time-series appear visually fine.

2. Gradient Test

This test checks the difference between vertically subsequent measurements of temperature, salinity.

Value = Obs2 – (Obs3 + Obs1)/2 , where Obs2 is the measurement being tested, and Obs1 and Obs3 are the values above and below the queried observation. For temperature :this value must be less than 9.0°C and for Salinity the value > 1.5 PSU.

3. Density Inversion Test

In this test, the potential density is calculated from temperature and salinity at each level. While traversing from top to bottom, if the potential density at lower level is less than the value at upper level by more than 0.03 kgm-3 then the temperature and salinity at upper level is flagged. Similarly, while traversing from bottom to top, if the potential density at lower level is less than the value at upper level by more than 0.03 kgm-3 then the temperature and salinity at lower level is flagged.

Summary

This article describes the difference in outliers picked by two types of standard-deviation trimming tests. It can be concluded that for the quality checking of sub-surface data, a climatology based standard deviation trimming test causes huge number of data outliers which is not acceptable. Hence, the local standard deviation trimming test has been applied for the same. Also, there are usually zero observations flagged by the gradient and density-inversion test. However, to ensure proper quality of the data, both these tests are applied.

This dataset is now available for serving the data requests sent to the Ocean Data Management Group, INCOIS. (uday@incois.gov.in, venkat@incois.gov.in)

Ocean Circulation

Multi-Scale Temporal Variability of Ocean Dynamical Processes in the Eastern Equatorial Indian Ocean

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The Indian Ocean is dominated by reversing monsoon system, and has complex circulation systems and air-sea interaction processes that significantly modulate global climate. As global warming continues, variability of circulation responding to seasonal monsoon and climate variability becomes more significant. Ecosystem of the Eastern Equatorial Indian Ocean (EEIO) also evolve tightly with the marine environments. However, EEIO has not yet been comprehensively explored relative to the Pacific Ocean and Atlantic Ocean due to lack of in-situ observations, and understanding of variability of circulation and ecosystem evolution remains limited. To explore the Indian Ocean dynamics, in winter of 2019/2020, we conducted a Joint Advanced Marine and Ecological Studies (JAMES) in the Bay of Bengal (BOB) and EEIO (Figure-1). Collaborated internationally with Myanmar, Sri Lanka and Thailand, this project aims to improve the understanding of multi-scale oceanic processes and ecosystem status in the EEIO through a multi-disciplinary scientific approach; and impacts of multi-scale oceanic processes on the marine ecological environment and climate of the Indian Ocean are aimed to be explored.

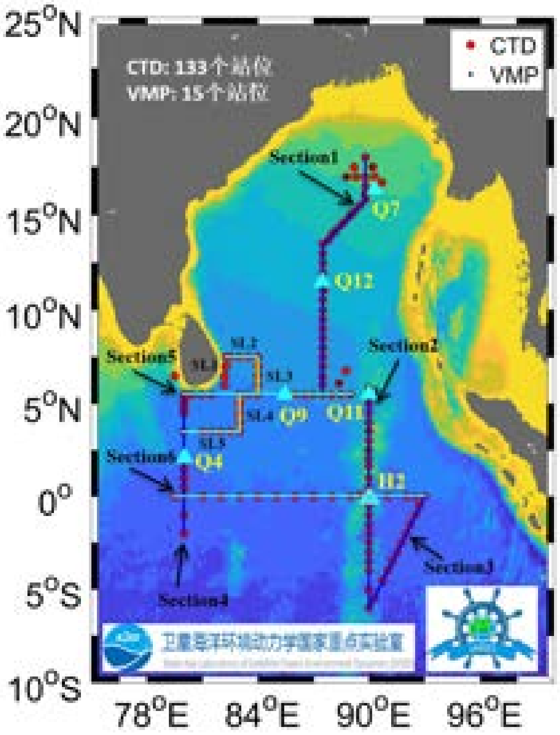

Figure-1: Network of Tide gauges locations in Indian Ocean

Based on the JAMES survey cruise, we have recently made new progress in understanding multi-scale oceanic processes in the EEIO, such as temporal variability of bottom current through the equatorial gap of the Ninety East Ridge, and upper oceanic response to tropical cyclone in the BOB. As is well known, large-scale overturning circulation in the ocean plays a crucial role in global oceanic energy transport, carbon cycling, and climate regulation. Deep oceanic currents constitute an important component of deep branches of oceanic large-scale overturning circulation that are key factor to global climate change. The Ninety East Ridge, located in the eastern Indian Ocean, divides the eastern Indian Ocean into the Central Indian Basin (CIB) and West Australian Basin (WAB); and deep water exchange occurs between the two basins through several major gaps in the Ninety East Ridge. Water mass exchanges through the gaps in the Ninety East Ridge are critical to deep water properties in the CIB and WAB. Despite the importance of water mass exchanges through the gaps in the Ninety East Ridge, little is known about their temporal variability, as direct, long-term measurements are sparse. Based on long-term bottom mooring deployed during the JAMES survey cruise (mooring H2 displayed in Figure-1), we provide a description of bottom current at the equatorial gap in the Ninety East Ridge and reveal its significant intraseasonal variability (ISV) with period of approximately 33 days, which is notably enhanced during summer and winter. Influenced by monsoons, rich seasonal oscillation signals are found in the upper ocean in the EEIO. Utilizing sea surface height data, we established a close connection between the intraseasonal variability of the bottom current at the equatorial gap of the Ninety East Ridge and upper ocean dynamic processes (Figure-2). Due to surface wind forcing, Kelvin waves are generated and propagate eastward in the upper ocean of the EEIO, reflecting at the eastern boundary to form westward Rossby waves. Westward-propagating Rossby waves can transmit intraseasonal oscillation signals from the upper ocean to the deep ocean, thereby enhancing the intraseasonal oscillation signals of bottom currents at the equatorial gap of the Ninety East Ridge (Figure-3). As an important component of water mass exchange between the CIB and WAB and a potential component of the Indian Ocean deep meridional overturning circulation (DMOC), the bottom current revealed in our study will not only help us understand the renewal of the deep water and modification of the deep circulation in the CIB and WAB, but also provide us comprehensive knowledge of the pathway and variation of the DMOC.

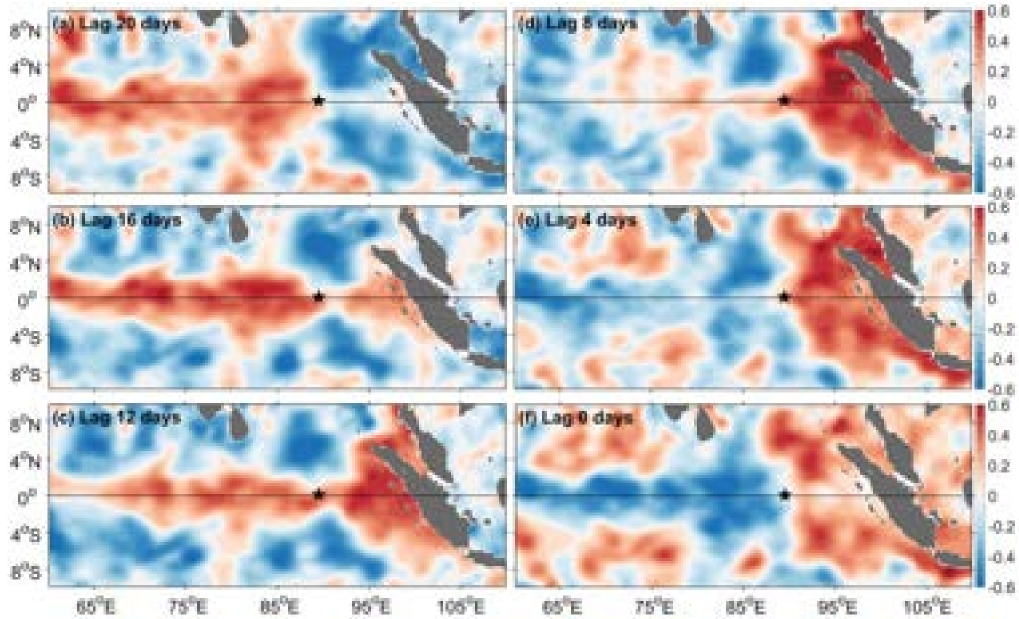

Figure-2: Correlations between the intraseasonal zonal velocities of the bottom current at NR and intraseasonal SSH with (a) 20 days lag, (b) 16 days lag, (c) 12 days lag, (d) 8 days lag, (e) 4 days lag, (f) 0 days lag. The black star denotes the location of the mooring at NR.

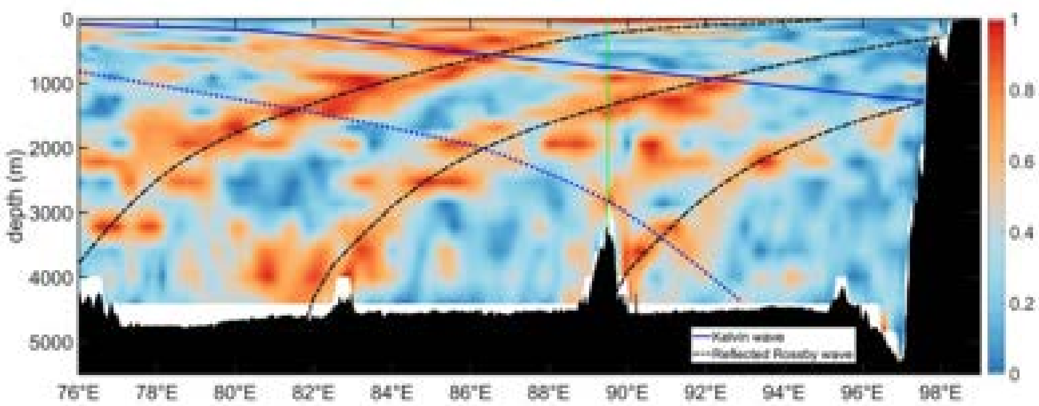

Figure-3: Longitude-depth of the standard deviation of zonal current variability at 33-day period from July to August 2020.

The standard deviation of the current variability is normalised at each depth. The dashed black lines indicate the ray path of reflected Rossby wave of the fourth meridional modes, and the slopes are calculated using (2n+1)ω0/Nb(z) for the nth meridional-mode Rossby wave, where ω0 denotes the intraseasonal frequency (33-day period) and Nb(z) the background Brünt-Väisälä frequency profile (based on the N value of the WOD data along the equator). The thin solid blue line displays the potential ray path of Kelvin wave generated in the upper ocean, and the vertical solid green line is the longitude of the mooring in this study.

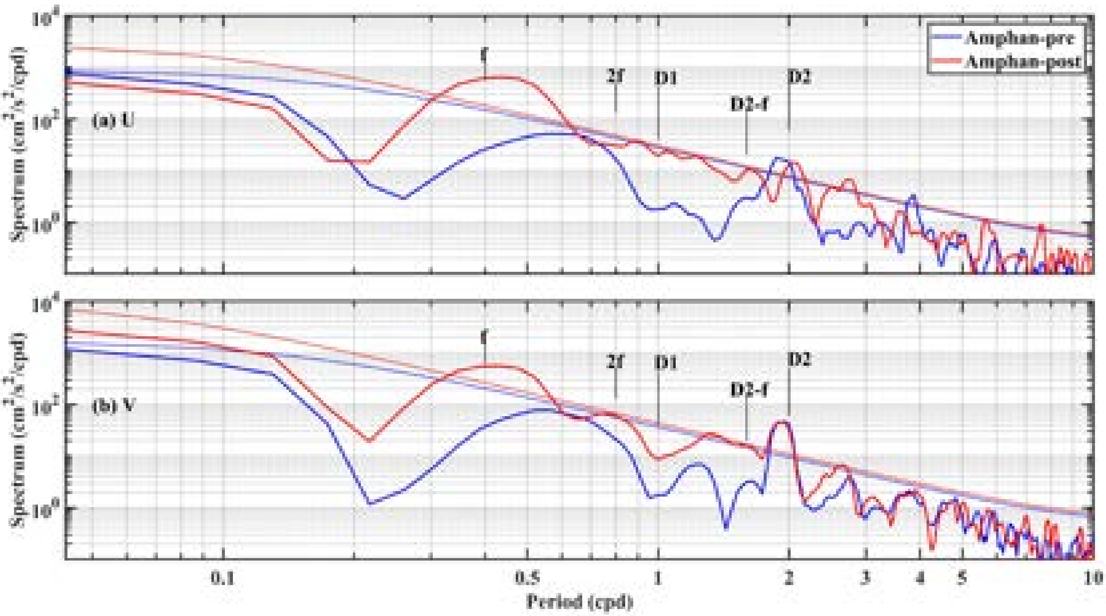

Figure-4: Depth-averaged power spectra (top layer to 122.6 m) of the U (a) and V (b) Amphan-pre (24 April-16 May, blue), Amphan-post (17 May-9 June, red) at the subsurface mooring Q12. The near-inertial wave (f), semi-diurnal tide (D2), diurnal tide (D1), D2-f and 2f are indicated. The smooth curves in blue and red correspond to a confidence level of 95%.

On the other hand, as a key region where air-sea interactions are intense, the BOB experiences the impacts of frequent Tropical Cyclone (TC). Strong TC wind stresses easily cause strong near-inertial oscillations in the mixing layer, and nonlinear interactions between near-inertial waves (NIWs) and internal tides are most common. Though the importance of TC on the air-sea interactions in the BOB, understanding of the upper ocean response to TC in the BOB remains limited due to lack of in-situ observation; complex interaction between TC-induced NIWs and internal tides in the BOB is not yet fully understood. Fortunately, one subsurface mooring (Q12 displayed in Figure-1) deployed during JAMES survey cruise monitored the ocean dynamic response to the TC Amphan (2020). Amphan was the first super cyclone to occur in the BOB since Odisha super cyclone in 1999. Moored observations showed the cold suction effect by strong upwelling, with the 13 °C isotherm increasing by about 50 m after the TC Amphan, resulting in substantial cooling throughout the thermohaline chain (150-800 m). At depths above 150-200 m, salinity increased during the TC Amphan, with a maximum increase in salinity of about 0.16 psu. The average depth power spectrum showed that the near-inertial band had a significant peak after the passage of Amphan (Figure-4).

The maximum near-inertial velocity triggered by Amphan was about 0.34 m/s at 122.6 m, and the maximum velocity amplitude was about 0.24 m/s. The e-folding decay time scale of the velocity was about 5.5 days. The wavelet power spectrum and bicoherence analysis indicated that, the nonlinear wave-wave interaction between NIWs (f) and semi-diurnal tide (D2), as well as the self-interaction of NIWs were enhanced after the passage of the TC Amphan (Figure-5). Although our mooring was not at the critical latitude, self-interaction still occurred, which could be related the positive relative vorticity that Amphan continued to input into the ocean (Figure-5).

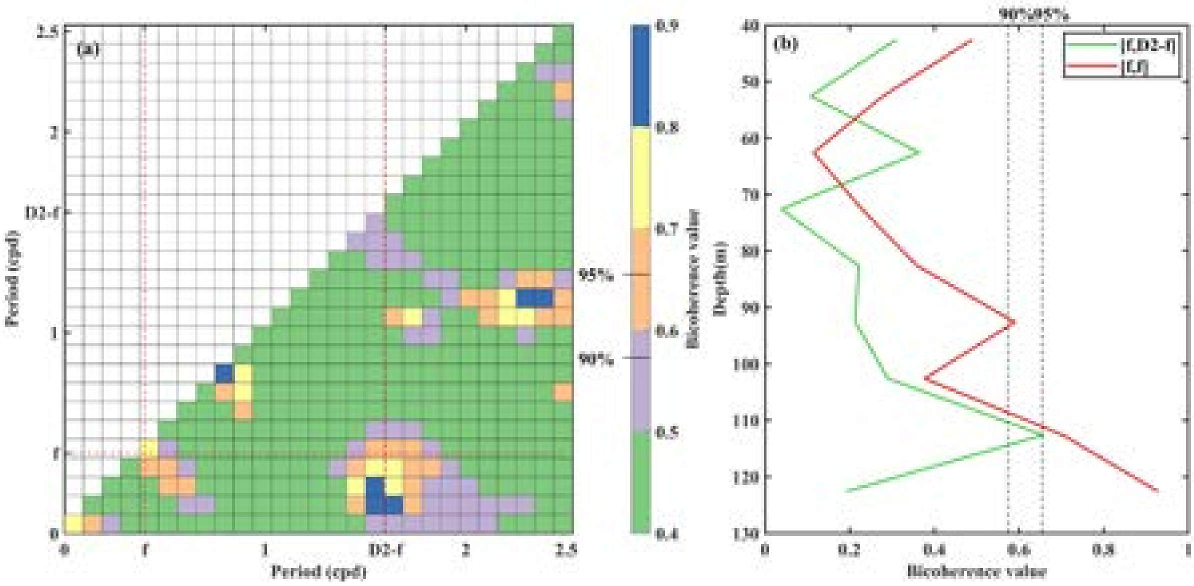

Figure-5: (a) Average bicoherence of u(t) and v(t) using the data obtained at 112.6 m at Mooring Q12. The 90% and 95% statistical significance levels are indicated in the colour bar. (b) Vertical profiles of bicoherence near the [f,f] and [f,D2-f] frequency pairs. The vertical dashed lines indicate the 90% and 95% significance levels.

The nonlinear wave-wave interaction processes were able to transfer energy to higher mode internal waves, thus accelerating energy attenuation. Hence, the observed e-folding time for near inertial kinetic energy (6.2 days) was only 41% of the theoretical e-folding time. Our study provided new evidence for the mechanism of energy dissipation of NIWs and semi-diurnal tide during a TC condition in the southern BOB. In the future, observational and numerical methods are needed to further investigate the dynamic properties and nonlinear interactions of the NIWs in the BOB.

In conclusion, with the existence of multi-scale ocean processes, the Indian Ocean has complex dynamics that impact air-sea interactions modulating the global climate; and systematic exploration of the Indian Ocean dynamics can significantly contribute to further development of global climate model. In the future, based on the JAMES survey cruise, we will continue to concentrate on analysis of the multi-scale oceanic processes in the EEIO, and positively share our study work in the Indian Ocean Bubble 2 with other researchers, hoping to create further collaborations with international oceanographers.

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Impact of Bathymetry on Indian Ocean Circulation in a Nested Regional Ocean Model

Hasibur Rahman, INCOIS

The ocean affects the weather and climate. Understanding the ocean is crucial for accurate weather and climate forecasts. The main transport mode for global trade is through ocean by shipping. Around 90% of traded goods are carried over the ocean by shipping. Maritime transport forms part of a whole cluster of economic activities that can create economic value added. On the other hand, shipping represents 2.9% of total greenhouse emissions. As demand for global freight increases, maritime trade volumes are set to triple by 2050. With almost saturated land resources for food and other essential human needs, the ocean is the new economic frontier. It holds the promise of immense resource wealth and great potential for boosting economic growth, employment and innovation.

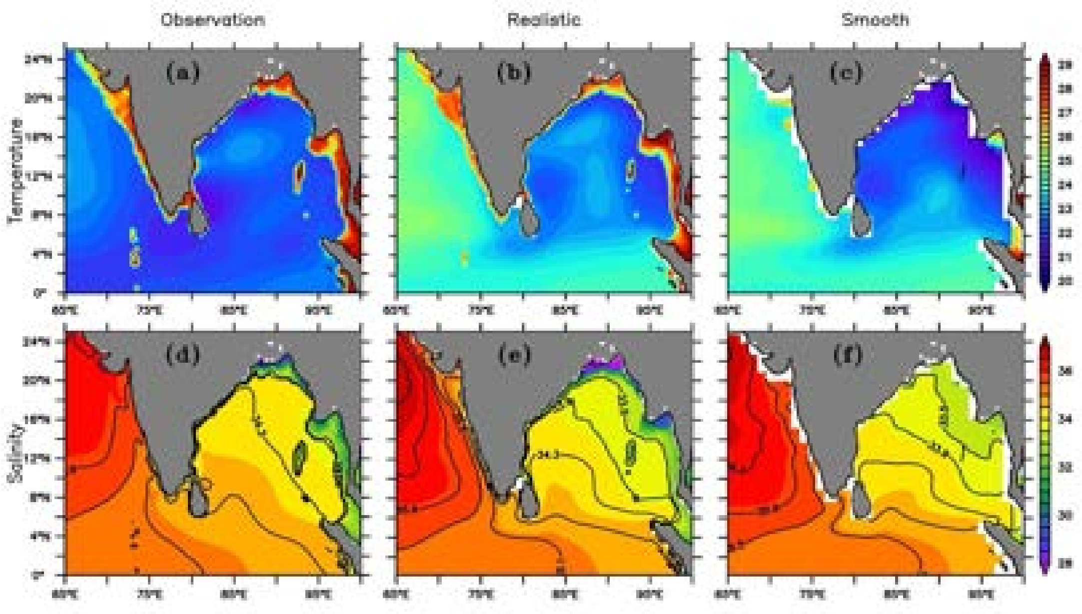


Figure-1: The upper ocean temperature and salinity for observation, Realistic bathymetry and Smoothened bathymetry.

it is increasingly recognised as indispensable for addressing many of the global challenges facing the planet in the decades to come, from world food security and climate change to the provision of energy, natural resources and improved medical care. While the potential of the ocean to help meet these challenges is huge, it is already under stress from over exploitation, pollution, declining biodiversity and climate change. Realising the full potential of the ocean will therefore demand responsible, sustainable approaches to its economic development.

Hence for both weather and climate prediction and for the maritime industry ocean plays a very critical role in the survival of mankind. Due to the vast economic benefits planning of maritime activities, it is essential to accurately forecast specific oceanographic parameters such as currents, temperature, and salinity of surface and subsurface on different time scales. For better prediction, the essential requirements are enhanced observations and improved models. In recent times, through the IndOOS programme, Indian Ocean observing systems have now been reasonably well represented on a space-time scale however, models are still unable to simulate its mean and variability accurately. Ocean model simulation errors are mainly caused by errors in forcing fields, model physics, numeric, and the representation of bathymetry. With the aim of improving the models, this study focuses on the importance of realistic representation of bathymetry in circulation models. In our recent paper published in Nature Scientific Reports, we explored the intricate dynamics of Indian Ocean circulation using advanced computer models. This study focused on how the shape of the ocean floor (bathymetry), impacts the state of the ocean, at the surface, and in the deep oceans. By incorporating more realistic ocean floor shapes into the models, we could achieve more accurate simulations of real-world ocean behaviour. This enhanced understanding allows us to make better predictions of salinity and temperature, particularly near coastal regions (please refer Fig. 1). The ocean currents are improved as well with more realistic bathymetry. The influence of islands, such as the Maldives and Andaman and Nicobar Islands, on ocean currents was also explored, we found that these islands significantly altered the current direction and speed to a greater extent. Additionally, evidence of deep swirling patterns in the ocean depths, which were opposite to surface currents is also noted. The most recent and widely used state-of-the-art modelling centres ocean reanalysis products i,e ORAS5 from ECMWF and SODA from the University of Maryland underestimate the observed coastal currents around India.

Main findings from this study are:

- We show that by the inclusion of realistic bathymetry, there is a significant improvement in the upper ocean salinity, temperature, and currents, particularly near the coast. The bias in the salinity and temperature was reduced to half in BLND simulation compared to OM3, which led to a more realistic East India Coastal Current (EICC).
- We show the first evidence of a basin-wide cyclonic gyre over the Bay of Bengal at 1000 m depth during spring, which is just opposite to that of a basin-wide anti-cyclonic gyre at the surface. We found the presence of poleward EICC during spring at 1000 m and 2000 m depth, which is opposite to that of the surface. The presence of this deeper EICC structure is completely absent during fall.
- We show the presence of a boundary current along the coast of Andaman and Nicobar Island at a depth of 2000 m.
- The observed Wyrtki Jet (WJ) magnitude and spatial structure are most realistically reproduced in BLND simulation as compared to OM3 simulations. Both ORAS5 and SODA reanalysis products underestimate the WJ magnitude.
- The presence of the Maldives Islands is responsible for the westward extent of Equatorial Under Current (EUC). The presence of Maldives also creates wakes on the leeward side in the EUC zonal current.
- During fall, EUC is better defined in the eastern Equatorial Indian Ocean and lies at a depth of between 50 and 100 m, unlike its spring counterpart, in which its core is located slightly deeper, between 100 and 150 m depth.
- During peak summer months, June–July, a strong eastward zonal jet is present at 1000 m depth, similar to Wyrtki Jet (WJ). Inter-monsoon Jets, i.e., spring and fall jets, are also seen but are in the opposite direction, i.e., westward, unlike eastward in WJ.

Overall, this study highlights the importance of bathymetry on ocean general circulation models in advancing our understanding of ocean dynamics and they're by will improve the ocean state forecast, weather, and climate forecast over the Indian Ocean rim countries and subcontinent.

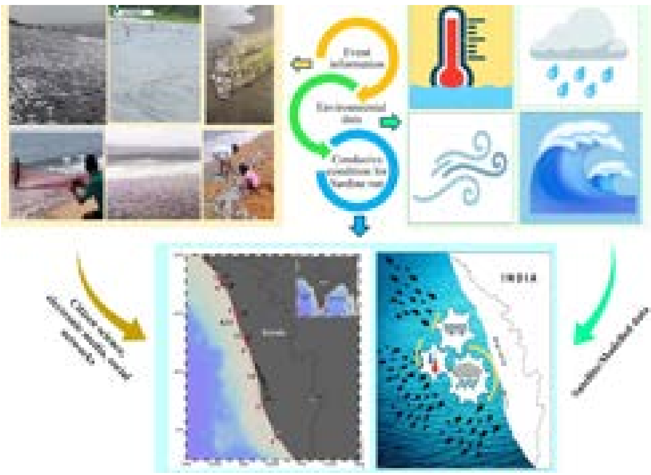
Rahman, R. and Rahaman, H. Impact of bathymetry on Indian Ocean circulation in a nested regional ocean model. Sci Rep 14, 8008 (2024). https://doi.org/10.1038/s41598-024-58464-2

Fish and Fisheries

Exploring the Enigma of the Sardine Run

Bhagyashree Dash, INCOIS

Indian oil Sardine (Sardinella longiceps) is one of the commercially important and favoured fish on the southwest coast of India, particularly on the Kerala coast. As the Malabar upwelling zone (Kerala and Karnataka coast) is one of the heavy upwelling zones, the nutrient-rich conditions attributed to upwelling, favour phytoplankton growth and make this region a productive ground for planktivorous fish such as sardines. However, in several instances, massive aggregations of live sardines are a frequently occurring scenario, especially in the coastal waters of Kerala, including beaching events. These events have been covered by different print and electronic media from time to time. The peculiarities of these events are as in most cases, Indian oil Sardine remained alive and packed at such a high density in the shallow water that they jumped out onto land. These ephemeral events are popularly termed "Sardine Run". In recent decades, these events have been on the rise and raising concern for environmentalists, fisherfolks, fishery resource managers, and local people.



Schematic showing the backtracking of conducive conditions for Sardine Run events.

In order to provide a scientific basis to these events and to investigate the conducive environmental conditions, a team of researchers from the Indian National Centre for Ocean Information Services, IIT Bombay, Kerala University of Fisheries and Ocean Studies, and Berhampur University have carried out a comprehensive retrospective analysis using satellite and model data. Their study highlighted the combined effect of physical, meteorological, and biological parameters in making the environment favourable for these sporadic events to happen. A comprehensive investigation of fourteen events for the year 2022-23 in a remote sensing perspective using the satellite/modelled derived data has been carried out for the Kerala coast collected through various sources. Inferences from the data analysis point towards the ephemeral aggregation events of sardines were attributed to a collective effect of sea surface temperature, precipitation, surface current, and wind. Specifically, the relatively lower temperature conditions in the regions of reported sardine aggregation events and associated local precipitation before most of the events might have attracted sardine shoals toward the near-coastal waters. The coastward sea surface current and wind complemented the propagation of live sardine shoals toward the beach. Despite the data gap at the event location the higher range of phytoplankton biomass in the peripheral region might also be one of the important conducive conditions for these aggregation events. Sardines are known to prefer a specific temperature range in Indian waters which could also be observed during the analysis of these extreme events as the sea surface temperature range was between 26–29 °C during most of the events. Sardines are small pelagic shoaling fishes known to be sensitive to environmental conditions like temperature, current/wind-induced turbulence, and precipitation as they are seasonal migrators. Hence the decrease in sea surface skin temperature, often linked to prior precipitation, along with wind and current towards the coast might have drawn sardine shoals to near-coastal waters resulting in these incidents.

The study also highlighted that anthropogenic perturbations potentially cause habitat degradation resulting in hindrance of organismal movement, and natural long-term effects of climate change, fishing, predation pressure, nearshore processes, and rise in the algal bloom events cannot be ruled out and need further investigation in order to understand sardine dynamics in the coastal waters. These findings highlight the recurring nature of extreme events like sardine beaching, emphasizing the role of oceanographic and climatic factors in controlling regional ecosystem ecology warranting enhanced coastal management and environmental monitoring endeavours. Mass stranding of sardines affects ecosystem balance, revenue loss in fishing, and deters recreational activities and tourism hence managing these events by tracking is vital for environmental conservation and coastal community well-being. Considering that Indian oil sardine fishery supports the livelihood of fishery communities there is an urgent need to effectively implement monitoring strategies in consonance with United Nations Sustainable Development Goal 14 (SDG 14) aimed at the conservation and sustainable exploitation of marine resources for the economic and social development of coastal populations.

To comprehensively study both the natural and anthropogenic effects, a long-term and regular analysis of biogeochemical parameters monitored with the aid of an autonomous coastal water quality observatory is the foremost task to unravel Indian oil sardine dynamics. Regionally parameterized coupled ocean hydrodynamic-biogeochemical ocean models and high-resolution satellite data can provide better insights into these sardine aggregation events in the future.

Source

Baliarsingh, S.K., Dash, B., Jena, A.K., Raulo, S., Samanta, A., Joseph, S., Balakrishnan Nair, T.M., Srichandan, S. & Sureshkumar, S. (2024). Investigating Indian oil sardine aggregation events in coastal waters of the southeastern Arabian Sea. Environmental Science and Pollution Research (2024). https://doi.org/10.1007/s11356-024-33519-z

Report Courtesy

Dr. Bhagyashree Dash (b.dash-p@incois.gov.in), Ms. Susmita Raulo (s.raulo-p@incois.gov.in), INCOIS, Hyderabad & Dr. Suchismita Srichandan, Berhmapur University, Odisha (suchismita.sima@gmail.com).

Tribute

The Journey of Oceanographer K. Megan McArthur

T. A. Peshala Ranmini

Department of Fisheries and Aquatic Resources of Sri Lanka

Introduction

Humanity has always been fascinated by the vastness of the oceans, which have always beckoned explorers to discover their mysteries and secrets. K. Megan McArthur, a well-known oceanographer whose curiosity for the oceans has driven her on an incredible voyage of exploration and discovery, is one of those drawn to the mysterious depths. This exploration of the life and accomplishments of K. Megan McArthur charts her journey from scientific curiosity to accomplished oceanographer.

Early Life and Education

K. Megan McArthur was raised in the United States and showed an early interest in the natural world. Her early years were characterized by a voracious curiosity about the oceans and their inhabitants, which sparked a passion for travel and learning that has lasted a lifetime. Her future pursuits in the field of oceanography were made possible by this early interest. McArthur went after her education with great fervor, graduating from the University of California, Los Angeles (UCLA) with a bachelor's degree in Aerospace Engineering and the University of California, San Diego (UCSD) with a master's and doctorate in Oceanography. Her multidisciplinary education in oceanography and engineering gave her a special skill set that combined a thorough grasp of the marine sciences with technical proficiency.

Career and Achievements

McArthur's career has been marked by a wide range of positions and accomplishments in the oceanography domain. Her contributions to our knowledge of marine ecosystems, ocean dynamics, and the effects of climate change on aquatic environments have been substantial.

McArthur made a significant contribution by working on the creation and application of cutting-edge oceanographic instruments. Because of her engineering expertise, researchers have been able to collect and analyze data with unprecedented precision and accuracy by designing and implementing cutting-edge tools. Apart from her contributions to instrument development, McArthur has carried out innovative studies on diverse facets of marine biology and oceanography. Her research has covered a wide range of subjects, such as the behavior of marine life, how ocean currents affect ecosystem dynamics, and how the oceans affect the regulation of the world's climate. In addition to working with government agencies, non-profits, and business partners, McArthur has undertaken research projects outside of academic institutions in order to address urgent environmental challenges. Her interdisciplinary methodology and collaborative demeanour have established her as a highly esteemed figure within the field, winning accolades for her contributions to conservation and marine science.

Space Exploration and Beyond

K. Megan McArthur's distinguished career has been further enhanced by her foray into space exploration in addition to her work in oceanography. She was chosen as a NASA astronaut candidate in 2000, and she started a demanding training program to get ready for space missions. Extravehicular activity (EVA), spacecraft operation, and scientific research in microgravity environments were all part of McArthur's astronaut training. Throughout this training, her background in oceanography and engineering proved invaluable as she applied her knowledge to the difficulties of space exploration. As a mission specialist on board the Space Shuttle Atlantis, McArthur made her space debut in 2009. She was instrumental in the upkeep and modernization of the venerable scientific instrument, the Hubble Space Telescope, during the STS-125 mission. Her work increased the telescope's useful life and improved its astronomical research capabilities. Because of her space exploration background, McArthur has a distinct viewpoint on the oceans of Earth and how they are related to the rest of the universe. Her space observations have brought to light the interdependence of the ecosystems on our planet and the pressing need for sustainable management of its natural resources.

Legacy and Inspiration

K. Megan McArthur is a trailblazing astronaut and oceanographer who has made a lasting impact on science and exploration. Numerous people have been motivated to pursue careers in STEM (Science, Technology, Engineering, and Mathematics) fields by her unwavering dedication to understanding the oceans and advancing human knowledge. McArthur's voyage is proof of the ability to discover the mysteries of the natural world through curiosity, tenacity, and multidisciplinary cooperation. Her ability to move between the fields of oceanography and space exploration with ease is a prime example of the infinite possibilities that come with scientific research and exploration. To sum up, K. Megan McArthur's life and accomplishments serve as a brilliant illustration of the revolutionary power of scientific inquiry and discovery. She has always been an example of the spirit of inquiry and discovery that propels people to explore the uncharted territory, from her early fascination with the seas to her groundbreaking work in space exploration. McArthur's legacy inspires future generations to reach for the stars and delve into the ocean's depths in quest of knowledge and understanding, as we continue to navigate the complexity of our planet and beyond.

UN Ocean Decade

UN OCEAN DECADE CONFERENCE, Barcelona (Spain) 08-10 April 2024 & IO-CON 24, Hyderabad (India) 01-03 February 2024

India was one of the 40 member states that had supported the resolution to establish IOC (Intergovernmental Oceanographic Commission) under UNESCO in 1961. India has been actively involved in IOC matters. Ministry of Earth Sciences (MoES) is India's nodal agency for the IOC's activities through its Indian National Centre for Ocean Information Services (INCOIS). Dr. M. Ravichandran (Secretary, MoES) is the primary focal point of India to the IOC-UNESCO, with Dr. T. Srinivasa Kumar (Director, INCOIS) being the secondary focal point. India and Indian Experts currently hold several important leadership positions of the IOC and its subsidiary bodies, including as the Executive Member of the IOC, Vice-Chairperson of IOC (Electoral Group IV), Chair of the UN Ocean Decade Tsunami Programme Scientific Committee (ODTP SC), IOGOOS, TOWS-WG and IOC WMO Joint Collaborative Board (JCB), in addition to membership of several other important working groups and task teams.

The IOC executive council meeting during Feb 3-9, 2021, India along with Germany, Norway, Argentina, and Morocco were the initial supporters of the draft resolution [EC-53/4.1] to support implementation of United Nations Decade of Ocean Science for sustainable development (2021-2030). ***India has been actively supporting the activities of UN Ocean Decade by constituting one of the earliest globally National Decade Coordination Committee (NDCC) and established the UN Ocean Decade Collaborative Centre for Indian Ocean Region (DCC-IOR) – the only geographic DCC covering entire major ocean basin.***

Within months of its formal launch, during 1-3 Feb 2024, the DCC-IOR at INCOIS, Hyderabad organized Indian Ocean Regional Decade Conference (IO-Con 2024) as an official prelude to the 2024 Ocean Decade Conference that was scheduled by IOC-UNESCO at Barcelona, Spain later in April 2024. ***Following the trait of many firsts by India for the UN Ocean Decade, this conference was also first-ever in-person international (regional) UN Ocean Decade conference in the Indian Ocean.*** During this policy conference, more than three hundred delegates from India and abroad brainstormed on the ocean decade challenges through the dedicated sessions. These discussions also contributed significantly to the review of Vision2030 draft white papers prepared by ocean decade challenge-oriented working groups. Additionally, there were two special sessions organized each focusing on a) the NDCs (National Decade Committees) and b) various regional frameworks in the IOR. Further, a side-event for young researchers was organized collaboratively by IIOE2-ECSN and ECOPs programme.

Three years after the start of the UN Decade of Ocean Science for Sustainable Development (2021-2030), a global conference was held to bring together the Ocean Decade community and partners to celebrate achievements and set joint priorities for the future of the Decade. Focused on Delivering the science we need for the ocean we want', the 2024 Ocean Decade Conference (2024-ODC), 10-12 Apr 2024, was one of the major event highlights of Ocean Decade Week (8-12 Apr 2024) that took place throughout Barcelona city.

The Indian delegation led by Secretary, MoES engaged with delegations and teams representing various countries and international forums throughout the Ocean Decade Week. One of the important on-site events at 2024-ODC was '***Bridging Billions to Barcelona'*** led by DCC-IOR. This session underlined the outcomes of the IO-Con 2024 at Hyderabad earlier and projected the requirements of the billions that reside in the rim-countries of the Indian Ocean region.

In addition, the delegation actively contributed to various other events viz, Invitation-only meeting of DCCs and DCOs, NDC showcase event and workshop, Eleventh GOOS Regional Alliance Forum (GRF-XI), as well as events by DCC-IOR partners such as UNESCO-IOC Tsunami Ready Recognition Programme (TRRP) led '*Coastal Cities and Communities Joining Tsunami Ready*'; IOC-UNESCO's Decade Coordination Unit (DCU) led '*Cities with Ocean' initiative;* DCC-Coastal Resilience (Univ. of Bologna, Italy) led *'Coastal futures: Charting priorities for coastal resilience*'; IOCINDIO led '*Enhancing coastal resilience in the Indian Ocean: Key contributions of ocean and climate sciences to institutional capacity development as a vital solution to coastal vulnerability and climate change*'; DCC-Ocean Predict (Mercator Ocean Intl., France) led '*Connecting the world around ocean prediction: A vision for the Decade and beyond*'; IMR, Norway led '*Linking science, policy and stakeholders for a sustainable ocean*'; G20-Brasil led '*Unveiling the Role of G20 in the Implementation and Legacy of the Ocean Decade*'; European Marine Board led '*Supporting a global collective vision for ocean science by matching regional priorities*'; World Ocean Council (WOC) led '*SMART Ocean – SMART Industries'* - to name a few.

Through such engagements India has not only reaffirmed its commitment to the UN and the Ocean Decade, but also underlined its importance and leadership in the ocean science of the IO region.

Additional Resources

Barcelona (2024 ODC official) statement: https://oceanexpert.org/document/34098

Draft IO-Con 2024 report (being finalized with stakeholders the Indian delegation engaged with at 2024 ODC): https://docs.google.com/document/d/15xgQMurBCs-Ymc6W8q0350Fjza1-a6gp/

Event Report

One Day Workshop and Outreach Events of National Space Day 2024 INCOIS as MoES Focal, 06 August 2024

As announced by the Hon'ble Prime Minister, the Government of India has declared 23rd August of every year as "National Space Day" to commemorate the success of Chandrayaan-3 mission, which accomplished safe & soft-landing of Vikram Lander at 'Shiv Shakti' point (Station Shiv Shakti) & deployment of Pragyaan Rover on the lunar surface on August 23, 2023. Being the maiden National Space Day, it was planned to organise widespread celebrations throughout the country in the month of August 2024. The objective was to engage & inspire the youth of the nation towards space technology & its applications. The theme for the National Space Day-2024 is "Touching Lives while Touching the Moon: India's Space Saga".

Photo: National Space Day 2024 event inauguration at INCOIS, Hyderabad by Dr. Ravichandran M (Secy, MoES) in presence of former secretaries Dr. Shailesh Nayak and Dr. Harsh K Gupta and Directors of INCOIS and NRSC among other dignitaries.

Photo: National Space Day 2024 remarks by Dr. Prakash Chauhan, Director, ISRO-NRSC, Hyd

Photo: National Space Day 2024 at INCOIS, Hyd: audience engagement in scientific talks

In this context, as a focal for Ministry of Earth Sciences, the Indian National Centre for Ocean Information Services organized a One-Day workshop "Applications of space technology for Earth System" on 6 August 2024 at INCOIS, Hyderabad, India. The workshop coincided with multiple outreach activities. A detailed agenda is provided herewith (Annexure-1). INCOIS had been identified as a focal due to being one of the prime users for the India's Ocean remote sensing satellites, the Oceansat series, to meet its mandate of providing operational ocean information and advisory services to a wide range of stakeholders not only from the nation, but also in the Indian Ocean region. INCOIS collaborated and successfully completed this event with ISRO agency in the city, National Remote Sensing Centre (NRSC).

Photo: National Space Day 2024 event inaugural at INCOIS, Hyderabad by Dr. Ravichandran M (Secy, MoES) in presence of former secretaries Dr. Shailesh Nayak and Dr. Harsh K Gupta and Directors of INCOIS and NRSC among other dignitaries.

In addition to the directors of both of the host institutes, the event witnessed eminent scientists of the country gracing the occasion in-person or virtually, including but not limited to the directors of both ISRO and MoES institutions. While delivering the keynote talk, Dr. Shailesh Nayak (former Secretary, MoES and Director, NIAS, Bengaluru) emphasised the importance of satellite data in earth and ocean system monitoring and the importance of continuous data availability. Dr. M. Ravichandran (Secretary, MoES) talked about the advancement of remote sensing in the past decades and the need of the hour being the development of Blue Economy mission from ocean resources, monsoon mission for the atmosphere and polar mission for the solid earth in his inaugural address. With the considerable presence and engaging panel comprised of space-tech industry partners and start-ups, the program also aligned with India's trust areas such as 'Make in India' and '***Atma-Nirbhar Bharat***'. A total of 11 (eleven) industry representatives participated in the event. The audience was not limited to the researchers, but also college students invited to these sessions with special intention to ignite these young minds towards country's space saga.

Photo: National Space Day 2024 high-school student visitors with exhibits by ISRO-NRSC at INCOIS, Hyderabad

Photo: National Space Day 2024 exhibits of Moon & space-suit by ISRO-NRSC at INCOIS, Hyderabad

Photo: National Space Day 2024 'Space on Wheels' by ISRO-NRSC at INCOIS, Hyderabad

The outreach component of the celebrations was achieved through Ideathon and Painting competitions, as well as educational visits specially arranged for high-school students. A total of more than 200 students from 15 schools participated in these events combined. As an encouragement to the budding citizens, prizes were given to them through the dignitaries. Outreach kits along with participation certificates were also distributed to all the students. The visit had major attractions from both of the hosts such as virtual space experiences (3D animated globe with satellite data depiction), ISRO's famous 'Space on Wheels' bus along with scaled models of rockets and satellites, as well as a giant 'moon' balloon as a reminder of the motive of the National Space Day.

Dr. Srinivasa Kumar T (Director, INCOIS) appreciated the support from ISRO-NRSC, Hyderabad and thanked the team lead by Dr. Balakrishnan TM Nair (Group Director, INCOIS) for meticulous planning and a memorable event.

Photo: National Space Day 2024 Ideathon Competition at INCOIS, Hyderabad

Photo: National Space Day 2024 Painting Competition at INCOIS, Hyderabad

Resources

Live-stream Archive of the Event: https://www.youtube.com/live/rCBVGxPPyWA

ISRO National Space Day 2024 portal listing zone-wise events including this event (in Zone-6): https://www.isro.gov.in/NSPD2024/NSPDLogo.html

A panel on IOGOOS-GOOS AFRICA & IOCINDIA-IOCAFRICA was hosted during 4th US-West Africa Coastal Resilience Research Consortium International Workshop at Lagos State University, Nigeria, 19-21 August 2024. INCOIS Scientist Dr. Nimit Kumar Delivered a Talk on India's Contributions to these Frameworks in the IOR.

This three-day hybrid (in-person and virtual) workshop was jointly hosted by multiple institutions in Nigeria led by Lagos State University (LASU). Major co-sponsors of the workshop included the Federal Ministry of Marine & Blue Economy, the National Space Research and Development Agency (NASRDA) Nigeria, Nigerian Meteorological Agency (NIMET), Nigerian Maritime Administration and Safety Agency (NIMASA), Nigerian Institute for Oceanography and Marine Research (NIOMR), Ministry of Environment and Water Resources Lagos State, Ministry of Health Lagos State, and several universities in Nigeria, including University of Benin, Igbinedion University Okada, University of Calabar, University of Port Harcourt, Rivers State University, and Niger Delta University.

This workshop was organized by the CRRC as a contribution to the UN Decade of Ocean Science for Sustainable Development. Collaborating partners include UN agencies, multilateral and intergovernmental organizations, international marine/ocean science institutions/organizations such as the African Development Bank (AfDB), the

African Union Commission (AUC), Intergovernmental Oceanographic Commission (IOC) of UNESCO; the Decade Collaborative Center for Coastal Resilience (DCC-CR) Bologna, Italy; Global Ocean Observing System (GOOS)-Africa; Nansen-Tutu Centre for Marine Environmental Research Cape Town, South Africa; Centre for Coastal Management Cape Coast, Ghana; and several other institutions in the Global South.

IOC-UNESCO during its 32nd session of Assembly, a resolution is approved for the elevation of the IOC Regional Committee for the Central Indian Ocean (IOCINDIO) to be the IOC Sub Commission for the Central Indian Ocean. It is to be noted here that Intergovernmental Oceanographic Commission (IOC) Regional Committee for the Central Indian Ocean (IOCINDIO) was reactivated in 2016, and the member institutes have strongly supported for its elevation to Sub Commission of IOC. IOCINDIO has held couple of meetings and had discussions on commemoration of launch of the Sub-commission. At these meetings, several of the representatives from member states participated along with members from IOGOOS, WMO and IOCINDIO. In the neighbourhood of IOCINDIO working region, IOCAFICA is already established sub-commission. Further, under the GOOS framework, IOGOOS and GOOS-AFRICA work in tandem as applicable. Additionally, INCOIS hosts IOGOOS secretariate (along with projects offices of its initiatives such as IIOE-2 and SIBER) as well as UN Ocean Decade Collaborative Centre for the Indian Ocean Region (DCC-IOR). The DCC-IOR (headed by Dr. Srinivasa Kumar T) has worked with DCC-CR (headed by Dr. Nadia Pinardi) in preparing the white paper for Vision2030 working group for Challenge-6 pertaining to coastal resilience, being led by the heads of both the DCCs.

In these contexts, Dr. Nimit Kumar, in his talk, elaborated on these linkages and drew parallels on south-south cooperation that African and Asian nations may mutually benefit from. He also described on the IOGOOS experience of IIOE-2, establishment of Early Career Scientists' Network (ECSN) as well as the aspirations from the region with coming years of IOCINDIO. At the end of his talk Mr. Justin Ahanhanzho (Programme Specialist, IOC-UNESCO, Paris) noted that INCOIS is working with IOC-UNESCO on a proposal to host international delegation of researchers on Indian ship and called for closer cooperation between GOOS counterparts as well as IOC sub-commissions from Africa and the Indian Ocean.

News Updates

IOPredict-2024- An International Oceanography Workshop: First Announcement Empowering the Next Wave of Indian Ocean Prediction

We are excited to announce the upcoming 'IOPredict-2024' workshop, organized by International Training Centre for Operational Oceanography, INCOIS, a Category-2-Centre of UNESCO during 9-13 December 2024 at ITCOcean, INCOIS Campus, Hyderabad, India. This international event will bring experts, early career researchers and students together to share new research and ideas in ocean processes, modelling and prediction to address important challenges in ocean sciences and its contribution to the Blue Economy.

This five-day workshop will provide a unique opportunity for early career researchers and students to learn various aspects of ocean modelling and data assimilation and their applications. Participants will engage in stimulating discussions, exchange of ideas and expertise and build lasting connections. The workshop will feature invited talks from leading experts in ocean sciences, offering insights and guidance on critical topics.

Additionally, a special three-day pre-conference tutorial to provide training on scientific data analysis, interpretation, scientific writing and presentation will also be conducted during 4-6 December 2024.

Workshop Themes

- Ocean General Circulation modelling
- Ocean Processes and Observation
- Wave, Storm Surge and Coastal Ocean Processes and Modelling
- Data Assimilation and Data Driven Methods
- Marine Biogeochemistry
- Operational Ocean Services and Blue Economy

In addition to the lectures by leading experts in the field, participants also will get the opportunity to showcase their research and innovative approaches either as oral or poster presentations at IOPredict-2024.

Who can Attend?

The workshop primarily targets Early Career Researchers and Students. The participants are encouraged to secure their own funds to enable their participation in the workshop. However, we will provide limited financial assistance to eligible candidates to cover either fully or partially their travel, accommodation and local expenses.

Mark Your Calendar

- Registration Opens: 2nd September 2024
- Registration Closes: 30th September 2024
- Intimation of selection: 5th October 2024
- Pre-conference Tutorial: 4-6 December 2024
- Workshop: 9-13 December 2024

Applicants will be required to register for the event by filling up the google form at this link:

https://docs.google.com/forms/d/e/1FAIpQLSdbgZvgU5fZq-tQ7oeMraFtA--tyVZks5mcJcn45iH3Ad0pfg/viewform

Do not forget to upload a personal statement describing their academic/professional background and how IOPredict-'24 will help you in advancing your research career in ocean sciences. Since there are only limited vacancies available for pre-conference tutorial and workshop, selection will be based on this personal statement. It is planned to have a limited number of contributed presentations (oral/poster form) from the participants during the workshop.

Selected abstracts will be part of the conference proceedings/abstract volume. Those who wish to present an original research work may please indicate the same in the google form and upload an abstract of the research (not exceeding 250 words). More information on the conference will be available at https://incois.gov.in/ITCOocean/IOPredict2024.jsp

Agulhas Current Observing System Design Workshop

As a part of the Ocean Observing Co-Design Programme, Agulhas Current Observing System Design Workshop is being organised during 9 – 12 Sep 2024 at Cape Town, South Africa. The Programme aims to evolve the ocean observing system so that it is co-designed with end-users and responds to their needs. Six exemplars were established under the program that are use areas or societal benefit areas around which we pilot and refine the ocean observing system through establishing co-design processes. The purpose of this workshop is to understand priority gap areas, develop observational requirements and a draft design of an ocean observing system to better understand key features in the Agulhas Current region that influence critical areas e.g., Tropical Cyclones, Marine Life and Marine Heatwaves.

For more information and registration: https://goosocean.org/event/4196

Agenda Overview

- Day 1: Defining the backbone of the Agulhas Current Observing System and prioritise gaps
- Day 2: Introduction into setting Requirements with breakout sessions on observing requirements and data and modeling scheme assessment
- Day 3: Establishing links to societal impacts (e.g., extreme weather, search and rescue, fisheries) and multi platform approaches
- Day 4: Draft design review and stakeholder assessment

Contact:

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PORSEC 2025, Taiwan

16th Pan Ocean Remote Sensing Conference

22nd~ 25th April , 2025

Researchers and experts from all over the world are invited to submit abstracts of papers for the presentation of original research around a specific topic, with/without discussant, via the circulation of open calls for papers. Each session will include limited (ideally 4-5) presentations and can be scheduled for more than one timeslot.

One of the features that makes PORSEC stand apart is that following the conference there is a special issue published of full paper at Tylor & Francis publication's International Journal of Remote Sensing. Being a well-respected peer-reviewed journal, it facilitates visibility to researchers' work at global level through this highly acclaimed platform.

The PORSEC 2025 will simultaneously address ten areas of critical importance to the achieving sustainability development under climate change through ocean remote sensing:

- Large and meso-scale oceanography
- Coastal impacts and management
- Emerging technologies for ocean and coastal applications
- Operational remote sensing
- Ocean-atmosphere interactions
- Remote sensing data for policy making
- Education and outreach
- Artificial intelligence and deep learning
- Fishery resources under climate impact
- Extreme events under climate change
- Application in blue carbon science

Important Due Dates:

01. Early bird registration and abstracts open, 20th September, 2024
02. Early bird registration close, 31st December, 2024
03. Abstract due: 28th February, 2025
04. Accepting letter will be sent by: 15th March, 2025
05. Last date for presenter to register: 28th February, 2025

Contact:

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14th International Conference on Southern Hemisphere Meteorology and Oceanography

CTICC, Cape Town, South Africa

31st March ~ 04th April , 2025

INTERCONNECTED EARTH SYSTEM AND SOCIETY

The NRF-SAEON, along with partner institutions in South Africa, are hosting the 14th International Conference on Southern Hemisphere Meteorology and Oceanography (ICSHMO) from **31 March to 4 April 2025**. The conference will take place at the Cape Town International Convention Centre (CTICC). The conference theme is Interconnected Earth System and Society, the flyer is attached with the website details here.

We are encouraging the submission of abstracts and early bird registrations at this stage. We have a number of oceanography sessions that may be of interest to you and your networks, including Southern Hemisphere Boundary Currents, Air-Sea interactions, Marine Heatwaves, Emerging Technologies, Ocean and Cryosphere interactions, Mesoscale and Submesoscale processes, ocean and ecosystem modelling and prediction. In addition, a number of sessions dedicated to atmospheric interactions are noted including extreme events, extra-tropical processes, and climate change to list only a few.

We would appreciate it if you could advertise this conference through your networks and encourage both established and emerging researchers to apply. Should you have any further questions, please contact the local organising team: icshmo2025@saeon.nrf.ac.za.

Registrations Open

Early bird rates are valid till 30 November 2024

For Registration Assistance Contact: thandeka@confco.co.za

Call for Contributions

Informal articles are invited for the next issue. Contributions referring Indian Ocean studies, cruises, conferences, workshops, tributes to other oceanographers etc. are welcome. Articles may be up to 1500 words in length (MS-Word) accompanied by suitable figures, photos (separate .jpeg files).

Deadline: **20th November, 2024**

Send your contributions as usual to **iioe-2@incois.gov.in**

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N. Kiran Kumar, Nimit Kumar, M. Nagaraja Kumar,
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