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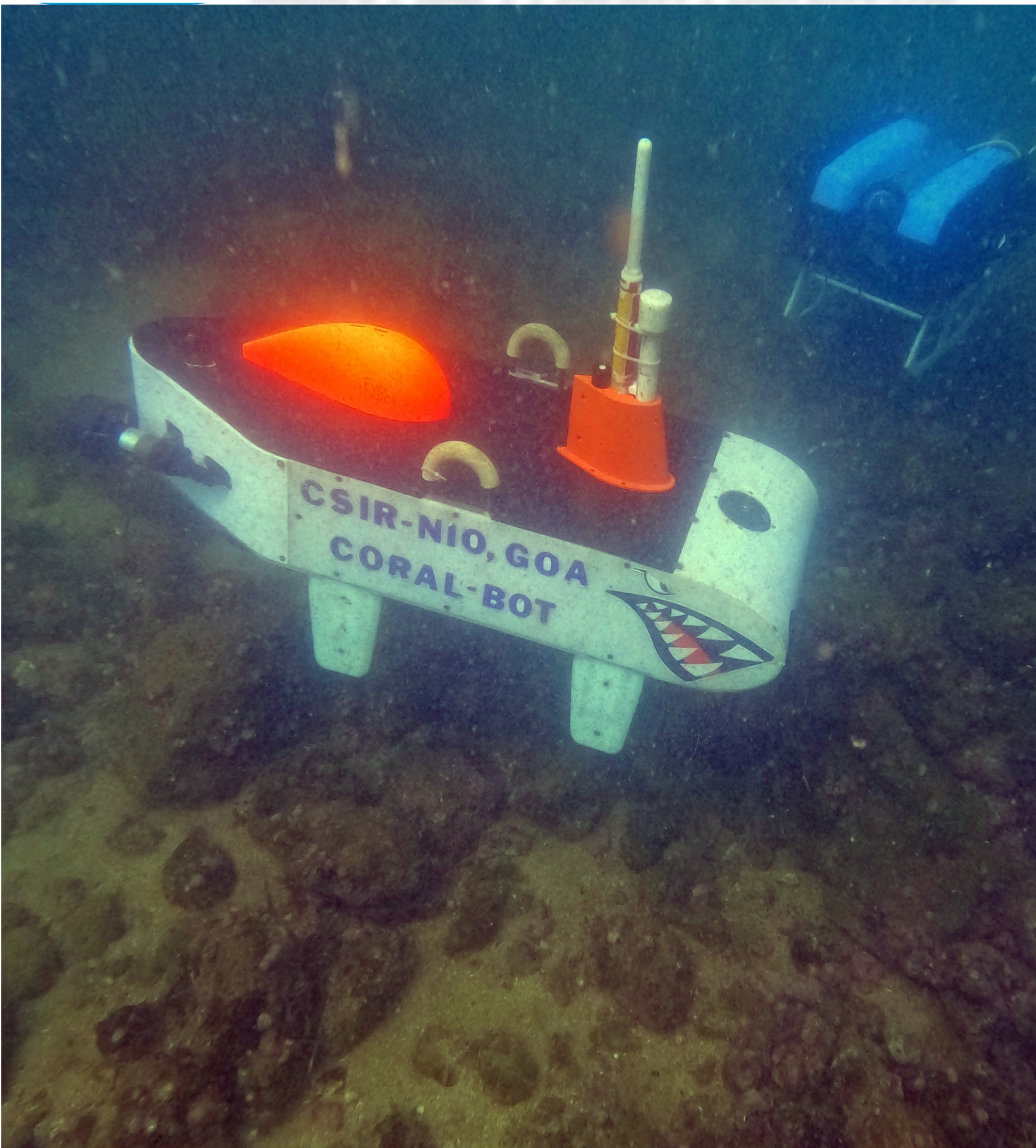

Detecting zooplankton biomass using ship mounted Acoustic Doppler Current Profiler and in-situ net sampling

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Abstract

The present study describes the use of acoustics and in-situ measurements to evaluate mixed-layer zooplankton biomass using Acoustic Doppler Current Profiler (ADCP). This study uses the ADCP profiles and the vertical zooplankton samples collected by the Multi Plankton Net (MPN) on-board the FORV Sagar Sampada in the Eastern Arabian Sea (EAS) during May-June and Sept-Oct 2005. An attempt was made to estimate zooplankton biomass acoustically using the volume backscatter strength [Sv dB re $(4\pi m)^{-1}$] obtained from the Vessel Mounted Broad Band ADCP operating at a frequency of 76.8 kHz. Backscatter intensity was determined using the operational form of the sonar equation. Regression equations providing proxies for zooplankton biomass were derived separately for the May-June and Sept-Oct periods. The estimation was restricted to the water column up to the mixed layer depth (MLD), excluding the upper layer's ringing distance. Additionally, care was taken to filter the Received Signal Strength Indicator (RSSI) to avoid the influence of larger organisms like fish. ADCP transects and net tows were utilized to capture signals from vertically migrating organisms. Comparing the acoustic technique-based estimates of zooplankton biomass with conventional techniques, a closer agreement was observed for the May-June period (correlation coefficient, r=0.58), while a weaker correlation was found for the Sept-Oct period (r=0.25). Additionally, the study highlights the connection between areas exhibiting significant acoustic backscattering and surface characteristics indicative of a productive environment.

Key words: Acoustic Doppler Current Profiler, zooplankton biomass, ecological interactions

1. Introduction

Zooplankton are essential intermediaries in all marine ecosystems, connecting primary producers to higher trophic levels, using their mobility to navigate and avoid predators, and playing a pivotal role in regulating population dynamics and maintaining overall ecosystem balance. To scientifically unravel complex ecological dynamics, it is essential to collect high-resolution zooplankton data using techniques like acoustic remote sensing on similar spatial and temporal scales as other environmental data, ensuring a comprehensive understanding on the marine ecosystems' dynamics. The groundbreaking first investigation by Flagg and Smith (1989) utilized a bottom-mounted ADCP to study zooplankton. Since then, numerous researchers have pioneered similar approaches, leveraging the backscattered acoustic intensity data obtained from ADCPs to explore both temporal and spatial variations in the distribution of zooplankton biomass, as well as to investigate Diel vertical migration patterns (Heywood et al., 1991; Heywood, 1996). In the late 1990s, within the framework of the Joint Global Ocean Flux Study (JGOFS) program, investigations on zooplankton dynamics utilized vessel-mounted ADCPs. These studies were instrumental in examining characteristics such as vertical migration patterns, as documented in works by Morrison et al. (1999) and Smith and Madhupratap (2005). In a recent investigation led by Aparna et al. (2022), a noteworthy analysis employed three moored ADCPs to delineate the seasonal variations in zooplankton biomass and standing stock within the EAS. This study marks the first attempt to quantify mixed-layer zooplankton biomass in the EAS, employing a ship-based ADCP along with in-situ measurements.

2. Data and Methods

Zooplankton sampling was conducted at multiple stations, as illustrated in Fig. 1, on-board FORV Sagar Sampada during the two cruises: May-June (Cruise No. 235) and August-September 2005 (Cruise No. 237). The sampling process involved deploying a MPN vertically. We focus in MLD, determined using a fixed criterion of a 0.03 kg/m^3 density difference from the surface (Boyer Montégut et al., 2004). Echo amplitude data were acquired from the measurements from both the cruises, utilizing an RDI 76.8 kHz Ocean Surveyor broadband ADCP. In this study, we adopted the latest and validated formulation of equation given below, as proposed by Mullison (2017), for the precise computation of Sv in decibels referenced to $(4\pi m)^{-1}$.

$$S_v = C + 10\log\left((T_x + 273.16)R^2\right) - L_{DBM} - P_{DBW} + 2\alpha R$$
$$+10\log\left(10^{K_c(E-E_r)/10} - 1\right)$$

P_{DBW} represents the power level, calculated as 10 log_{10} P(with P being the transmitted power in watts), while C is an empirical constant utilized in the calculations. The value $P_{DBW} = 23.8$ and $C = -153.3$ were provided by Deines (1999), as documented in the study. These values serve as crucial constants in the context of the Vessel Mounted Broad Band ADCP operating at a frequency of 76.8 kHz. The parameter L_{DBM}

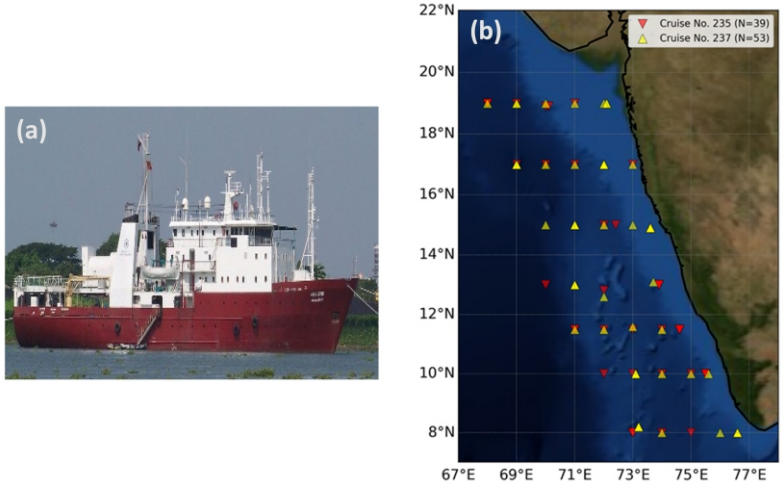

Figure 1. (a) Platform-FORV Sagar Sampada, (b) Study area-EAS, highlighting the locations of zooplankton sampling and ADCP data capture.

stands for 10 log_{10} L with L representing the transmit pulse length. The instrument captures this length, which closely aligns with the bin size, for cruise 235 and 237, the bin sizes are 16 m and 8 m respectively. T_x is the temperature of the water beneath the ship's hull at the transducer depth, measured in °C. K_c is a system-specific parameter signifying the conversion factor (in dB/count) for each beam. For the ADCP used in the present study, RDI provided the values of 0.39, 0.38, 0.40, and 0.39 dB/count. The recorded parameter E corresponds to the amplitude of the RSSI as reported by the ADCP. Sound absorption coefficient (α in dB/m), was calculated following the framework of Francois and Garrison (1982), considering contributions from chemical relaxation processes and absorption by pure water. The slant range (R) to a depth cell (m) represents the distance to the relevant scattering layer along the acoustic beam. The calculation of R follows the methodology outlined by Zhou et al. (1994). E_r represents the observed RSSI amplitude, reported in counts, by the ADCP in the absence of any signal (Deines, 1999), commonly referred to as noise (counts). E_r values for each cruise were determined separately by calculating the average of noise values across all profiles.

3. Results and Discussion

Zooplankton biomass and ADCP backscatter relationship in MLD

The scatter plot delineates specific sampling points within the MLD, with the x-axis representing ADCP backscatter values and the y-axis corresponding to zooplankton biomass (log) values. The dispersion of data points across the plot signifies variability in both zooplankton biomass and ADCP backscatter at the sampled locations. As illustrated in Fig. 2, a positive correlation between zooplankton biomass and ADCP backscatter values is evident for both time periods. However, statistical significance (r=0.58) in this correlation is observed only during the May-June period, and a weaker correlation (r=0.25) during Aug-Sep. A regression line, portraying the optimal fit between zooplankton biomass and ADCP backscatter, is integrated into the plot, providing insights into the direction and strength of the correlation. Additionally, the figure presents the regression equation, $\log(\text{Biomass}) = b + m \times \text{ADCP}_{\text{Backscatter}}$, explicitly expressing the mathematical relationship between bulk zooplankton biomass and vertically averaged ADCP backscatter. The slope 'm' of the regression line indicates the rate of change of ADCP backscatter concerning zooplankton biomass, while 'b' represents the y-intercept. This derived relationship holds significant value for efficiently estimating column secondary production on a more refined spatio-temporal scale, minimizing the necessity for extensive in-situ sampling. Such insights are crucial for enhancing the effectiveness of ecosystem assessments.

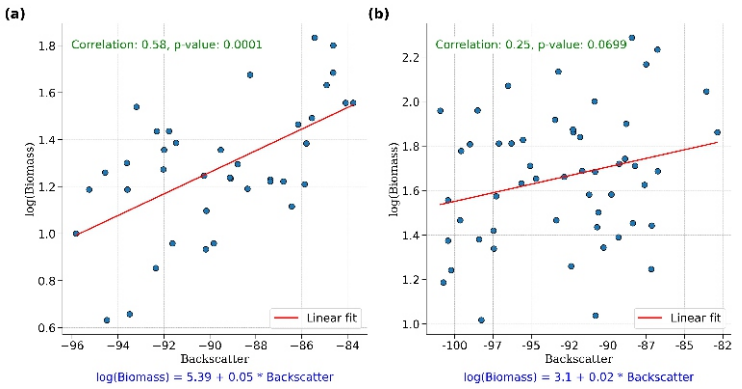

Figure 2. Correlation between the zooplankton biomass (dry weight mg/1000 m^3) and the vertically averaged ADCP backscatter (dB) in MLD for (a) May-June and (b) Aug-Sep period.

Diel vertical migration

The authors examined the vertical variation in ADCP backscatter with depth to comprehend the diel vertical migration of zooplankton in two designated transects (Fig. 3b - 8°N, 10°N) within the oceanic region (Fig. 3a). The careful selection of transects, corresponding to the ship's continuous movement offshore or towards the shore, facilitated the capture of spatial variations in zooplankton distribution. During night hours (18:00-06:00 IST), ADCP backscatter exhibited elevated values, indicating the aggregation of zooplankton near the surface during darkness. This behaviour aligns with the concept of Diel Vertical Migration (DVM), a crucial phenomenon in zooplankton ecology (Jiangang et al., 2000). DVM serves as a vital survival strategy for various zooplankton species, optimizing their feeding, predator avoidance, and reproductive success. Specific observations indicated a downward migration of scatterers during dawn (06:00-07:00 IST) and an upward migration during dusk (18:00-19:00 IST), validating the classic DVM pattern. These temporal movements of zooplankton as evident in the ADCP backscatter profiles are critical for their survival, optimizing their position in the water column, to balance predation risk and foraging opportunities. These findings were consistently supported by observations during the ship's stationary period near the coast at station 8°N (Fig. 3c). The observed pattern of zooplankton concentration near the surface up to approximately 80m depth during nighttime reinforces the robustness of DVM as a widespread and ecologically significant phenomenon. The successful capture and elucidation of DVM using ADCP backscatter data underscore the necessity for continuous monitoring in studying zooplankton dynamics, offering broader implications for advancing marine ecological understanding and emphasizing the importance of considering diel patterns in ecosystem management and conservation efforts.

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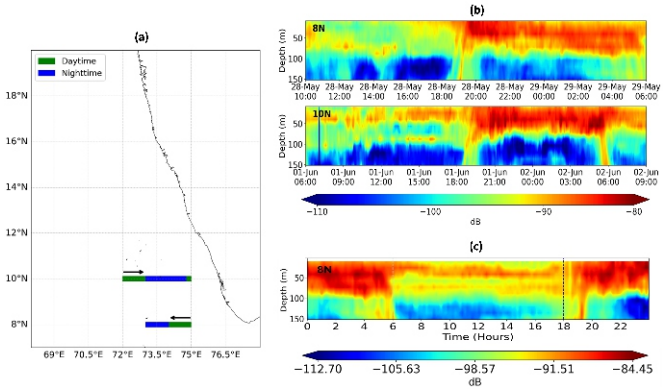

Figure 3. (a) Ship transect: daytime and nighttime segments, (b) ADCP backscatter (dB) as a function of along-track distance and time (Ship in motion), (c) ADCP backscatter (dB) as a function of time (Ship stationary) [Date: 29 May 2005, Location: Approximately 8°N, 73°E]. Blue and black dotted lines separate day and night-time.

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Deciphering Coastal Dynamics: Data-Driven Models and Empirical Analyses in Unraveling Sediment Characterisation and Morphodynamics along the Central West Coast of India


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Beaches exhibit remarkable dynamism as they undergo continuous transformations due to the intricate interplay between various natural forces, human interventions, and environmental fluctuations. The Central West Coast of India, adorned with captivating beaches, abundant biodiversity, and profound cultural significance, exemplifies a realm of ever-evolving coastal terrains. Nevertheless, it is imperative to acknowledge that these coastal areas are subject to the relentless and ever-changing forces of nature and the interventions of human activities, which inevitably contribute to the intricate dynamics of erosion and ultimately influence the stability and future of these shores. The composition and behaviour of sediments significantly influence the stability and resilience of coastal systems. Gaining a comprehensive grasp of the complex interplay between sediment properties and the dynamic processes shaping the coastal beaches in this area is of utmost importance to facilitate optimal management strategies, promote conservation efforts, and foster sustainable development initiatives.

The conventional approaches to comprehending sediment dynamics in these coastal areas were predominantly centred around labour-intensive field surveys, manual sampling, and localised laboratory analyses. Nevertheless, it is essential to acknowledge that these conventional methodologies frequently encountered constraints in comprehensively capturing the entirety of beach dynamics, primarily due to their inherent spatial and temporal limitations. Incorporating data-driven models and empirical analyses has brought about a transformative shift in the methodology employed for comprehending sediment characterisation and morphodynamics along the central west coast of India.

To develop comprehensive databases, data-driven models utilise various datasets from various channels, such as remote sensing data, bathymetric surveys, sediment samples, and historical records. We can process these datasets by harnessing the power of machine learning algorithms, statistical analysis, and numerical modelling techniques. These models serve as valuable tools for predicting sediment transport, erosion, and accretion patterns and for comprehending the impact of both natural and human-induced factors on the morphology of coastal beaches.

Empirical analyses play a pivotal role as a connecting link and a fundamental instrument for corroborating the relationship between theoretical models and real-world observations. The process of ground-truthing model outputs, conducting field data collection, and validating model predictions against real sediment behaviours is of utmost importance in enhancing the precision and dependability of these models. Through the meticulous comparison of empirical observations and model predictions, coastal engineers diligently refine and augment the capabilities of these data-driven models, thereby rendering them increasingly adaptable to the dynamic coastal environment of the central west coast of India. Collecting field data, validating model outputs through comparison with observed sediment behaviours, and ground-truthing are crucial steps in enhancing the precision and dependability of these data-driven models. The iterative process is essential in ensuring that the models are appropriately tailored to the ever-changing and diverse coastal environments found along the central west coast of India.

The central west coast of India exhibits a diverse coastal topography comprising sandy beaches, rocky shores, and estuaries. Additionally, it is home to a densely populated and rapidly urbanising coastal zone, characterised by a significant presence of industries and infrastructure. Urbanisation has led to a change in land use/land cover, increased construction endeavours, and modifications of inputs to coastal hydrodynamics. These changes subsequently impact sediment movement and the beach's shape. A convergence of various factors, such as the impacts of monsoonal forces, the influx of sediment from rivers, the ebb and flow of tides, and the interventions of human activities, intricately influences the coastal dynamics of the region. The interplay of these various factors profoundly influences the intricate sediment deposition mechanisms, erosion patterns, and alterations in beach morphology, thereby sculpting the dynamic coastal setting.

To effectively tackle the intricate issues presented by sediment dynamics and morphodynamics along the central west coast of India, it is imperative to adopt a comprehensive approach that encompasses empirical field studies, laboratory analysis, and advanced data-driven modelling techniques. Coastal Management in India is an ongoing effort by the Government of India, signifying the profound acknowledgement of the utmost significance of coastal management and the pursuit of sustainable development along the coastal regions within our nation.

Recent scholarly investigations by Okon et al. (2023) and Okon and Seelam (2023), which are the primary sources for this article, underscore the paramount significance of sediment origins and conveyance in sculpting coastal topography. These studies highlight the imperative nature of meticulous empirical scrutiny in discerning the precise pathways through which sediment is transported.

In this article, our objective is to probe into the interplay between data-driven models and empirical analysis techniques to tackling the sediment characterisation and morphodynamics of coastal beaches in the central west coast of India, as evidenced by the findings from the recent studies (Okon et al. 2023; Okon and Seelam 2023). Through a comprehensive analysis of the available literature, our objective is to offer valuable perspectives on the proficient utilisation of these methodologies to inform coastal management strategies rooted in empirical evidence. This, in turn, will guarantee these vital coastal ecosystems' long-term viability and resilience.

The coastal geomorphic systems are subject to considerable influence from local and regional climatic pressures, which operate on various spatial and temporal scales.

In the study conducted by Okon et al. (2023) the impact of the juxtaposition of regional climates on the intricate heterogeneity of grain size distributions found within the beach sediment along the Goa Coast, situated in the central West of India, is investigated. This comprehensive analysis spanned a duration of five years, during which the researchers employed the renowned End-member modelling analysis (EMMA) technique to characterise the seasonal variations in grain size distribution effectively. Furthermore, they established meaningful connections between the seasonal end members and their proximal sources, enhancing an understanding of this coastal phenomenon. EMMA, is a robust methodology employed in coastal engineering to separate and identify distinct grain sizes within sediment samples effectively.

By utilising a deterministic approach, EMMA allows for the accurate unmixing of various grain populations, thereby providing valuable insights into the geological characteristics of coastal environments. It facilitates inquiries into the underlying factors contributing to the temporal and spatial variations in grain size, which can be challenging to ascertain solely through univariate grain-size data analysis. EMMA is a crucial instrument in sedimentology, where its primary function is identifying subpopulations within sediment grain size distributions (GSDs), which may not be immediately discernible when examining individual sample GSDs. By utilising grain size modal classes, the researchers could discern four distinct end-members (1-4 EMs), which can be attributed to coarse silt, very fine sand, fine sand, and medium sand size fractions.

The study's findings indicate that the Southwest and Northeast monsoons notably influence the sediment distributions along the Goa Coast. Moreover, it is observed that the deposits' underlying end-members (EMs) exhibit distinct characteristics that reflect the interplay between the dominant forces of these two seasons. The research presents a non-parametric end-member algorithm that effectively identifies resilient sediment components within an established detrital system along the Goa Coast. The spatial pattern of EM distribution reveals a notable prevalence of EM2 and EM3 in the coastal region. The observations indicate a discernible influence of seasonal variations on the shape and structure of the beach, while the origin and transportation of these sediments have not been thoroughly investigated and understood (Figure 1).

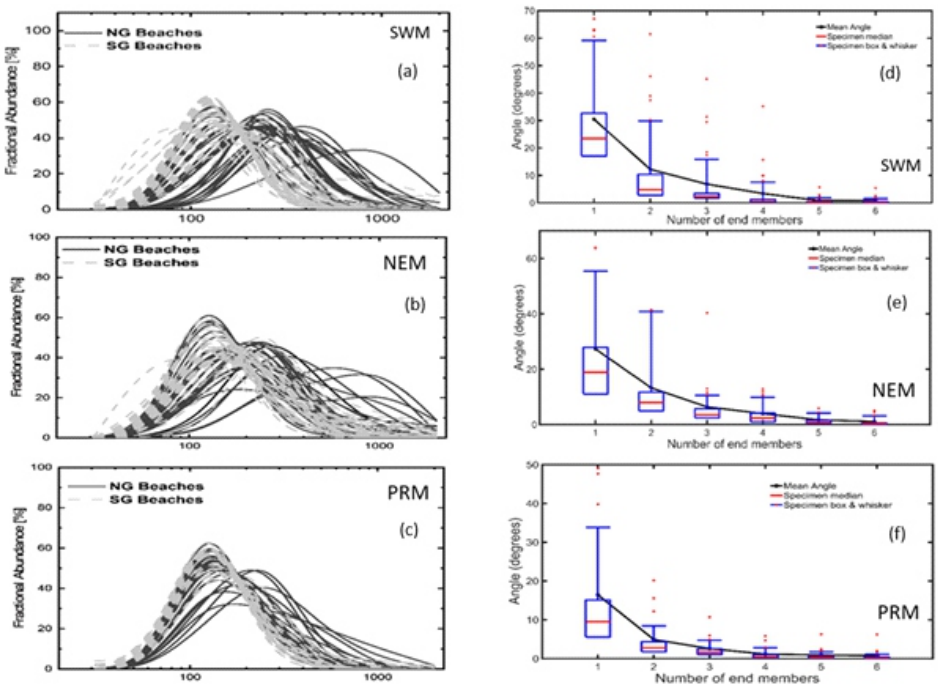

Figure 1. EMMA results of grain-size data from the north and south Goa beaches during NEM (a-c) multiple grain size frequency distribution. (d-f) Angular differences (in degrees) between the modelled and observed data for 1 to 6 EMs [modified from Okon et al. 2023].

Hence, it is imperative to acknowledge the significant influence of local and regional climatic forces on the sediment dynamics of tropical open coast beaches, particularly along the central west coast of India, and their intricate interplay with environmental processes. This study provides valuable insights into the dynamic nature of coastal geomorphic systems and their intricate relationship with environmental processes. These findings contribute to a deeper comprehension of the complex interactions between the ocean, coast, rivers, and the hinterland in the central west region of India.

In a pertinent investigation conducted by Okon and Seelam (2023), the utilisation of Empirical Orthogonal Function (EOF) analysis and Canonical Correlation Analysis (CCA) was employed to assess the interplay between beach-face slope, nearshore parameters, and environmentally sensitive sediment grain size parameters. The investigation was centred around comprehending the cross-shore morphodynamic fluctuations of the Goa coastline in India.

The EOF analysis technique was employed to gain a deeper comprehension of beach-face dynamics by effectively isolating the spatial and temporal interdependencies within the dataset. EOF analysis is a valuable tool in coastal engineering, allowing us to assess the seasonal changes in cross-shore variation. By considering the spatial and temporal variance modes, one can comprehensively understand how these variations occur. The proposed methodology entails the development of a regression matrix that enables the prediction of beach profiles by taking into account anticipated wave conditions.

On the other hand, CCA is employed to assess the correlation between sediment grain size, beach-face slope, and the local climate conditions, with a specific emphasis on the predictive capabilities of the climate concerning grain size and beach-face slope. The investigation focuses on exploring the statistical correlation between various coastal engineering parameters such as root mean square wave height (Hrms), wave period (T), mean wave energy (E), wave energy flow (Fx), dimensionless fall velocity (w), as well as environmentally sensitive sedimentary parameters including D10, D50, D90, D85/D16, D90/D10, mean, sorting, skewness, and kurtosis. After analysing data sets from 45 surveys conducted during various seasons, three statistically significant EOF modes were identified.

The results obtained from the data collected during different seasons exhibited variations, primarily attributed to the first three eigenfunctions corresponding to the three highest eigenvalues, accounting for most of the changes observed in the beach-face configuration. The dominant eigenfunction manifests the mean gradient of the beach profile.

The variability of the slope of the second eigenfunction is most pronounced in relation to the mean. The coastal zone is exhibiting characteristics typically associated with an intermediate stage of development, characterised by periodic fluctuations in beach morphology. The findings from the EOF and CCA investigations validate the well-established hypothesis that the beach face is indeed the zone of highest morphodynamic activity.

It is worth noting that both North and South Goa beaches exhibit consistent rhythmic variations throughout the year, with the most pronounced slope modulation occurring during the northeast monsoon season. These methods offer significant advantages as they establish a comprehensive framework for characterising beach morphology in relation to climate change and provide a comprehensive analysis of grain size and slope distribution on sandy coastlines.

These articles delve into the crucial significance of data-driven models and empirical analyses in unravelling the intricate nature of sediment properties and morphodynamic processes along India's central west coast beaches. Through the integration of empirical data and the utilisation of advanced modelling techniques, the primary objective of this study is to offer valuable insights crucial for making well-informed decisions and developing adaptive strategies in coastal preservation and management.

Using empirical data and advanced modelling techniques, coastal engineers and environmental specialists acquire invaluable knowledge regarding sediments' composition, dynamics, and ramifications. This knowledge empowers them to make well-informed decisions and develop adaptive strategies for effectively managing and preserving beaches.

In this context, using data-driven models and empirical analysis presents a promising methodology for thoroughly evaluating sediment characterisation and morphodynamics. This approach significantly contributes to making well-informed decisions and promoting sustainable coastal development. This article comprehensively examines the application of data-driven models and empirical analysis in the realm of sediment characterisation and morphodynamics along the central west coast of India.

Through integrating these methodologies, researchers and coastal practitioners can acquire a comprehensive comprehension of the mechanisms governing sediment dynamics in this area, thus enabling them to make well-informed choices to alleviate the detrimental consequences of coastal erosion. This holistic comprehension enables the formulation of well-informed approaches for managing coastal areas, implementing erosion mitigation measures, and conservation endeavours, thereby supporting the sustainable utilisation and safeguarding of these invaluable coastal ecosystems.

In conclusion, there is a pressing necessity for implementing comprehensive methodologies that incorporate empirical data, field observations, and data-driven models. This is of utmost importance to fully comprehend the intricate intricacies of sediment dynamics in coastal beach environments. The significance of integrating field observations with numerical models to improve the precision of forecasting coastal alterations has been underscored by Okon et al. (2023) and Okon and Seelam (2023). Moreover, it is imperative to acknowledge the intricate complexities associated with sediment characterisation and morphodynamics along the central west coast of India and other coastal regions in India.

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Design Optimization of Long-Span Flood Gates in Coastal Reservoirs

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Abstract

Coastal reservoirs have gained popularity in recent times as they can provide a sustainable and reliable source of drinking water to coastal communities, particularly in regions where freshwater resources are limited. They not only provide fresh water but also prevent flooding during cyclones. They involve the construction of dyke or bunds across the river or into the sea and store fresh water on the riverside. The major challenge for these reservoirs is discharging flood water into the sea during extreme rainfall events, which is done using a flood regulator. This operation becomes quite complex due to seaside water level variations for reservoir operating water levels. In locations of semi-diurnal tides, gates have to be closed during high tide and opened during low tide making four times a day making the operation quite complex. The complexity of operations can be minimized by using a smaller number of long-span gates. Conventionally, flood regulator gates, onshore, are designed for a low span in the range of 15 to 25 m as it will be difficult to lift long-span gates due to their massive weight. In this study, three different configurations of 50 m span vertical gates are studied for flood regulators based on previously executed storm surge barriers. The gates are designed for storm surge events on the seaside and maximum flood conditions on the riverside. Based on the analysis, the study reveals that lens gates are ideal and optimum for long spans with reduced plate stresses, bending moment, and deflection.

1. Introduction

In recent times, the shortage of freshwater reserves has been a worldwide problem, which may lead to a global crisis. This occurs due to various factors, including but not limited to population growth, increased agricultural and industrial activities, climate change, and poor water management practices. Agriculture uses between 70 and 85 percent of water, and it is estimated that the biggest threat to agricultural expansion is that 20 percent of the world's grain production will not have enough water in the future to be irrigated [1]. Rapid urbanization has resulted in water scarcity due to ineffective management of the precipitation received.

The primary renewable source of freshwater is rainfall. The alternatives practiced worldwide to address water scarcity are inland reservoirs, groundwater, desalination plants, wastewater reuse facilities, interlinking of rivers to optimize surface water, and coastal reservoirs. In the Indian scenario, although extreme rainfall events are significantly increasing, there is a spatial non-uniformity in the rainfall events that occur. Because there aren't enough storage facilities to completely store the fresh water from wetlands, groundwater, and river systems, it effectively flows into the ocean. Water can be retained in an estuary or sea which forms 100% of the catchment area, in contrast to being retained in mountainous dams that only collect water from a small section of the watershed. The coastal reservoir has many advantages such as minimal land acquisition, and no land submergence or forest submergence compared to inland reservoirs. Thus, storing water in coastal reservoirs offers the solution to India's water problem by conserving the abundant monsoon water bounty for future use [2]. A coastal reservoir is formed by constructing a long oceanic dyke to impound surplus water that is flowing to the sea from a river basin [3].

Coastal reservoirs have the potential to become a major source of freshwater in coastal areas, alongside existing inland reservoirs, desalination plants, wastewater recycling plants, and rainwater tanks [4]. A study in 2001 indicated that over half the world's population lived within 200 km of the coastline. Implementation of coastal reservoirs has the potential to harness water for coastal communities that would otherwise flow to the sea [5]. The ability to preserve natural environmental flows, collect riverine water at the catchment's end, mitigate coastal floods, and develop water resources is one of coastal reservoirs' most important benefits.

2. Coastal Reservoir and its Challenges

Saemanguem (South Korea), Marina Barrage (Singapore), Qingcaosha (China), Plover Cove (Hong Kong), Afsluitdijk (Netherlands), and Thanneermukkom Bund (India) are a few existing coastal reservoirs [Figure 1]. Sarovar Mala is a concept of linking coastal reservoirs i.e., freshwater ponds (Sarovar(s) in the ocean) at the mouth of rivers in the Indian Peninsula where it converges with the ocean [6]. Out of the potential areas identified in the feasibility study, the Gulf of Khambhat Development Project or Kalpasar Project draws more attention for its huge storage potential. The Gulf of Khambhat extends about 200 km from North to South and the width varies from 25 km at the inner end to 150 km at the outer mouth, covering an area of around 17,000 km^2, of which only

Figure 1. Popular Coastal Reservoirs Worldwide

2,000 km^2 is planned to be enclosed by constructing a dam across the Gulf between Bhavnagar and Dahej having 7700 MCM of water storage capacity. The Reservoir will have the storage more than double the Sardar Sarovar (Narmada Reservoir) capacity [7].

One of the key components for the safe functioning of the coastal reservoir is the implementation of flood regulators. The major function of flood regulators is discharging flood water into the sea during extreme rainfall events in river catchments, and retaining the seawater from entering into the reservoir during storm events in the open ocean. These pose the challenge in designing the gates for a) Water levels corresponding to extreme events on the seaside with dead storage on the reservoir and b) Full reservoir conditions with seaside water levels corresponding to low tide. As an example, the Gulf of Khambhat shall experience a tidal range of about 11.5 m with a High Tide Level (HTL) of +6.2 m and a Low Tide Level (LTL) of -5.3 m. On the Reservoir side, the Maximum Water Level (MWL) is +5 m, and the Maximum Draw Down Level (MDDL) is -4 m. In this case, flood regulator gates remain closed in high tide and can be opened only during low tide which leads to four operations a day. For a specific discharge, smaller gates of large numbers or larger gates of few numbers can be utilized.

However, the number of gates that need to be operated is quite high if small gates are used especially if operated four times a day. This emphasizes the need for large gates to minimize the operation frequency. Commonly used types of gates worldwide for controlling water levels in weirs and storm surge barriers are Vertical lift, Sector, Visor, Inflatable, Radial, and Arch or Flap gates [8]. Vertical lift gates are widely used for navigation lock chamber gates, emergency closure gates for powerhouse intakes and outlet works, and spillway crest gates [9]. The vertical lift gates are utilized in cases of differential water heads and high head discharge due to ease of operation as is the case analyzed here. This study deals with three different configurations for a 50 m span vertical gate such as (a) a flat gate, (b) a flat gate with arch girders, and (c) a lens-shaped gate [Figure 2].

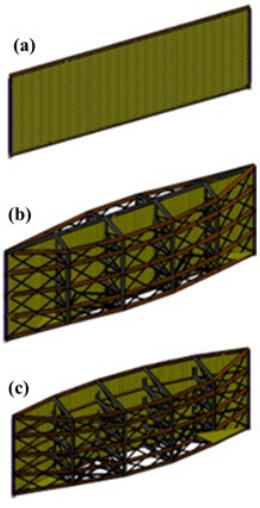

Figure 2. 3 D Wire Frame model (a) Flat Gate (b) Flat Gate with Arch Girders (c) Lens Shaped

3. Analysis and Design Methodology of Flood Regulator Gates

A comparative study is carried out for the three configurations. To accomplish the comparative analysis STAAD PRO finite element tool is utilized to analyze the steel structural system. The analysis proceeded through three phases, modelling of the structure followed by the application of environmental loadings, and finally the analysis of results to design the appropriate cross-sections to sustain the loadings. The use of STAAD Pro ensures that the design is safe and structurally sound, while the three-phase modelling approach and through analysis of different load cases provide valuable insights into the performance of different configurations. All the above-said configurations are optimized iteratively to withstand the limit state of collapse loads and serviceability criteria along with structural integrity and safety. After modelling, the structure was analyzed mainly for two hydraulic load cases with MWL on the reservoir side and LTL on the seaside and, MDDL on the reservoir side with Storm surge on the seaside to simulate its responses under different water level conditions.

The results of the three gates were compared for plate stresses, bending moments, and deflections. This analysis provides valuable information for optimizing the design of gates, improving their performance, and ensuring their long-term safety and reliability.

4. Results and Discussion

A finite Element Analysis was carried out employing beams and plates for all three configurations to assess the displacement, bending moment, and plate stresses. The Maximum Bending Moment on the lens-shaped gate is about 50 kNm whereas the flat gate with lens-shaped girders and the flat gate has 203 kNm and 7550 kNm, respectively. This depicts the reduction of moment of about 80% by adopting lens shaped plate system. The Maximum Plate Stress developed in lens shaped gate is 0.59 MPa whose percentage of change in stress is about 85 % compared to the flat gate having a maximum stress of 3.9 MPa. With 50 m large span gates, to retain large water level difference the resulting horizontal deflection would be high. These deflections are large and visible to the naked eye, in case of a completely flat gate. When the deflection profiles are compared, lens shaped gate has the least deflection. [Figure 3].

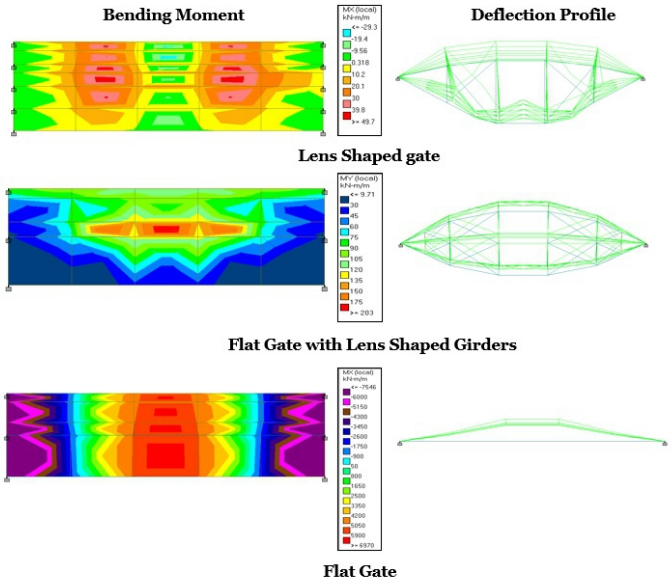

Figure 3. Bending Moment and deflection profile for all gate configurations

5. Conclusion

Vertical gates are preferred in cases of large water head differences. Large span gates are preferred for the least maintenance of the gates when large discharges are anticipated. The analysis of the three vertical gate types indicates that the lens-shaped gates have the least bending moment, deflection, and plate stresses. 80% reduction in bending moments and 85% plate stresses are observed when compared to the flat vertical gates.

This study reveals that lens shaped gate is the most preferable type of vertical gate for long-span flood regulator gates due to minimal bending and plate stress. However, when placed on some control structures like the ogee weir, a flat base is required for water tightness at the base. Gates with lens-shaped girders are suitable in these cases as they are still better performing than just a flat gate. The arching effect of the girders reduces the deflection and the stress acting on the plate.

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CHALLENGES OF CYCLONES, STORM SURGES AND WAVES

Study on tropical cyclone activity, associated storm surges and extreme wind waves is a quite fascinating subject having many challenges according to Prof. Prasad K. Bhaskaran, Dept.of Ocean Engineering and Naval Architecture, IIT, Kharagpur. He was talking on the occasion of the Awareness Seminar held during the World Ocean Day 2023 by OSI Cochin Chapter jointly with the Department of Chemical Oceanography, CUSAT at School of Marine Sciences CUSAT. The challenges have unequivocally drawn attention of the scientific community world-wide. The idea is to provide better quality forecast in terms of cyclone track, intensity and probable landfall location. This is finally to aid timely warnings for better emergency operations and efficient coastal zone management.

In a global perspective, about 80 tropical cyclones form in the global ocean basins annually, of which 5-6% of the total number form over the North Indian Ocean region. From the year 2000 onwards, the North Indian Ocean region is seen acting as a major sink of ocean heat clearly visible in the sub-surface warming trend. Dramatic variations are seen in the recent sub-surface warming over Arabian Sea sector that has direct repercussions on intense tropical cyclone activity.

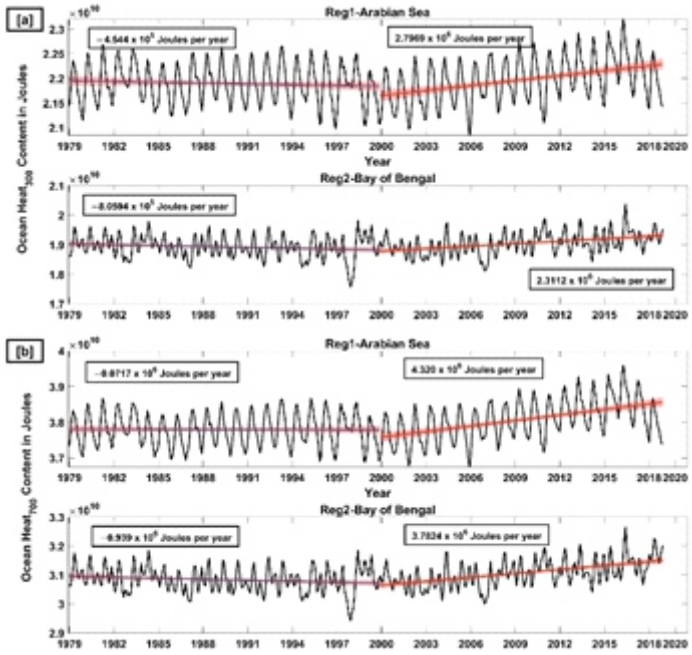


Figure 1. Variability in Ocean Heat Content at (a) 300 m (top panel), and (b) 700 m (bottom panel) during the period 1979-2000 (trend separated before and after the year 2000).

Figure 1 shows the time-series trend in ocean heat content for two epochs (before and after the year 2000) over both Arabian Sea and Bay of Bengal basins at depth levels of 300 m and 700 m showing a distinct 10-year cycle. These indicate that warming trend in Arabian Sea since 1979 until present has been consistent and the ocean heat content warming trend at 700 m depth level is much higher (4.32×106 J yr^{-1}) as compared to the Bay of Bengal (3.78×106 J yr^{-1}). Increased warming for Arabian Sea in the present decade (2000–2020) is about 0.54×106 J yr^{-1} higher compared to the Bay of Bengal and this enhanced warming in Arabian Sea has a consequence on increased tropical cyclone activity.

In a changing climate, some of the challenges and future directions ahead are: (i) to develop better and effective formulations for wind speed structure considering changes in the radial distance connecting increasing

cyclone size, (ii) to develop a framework for wave-current-surge-tide-river interactions in hydrodynamic models to improve the prediction skills in coastal and nearshore regions, (iii) to develop a framework for surge-wave-tide-mangrove interaction for nearshore environment in mangrove swamps and wetlands dominated regions.

A pertinent question and puzzle remains as to what are the factors that limit the intensity of tropical cyclones? Prof. Bhaskaran emphasised that detailed study is warranted on internal dynamics focusing on asymmetric structure of eye-wall and spiral rain bands. Role of cyclone translation speed influencing maximum intensity is also a subject that is not well studied. Upwelling effects from ocean and feedback mechanism for the Bay of Bengal region requires a detailed investigation. There are few studies that document on feedback from oceans connecting translational speed, size, intensity and ocean mixed layer depth on tropical cyclone intensity. Rapid intensification of tropical cyclones that developed over North Indian Ocean region is not well represented in operational forecast provided by IMD. Role of moisture convergence and its vertical distribution needs a detailed study. There is no theoretical understanding of cyclone size in a changing climate scenario reported so far. In this context, what controls the tropical cyclone size remains as another puzzle.

The Seminar inaugurated by Prof.P.G. Sankaran, Vice Chancellor of CUSAT was attended by more than 100 scientists, researchers and students from School of Marine Sciences (CUSAT), KUFOS, CMFRI, DRDO-NPOL, CMLRE and others.

(Prepared by Dr.M.Baba, Chairman, OSI Cochin Chapter and Dr. S.S. Shaju, Head, COD, CUSAT and Secretary OSI Cochin Chapter)

The Eighth Biennial Conference of the Ocean Society of India (OSICON-23)

The 8th Biennial National Conference of the Ocean Society of India (OSI), known as OSICON-23, took place from 23 to 25 August 2023, at the Indian National Centre for Ocean Information Services (INCOIS) campus in Hyderabad. The conference attracted oceanographers, scientists, researchers, technologists and professionals from across the country to explore the theme of "Operational Oceanography- Science to Services."

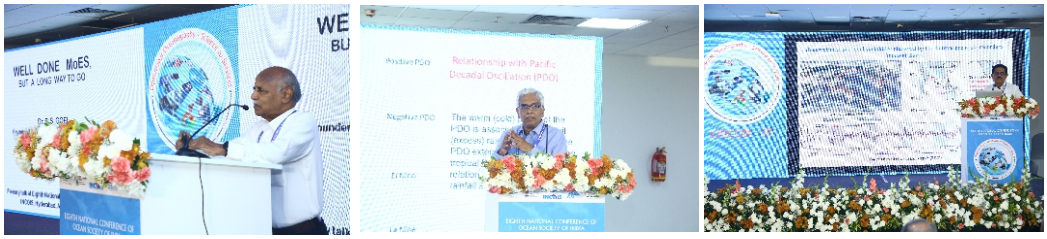
Dr. T. Srinivasa Kumar, Director, INCOIS & Chairman, Organizing Committee, OSICON-23 extended warm welcome to the dignitaries and participants to the 3-day conference. During his opening remarks, he conveyed heartfelt gratitude to the Ocean Society of India (OSI) for selecting INCOIS to host the OSICON-23 in the silver jubilee year of INCOIS. He noted the remarkable response the conference garnered in terms of scientific papers, exhibitors, and special sessions.

The conference was inaugurated by Dr. M. Ravichandran, Secretary, Ministry of Earth Sciences, Govt. of India on 23 Aug 2023. In his inaugural address, Dr. Ravichandran emphasized the role of collaborative research and development in ocean science and technology, the focus is on realising the objectives of the nation's blue economy policy especially pertinent to in addressing challenges in the energy, food, fresh water and health sectors amid the backdrop of climate challenge. During the inaugural plenary talk on 'Three Great Tsunamis', Prof. Harsha Gupta, Former Secretary, Department of Ocean Development discussed the conceptualization and evolution of the Indian Tsunami Early Warning Centre at INCOIS, delving into the scientific and technological aspects involved in its design. The dignitaries released OSICON-23 Abstract Volume and launched several products and services developed by INCOIS. Dr. N.P. Kurian, President, OSI thanked INCOIS for organizing OSICON-23 and highlighted the objectives of the OSI. He also mentioned that the conference received overwhelming response with the submission of more than 500 abstracts and associated exhibition with several 'firsts' in the history of OSICON. He commended the dedicated efforts of the INCOIS team in ensuring the successful execution of the conference. Mr. E. Pattabhi Rama Rao, Group Director, INCOIS & Convener, OSICON-23 thanked the sponsors, exhibitors, and participants for their invaluable contributions, which played a pivotal role in making the conference a resounding success.

Inauguration of OSICON-23 by Dr. M. Ravichandran, Secretary, Ministry of Earth Sciences

Release of OSICON-23 Abstract Volume

The first ever Dr. N. K. Panikkar Memorial Lecture of OSI was delivered by Dr. Shailesh Nayak, Former Secretary, MoES and Honorary Fellow, OSI during the plenary session in the evening on 23 Aug 2023. In his talk on 'Ocean Science to Services: A Perspective for Blue Economy', he brought out the current trends in the ocean science and services and provided a clear vision on how the oceanographic community should gear up to address the challenges in operational oceanography and promoting the Blue Economy. There were three plenary talks by Dr. P. S. Goel, Dr. M. Rajeevan, former secretaries of Ministry of Earth Sciences and Dr. S. S. C. Shenoi, former Director of INCOIS during the conference.



Plenary talks by Dr. P.S. Goel, Former Secreatary, DOD; Dr. M. Rajeevan, MoES Distinguished Professor & Former Secretary, MoES and Dr. S.S.C. Shenoi, MoES Chair Professor &Former Director, INCOIS

Dr. D. Srinivasan Endowment award instituted by OSI was awarded to Prof. A. D. Rao. Dr. P. V. Joseph was conferred with the OSI Honorary Fellowship award and Dr. S.S.C. Shenoi was conferred with OSI Fellowship award during the OSICON-23.


Prof. A. D. Rao


Dr. P. V. Joseph


Dr. S.S.C. Shenoi

With a turnout of over 500 delegates, the event featured the presentation of 343 research papers, spanning 13 sub-themes in 6 parallel sessions during first two days and 5 parallel sessions on the last day and witnessed substantial engagement and fruitful scientific discussions. Among these, 266 oral presentations and 77 posters were showcased. The overarching theme of the presentations centered on the application of oceanographic knowledge and technological advancements in service to society. A significant portion of the discussions in the 'Ocean Information and Advisory Services' sub-theme revolved around the operational services provided by INCOIS. 'Ocean Observations' sub-theme covered oceanographic data obtained through remote sensing and in situ observations, algorithms for retrieving satellite-based observations, and the validation of remote sensing data. The sub-theme 'Ocean and Climate Change' featured several papers addressing the observed long-term changes in climate indicators, including sea level, marine heat waves, coral bleaching, and extreme waves. Presentations in the 'Ocean Modelling and Data Assimilation', 'Coastal and Open Ocean Processes', 'Air-sea Interaction' and 'Biogeochemistry of Oceans' subthemes described the observed variability in the physical and biogeochemical properties of the Indian oceans, some of the presentations discussed their representations in the numerical models and the processes responsible for these variabilities. Additionally, the conference covered a range of topics including Ocean Engineering and Technology, Marine Geology and Geophysics, Biodiversity and Ecology, Polar Sciences and Cryosphere Studies, Blue Economy, and Marine Resource Management.

Two special sessions on 'Energy & Fresh Water from the Ocean' by the Federation of Indian Geosciences Association (FIGA) and 'Importance of Ocean Observations to Monsoon Weather and Climate Forecasting' by the India Meteorological Society (IMS) were also organized during the conference.

A one-day pre-conference tutorial on 'Earth Observational Satellites, Data for Ocean Applications' was held jointly by Indian National Centre for Ocean Information Services (INCOIS) and the National Remote Sensing Centre (NRSC). About 60 students from different universities across the country attended the pre-conference tutorial at INCOIS. Durning the one-day pre-conference tutorial, the participants were demonstrated the utilisation of Earth Observation satellites data especially EOS-04 and 06 providing Ocean Color Monitor and Scatterometer data for various ocean applications. Further, the participants were given demonstration on various in-situ and remote sensing data products and exposed to software packages for processing and visualisation of data made available by INCOIS.

An exhibition was organized to showcase the latest innovations, technologies, products, and services relevant to Oceanography and allied sciences by government agencies and industry. The exhibition provided a conducive environment for networking among scientists, students, academia and industry.

To encourage young researchers in various fields of Oceanography, OSI instituted PG Dissertation Awards in 7 different categories (Physical, Chemical, Geological, Biological oceanography, Ocean Atmospheric Sciences, Ocean Engineering & Technology and Marine Microbiology & Biotechnology). For the year 2022, OSI PG Dissertation Awards in six disciplines (Physical, Chemical, Biological and Geological Oceanography, Ocean and Atmospheric Sciences, and Marine Microbiology and Biotechnology) were awarded to the PG students during the valedictory session. Further, best oral and poster awards to the best presentations made under each category in each sub-themes of OSICON-23 were also awarded to the students/research scholars/young scientists during the valedictory function.

OSICON-23, with its theme of "Operational Oceanography-Science to Services," successfully facilitated the exchange of knowledge, experiences, and advancements in the field of oceanography. The conference played a crucial role in promoting collaboration between academia, research institutions, and industry, ultimately contributing to the effective utilization of ocean science for practical applications. The conference provided ample networking opportunities, allowing participants to engage in meaningful discussions, exchange ideas, and establish collaborations. Networking sessions were held during breaks, poster presentations, and a conference dinner, fostering a sense of community among the participants.

The conference introduced several new events first time in the OSICONs, viz., Dr. N.K. Panikkar Memorial Lecture, special sessions of the Federation of Indian Geosciences Association (FIGA) and the India Meteorological Society (IMS) and one day pre-conference tutorial. Further, two sessions were conducted for Early Career Ocean Professionals (ECOP) and OSI PG Dissertation Awardees. The conference experienced an unprecedented response to the call for papers, with over 500 abstract submissions—an historic milestone in its history. These "firsts" contribute to scientific progress, fostering collaboration and the exchange of knowledge within the broad research community in the earth, ocean and atmospheric sciences.

The event also marked with the inauguration of the UN Decade Collaborative Centre for the Indian Ocean Region (DCC-IOR), inauguration of Regional Specialized Meteorological Centre (RSMC) for Numerical Ocean Wave Prediction and Global Numerical Ocean Prediction at INCOIS. OSICON-23 concluded with a panel discussion chaired by Dr. Srinivasa Kumar, Director, INCOIS and Dr. N.P. Kurian, President, OSI on 25th August 2023. Session chairs of each sub-themes, summarized the major outcomes of each session, including the major gap areas and recommendations to bridge them during the panel discussion. The Organizing Committee of OSICON-23 expressed profound gratitude to all the participants, sponsors and exhibitors for their unwavering support in making the conference a grand success. Dr. Mani Murali, General Secretary, OSI extended sincere gratitude to the Organizing Committee for their outstanding efforts in ensuring the grand success of the conference. The meeting ended with vote of thanks proposed by Dr. P. G. Remya, Co- Convenor, OSICON-23.

(OSICON-23 report prepared by Mr. E. Pattabhi Rama Rao, Convener & Dr. P.G. Remya, Co-convener, OSICON-23).

OSI Webinar Series (July-September 2023)

July 2023

Topic: Polar Ocean - Monsoon Teleconnections: Evidences from the Past

Speaker: Dr. Manish Tiwari, NCPOR Goa

Date & Time: 31 July, 2023; 04:00 PM – 05:00 PM IST

About the Talk:
The polar and the high-latitude regions (Southern Ocean, Arctic Ocean, and North Atlantic Ocean) play an important role in governing earth's climate through the formation of major deep and intermediate water masses and air-sea interactions. Processes occurring in the polar oceans have also been proposed to influence monsoon variability via "atmospheric bridges" and "oceanic tunnels". This complex interaction between the monsoon and the polar oceans remains to be fully explored. Talk will cover the findings about the past climate variability of the polar regions and explore its teleconnections with the Indian monsoon on multi-centennial to multi-millennial timescales.

September 2023

Topic: Polar Ocean - Importance of storm surge and associated coastal inundation estimation during cyclones along the coast of India: A satellite data perspective

Speaker: Dr. Anup Kumar Mandal, Space Applications Centre, Ahmedabad

Date & Time: 22 September, 2023; 04:00 PM – 05:00 PM IST

About the Talk:
Accurate prediction of storm surge and associated coastal inundation is extremely important due to its huge socio-economic impact on the coastal zones. Precise representation of the coastal geometry including bathymetry at low lying regions, small creeks and river deltas is extremely important. Various satellite datasets can be used for improving topography/bathymetry. The wind speed is another important factor that governs the surge generation mechanism. Talk will discuss the role of satellite derived winds related to generation of extreme water levels due to cyclones.

Articles/research highlights of general interest to the oceanographic community are invited for the next issue of the Ocean Digest. Contributions may be emailed to osioceandigest@gmail.com

Cover Photo: *The image shows the C-Bot developed at CSIR-National Institute of Oceanography, Goa.*
Coral reefs, crucial hubs of marine life, are facing threats from climate change, pollution, and excessive use. Monitoring robots provide real-time information about reef health, helping us spot issues like coral bleaching early on. This data guides policies for responsible marine resource use, a vital part of the blue economy. Tourism, a big part of the blue economy, relies on the beauty of healthy coral reefs. Monitoring robots help manage risks like overcrowding and environmental damage, ensuring tourism can last in the long run. To contribute to this, the CSIR NIO has made an autonomous underwater robot called C-Bot. It's like an underwater drone that can explore coral reefs, take detailed pictures, and record information about the environment. It can go deep into the sea, up to 200 meters, and work for more than 10 hours. Further development is ongoing to make it stay at sea for longer period by docking and recharging itself. The application of the C-Bot are not limited to the coral reef monitoring but also in the strategic sectors. The use of these monitoring robots fits well with the blue economy idea—balancing environmental care with economic growth. These robots, with their advanced technolgy are crucial in protecting coral reefs and the life they support.
Image courtesy: Dr. Pramod Kumar Maurya, Principal Scientist, CSIR - National Institute of Oceanography, Goa.