Newsletter

2nd International Indian Ocean Expedition IIOE-2 2015-2025

(A basin-wide research program co-sponsored by IOC-UNESCO, SCOR and IOGOOS)

Volume-8, Issue-9
September, 2024

To advance our understanding of interactions between geologic, oceanic and atmospheric processes that give rise to the complex physical dynamics of the Indian Ocean region, and to determine how those dynamics affect climate, extreme events, marine biogeochemical cycles, ecosystems and human populations.

Impact of the Pacific-Japan pattern on the tropical Indo-western Pacific Ocean Surface Waves

The tropical Indo-Western Pacific Ocean experiences peak ocean surface gravity wave activity during boreal summer season due to the strong monsoon winds. The coastal and offshore infrastructures, navigation, and coastal dynamics are all impacted by monsoon waves. The wave variability of the tropical Indian Ocean (TIO) on interannual timescales are driven by potential climate modes such as El Niño Southern Oscillation, Indian Ocean Dipole and Southern Annular Mode. Identifying the dominant climate modes apart from the known modes that impact the TIO surface wave variability is crucial. One of the important climate modes over the tropical Indo-Western Pacific Ocean region is the Pacific-Japan (PJ) pattern, which is a low-level circulation variability mode in the Western North Pacific (WNP) region (Figure 1a, below). The PJ pattern features a meridional dipole structure in lower-tropospheric circulation with the tropical and midlatitude WNP lobes and provides a crucial link between the tropics and midlatitudes. The positive PJ enhances the summer monsoon rainfall over the southern and northern parts of India through northeastward atmospheric Rossby wave propagation from the tropical WNP, while the negative phase suppresses the precipitation. Though the PJ pattern has a profound impact on the Indian summer monsoon, there is no study depicting the influence of the PJ pattern on the TIO surface waves. For the first time we have explored the impact of PJ pattern on the ocean surface waves.

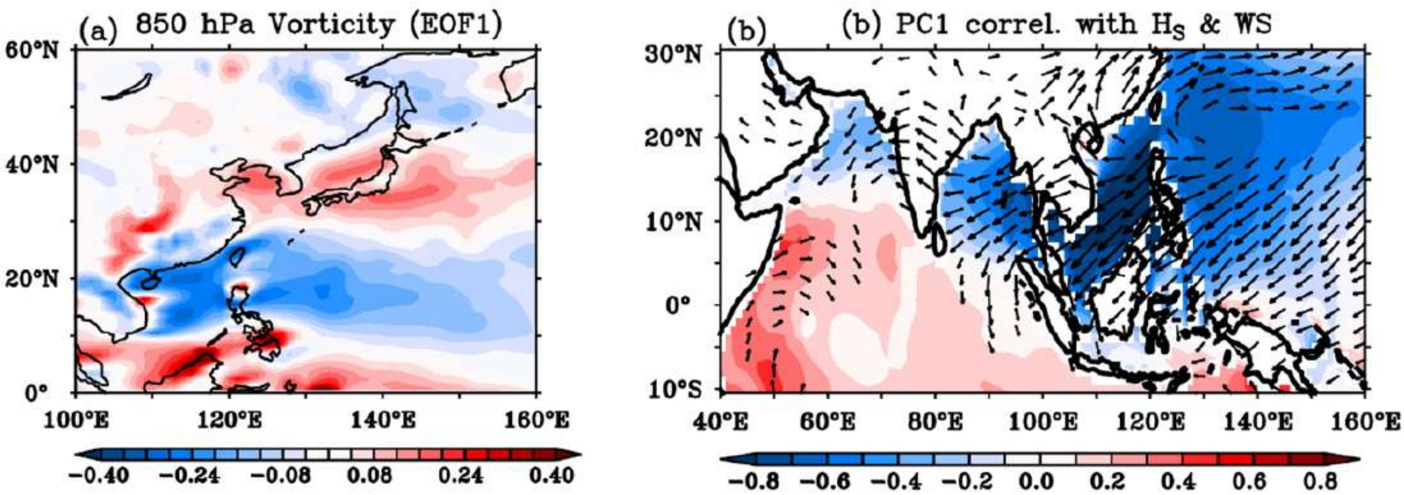

Figure-1: (a) Spatial pattern of the Pacific-Japan (PJ) climate mode, and its (b) correlation with significant wave heights (Hs) and surface winds.

The leading EOF pattern identified a tripole pattern with positive vorticity anomalies extending from the equator to 10°N and in the mid-latitudes (25°–45°N), with negative vorticity anomalies observed at 10°–25°N in the WNP (Figure-1a). The correlation of the corresponding leading principal component of relative vorticity with significant wave height (Hs) and surface winds reveals an anomalous anticyclonic circulation over the tropical WNP region and north-easterlies in the northern Arabian Sea (AS) and south-westerlies in the southern AS, as part of the PJ pattern. The Hs anomalies display a strong negative correlation over WNP and TIO, and a positive correlation in the south-western Indian Ocean regions (Figure-1b).

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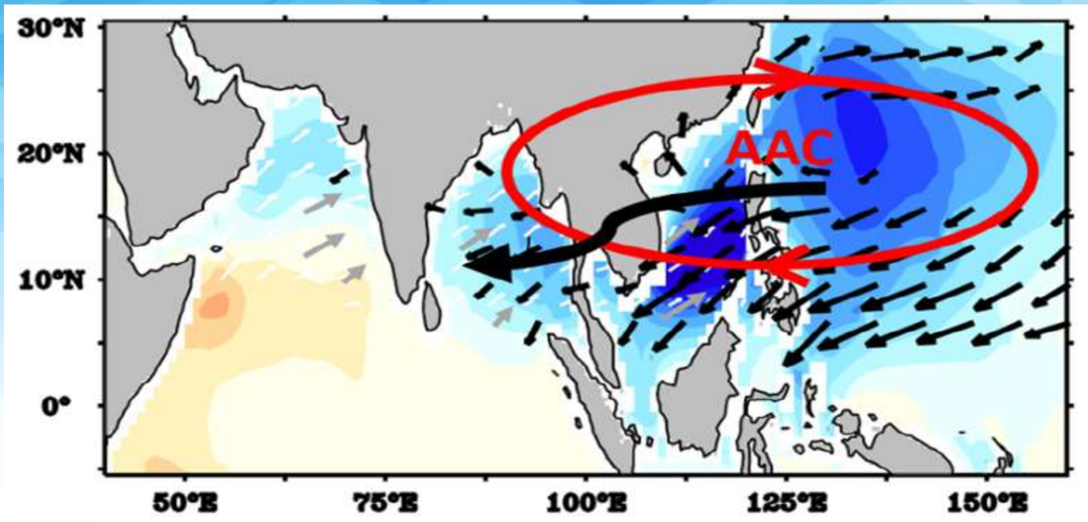

Figure-2: Schematic diagram that shows the PJ impact on Indo-western Pacific significant wave heights. The shading is Hs and vectors are surface wind anomalies. The mean south-westerly winds are marked as white/grey vectors. The elliptical red circle shows the anomalous anticyclonic circulation over the BoB and WNP regions.

The regression analysis of significant wave height anomalies on the PJ index exhibits strong negative wave height anomalies over the Bay of Bengal (BoB), the tropical WNP region and slightly weaker negative anomalies over the Arabian Sea (AS) due to a reduction in the wind-wave growth (Figure-2). The weakening of wave heights in the BoB and WNP regions during PJ is attributed to the anomalous low-level anticyclonic circulation accompanied by high sea-level pressure anomalies over the BoB and WNP regions. The anomalous anticyclonic circulation opposes the mean south-westerlies and reduces the wave heights over the TIO and WNP. Thus, our findings suggest that the WNP region's climate conditions strongly modulate the tropical Indian Ocean's surface waves.

Citation: Srinivas, G., Remya, P.G., Dey, S.P. et al. Impact of the Pacific-Japan pattern on the tropical Indo-western Pacific Ocean surface waves. Clim Dyn (2024).

https://link.springer.com/article/10.1007/s00382-024-07357-1

[Report Courtesy: Dr. Srinivas G, Scientist, CSIR-NIO, Dona Paula, Goa, India; E-mail: srinivasg@nio.res.in]

Indian Ocean acidification and its driving mechanisms over the last four decades (1980–2019)

The oceans play a significant role in regulating the amount of CO_2 in the atmosphere. The increasing oceanic uptake of CO_2 counterbalances the increase in atmospheric CO_2. This uptake considerably impacts marine biogeochemistry, leading to pH and alkalinity imbalances in the water column, commonly referred to as ocean acidification. In an acidic ocean, excess CO_2 reacts with seawater to form carbonic acid, which is highly unstable and undergoes further reduction by releasing hydrogen ions ($H+$) and acidifying the seawater (reduces the pH). Several studies have projected a decline of upper ocean pH by 0.3-0.4 by the end of the 21st century, which has the potential to reduce oceanic biological production considerably. There is a critical need to understand the present status of Indian Ocean acidification and identify its key drivers. However, the number of spatially and temporally varying available observations to examine the present state of Indian Ocean acidification is limited. The numerical ocean models have a unique ability to integrate the empirical and theoretical understanding of the marine environment. Therefore, a comprehensive assessment of the present state of Indian Ocean acidification and its driving mechanisms has been carried out using a regional high-resolution model simulated outputs from 1980-2019. The major findings of this study are (i) the Indian Ocean has been acidifying at an average rate of 0.015 dec^{-1} from 1980-2019, (ii) in the recent decade (2010-2019), the rate of surface acidification has been accelerated throughout the Indian Ocean compared to the previous decades, (iii) the increasing anthropogenic CO_2 uptake by the ocean primarily drives an increasing Indian Ocean acidification trend and (iv) the climatic events such as El Ninõ and positive IOD lead to an enhancement of the Indian Ocean acidification. In summary, this research work consolidates the current level of understanding about the Indian Ocean acidification based on the available field observations, reconstructed data sets, and model simulations.

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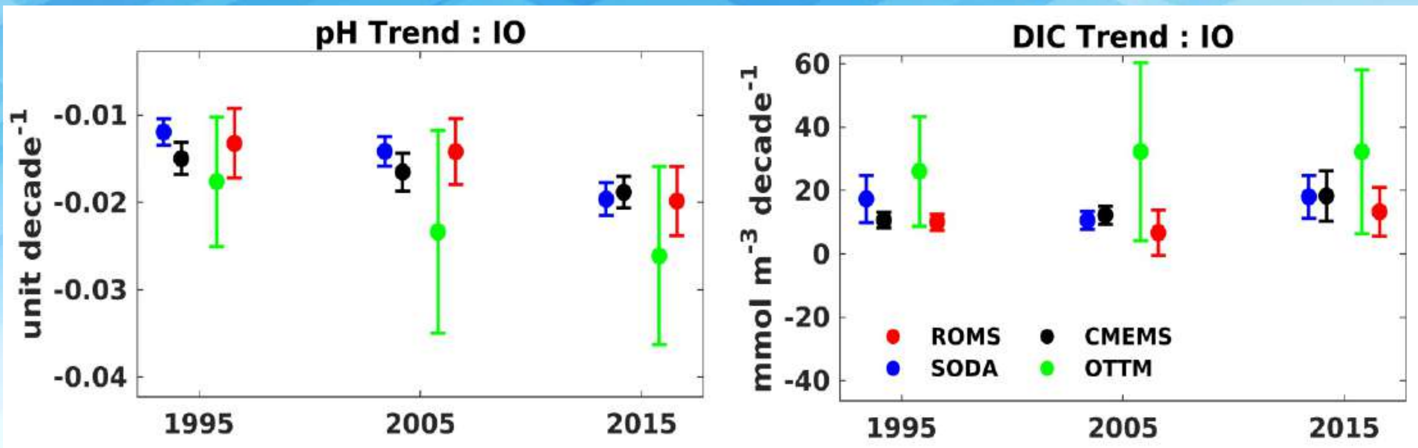

Figure: Decadal trends of pH and DIC in the Indian Ocean based on two observations-based products (SODA and CMEMS) and two ocean models (ROMS and OTTM). The decrease of pH is mainly linked to the increase of DIC (CO_2 uptake) and the pH trend accelerated in the last decade. Adapted from Chakraborty et al. (2024).

Citation: Chakraborty, K., Joshi, A. P., Ghoshal, P. K., Baduru, B., Valsala, V., Sarma, V. V. S. S., et al. (2024). Indian Ocean acidification and its driving mechanisms over the last four decades (1980–2019). Global Biogeochemical Cycles, 38, e2024GB008139.

https://doi.org/10.1029/2024GB008139

[Report Courtesy: Kunal Chakraborty (kunal.c@incois.gov.in), A. P. Joshi (ap.joshi-p@incois.gov.in), INCOIS, Hyderabad, Telangana, India and Nicolas Metzl (nicolas.metzl@locean.ipsl.fr), Laboratoire LOCEAN/IPSL, Sorbonne Université-CNRS-IRD-MNHN, Paris, France.]

Understanding the impact of oceanographic events on Indian mackerel landings in the Malabar upwelling region

Indian Mackerel (Rastrelliger kanagurta) is a crucial component of India's marine fisheries, contributing significantly to the nation's economy. However, its stock status and life cycle remain poorly understood, hindering effective management. Oceanographic factors, including mesoscale events, salinity, chlorophyll and seawater temperature are pivotal in influencing this small pelagic species' availability, migration, feeding, and reproductive activities. The Malabar upwelling region, located along the southwest coast of India, is a significant upwelling system that experiences enhanced primary productivity during monsoon months due to nutrient-rich waters. This productivity supports a diverse fishery, including commercially important species like sardines, mackerels, and anchovies. Our study has been aimed at investigating the relationship between Indian mackerel landings and various oceanographic parameters in the Malabar upwelling region (Figure-1), identifying the key oceanographic factors influencing mackerel catch trends and developing predictive models to forecast mackerel landings based on environmental conditions. Pearson's correlation analysis was employed to assess the relationship between Indian mackerel landings, rainfall, seawater temperature (SWT) at different depths, mixed layer depth (MLD), their anomalies, and the occurrence of Potential Fishing Zone (PFZ) lines (Figure-2) along the Malabar upwelling region.

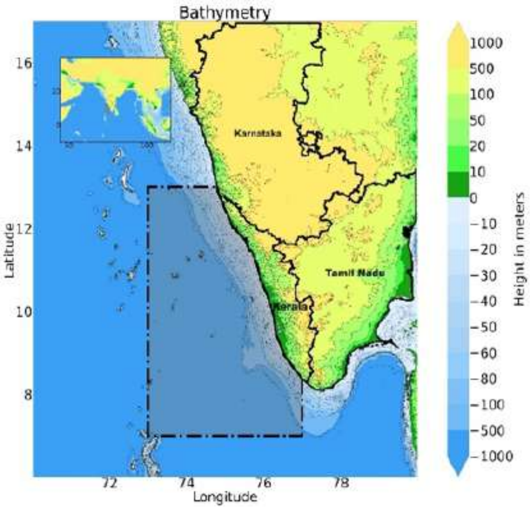

Figure-1: Map of the study area

Time series analysis of mackerel landings revealed significant autocorrelation at a four-quarter lag. Additionally, the landings were found to correlate significantly with rainfall anomalies (with a one-quarter lag), PFZ lines and MLD (with a three-quarter lag), SWT at 50 m depth and SST anomalies (with a two-quarter lag), as shown in Figure-3. Upwelling events, as indicated by the presence of PFZ lines were shown to have a substantial impact on mackerel landings. Polynomial equations effectively captured the influence of these environmental factors on catch trends. The findings suggest that oceanographic factors are crucial in driving Indian mackerel landings in the Malabar upwelling region. Upwelling events, associated with increased primary productivity, provide favourable conditions for mackerel recruitment, growth, and aggregation. Rainfall anomalies, likely influencing plankton abundance and prey availability, also impact mackerel landings. These results have significant implications for fisheries management and conservation.

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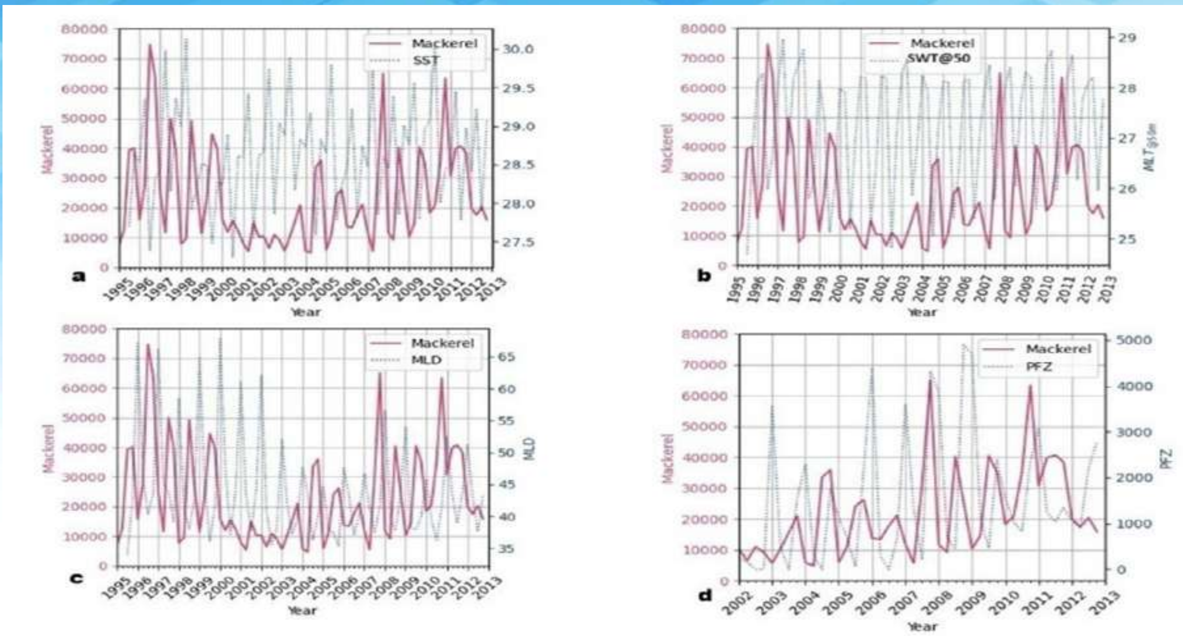

Figure-2: Comparison of quarter-wise mackerel landing with (a) SST, (b) temperature at 50 m depth (SWT@50), (c) mixed layer depth, and (d) PFZ lines

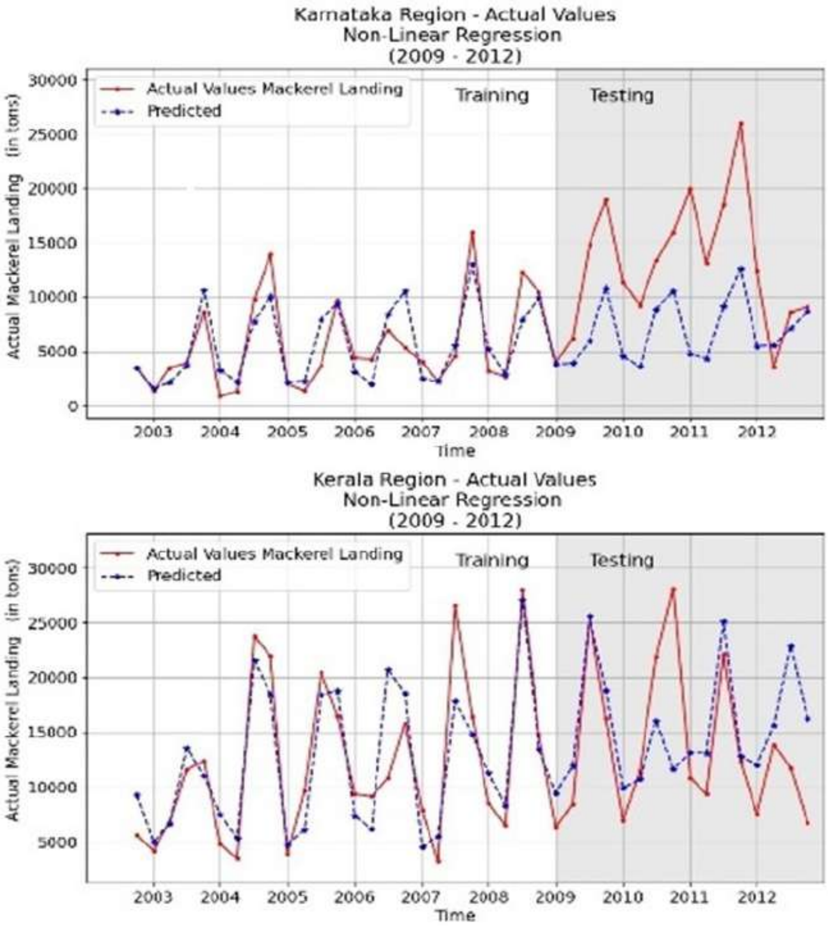

Figure-3: Prediction and observation values of mackerel landings from 2009-2012 in Karnataka and Kerala. The non-shaded area shows the training values and the shaded region shows the testing values.

Citation:Jha, S., Sudhakar, S. D., Majumder, S., Joseph, S., & Nair, B. T. (2024). A multidecadal study of the Malabar upwelling system influencing Indian Mackerel landings along the coasts of Karnataka and Kerala, south-east Arabian Sea. Journal of Marine Systems.

https://doi.org/10.1016/j.jmarsys.2024.104012

[Report Courtesy: Sneha Jha, INCOIS, Hyderabad, Telangana, India; E-mail:s.jha-p@incois.gov.in]

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Tidal-scale carbon dynamics in a tropical estuary

Estuaries are highly dynamic and biologically active regions that play a crucial role in the global carbon cycle. This is because estuaries receive large amounts of organic matter from land and exchange materials with the ocean and atmosphere. This organic matter undergoes biogeochemical processes where organic carbon consumption surpasses net primary production, leading to a net heterotrophic state. The net heterotrophic state of the estuary results in high pCO_2 levels and significant CO_2 emissions into the atmosphere. Studies show that the CO_2 emissions from estuaries are comparable to the total flux of riverine dissolved inorganic carbon (DIC) to oceans. The tropical rivers contribute disproportionately (~ 66.2 %) to global freshwater discharge and 73 % of the total sediment load to the world ocean, flushing around 0.53 Pg of terrestrial carbon to estuaries annually. The major components of this carbon are in the forms of DIC (~39.8%), dissolved organic carbon (DOC) (~25.7%), and particulate organic carbon (POC) (~24.8%). Although DIC and POC dynamics have been extensively studied on monthly, seasonal, and annual timescales, the effect of tidal and diel cycles on the processes modulating DIC and POC dynamics along the estuarine gradient remains poorly understood. Against this backdrop, a team of Indian researchers from the Physical Research Laboratory, Ahmedabad, the National Remote Sensing Centre, Hyderabad, and the Indian National Centre for Ocean Information Services, Hyderabad, investigated the dynamics of dissolved inorganic and particulate organic carbon at the tidal scale in one of the major river estuaries of the Indian subcontinent, Mahanadi Estuary, that joins the Bay of Bengal on the east coast.

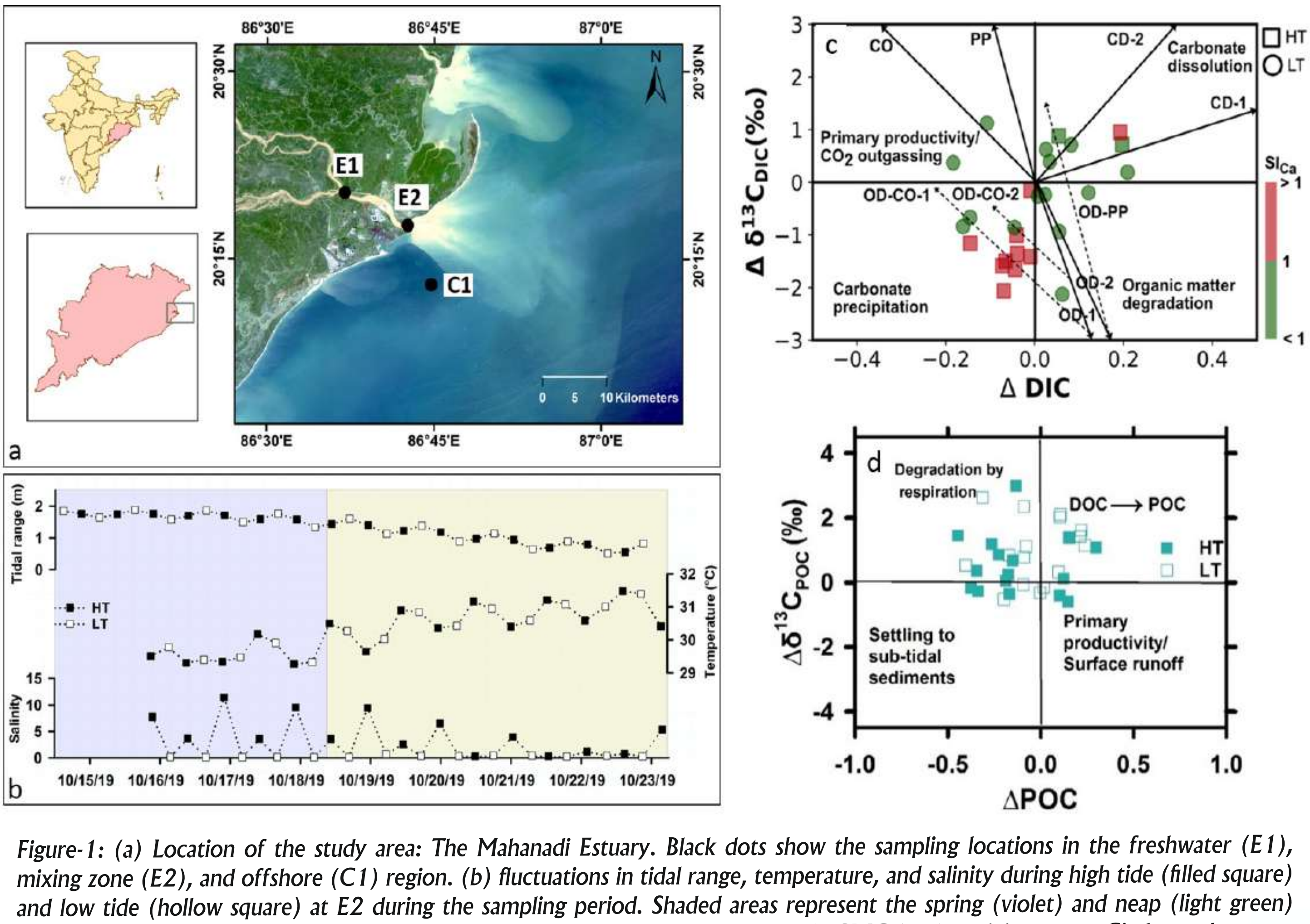

Figure-1: (a) Location of the study area: The Mahanadi Estuary. Black dots show the sampling locations in the freshwater (E1), mixing zone (E2), and offshore (C1) region. (b) fluctuations in tidal range, temperature, and salinity during high tide (filled square) and low tide (hollow square) at E2 during the sampling period. Shaded areas represent the spring (violet) and neap (light green) tide days during the sampling period. (c) The calculated ΔDIC against the Δδ13CDIC in the mixing zone. Circles and squares represent low and high tide samples, respectively. Pink colour represents samples with SICa of more than 1 (calcite oversaturation), whereas green colour represents samples with SICa of less than one (calcite undersaturation). (d) The calculated ΔPOC against the Δδ13CPOC in the mixing zone. In plots c and d, the locus represents the conservative behaviour of the parameter, indicating the absence of any processes. Samples influenced by physical and biological processes diverge from the locus in four quadrants suggesting the dominant processes affecting them.

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In their study, the researchers decoded the biogeochemical processes affecting DIC and POC at the tidal scale by measuring their concentration and isotopic composition at three locations (E1, E2, and C1) in the Mahanadi estuary along salinity gradients at every high and low tide for nine consecutive days (14–23 October 2019) (Figure-1a). Deviations of observed DIC concentrations and δ^{13}CDIC from the conservative mixing values suggested pronounced alteration of the DIC source signature in the mixing zone of the estuary. A process-based model aimed at delineating possible biogeochemical processes affecting DIC dynamics indicated calcite dissolution during low tide and calcite precipitation during high tide, to be dominant processes in the mixing zone (Figure-1c). Additionally, signatures of more than one simultaneous biogeochemical process modulating the DIC dynamics were observed (Figure-1c). POC pool in the mixing zone was primarily influenced by its removal through rapid remineralization during both high and low tides (Fig. 1d). δ^{13}CPOC, along with the C/N ratio of POM, indicated that C3 plants and/or their derived soil were the major source of POM in the freshwater, whereas the higher contribution of riverine POM and marine phytoplankton was observed in the mixing zone and saline location. This study highlights the importance of semi-diurnal tidal cycling in understanding carbon dynamics in a tropical estuarine system. The findings reveal how biogeochemical processes, influenced over a short time duration (tidal scale), significantly impact carbon dynamics in the estuarine system. This highlights the need to consider these rapid, tidal-driven changes when assessing carbon pools and fluxes in estuarine environments.

Report Source: Khan, M. A., Kumar, S., Roy, R., Prakash, S., Lotliker, A., & Baliarsingh, S. K. (2024). Tidal scale dissolved inorganic and particulate organic carbon dynamics in a tropical estuary. Marine Chemistry, 104451

https://doi.org/10.1016/j.marchem.2024.104451

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DEEP-SEA RESEARCH PART II

THE SUBMISSION PORTAL FOR VOL. 7 OF THE DEEP-SEA RESEARCH II SPECIAL ISSUE SERIES ON THE IIOE-2 IS NOW OPEN

Submission of manuscripts that describe the results of studies related to the physical, chemical, biological, and/or ecological variability and dynamics of the Indian Ocean (including higher trophic levels) is encouraged.

Submission of manuscripts from students and early career scientists is also encouraged.

If you are interested in submitting a manuscript, please contact Raleigh Hood (rhood@umces.edu).

Important Dates:
Editorial Acceptance Deadline: **February 15, 2025**
For more details please visit
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Endorse your projects in IIOE-2

Don't miss the opportunity to network, collaborate, flesh out your research project and participate in IIOE-2 cruises!!

The endorsement of your scientific proposal or a scientific activity focusing on the Indian Ocean region is a recognition of the proposal's or activity's alignment with the mission and objectives of IIOE-2, of its potential for contributing to an increased multi-disciplinary understanding of the dynamics of the Indian Ocean, and of its contribution to the achievement of societal objectives within the Indian Ocean region. Over 55 international, multi-disciplinary scientific projects have already been endorsed to date by the IIOE-2. Yours could be the next one!

Visit https://iioe-2.incois.gov.in/IIOE-2/EndorsementForm.jsp for further details and for projects already endorsed by IIOE-2 https://iioe-2.incois.gov.in/IIOE-2/Endorsed_Projects.jsp.

Call for Contributions

Informal articles/short notes of general interest to the IIOE-2 community are invited for the next (October-end) issue of the IIOE-2 Newsletter. Contributions referring IIOE-2 endorsed projects, cruises, conferences, workshops, "plain language summary" of published papers focused on the Indian Ocean etc. are welcome. Articles may be up to 500 words in length (Word files) accompanied by suitable figures, photos.(separate.jpg files).

Deadline: **25 October, 2024**

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