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

Newsletter

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

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.

Univariate deep learning framework for short-term SST forecasting at high spatio-temporal scales

Background: Sea Surface Temperature (SST) is a critical parameter influencing ocean dynamics, weather systems, fisheries, aquaculture, and marine ecosystems. Accurate short-term SST forecasts can improve weather prediction, identification of potential fishing zones, and provide early warnings for marine heatwaves (MHWs) and coral bleaching events. Traditional dynamical models, though widely used, often suffer from issues such as coarse resolution, uncertain parameterizations, and limited forecast skill in coastal and fine-scale regions. With the rapid growth of satellite SST observations and advances in machine learning, deep learning frameworks offer new opportunities for high-resolution SST prediction. This study presents a univariate deep learning framework for predicting daily SST at high spatio-temporal resolution (5.5 km, 1–7 day lead times)(Figure - 1).

Methodology: The study introduces a hybrid univariate framework that couples Variational Mode Decomposition (VMD) with a Long Short-Term Memory (LSTM) neural network. Daily SST data at ~5.5 km resolution from the Sea Surface Temperature and Ice Analysis (OSTIA) product (2012–2019) was used for training, and predictions were tested over the Gulf of Kutch (67°E–73°E; 18°N–23°N) and surrounding northeastern Arabian Sea for 2020–2021. The SST time series at each grid point was decomposed into five intrinsic mode functions (IMFs) using VMD, each representing distinct frequency bands of variability. Separate LSTM models, configured with one hidden layer of 50 neurons and trained with recent IMF values, were developed for each mode and for multiple forecast lead times. The final SST prediction was obtained by summing the outputs from all IMF-specific LSTM models. This approach allowed the framework to generate forecasts at both daily and high-frequency (3-hourly) scales. Performance was benchmarked against GLORYS reanalysis, IO-HOOFS forecasts, and in situ buoy observations using correlation, RMSE, and probability-based reliability metrics.

Results and Discussion: The hybrid VMD-LSTM framework demonstrated impressive accuracy in reproducing daily SST variations. For 3-day forecasts, the model achieved correlations as high as 0.97 and RMSE values near 0.39 °C, outperforming the GLORYS reanalysis which showed higher errors (~0.47 °C). Reliability analysis further confirmed that the hybrid system provided sharper, more consistent forecasts across the observed SST range, particularly at lower temperatures where dynamical models faltered. The hybrid model's performance was assessed through conditional probability distributions, which revealed a closer alignment with observations compared to GLORYS. These results underscore that the hybrid model not only improves average forecast skill but also enhances confidence in its predictions.

A notable strength of the framework lies in its ability to reproduce fine-scale spatial features, such as SST fronts. These fronts are important for potential fishing zone (PFZ) advisories and are often poorly represented in coarser-resolution reanalyses. The hybrid model accurately predicted observed SST fronts with a 3-day lead time, whereas GLORYS produced spurious patterns. By faithfully capturing such fine-scale ocean structures, the hybrid approach demonstrates operational potential for fisheries and coastal applications.

In addition, the VMD-LSTM framework proved capable of forecasting marine heatwaves (MHWs), which are prolonged anomalous warm events with severe ecological impacts. Using 30-year climatology, the study found that the hybrid model could predict most major MHWs up to three days in advance, closely matching observed SST anomalies. The hybrid model successfully tracked multiple marine heatwave events that were largely missed by GLORYS (Figure - 2).

These findings suggest that the system could provide valuable early warnings for coral bleaching, ecosystem stress, and aquaculture risks. Although the hybrid model showed limitations during extreme events like cyclones—where its SST response lagged observations by more than a day—it remains a robust and computationally efficient tool for high-resolution SST forecasting in normal to moderately extreme conditions.

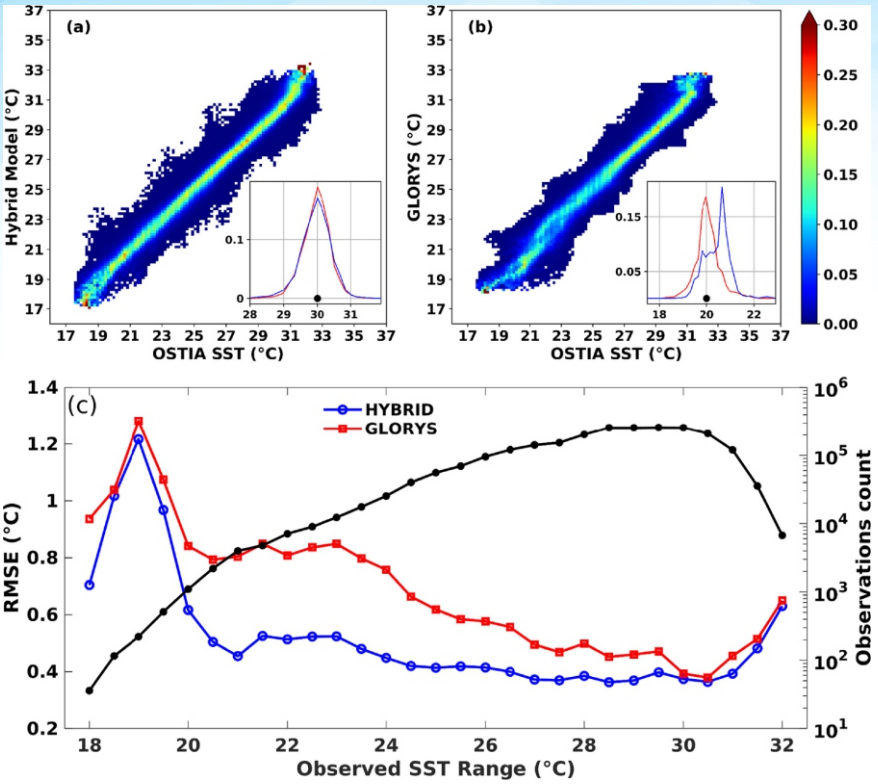


Figure-1: Conditional probability distributions of observed SLA given (a) hybrid model and (b) GLORYS forecasts. (c) RMSE of SST for the hybrid model (blue) and GLORYS (red) across 0.5 °C temperature bins; black line shows number of observations.

Key Highlights

- Outperforms GLORYS reanalysis in daily SST prediction, with skill up to 7 days.
- Reproduces fine-scale SST fronts, aiding potential fishing zone advisories.
- Reliable high-frequency (3-hourly) SST forecasts, better than operational models.
- Detects marine heatwaves up to 3 days in advance, supporting early warning systems.
- Limited skill during cyclones; improvements possible with multi-variable predictors.

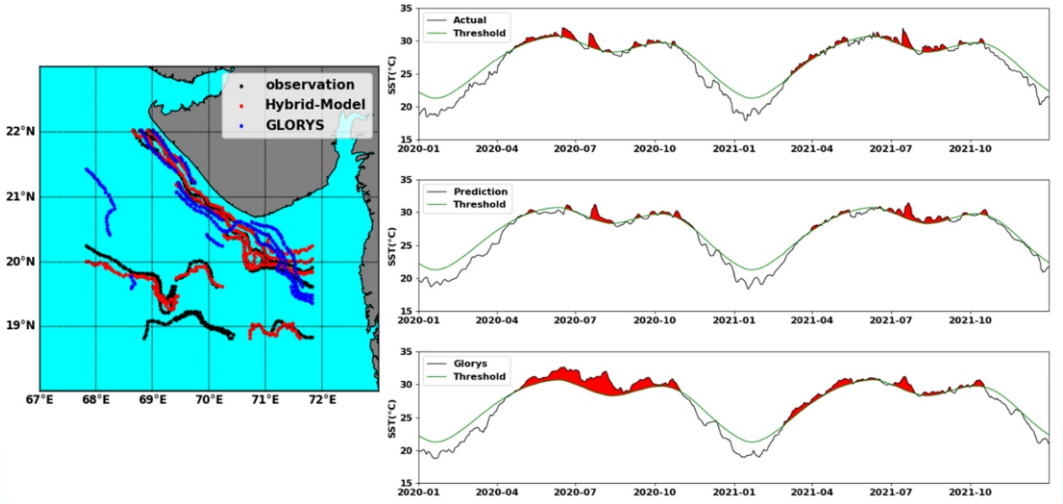


Figure-2: Fine-scale SST fronts and marine heatwaves. The hybrid model accurately predicts SST fronts with a 3-day lead time and successfully captures multiple marine heatwave event.

Citation: Jagdish Prajapati, Balaji Baduru, Athul C R, Biswamoy Paul, Vinod Daiya and Arya Paul. (2025). Univariate deep learning framework for short-term SST forecasting at high spatio-temporal scales. Environ. Res. Commun. 7 075002 DOI:10.1088/2515-7620/ade7d6

[Report Courtesy: Jagdish Prajapati (j.prajapati-p@incois.gov.in), B Balaji (balaji.b@incois.gov.in), and Dr. Arya Paul (aryapaul@incois.gov.in), INCOIS, Hyderabad, India]

Deriving key ocean circulation variables to enhance IMOS observations off Western Australia

Along the west coast of Australia, long-term moored observations off Ningaloo in the north (22°S, since 2010) and off Two Rocks/Rottnest Island in the south (32°S, since 2011) have been maintained through the Integrated Marine Observing System (IMOS). These moorings mainly measure the physical variables of ocean temperature and current velocities. Quality-controlled datasets are produced by the IMOS Australian National Mooring Network facility and are available through the Australian Ocean Data Network (AODN).

Supported by the Western Australia State Government, CSIRO, and IMOS, we have designed a two-year project to take advantage of the long-term observations and derive indices for the strength and variability of the Leeuwin Current, the variability of the wind-driven coastal currents, the Ningaloo and Capes Currents, and the upwelling strength associated with these coastal currents during 2011-2026. Based on ocean reanalysis products, the project plans to derive Indonesian Throughflow indices for its transport and induced heat content variability off northwest Australia. We plan to service the derived ocean indices to the public through the IMOS OceanCurrent web server

(https://oceancurrent.aodn.org.au/index.php).

Variations of the Indonesian Throughflow affect the upper ocean heat content in the southeast Indian Ocean and the strength of the Leeuwin Current, which are the key drivers of the recent extreme marine heatwaves off the northwest and west coasts of Australia, such as the unprecedented 2011 Ningaloo Nino, and the recent 2025 marine heatwave. Under the influence of anthropogenic climate change, similar extreme events may become more frequent in a warming climate.

Understanding the strength and variability of ocean boundary currents is crucial for informing operational decisions in fisheries and aquaculture, as well as for understanding coastal change, including erosion and inundation, and predicting potential marine heatwave events and their associated marine environmental impacts. Ocean boundary currents off the West Australian coast provide a key mechanism of seasonal enhancement of ocean production and larval transport, and these processes will evolve under the influence of climate variability and climate change. This project is a key step toward understanding boundary current variability and how it influences marine conservation and the fishing industry along the west coast of Australia. The project will help promote the values of the ocean observing system and enhance data uptake of ocean observation data by the stakeholders.

The research will be undertaken by CSIRO and the Australian Institute of Marine Science (AIMS) in the next two years. We welcome international collaborations on ocean boundary current research.

Feng, M., Meyers, G., Pearce, A. and Wijffels, S., 2003. Annual and interannual variations of the Leeuwin Current at 32 S. Journal of Geophysical Research: Oceans, 108(C11), 3355.

Feng, M., Waite, A.M. and Thompson, P.A., 2009. Climate variability and ocean production in the Leeuwin Current system off the west coast of Western Australia. Journal of the Royal Society of Western Australia, 92, p.67.

Feng, M., Bui, T. and Benthuysen, J.A., 2025. Seasonal climatology of the Leeuwin Current Capes Current system off southwest Australia from long term moored observations. Journal of Geophysical Research: Oceans, 130(5), p.e2025JC022662.

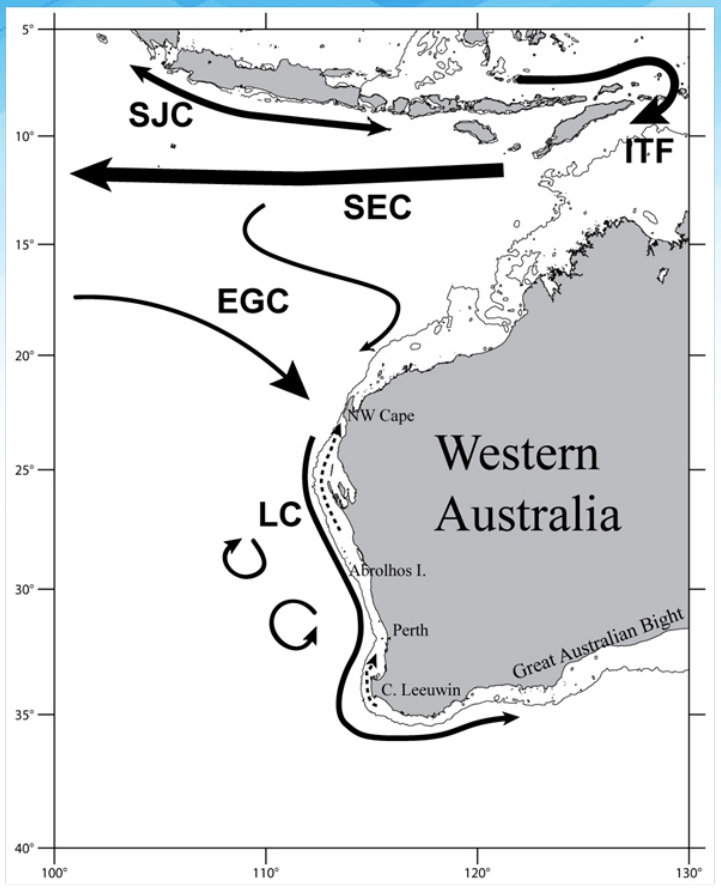


Figure-1: Regional currents in the East Indian Ocean and off the WA coast. ITF: Indonesian Throughflow; SJC: South Java Current; SEC: South Equatorial Current; EGC: East Gyral Current; LC: Leeuwin Current; NW Cape: Northwest Cape; Abrolhos I.: Abrolhos Islands; C. Leeuwin: Cape Leeuwin. The 200 m isobath of bottom bathymetry is shown as solid lines and the dashed lines denote the inshore wind-driven currents (Modified from Feng et al. 2003; 2009).

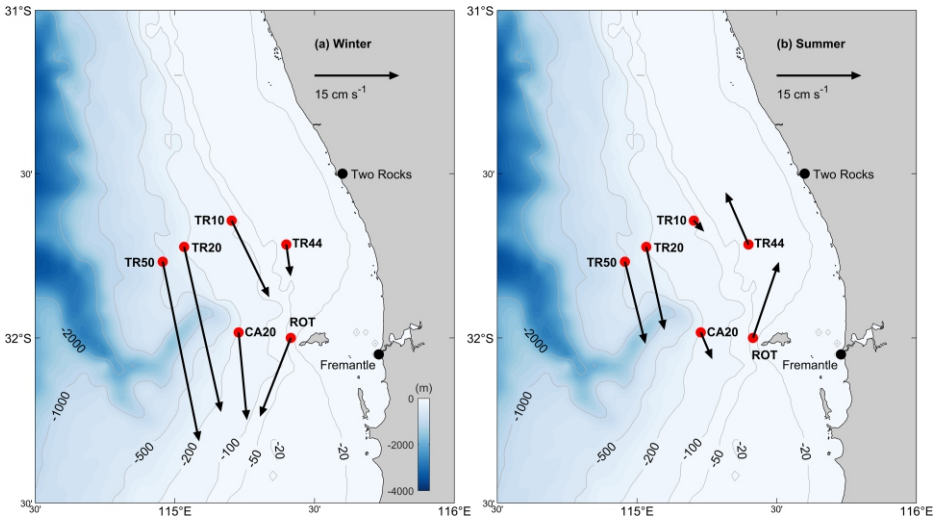


Figure-2: Mooring locations and seasonal variations of surface current off southwest Australia (from Feng et al. 2025).

[Report Courtesy: Ming Feng (Ming.Feng@csiro.au), CSIRO, Indian Ocean Marine Research Centre, The University of Western Australia, Australia]

On the collection of Crustaceans made by the IIOE in the Northeastern Indian Ocean

Introduction

The International Indian Ocean Expedition (IIOE) 1960-65 obtained a large collection of planktonic samples. The crustaceans were sub-sorted and studied at the Marine Reference Collection and Resource Centre, University of Karachi.

In this note the articles published on these samples from Pakistan are brought together. The crustaceans belonged to copepods, isopods, sergestids, carideans, porcellanid and galatheids. The list is arranged group wise. To my knowledge this is the first such compilation.

Sergestidae

Systematic study and distribution of planktonic shrimps of family Sergestidae in the Indian Ocean Collected by International Indian Ocean (IIOE). 2006.
Dissertation, F.Yousuf ,University of Karachi

On Abundance And Occurrence Of Sergestids Sergestes And Sergia (Crustacea: Decapoda) In The Samples Collected During International Indian Ocean Expedition (Iioe). 2005
Q. B. Kazmi, F. Yousuf, S. Shaukat, Environmental Science, 2 (2): 313-319.

New Records for Two Sergestids: Sergestes orientalis Hansen, 1919 and Sergia umtakae Hashizume and Omori, 1995 (Crustacea, Decapoda, Sergestidae). 2008
F.Yousuf and Q. B. Kazmi, Turkish Journal of Zoology 32(3),:

First record of Sergestes belonging to edwardsii species group (Sergestidae, Crustacea) from the Indian Ocean 2005
F. YOUSUF and Q. B. Kazmi, Zootaxa 1092:47-63

Distribution and range extension of pelagic shrimp Sergestes belonging to corniculum species group. 1997
N. Qureshi & N. M. Tirmizi, Biodiversity of Pakistan, 278-289

Distribution of planktonic shrimp Sergestis semissis Burkenroad,1940 (Decapoda, Sergestidae) in the Indian Ocean with Notes on Juveniles. 1987
N. M . Tirmizi, N.Aziz and W. M. Qureshi. Crustaceana 53(1):15-28

First subsequent record of Sergestes hamifer Alcock and Anderson, 1894 (Sergestidae, Crustacea) Collected from the Indian Ocean 2016,
F. Yousuf and Q. B. Kazmi, International Journal of Fauna and Biological Studies 3(3): 05-08

Sergestids collected by International Indian Ocean Expedition (IIOE). National Symposium on Arabian Sea as a Resource Of Biological Diversity. 2000.
Poster Abstract: 45. Q. B. Kazmi and F. Yousuf

Isopoda

A Compendium of Crustaceans of Pakistani Waters Living in Partnership: Concise compilation of symbiotic crustaceans of Pakistan with all necessary information (with a chapter on IIOE samples), LAP LAMBERT Academic Publishing ,2016
Q.B.Kazmi

Gnathia arabica, n. s. first record of a gnathiid from the Arabian Sea, and new records of isopods (Crustacea: Isopoda) from Pakistan in collections of the Smithsonian Institution. 1995
M.Schotte,. 111–118 in M.F. Thompson and N. M. Tirmizi, eds., The Arabian Sea living resources and the environment Vanguard Press, Lahore

A new locality and host for Pseudione minimocrenulata Nierstrasz& Brender à Brandis, 1931 (Crustacea: Isopoda: Bopyridae) in the Indian Ocean, with comments on the identity of the type specimens. 2005
Q. B. KAZMI1 & C. B. BOYKO ,Zootaxa 925: 1–10; Caridea

Record of Deep-Sea Shrimp of Pasiphaea sivado Species Group (Decapoda: Caridea: Pasiphaeidae) in the Western Indian Ocean Collected by R/V Anton Bruun (IIOE Cruise). 2022
Q. B. Kazmi and M. A. Kazmi, International Journal of Animal Science and Technology , 6(2):42-47

Copepoda
Studies on the adults and copepodite stages of Temora discaudata (Copepoda: Calanoida), collected on Meteor cruise 1, 1964/1965 during the International Indian Ocean Expedition. 2002
S. Ali-Khan and J. Ali-Khan, Pakistan Journal of Zoology 34(4): 311-318

Adults and Copepodite Stages of Temora turbinata (Copepoda: Calanoida) from the Indian Ocean.2006
S.Alikhan , Pakistan J. Zool., 38(3) : 201-205.

Two New Records of Heterorhabdidae (Copepoda, Calanoida) From the Arabian Sea Off Pakistan, 1993
S.Alikhan, Crustaceana . 65, 1 : 120-126

Galatheidae
INDIAN OCEAN GALATHEIDS (CRUSTACEA: ANOMURA) 1993
W.Javed and N.M.Tirmizi, ,UNIVERSITY GRANTS COMMISSION Sector H-9, Islamabad, Pakistan .pp147

Two new species and one new record of Phylladiorhynchus Baba from the Indian Ocean (Decapoda, Galatheidae). 1980
Tirmizi NM and Javed W,. Crustaceana, 39, 255–262.

Two New Species of Munida Leach, 1820 (Decapoda, Anomura, Galatheidae) from the Indian Ocean. 1992.
Tirmizi, NM and W. Javaid Crustaceana. 62, 3: 312-318.

Porcellanid
New record of Lissoporcellana demani Dong & Li, 2014 (Decapoda, Anomura, Galatheoidea, Porcellanidae) from southeast Africa. 2021,
Dong Dong, Q.B. Kazmi, and F.A.Siddiqui. Crustaceana 94(3):381-386

Different decapods
Some undocumented decapodans from the Indian ocean in the galatheid Collection of IIOE (1963-64) by the ship Anton Brunn.2021
(Abstract only) 40th Pakistan Congress of Zoology, Sindh Agriculture University, Tandojam. Q.B. Kazmi and F. A. Siddiqui.

Acknowledgments
I wish to acknowledge the late Professor Dr. N. M. Tirmizi, as Director of the Marine Reference Collection and Resource Center, University of Karachi, who gave me the opportunity to examine and report on this interesting material from the western Indian Ocean.

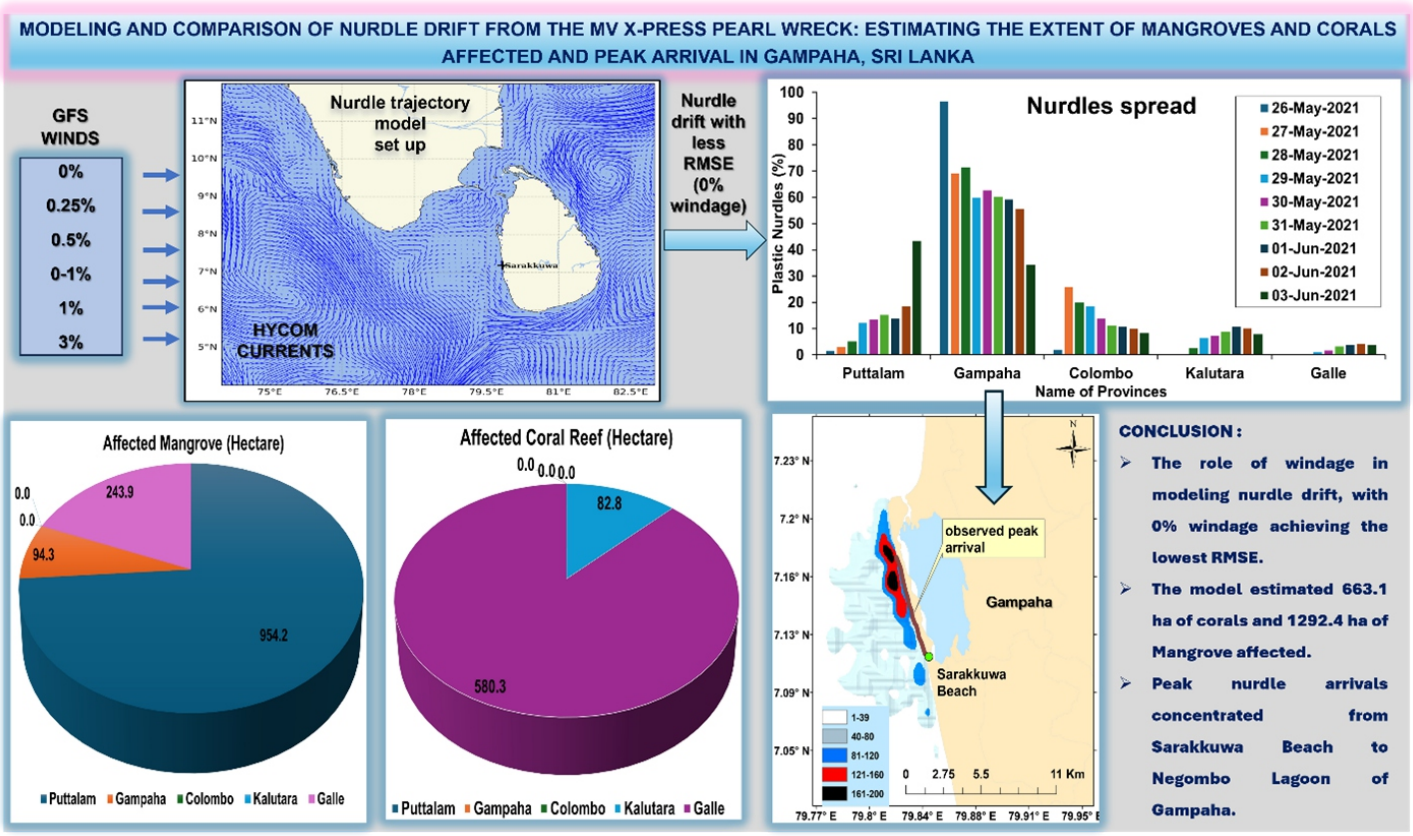
The author also extends sincere thanks to IIOSC-2020 for kindly accepting her abstract of a poster for the second International Indian Ocean Science Conference (No. ABS-06-0295) which was postponed due to COVID-19 pandemic situation and she were not able to represent.

[Report Courtesy: Quddusi Kazmi (qbkazmi@yahoo.com), University of Karachi, Pakistan]

Modeling and comparison of plastic nurdle drift from the MV X-Press Pearl wreck: Estimating the extent of mangroves and corals affected and peak arrival in Gampaha, Sri Lanka

This study developed and validated a regional trajectory model to simulate the drift of nurdles released during the MV X-Press Pearl disaster off Sri Lanka in May 2021. Using GFS winds and HYCOM ocean currents, the model treated nurdles as non-weathering particles and achieved the best accuracy with 0% windage, closely matching observed distributions along the coast, particularly near Sarakkuwa Beach and Negombo Lagoon. The analysis estimated significant ecosystem impacts, with 663.1 ha of coral reefs and 1292.4 ha of mangroves affected. Kernel Density Estimation (KDE) was applied to identify peak accumulation zones, improving spatial prediction in the absence of detailed spill data. Overall, the GNOME model proved effective in simulating nurdle transport, validating field observations, and demonstrating strong potential for disaster response planning and future marine pollution studies.

https://www.sciencedirect.com/science/article/pii/S0269749125014186?via%3Dihub



[Report Courtesy: SJ Prasad, PC Mohanty, TM Balakrishnan Nair, Sudheer Joseph (sjo@incois.gov.in) and T. Srinivasa Kumar INCOIS, Hyderabad, India]

Mechanism and potential of Carbon Storage in the upper-mesopelagic layer of Tropical East Indian Ocean (MeCS-EIO)

The Indian Ocean plays a crucial role in regulating large-scale mass and heat transport. Over the past two decades, the Indian Ocean has absorbed nearly one-quarter of the global oceanic heat uptake, with profound impacts on both global and regional climate systems, particularly across its densely populated rim nations. Despite its significance, the Indian Ocean remains the least understood among the three major ocean basins, primarily due to the complexity of monsoon-driven seasonal reversing responses, climate modes' interaction, and basin-scale fast warming. Along the equator, wind-driven ocean waves propagate zonally and vertically, while also transferring energy poleward via coastal Kelvin waves and boundary-reflected Rossby waves (Figure - 1).

Theoretical and modeling studies suggest these waves can traverse the basin in a few months, making them key modulators of both surface and subsurface ocean currents across a range of timescales. Recent advances in satellite remote sensing and in situ mooring arrays have significantly improved our ability to monitor and interpret Indian Ocean circulation variability and associated wave dynamics. Our recent progress synthesizes the role of equatorial ocean waves in shaping tropical Indian Ocean circulation, with a particular focus on multi timescale variability of Equatorial Undercurrent (EUC) and Equatorial Intermediate Current (EIC). A coherent lead-lag evolution between the first two leading EOF modes reveals an intrinsic EUC life cycle regulated by wind-forced and boundary-reflected equatorial waves associated with phase transition of positive and negative Indian Ocean Dipoles. Our mooring captured an unprecedented early re-emergence of EUC during boreal summer 2008 under the early-IOD that developed and matured within summer. These findings significantly enrich our understanding of EUC diversity and facilitates subsequent research on circulation-ecological effects.

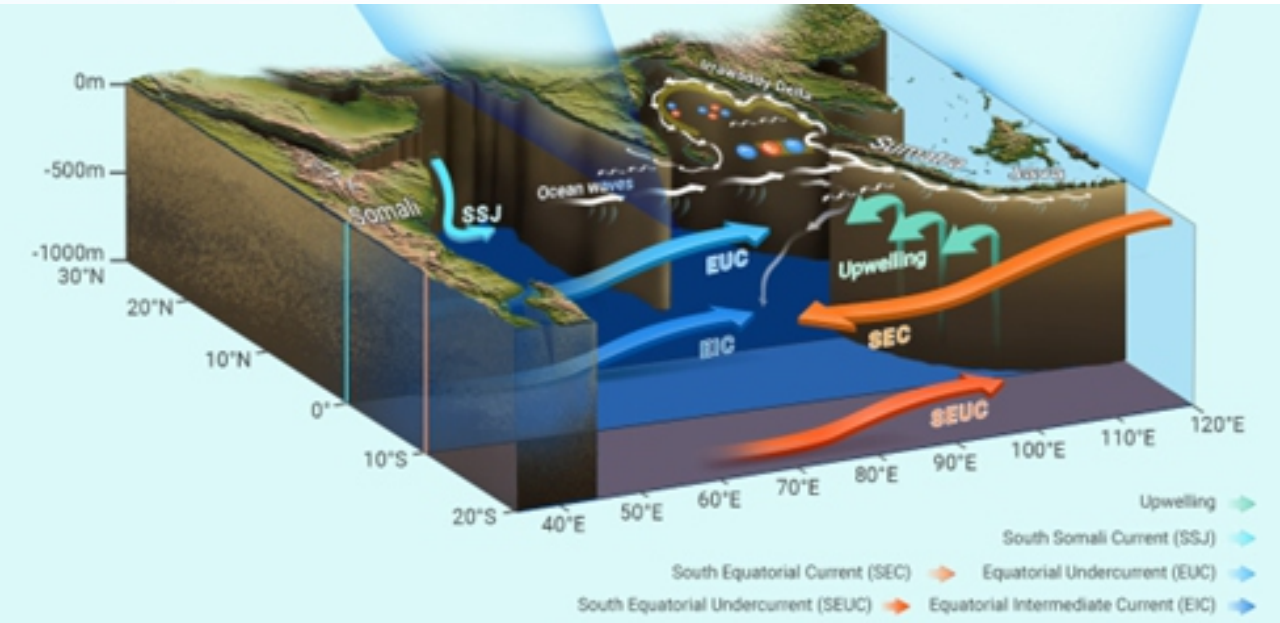


Figure-1: Schematic of equatorial currents in the Indian Ocean (Chen et al., 2024)

The Eastern Indian Ocean, characterized by pronounced spatiotemporal variability driven by monsoonal reversals, also represents an ecological hotspot for studying oceanic carbon dynamics. The role of dissolved organic matter (DOM) in oceanic carbon sequestration, and its response to climatic change, has become a central focus in marine biogeochemistry. While the efficiency of the biological carbon pump is projected to decline with ongoing ocean warming, predicting the long-term stability of DOM reservoirs remains challenging due to the intricate mechanisms governing DOM production, transformation, and accumulation across diverse spatial and temporal scales. Our recent findings demonstrate that microbial processing of DOM is highly active in the mesopelagic and deep waters of the central basin, where a substantial number of molecular formulas (MFs)—likely representing metabolic intermediates or by-products of microbial respiration—accumulate. We show that heterotrophic microbial transformations preferentially convert relatively saturated compounds into highly unsaturated, oxygenated, and higher molecular weight molecules, thereby enhancing DOM recalcitrance. Notably, microbial respiration in the Central Indian Ocean appears to be the dominant mechanism driving the accumulation of nitrogen-containing DOM (CHNO), resulting in the production of nitrogen-rich MFs with low C/N ratios and highlighting this region's role in long-term nitrogen sequestration (Figure - 2). These results advance our understanding of carbon and nitrogen cycling in the ocean interior, with significant implications for predicting microbially mediated coupling of carbon and nitrogen under climate change. As ocean warming intensifies, microbial respiration may increasingly facilitate the accumulation of recalcitrant dissolved organic nitrogen (RDON), contributing to the formation of a persistent nitrogen pool in the mesopelagic zone of the central basin. Collectively, our study provides new molecular-level insights into the mechanisms underpinning carbon and nitrogen sequestration in the warming Indian Ocean.

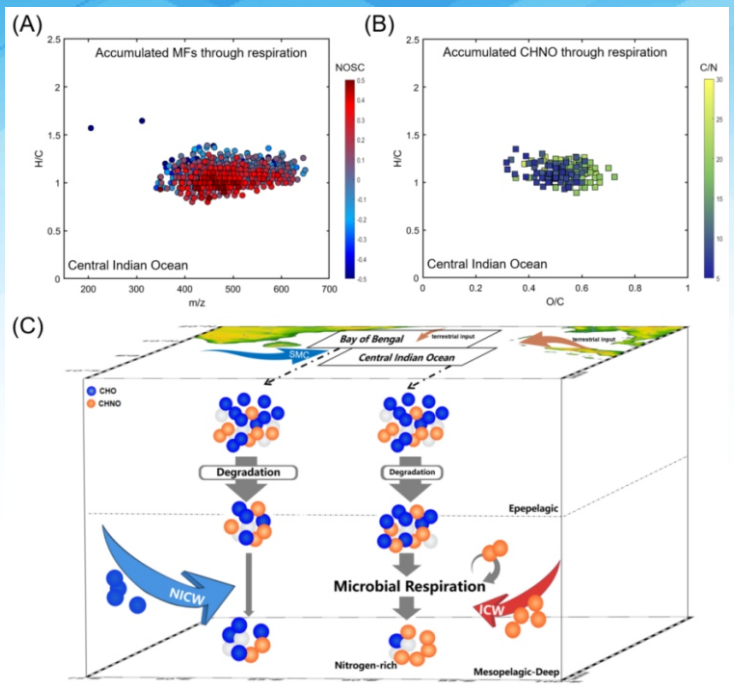


Figure-2: DOM molecular composition accumulated through microbial respiration and the conceptual implications

[Report Courtesy: Ke Huang South China Sea Institute of Oceanology, CAS, P.R. China, Yixue Zhang, Ying Wu, State Key Laboratory of Estuarine and Coastal Research, East China Normal University, P.R. China]

International Indian Ocean Science Conference (IIOSC) 2025

The International Indian Ocean Science Conference (IIOSC)-2025 will be held from 01–05 December 2025 in Hyderabad, India. The event will be hosted by the Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences (MoES), Govt. of India.

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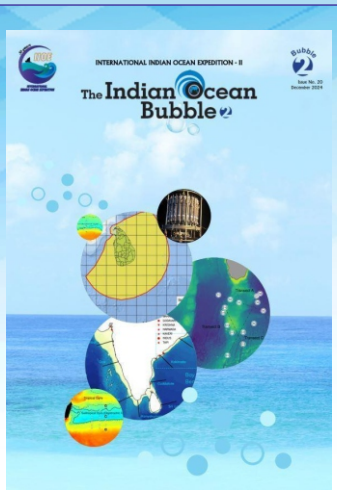

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Informal articles are invited for the next issue. Contributions referring Indian Ocean studies, cruises, conferences, workshops, tributes to other oceanographers etc. are welcome.

Articles may be up to 1500 words in length (MS-Word) accompanied by suitable figures, photos (separate .jpeg files).

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

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 62 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, 2025

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

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