2nd International Indian Ocean Expedition 2015-2025

Newsletter

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

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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.

Cruise SO308 South Indian Ocean GEOTRACES Gi07

The GEOTRACES research cruise SO308 on the German vessel SONNE sailed from Durban (South Africa) to Fremantle (Australia) across the South Indian Ocean during the period October 31 to December 22, 2024. We sampled shelf and slope stations along the Mozambique coast, crossed the Mozambique Channel and sampled along the EEZ of Madagascar. We crossed the oligotrophic gyre of the South Indian Ocean along about 23°S and visited stations on the Central Indian Ridge. Furthermore we studied the shelf and slope system off Western Australia whilst sailing south with the Leeuwin current.

At each Station we sampled in detail, the water column from the surface ocean to the seafloor, and collected water and particle samples. We used a titanium CTD rosette frame (Fig. 1) for sampling of contamination-prone elements. The stainless steel CTD frame was used for non-contamination-prone sampling of elements and isotopes like radium, thorium,uranium, rare earths and neodymium. This CTD was also used for sampling of microbial communities, metagenomics and proteomics. The CTD frames are full of biogeochemical sensors, and cameras to observe zooplankton and sinking particles. Every 2 or 3 days, at our superstations, we also added an additional stainless steel CTD cast, and deployed 7 in situ pumps to a maximum depth of 800 m for particle collection.

In addition, we sampled aerosols and also sediments with a mini multicorer (MUC). To operate in a time efficient manner, we hung the mini MUC underneath the CTD frame. The combined deployments have been very successful. One of the 4 cores was used for pore water extraction to allow determination of benthic fluxes to the bottom waters.

Figure-1: Titanium CTD frame comes on deck on RV SONNE. Photo A. Hollister.

The research objective of the cruise is to determine in detail the distributions, sources and sinks of trace elements and their isotopes (TEIs) in the water column along a zonal section in one of the least studied ocean regions on earth. We aim to investigate the biogeochemical cycling of TEIs, and their interactions with surface ocean productivity and the carbon and nitrogen cycles (incl. N_2 fixation) given that some TEIs act as micronutrients. The supply pathways of TEIs to the South Indian Ocean from ocean boundaries will be investigated, including inputs from the atmosphere (east African and northwest Australian dust), continents (Zambezi river), sediments (on continental shelves/slopes and deep seafloor), and ocean crust (hydrothermalism). The TEI transport within water masses will be determined with a focus on the flow of hydrothermally derived TEIs towards the Southern Ocean but also the deep inflow of Southern Ocean waters into the SIO. The TEI transport assessment along the cruise track will also allow a more reliable use of some TEIs as paleo circulation proxies. The cruise forms an official contribution to the International GEOTRACES Programme and the Second International Indian Ocean Expedition.

At the end of the cruise, we have in total sampled 51 stations along our transect of about 11500 km between Durban and Fremantle (Fig. 2). A total of 16 stations were superstations with an additional CTD deployment with seven in situ pumps. We had planned 51 stations, and we also completed them, with the locations of most stations as initially planned. This is rather unique as typically there are a range of changes to the station programme on our expeditions. We had to sail somewhat further south in the region south of Reunion and Mauritius, in order to avoid the strongest impacts of a westwards moving hurricane.

The Sonne cruise SO308 was very successful, and we achieved the majority of our objectives. We sampled for aerosols, dissolved and particulate trace elements and isotopes in the water column, sediments using a mini-multi-corer, and particle export including biomarkers for particle degradation. In addition, we conducted an extensive biology programme, aligned with the ambitions of BIOGEOSCAPES, which included collection of proteomic and metagenomic samples, assessment of microbial methane producers, (micro)nutrient limitation bioassays of phytoplankton growth, and assessment of diazotrophy. We deployed 19 Argo profiling floats, many of them with biogeochemical sensors, along the transect for the US and German Argo communities.

The cruise involved a range of national and international research groups and we had 15 different nationalities on board which created an excellent multi-cultural environment. The cruise was led by GEOMAR, and we had scientists involved from Constructor University, ZMT Bremen, the Universities of Tasmania, Xiamen, Zhejiang, Minnesota, South Florida, Chicago, Stanford, University College London, the Alfred Wegener Institute, Woods Hole, Max Planck Institute for Marine Microbiology (Bremen), IAEA Monaco, Helmholtz-Zentrum Hereon.

In the coming months there will be plenty of samples to be analysed, and then manuscripts to be written. The success of the cruise was due to the great international team effort by all involved (Fig. 3), both on land and on the vessel. In particular I would like to mention the captain and crew, who contributed greatly to the success of the cruise.

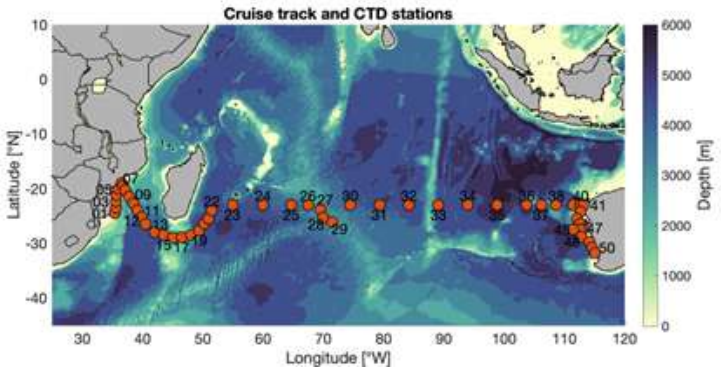

Figure-2: The cruise track with 51 stations (red dots) along the section.

Figure-3: Scientists of SO308. Photo by Eric Achterberg

*[**Report Courtesy:** Eric Achterberg and SO308 team, GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, E-mail: eachterberg@geomar.de]*

Bay of Bengal river plume response to a tropical cyclone in high-resolution numerical simulations

The response of a river plume to a tropical cyclone (TC) is a lesser-known aspect of tropical oceanography. River plumes are freshwater outflows from rivers into the ocean, significantly influencing coastal and open ocean dynamics. i.e., surface salinity distribution, subsurface stratification, air-sea interactions etc. Tropical cyclones, on the other hand, are powerful, vigorous storms that can drastically alter upper ocean conditions. Understanding how these two phenomena interact is crucial for predicting changes in ocean circulation, marine ecosystems, and coastal environments.

In this research, we have investigated the interaction between a river plume and a category 5 TC, Phailin (8-14 October 2013), in the Bay of Bengal using high-resolution simulations of ROMS (Regional Ocean

Modelling System). Two distinct experiments were performed: one including the river runoff into the ocean (Riv) and the other excluding it (NoRiv). From the east coast of India, a river plume advected offshore along the southern arm of a cyclonic eddy. The cyclone destroyed the river plume and scattered the low salinity water over a large region. The presence of a river plume made the pre-storm north bay a fresh, warm, and stably stratified basin, with a shallow mixed layer (ML) and thick barrier layer (BL). Upon the passage of Phailin, the stratification weakened, ML deepened, and BL thickness decreased. Maximum temperature drop and salinity rise were seen along the southern flank of the cyclonic eddy. The terms of salinity and temperature equations show that vertical mixing and advection caused these responses, aided by the cumulative effect of upwelling induced by the cyclonic eddy and storm and the advection of redistributing river water.

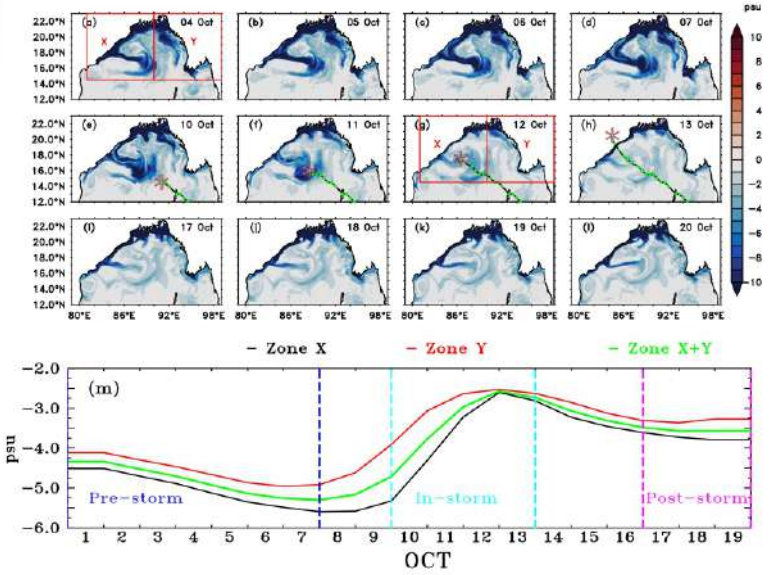

Figure-1: Evolution of river plumes before (panels a–d), during (panels e–h) and after (panels i–l) the arrival of Phailin. We have denoted that the difference in the SSS field between the Riv and NoRiv, i.e., ΔSSS = SSSRiv - SSSNoRiv, measures the distribution of river freshwater. A black track with solid green circles represents the storm track with coordinates of the storm centre at 3-h intervals taken from RSMC, IMD, 2013. The green star with red highlights along the track represents the location of the storm centre at 0000 UTC on a particular day. Area average time series of ΔSSS for northwestern (zone X), northeastern (zone Y) and north bay (zones X and Y) are shown in panel (m). The time series is divided into pre-storm (1–7 October), in-storm (10–13 October) and post-storm (17–20 October).

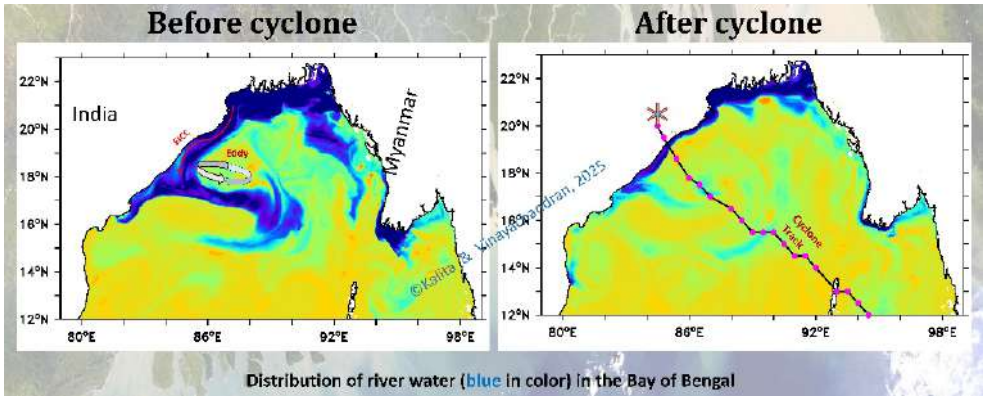

Figure-2 : Schematic: Cyclone scatters Bay of Bengal river plumes. Paths of river plume (EICC and southern flank of a pre-existing cyclonic eddy) in the north bay. Cyclone track with 3-hourly eye positions in solid black lines with magenta bullets, respectively.

Citation: *Kalita, B. K., & Vinayachandran, P. (2025). Bay of Bengal river plume response to a tropical cyclone in high–resolution numerical simulations. Ocean Modelling, 194, 102498. DOI– https://doi.org/10.1016/j.ocemod.2025.102498*

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Illuminating an Overlooked Microbial Sink of N_2O

The greenhouse gas nitrous oxide (N_2O) is an important contributor to global warming, and the ocean is the second-largest source of N_2O after soils. However, the ocean's role as N_2O sink is severely overlooked. Lately a decade back, besides denitrification (a process in which microbes convert N_2O to N_2), scientists have discovered that diazotrophs that fix triple-bonded N_2 gas to NH_4^+ are susceptible to fix N_2O molecules. Thus, assimilatory N_2O fixation by diazotrophs appears a novel N_2O consumption pathway.

Coastal and upwelling areas are the hot spots of N_2O flux to the atmosphere. Notably, the coastal waters of the Arabian Sea are among the biggest contributors to marine N_2O emissions (Figure 1b). The coastal Arabian Sea has global implications due to its significant contribution toward nitrogen loss and N_2O-driven global warming. Understanding the process of N_2O consumption is therefore critical, especially in the face of human impacts. Thus, we investigated diazotrophic N_2O consumption and examined the anthropogenic influence on N_2O dynamics in the coastal northeastern Arabian Sea (Figure 1c,d).

Our findings reveal that the coastal region, excluding the near-fishery harbor waters, acts as a minor net sink for N_2O (98% saturation), contrary to previous reports and in parallel contrast to the global N_2O flux estimations. N_2O fixation likely explains N_2O undersaturation in surface waters. Interestingly, N_2O fixation remains active in the near-fishery harbor eutrophic waters unlike N_2 fixation (Figure 2), and thus, can meaningfully contribute to reducing N_2O emissions. To our counter intuition, N_2O fixation however appears to be an insignificant source of bioavailable nitrogen to primary production based on the current in situ concentrations of N_2O. Our study reveals the significance of N_2O fixation in the context of CO_2, yielding global N_2O fixation estimates equivalent to 0.3 Tg C y^{-1} global ocean net primary production. The established negative feedback of N_2O fixation with N_2O concentrations, and by extension to N_2O emissions, additionally underscores the potential of N_2O fixation as a natural climate regulator. Future research and marine N_2O budgets should thus incorporate N_2O fixation as an N_2O sink, as it holds the potential in climate mitigation strategies.

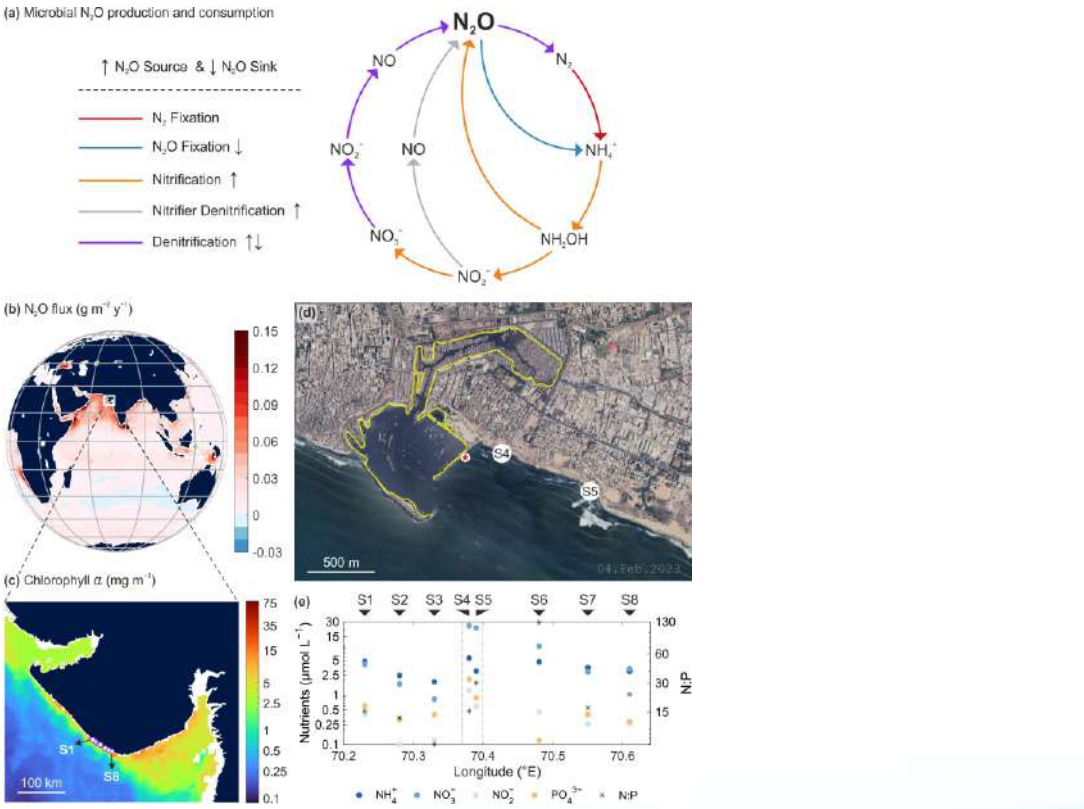

Figure-1: (a) Microbial production and consumption pathways of N_2O, (b) annual mean N_2O flux (adapted from Yang et al., 2020, https://doi.org/10.1073/pnas.1921914117), (c) surface seawater sampling stations in the coastal Arabian Sea overlaid on mean chloroph fyll a concentration for October 2023, (d) sampling stations near the fishery harbor of Veraval, Gujarat, where the yellow line on satellite imagery outlines the harbor, and (e) nutrients concentration and N:P ratios at the stations. Data between the vertical dashed lines in (e) represent stations near the fishery harbor.

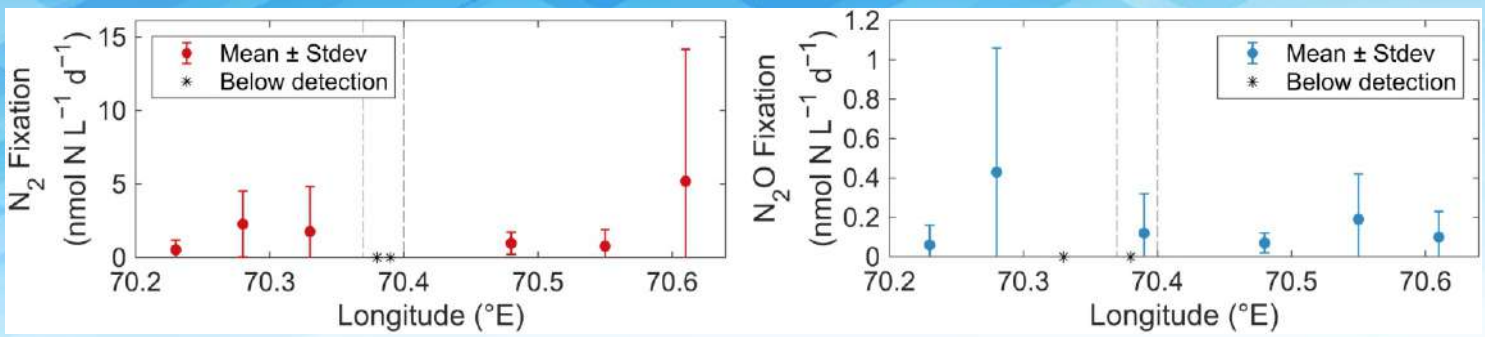

Figure-2: N_2 and N_2O fixation rates. Data between the vertical dashed lines represent stations near the fishery harbor.

Citation: *Saxena, H., Mehta, S., Nazirahmed, S., Kumar, J., Kumar, S., & Singh, A. (2025). Diazotrophs: An overlooked sink of N_2O. Geophysical Research Letters, 52, e2024GL114117. DOI– https://doi.org/10.1029/2024GL114117*

[Report Courtesy : *Himanshu Saxena, Physical Research Laboratory (PRL), Ahmedabad, Gujarat, India; E–mail: saxena2507@gmail.com]*

Pan-CLIVAR 2025 Meeting and abstract submission for the Symposium "Bridging Science and Society in Southeast Asia and Beyond"

We are excited to announce that registration for the Pan-CLIVAR 2025 Meeting and abstract submission for the Symposium "Bridging Science and Society in Southeast Asia and Beyond" are officially open! Join us to explore the latest advancements in climate and ocean variability and predictability.

Pan-CLIVAR 2025 will be held in hybrid mode (in person and online), consisting of CLIVAR panels and Research Foci meetings, Scientific Steering Group sessions, cross-panel meetings, plenaries, and a Symposium on 24 September with breakout sessions in the morning of 25 September.

The symposium will accept abstracts for oral and poster presentation on:

- Climate Variability and Change
- Ocean Processes and Extremes (e.g., MHW, sea level rise, Indonesian throughflow)
- Atmospheric Processes and Climate Dynamics (e.g., Monsoons, inter-basin interactions)
- Cascading and Compound Event
- Biogeochemical Processes and Climate Interactions
- Artificial Intelligence: Role in Climate-Ocean Research and Prediction
- Ocean-Climate Observations and Modelling
- Societal Impact

When and where

- Pan-CLIVAR: **22-26 September**
- Symposium: **24 September (inc. meetings on 25 Sep. morning)**
- Location: **Bali, Indonesia**
- Website: https://pan-clivar2025.sciencesconf.org/

Key Deadlines:

- Symposium Abstract Submission: **11 April 2025**
- Symposium and Pan-CLIVAR Meeting Registration: **15 June 2025**

IMBeR Synthesis and Future Planning Conference (Future Oceans 3)

As IMBeR (Integrated Marine Biosphere Research) approaches the conclusion of its decade-long journey from 2016 to 2025, we invite you to join us at the IMBeR Synthesis and Future Planning Conference (Future Oceans 3, Fo3). This pivotal event will explore three core themes: Looking Inward, Looking Outward, and Looking Forward.

Core Themes:

- Theme 1: Looking Inward: Reflecting on IMBeR's scientific achievements over the past decade (2016-2025).
- Theme 2: Looking Outward: Reviewing IMBeR's interactions with relevant scientific projects, programs, organizations, and initiatives.
- Theme 3: Looking Forward: Envisioning the future of marine biosphere research post-IMBeR

Future Oceans 3 will bring together IMBeR's diverse science teams—including Regional Programs, Working Groups, Endorsed Projects, Study Groups, national committees, and the Interdisciplinary Marine Early Career Network (IMECaN)—as well as representatives from international organizations, policymakers, and early career researchers. Participants are encouraged to present their achievements, propose new projects, and organize specialized sessions tailored to their needs.

Join us in shaping the next phase of marine biosphere science for a sustainable future.

When and where

- Time: **2025.05.13 – 2025.05.16**
- Location: Hybrid – **Shanghai, China & Online**

Important Dates:

- Abstract Submission Opens: **27 January 2025**
- Abstract Submission Deadline: 20 March Extended to **31 March 2025**
- Notification of Abstract Acceptance: Extended to **7 April 2025**
- Early Bird Registration Deadline: **13 April 2025**
- Late Registration for On-site Attendance Closes: **02 May 2025**

Registration: https://internationalmeeting.ecnu.edu.cn/v3/#/events/67d27e32391f2c2fdd95b2d9

Special Session Announcement: IMBeR Doctoral Forum:

The IMBeR Future Oceans 3 (FO3) meeting proudly presents the IMBeR Doctoral Forum, a platform for recent and soon-to-be PhD graduates in marine sciences to showcase their research and engage with leading scientists, policymakers, and peers. Aligned with FO3's mission of reflecting on past achievements, strengthening interdisciplinary partnerships, and shaping ocean sustainability, this forum fosters global collaboration, with a strong focus on early-career researchers (ECRs) from low- to medium-income countries. Participants will present their thesis work through oral presentations, speed talks and posters, while also contributing as session rapporteurs, gaining hands-on mentorship from senior researchers. To support inclusivity, SCOR Travel Support grants will subsidize travel and registration costs for 6–8 eligible applicants. Inspired by successful initiatives like DISCO (Dissertations Symposium in Chemical Oceanography), this forum builds capacity, amplifies early-career voices, and integrates diverse perspectives into global ocean science. Join us in Shanghai or online to share your research, connect with international partners, and contribute to shaping the future of marine biosphere research and marine sustainability. Apply now to be part of this transformative scientific network!

The Indian Ocean Bubble, Issue No. 19 is now available online

Web Link: https://iioe-2.incois.gov.in/IIOE-2/pdfviewer_pub.jsp?docname=IIOE-2-DOC_OM_301.pdf

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 57 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 (April-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 April, 2025

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

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GOOS GLOBAL OCEAN OBSERVING SYSTEM FOR INDIAN OCEAN

UNESCO United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

SCOR Scientific Committee on Oceanic Research