2nd International Indian Ocean Expedition 2015-2025

Newsletter

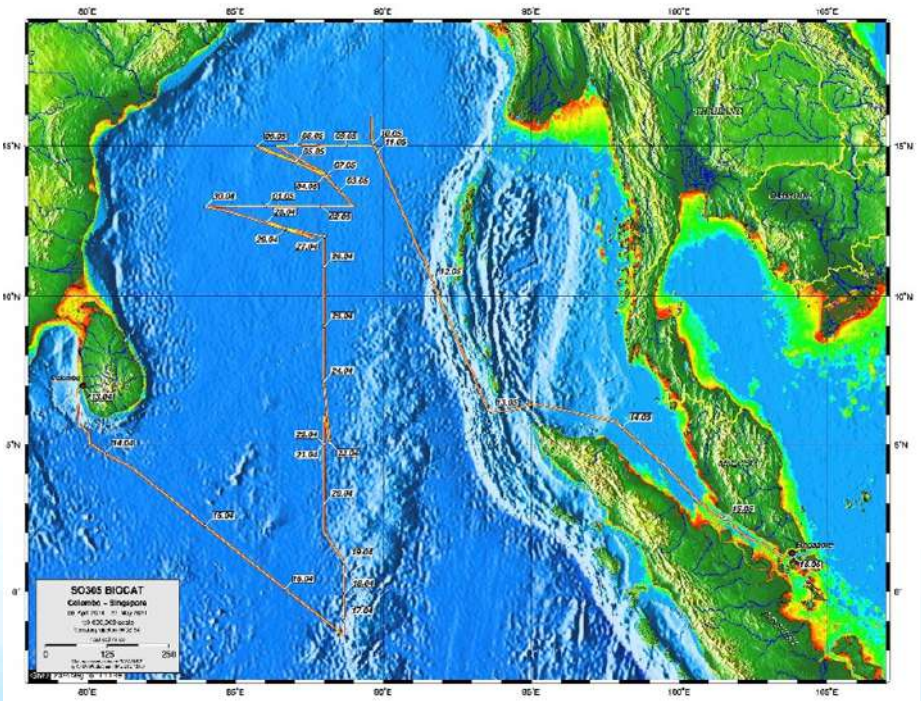
(A basin-wide research program co-sponsored by IOC-UNESCO, SCOR and IOGOOS)

Volume-8, Issue-5
May, 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.

The R/V Sonne cruise SO305 BIOCAT-IIOE2 to the Bay of Bengal (13 April – 16 May 2024)

Climate change and pollution are current changes in the Earth system that also strongly affect the sensitive ecosystems of the ocean. Oceanic areas such as the Bay of Bengal are particularly vulnerable to the effects of human activities such as widespread air pollution, warming, and increased inputs of nutrients (eutrophication). The Bay of Bengal also has a unique, distinct oxygen minimum zone (OMZ) in water depths of 100-500m, with only few equivalents in other oceanic regions. The overarching goal of BIOCAT-IIOE2 (Biogeochemistry/atmosphere processes in the Bay of Bengal: A contribution to the '2nd International Indian Ocean Expedition' program) was therefore to quantify key (micro)biological processes in the water column and ocean/atmosphere exchanges to assess their impact on the OMZ of the Bay of Bengal. To this end, we conducted a measurement campaign with the research vessel (R/V) Sonne from 13 April to 16 May 2024 (SO305), resolving the main carbon and nitrogen cycles and physical processes in the water column of the Bay of Bengal. The oceanic measurements were complemented by an intensive atmospheric program to investigate the effects of atmospheric inputs on water column processes. In BIOCAT-IIOE2, the GEOMAR Helmholtz Centre for Ocean Research Kiel, the University of Hamburg, the Leibniz Institute for Tropospheric Research (TROPOS, Leipzig), the University of Southern Denmark (SDU, Odense, DK), Hereon Helmholtz Centre Geesthacht and the University of Oldenburg were collaborating. A team of 39 scientists, students and technicians performed measurements in the water column and in the atmosphere - 38 stations and five 24-hour stations along the cruise route, from the equatorial eastern Indian Ocean to central Bay of Bengal. In total, we carried out 114 CTD casts, 27 GoFlo casts, deployed the microstructure probe 42 times, deployed drifting particle (sediment) traps 3 times and, last but not least, deployed a long-term deep-sea mooring at the equator. The cruise track of SO305 BIOCAT-IIOE2 is shown in the map below:



During our campaign, a deep Chlorophyll a maximum evolved between 50 and 100 m depth (Figure-1a). The Bay of Bengal was furthermore characterized by an expanded OMZ below a varying depth of 100 to 200 m (Figure-1b). Depending on the stations, it expands towards more than 600 m depth (Figure-2).

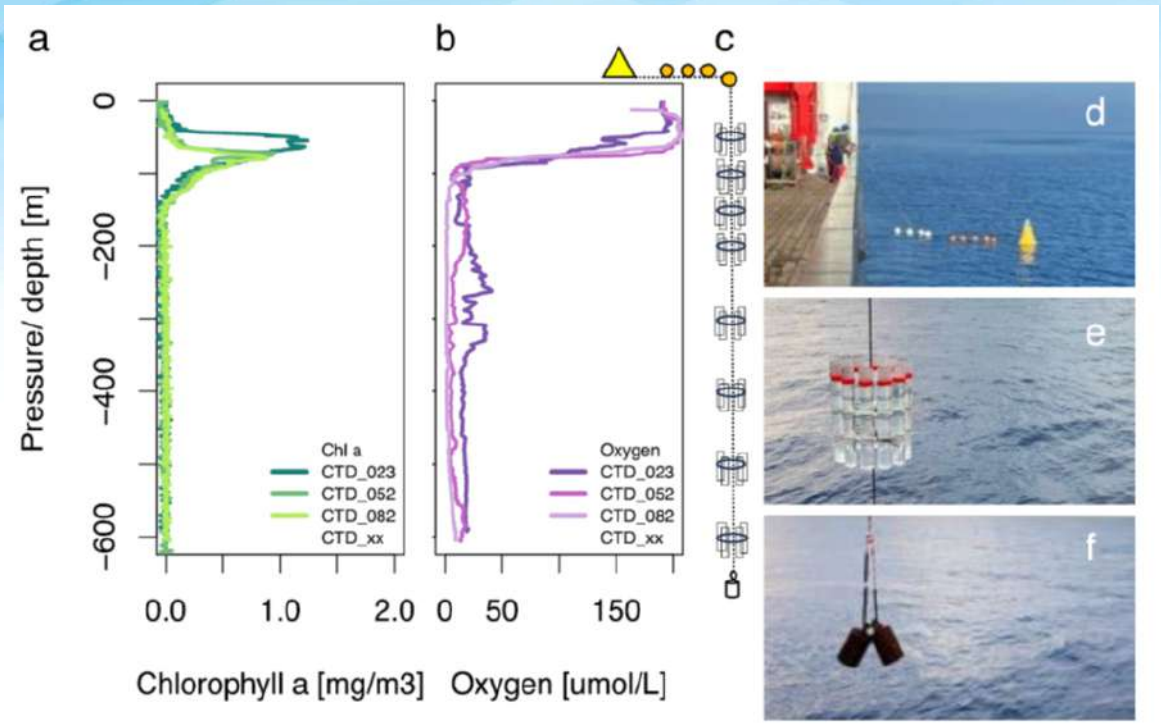


Figure-1: The drifting sediment traps were deployed four times along a S/N transect during the So305 scientific cruise in the Bay of Bengal. a) The Chlorophyll a maxima were located between a depth of 50 to 100 m. b)From S to N oxygen was depleted beyond a depth of 200 to 100 m to concentrations < 10 µM.c). The rosettes of the drifting sediment traps collected sinking particles at eight depths, with a higher resolution until 200 m and a lower resolution until 600 m. The sediment traps are composed of three basic modules including d) the drifting surface buoys equipped with a GPD tracker, e) the eight rosettes in which 12 sedimentation tubes were mounted. and f) the ground weight.

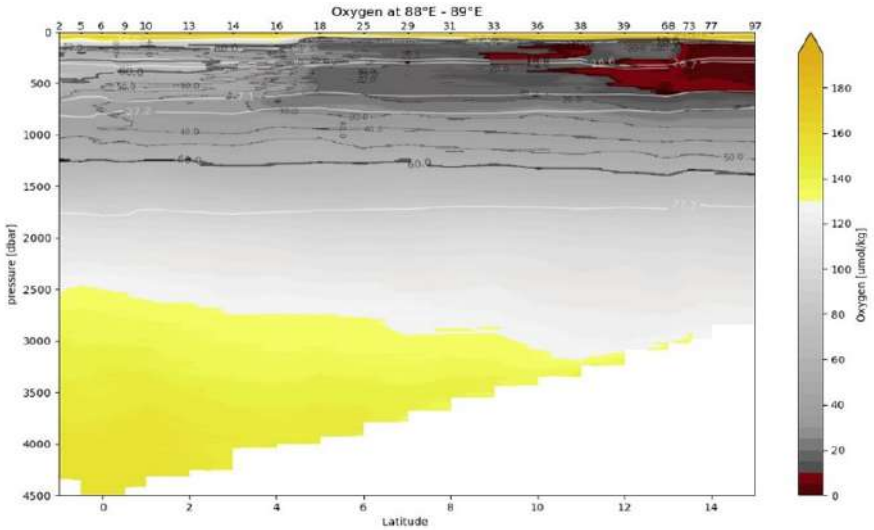


Figure-2: Dissolved oxygen along 88/89°E during SO305 in April/May 2024 (preliminary data).

To assess biogenic particle export dynamics out of the surface mixed layer into the OMZ, we deployed drifting sediment traps along the transect from 5°N to 15°N. The drifting sediment traps resolve the sedimentation flux at high resolution in the surface ocean and at lower resolution down to a depth of 600 m (Figure-1c). The sediment trap deployments lasted between 48 and 69 hours. To define particle export dynamics, we have collected samples for the analysis of e.g., particulate organic carbon (POC) and its molecular components including lipids, amino acids, and carbohydrates. Samples for biogenic silica (BSi) and total particle mass were also collected, enabling us to deduce the contribution of lithogenic material. The contribution of different organisms to particle formation and degradation along its sedimentation pathway will be complemented by meta-genome and -transcriptome analysis. To estimate the influence of enzymatic degradation on particles, enzymatic activity was measured.

BIOCAT-IIOE2 is funded by the German Federal Ministry of Education and Research (BMBF) and is coordinated by Prof. Dr. Hermann Bange (GEOMAR, Kiel). It is a contribution to both the MARE:N program of the German Federal Government and the international programs IIOE2 (iioe-2.incois.gov.in) and SOLAS (www.solas-int.org).

[Report Courtesy: Hermann W. Bange, GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany; E-mail: hbange@geomar.de]

Key results and contributions of Ukrainian marine geologists to the geological and geophysical studies of the Indian Ocean

Ukrainian oceanologists, who participated in numerous marine research expeditions from the 1970s to 1990s, made significant contributions to studying the World Ocean. During this time, Ukrainian marine geologists also made essential progress, expanding their knowledge of the geological and geophysical features of the Indian Ocean, the third-largest ocean on our planet. Ukrainian scientists wrote a particularly notable chapter in the history of complex geological study of the Indian Ocean as a result of the specialized geological and geophysical expedition of the 19th cruise of the R/V "Academician Vernadsky" (Figure-1), which operated in the Indian Ocean 45 years ago, from late January to March 1979. In early April, the expedition successfully returned to its home port, the city of Sevastopol, having collected a large amount of new and interesting geological and geophysical data.

Figure-1: Flagship of the scientific fleet of the Academy of Sciences of Ukraine, R/V "Academician Vernadsky"

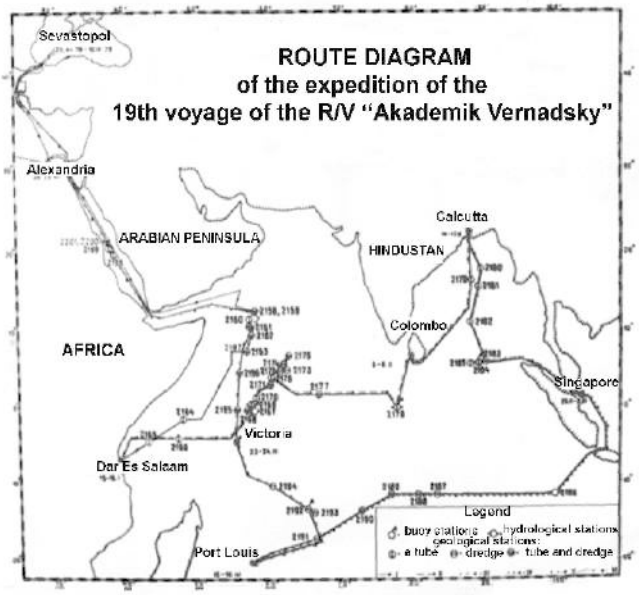


Figure-2: Scheme of the locations in the Indian Ocean of the research stations during the 19th cruise of the R/V "Academician Vernadsky" (December 1978 - April 1979).

We emphasize that this expedition, involving representatives from various geological specialized institutes of the Academy of Sciences of Ukraine, conducted a wide range of geological and geophysical studies in different areas of the Indian Ocean: the Bay of Bengal, the Somali and Central Troughs, and the Arabian-Mid-Indian Ridge (Figure-2). These areas differ in their geological structure, tectonic features, bottom geomorphology, hydrological, hydrochemical, and hydrobiological conditions of both modern and ancient sedimentation. Considerable attention was paid to studying the peculiarities of biogenic and terrigenous sedimentation and the role of aqueous solutions contained in various material-genetic types of bottom sediments in forming their physical-mechanical, physicochemical, and other properties. This included depositing various kinds of polymetallic ore and non-metallic minerals on the ocean floor. For the first time, a large range of engineering and geological properties of bottom sediments was also examined, including the use of radioisotope and acoustic methods.

As a result of this expedition, Ukrainian oceanologists, for the first time, obtained a large amount of experimental geological and geophysical data. The analysis of this data allowed them to determine the features of magnetic, gravimetric, and thermal fields in the study area, reveal the relationships between the material-genetic, physical-mechanical, and acoustic characteristics of different lithological types of bottom sediments, and understand the chemical composition and properties of the pore solutions contained within them, as well as the conditions of their formation.

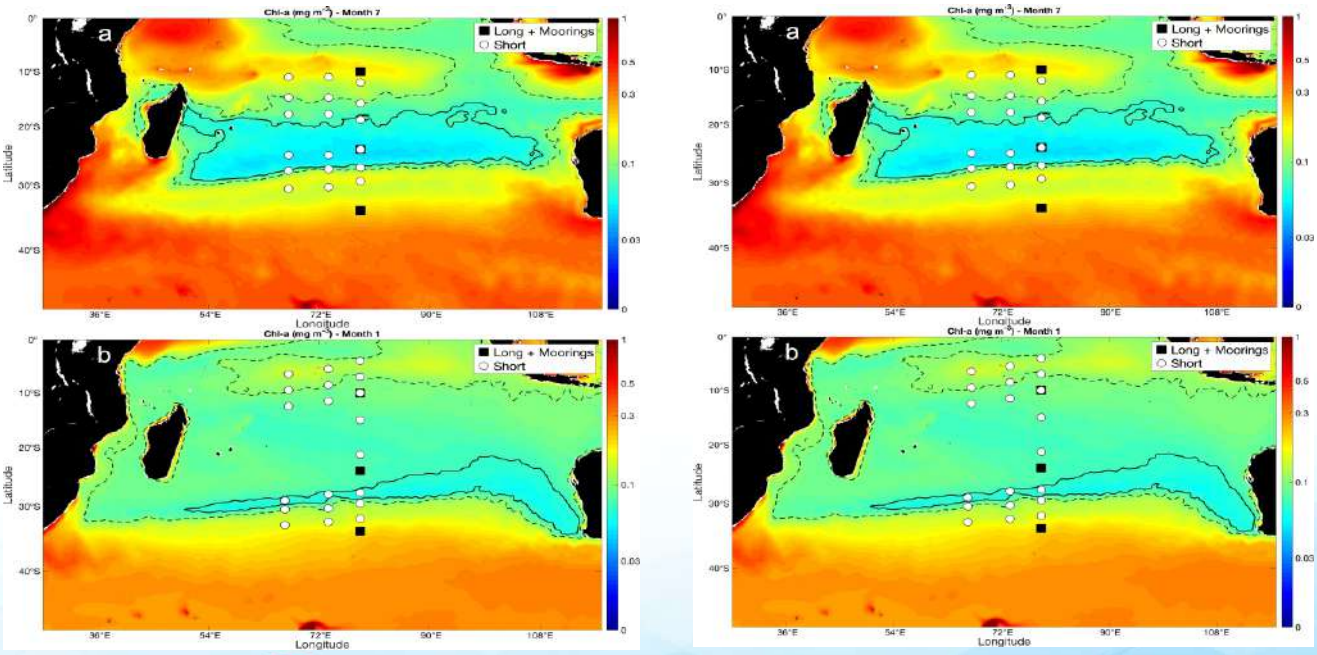
The research results obtained by the participants of this expedition, among whom were the author of this communication (V. Iemelianov) and the father of the second author(O.Ivanik) and the famous Ukrainian paleontologist Mykhailo Ivanik, have been and continue to be employed for solving many fundamental problems in oceanology, marine engineering geology, and hydrogeology. In particular, the conclusions drawn from the study of the materials obtained by this expedition are important for a deeper understanding of the peculiarities of the evolution of the oceans and the formation of sedimentary groundwater. They are also crucial in assessing the role of the liquid component of bottom sediments in the water-salt balance of the oceans, as well as in addressing many practical issues related to the exploration of resources from the geological formations of the Indian Ocean floor. Thus, the results obtained by analyzing the bottom geomorphology and sediment composition in certain study areas allowed us to confirm the important transporting and accumulative role of bottom ocean currents and their decisive influence on forming the equatorial belt of silica accumulation. It was confirmed that up to 10-13% of Antarctic siliceous sediment species are present in the bottom sediments accumulating in some parts of this belt, highlighting the global significance of the sediment transport mechanism carried out by the bottom currents. At the same time, the data obtained from the expedition's work in different areas of this crucial ocean basin made it possible to assess conditions for underwater construction. This includes evaluating the specific requirements for using and placing various mechanisms necessary for mining and laying communications on the ocean floor for various purposes.

It should be noted that the results obtained by Ukrainian scientists during a number of expeditions of Ukrainian R/Vs to the Indian Ocean and, above all, in the first specialized geological and geophysical expedition of the 19th voyage of the R/V Akademik Vernadsky, were presented in Ukrainian and foreign publications in more than 20 scientific works, including the famous monograph "Geology and metallogeny of the northern and equatorial parts of the Indian Ocean", published in the Academic Publishing House "Naukova Dumka", Kyiv, 1984.

[Report Courtesy: Volodymyr Iemelianov (volodyasea1990@gmail.com), Olena Ivanik(om.ivanik@gmail.com), Vladislav Golovatyi *(vlad.golovaty@gmail.com), MarGeoEcoCenter of the National Academy of Sciences of Ukraine, Kyiv, Ukraine]*

Will Nitrogen Fixation offset Nitrogen depletion in expanding Ocean Deserts? (EXPAND)

Often called 'ocean deserts', subtropical gyres have low biological productivity but due to their immense size, contribute significantly to carbon sequestration regulating global climate. In gyres, biological productivity strongly depends on nitrogen supplied by microbes called diazotrophs, capable of fixing molecular nitrogen (N_2) into bioavailable nitrogen forms. Earth system models predict increasing uncertainty in biological productivity towards the end of the 21st century. Such uncertainty responds to N_2 fixation parametrisation in models and is largely driven by the scarce observations available in the Indian Ocean (IO), representing only 1% of the N_2 fixation data available globally. Moreover, our current understanding of N_2 fixation is mainly based on nutrient availability (phosphorus and iron) impacts on diazotrophs. However, my previous research shows that other controls including ocean circulation and diazotroph/non-diazotroph interactions are keys in shaping N_2 fixation inputs locally.



None of these controls have been comprehensively examined over the vast expanse of the IO, nor throughout seasons. We plan to conduct oceanographic expeditions covering the full extension of the IO gyre at its minimum and maximum expansion seasons. Gyre expansion will be tracked with satellite and in situ hydrographic and current speed measurements. The impact of chemical (nutrients), physical (ocean circulation), and biological (species interactions) controls on N_2 fixation will be comprehensively measured, using at-sea experiments and up-to-date isotopic and molecular analyses. Moreover, seasonal variability will be monitored over a full year with mooring lines anchored at the centre, northern and southern edges of the gyre, equipped with DNA samplers and a newly designed automatic device measuring N_2 fixation rates. These datasets will link cellular to ecosystem processes, bridging the gap between ocean desert expansion and N_2 fixation in the world's least explored gyre.

[Report Courtesy: Mar Benavides, Mediterranean Institute of Oceanography, Batiment OCEANOMED, Campus de Luminy 1328, Marseille, France; E-mail: mar.benavides@ird.fr*]*

Development of machine learning-based sea-surface pCO_2 maps for the Bay of Bengal

Understanding the spatial and temporal variations of the sea-surface partial pressure of carbon dioxide (pCO_2) for the Bay of Bengal (BoB) has been limited due to the unavailability of a sufficient number of observations. The limited number of observations results in high prediction errors in the machine learning (ML) based available products for the BoB. Using a significant number of open and coastal ocean pCO_2 measurements and collocated variables controlling pCO_2 variability in the BoB, an ML-based high-resolution (1/12°) climatological data product (known as INCOIS-ReML) has been developed, which provides sea-surface climatological pCO_2 maps and associated air-sea CO_2 fluxes for the BoB. The capability of INCOIS-ReML has been demonstrated by comparing it with sea-surface pCO_2 data available from the BoB Ocean Acidification mooring-based observations and gridded SOCAT data product. INCOIS-ReML is performing better than six widely used ML-based pCO_2 data products. The high-resolution INCOIS-ReML greatly captures the spatial variability of pCO_2, and associated air-sea Co_2 flux compared to other ML products in the coastal BoB and the northern BoB. This data product is expected to help the researchers to distinguish the source/sink behavior of the BoB, which essentially improves the Indian Ocean carbon budget in a changing environment.

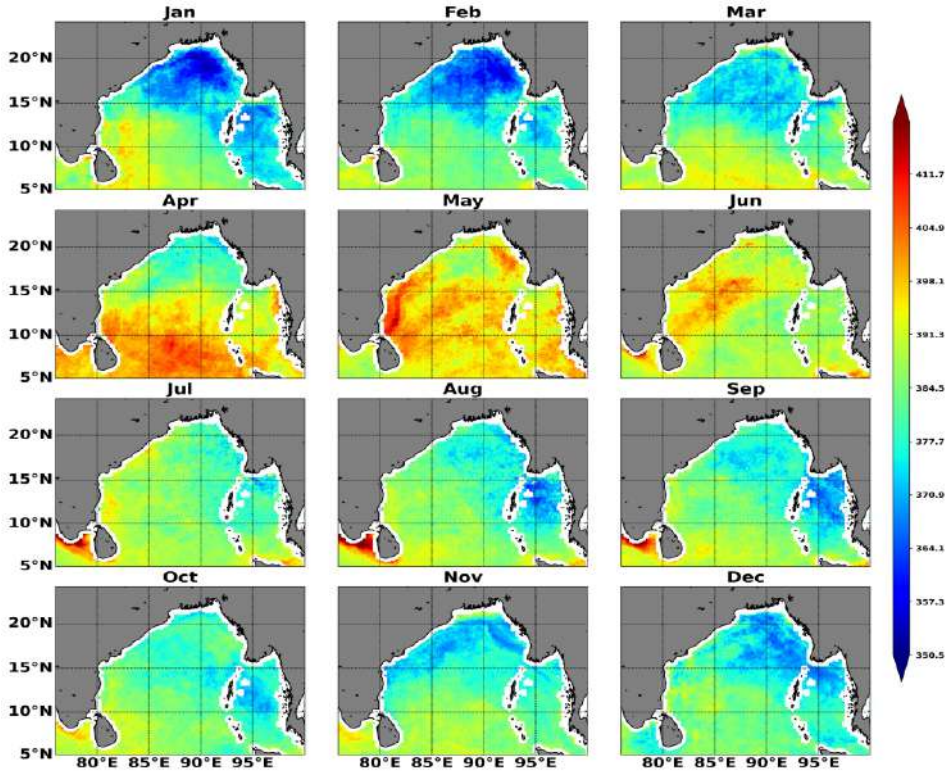


Figure: Climatological monthly variability of the sea-surface pCO_2 produced by INCOIS-ReML. The climatological reference year for this dataset is 2015.

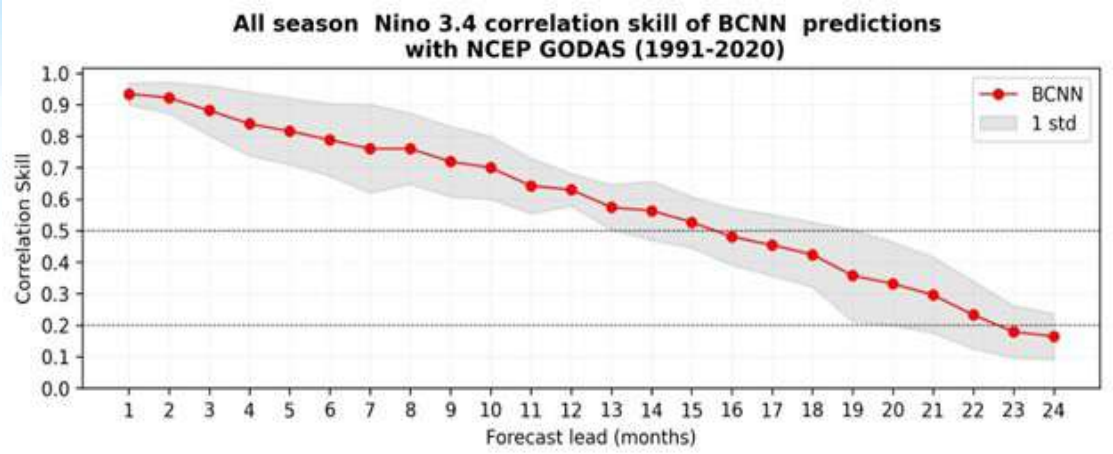
Citation: Joshi, A. P., Ghoshal, P. K., Chakraborty, K., & Sarma, V. V. S. S. (2024). Sea-surface pCO_2 maps for the Bay of Bengal based on advanced machine learning algorithms. Scientific Data, 11(1), 384.

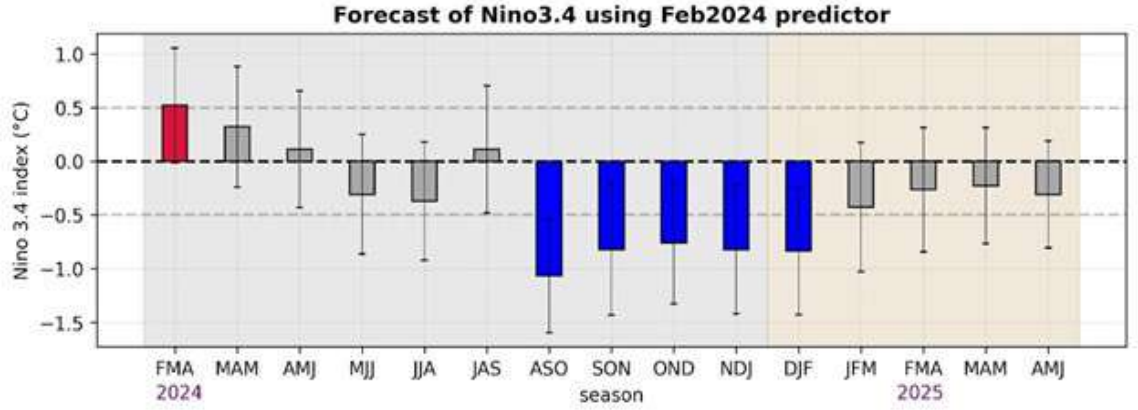
https://www.nature.com/articles/s41597-024-03236-w

[Report Courtesy: Apurva P Joshi, *Scientist, INCOIS, Hyderabad, Telangana, India; E-mail:* ap.joshi-p@incois.gov.in*]*

El Niño/La Niña Outlook from a Bayesian Convolutional Neural Network Approach

A reliable prediction of the El Niño - Southern Oscillation (ENSO) is crucial for monitoring global climate patterns, regional monsoons, and extreme weather events. Despite extensive efforts over many years, accurately forecasting ENSO events beyond a few seasons remains a significant challenge in numerical modeling. The emergence of deep learning techniques represents a transformative shift in climate and weather prediction. However, many machine learning approaches to ENSO prediction offer only single-point estimates, lacking proper quantification of parameter uncertainties and overlooking the need for nuanced confidence in predictions.





We introduce a deep learning-based Bayesian Convolutional Neural Network (BCNN) model that delivers robust probabilistic forecasts for ENSO up to 16 months in advance, covering all seasons and surpassing present state-of-the-art dynamical forecast systems. With additional bias correction, our model accurately reproduces the Niño 3.4 index's amplitude, even for extended lead times. The incorporation of Bayesian layers within the CNN enables the prediction of parameter distributions, enhancing uncertainty modeling and bolstering the reliability of Bayesian Neural Networks (BNNs), making them particularly valuable for operational forecasting services. Like most of the statistical models, the forecast suffers from amplitude underestimation of the Niño 3.4 index which has been mitigated using empirical quantile mapping bias correction technique. This research carries significant socio-economic implications by improving forecasting capabilities and rigorously quantifying forecast uncertainties, thereby offering valuable insights for planning and policymaking.

[Report Courtesy: Arya Paul, *Scientist, INCOIS, Hyderabad, Telangana, India; E-mail:* aryapaul@incois.gov.in*]*

Improvements in Regional Analysis of Indian OceaN (RAIN) with sea-level anomaly (SLA) assimilation

We had developed earlier the assimilation system RAIN (Regional Analysis of Indian OceaN) using Local Ensemble Transform Kalman Filter (LETKF) and interfaced with the Indian Ocean Regional Ocean Modeling System (ROMS; ~9 km horizontal resolution) that assimilates in-situ temperature and salinity from RAMA moorings, NIOT buoys and Argo floats. The system also assimilates satellite track data of sea-surface temperature from GHRSST. The speciality of this assimilation system is that it comprises ensembles that are initialized with different model coefficients like diffusion parameters, and the ensemble members also respond to two different mixing schemes - K profile parameterization (KPP) and Mellor-Yamada. This helps to maintain the ensemble's spread,which has always been a formidable challenge. RAIN

provides an improved initial condition to the operational ocean forecast model ROMS. In order to improve the ocean state forecast, the RAIN system has now been modified to assimilate sea-level anomaly (SLA). The assimilation of SLA happens in two phases in a sequential manner. In the first phase, all temperature and salinity data including SST data is assimilated to get the analysis. Using this analysis, the steric height is computed at each model grid point. Using this steric height, the observed SLA is recast into absolute dynamic topography (ADT) which is then assimilated into the model in the second phase to get the improved and final analysis which is thereafter used as the initial condition for the next assimilation cycle. We call it the RAIN-SLA System.

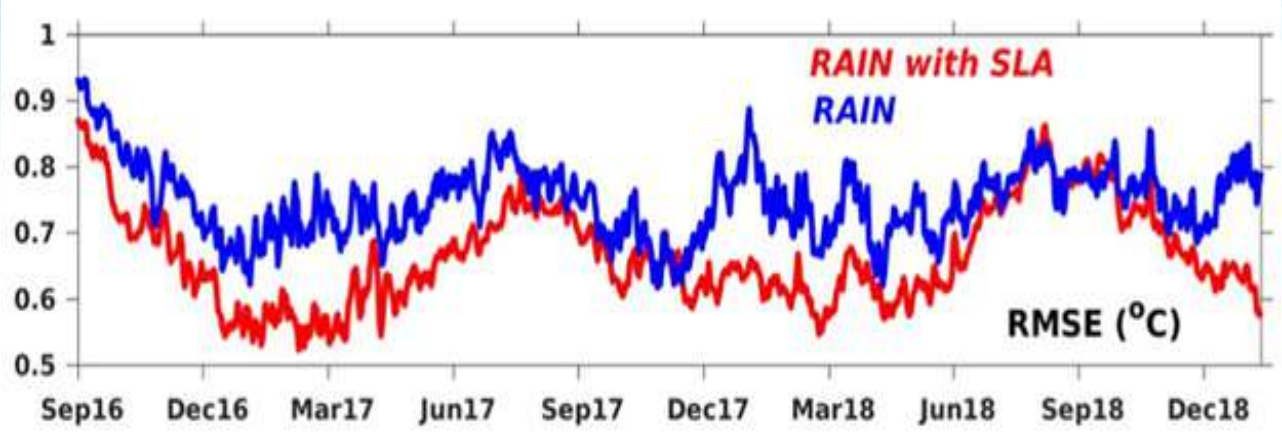
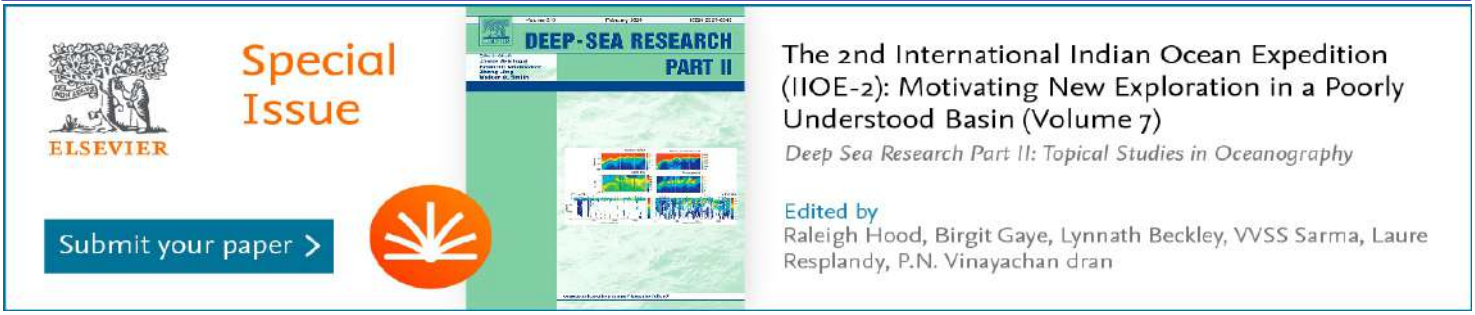


Figure-1: RMSE of SST from RAIN-SLA (red) and RAIN (blue) with respect to AVHRR SST.

We validate the RAIN-SLA system extensively against multiple observations ranging from RAMA moorings to ADCP observations across both dependent variables like temperature and salinity and independent variables like currents. We show that SLA assimilation improves the overall ocean state except at a few isolated locations. It improves the correlation with respect to observations and reduces the root-mean-squared error. We also show that SLA assimilation improves the estimation of currents.

[Report Courtesy: Balaji B, *Scientist, INCOIS, Hyderabad, Telangana, India; E-mail:* balaji.b@incois.gov.in*]*

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:

Manuscript Submission Deadline: August 15, 2024
Editorial Acceptance Deadline: February 15, 2025

For more details please visit

https://www.sciencedirect.com/journal/deep-sea-research-part-ii-topical-studies-in-oceanography/about/call-for-papers#the-2nd-international-indian-ocean-expedition-iioe-2-motivating-new-exploration-in-a-poorly-understood-basin-volume-7

Asia Oceania Geosciences Society (AOGS) was established in 2003 to promote geosciences and its application for the benefit of humanity, specifically in Asia and Oceania and with an overarching approach to global issues. Asia Oceania region is particularly vulnerable to natural hazards, accounting for almost 80% human lives lost globally. AOGS is deeply involved in addressing hazard related issues through improving our understanding of the genesis of hazards through scientific, social and technical approaches. AOGS holds annual conventions providing a unique opportunity of exchanging scientific knowledge and discussion to address important geo-scientific issues among academia, research institution and public. Recognizing the need of global collaboration, AOGS has developed good co-operation with other international geo-science societies and unions such as the European Geosciences Union (EGU), American Geophysical Union (AGU), International Union of Geodesy and Geophysics (IUGG), Japan Geo-science Union (JpGU), and Science Council of Asia (SCA).

The website may be accessed here: https://www.asiaoceania.org/aogs2024/public.asp?page=home.asp

Session-OS06: Physics, Biogeochemistry, and Climate Dynamics of the Indian Ocean

Session Details

Section(s):
OS - Ocean Sciences (Primary)
AS - Atmospheric Sciences

Announcements

SUBMIT ABSTRACTS	APPLY FUNDING SUPPORT	2024 AWARD NOMINATIONS
17 Oct 2023 – 02 Jan 2024	17 Oct 2023 – 02 Jan 2024	17 Oct 2023 – 02 Jan 2024
Instructions | Submit Now	Instructions | Apply Now	Guidelines

Conveners

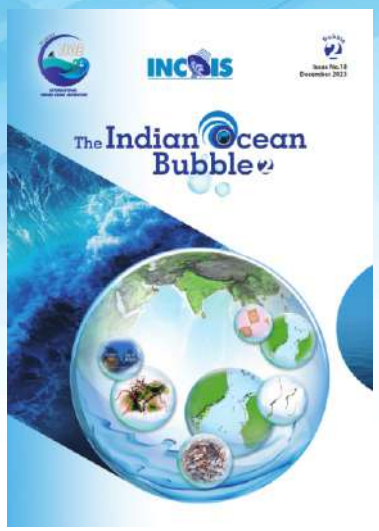
* Prof SungHyun Nam (Seoul National University)
Dr Nicolino (Nick) D'Adamo (Adjunct Research Fellow, Oceans Institute of the University of Western Australia)
Dr Dong-Jin Kang (Korea Institute Of Ocean Science And Technology)
Dr Yukio Masumoto (The University of Tokyo)

Session-OS06: Description

Recent increases in extreme events such as flooding, droughts, heatwaves, and tropical cyclones have a large impact on the population living in the Asia and Oceania countries. Increasing evidence on the roles of Indian Ocean in impacting climate extremes, climate variability, and climate change via changes in energy, hydrological and biogeochemical cycles has been reported. The Indian Ocean is of particular interest, for example, as influenced by the seasonally reversing monsoon forcing and upwelling centers in the Indian Ocean are found in the off-equatorial regions unlike in the easterly wind-forced Pacific and Atlantic Oceans. The northern region is dominated by the monsoons whereas the seasonal reversal is less pronounced in the southern region. This session invites contribution of physics, biogeochemistry, and climate dynamics of Indian Ocean based on in-situ and remotely-sensed observations, models, theories, and paleo proxies that reveal processes, variability, and projected changes within the Indian Ocean. This includes, but not limited to 1) Indian Ocean variability such as Indian Ocean Basin Mode, Indian Ocean Dipole Mode, Madden-Jullian Oscillations, 2) Upwelling in the Indian Ocean such as open-ocean upwellings or thermocline ridge/dome (e.g., Seychelles-Chagos Thermocline Ridge) and coastal upwellings at both western and eastern sides, 3) Processes underlying basin-scale or regional circulation, 4) Ocean-atmosphere interaction processes (heat, freshwater, momentum, carbon, etc.), 5) Biogeochemistry of the Indian Ocean water masses, 6) Links between ocean sciences and socio-economic requirements in the Indian Ocean, and 7) Interactions and exchanges between the Indian Ocean and other basins. Abstracts on related activities, such as capacity building, education, outreach, project development in the Indian Ocean, contributing to the UN Decade of Ocean Science for Sustainable Development and to the Second International Indian Ocean Expedition are also welcome.

Keyword(s): Indian Ocean; Physics; Biogeochemistry

The Indian Ocean Bubble, Issue No.18 is now available online



Web Link: https://iioe-2.incois.gov.in/IIOE-2/pdfviewer_pub.jsp?docname=IIOE-2-DOC_OM_293.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 (Word files) accompanied by suitable figures, photos (separate .jpg 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 54 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 (June-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 June, 2024**

The Indian Ocean Bubble-2

Access the latest issue of Indian Ocean Bubble-2
https://iioe-2.incois.gov.in/IIOE-2/Bubble.jsp

Join IIOE-2 Community

Enroll yourself with IIOE-2 Community
https://iioe-2.incois.gov.in/IIOE-2/Signup.jsp

Follow us:

iioe-2.incois.gov.in

@IIOE2

@iioe_2

Feedback? iioe-2@incois.gov.in

The IIOE-2 Newsletter is published online by:

INCOIS

2nd International Indian Ocean Expedition 2015-2025