International Indian Ocean Science Conference
01-05 December, 2025
Hyderabad, India

IIOSC-2025

INTERNATIONAL INDIAN OCEAN SCIENCE CONFERENCE (IIOSC) - 2025

Celebrating 10 years of the Second International Indian Ocean Expedition

01-05 December 2025

ABSTRACTS

ORGANIZERS

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

IOGOOS GLOBAL OCEAN OBSERVING SYSTEM FOR INDIAN OCEAN

International Science Council SCOR Scientific Committee on Oceanic Research

UNESCO United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

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Indian National Centre for Ocean Information Services (INCOIS)
Ministry of Earth Sciences, Govt. of India
Hyderabad, Telangana, India

https://iiosc2025.incois.gov.in

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PREFACE

The International Indian Ocean Science Conference (IIOSC-2025) is a major scientific programme scheduled to be hosted by the Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences, Government of India, Hyderabad, from 01–05 December 2025. With active participation from scientific institutions from about 22 countries, IIOSC-2025 aims to enhance our understanding of the physical, chemical, biological, geological, and climatological processes of the Indian Ocean. The knowledge generated will contribute to the sustainable management of this vital region, which supports the livelihoods and economies of millions residing in the Indian Ocean rim and island nations. The event is expected to foster many international research collaborations and strengthen e Early Career Scientist Network (ECSN) through exchange of ideas and capacity development.

The conference aims to highlight the progress and scientific advancements made over the past decade of IIOE-2 (2015–2025). Outcomes of the research aligned with the nine thematic areas comprising the six core themes of the IIOE-2 Science Plan and three additional themes proposed in the addendum will be deliberated during the conference. The call for papers received an overwhelming response from the global oceanographic community. Following a rigorous peer-review process, 309 research papers addressing at least one of the nine sub-themes have been selected for presentation.

This abstract volume presents a diverse and comprehensive set of scientific contributions from the Indian Ocean research community. It includes 82 abstracts submitted by members of the Early Career Scientist Network, along with 30 contributions received through the IIOE platform. The conference is further strengthened by strong industry participation, with 14 industrial partners contributing to the event through a dedicated industry session entitled *"Technological Innovation and Capacity Development for Harnessing Blue Economy Potential."* In addition, a workshop of the Early Career Scientist Network (ECSN) is planned alongside IIOSC with the theme "*Empowering Early Career Researchers for Collaborative Ocean Science and Leadership"*.

On behalf of the IIOSC-2025 organising committee, we warmly welcome all participants to join the conference sessions and engage in meaningful discussions that will contribute to the success of this significant scientific event.

Organizing Committee

IIOSC-2025

International Indian Ocean Science Conference

01-05 December, 2025

Hyderabad, India

ORGANIZING COMMITTEE

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES (INCOIS)

MINISTRY OF EARTH SCIENCES, GOVT. OF INDIA

HYDERABAD, TELANGANA, INDIA

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	First Floor	**First Floor**	**First Floor**	**Ground Floor**
	Plenary Hall	**E-classroom**	**Training Room**	**Breakout Room**
	Day-1: 01-December-2025 (Monday)			
09:00-09:30	**Registration**			
09:30-11:00	**Inaugural Session** **Venue: Plenary Hall**			
11:00-11:30	**Group photo followed by inauguraiton of Exhibition and Refreshment**			
11:30-13:00	Theme-6: Unique geological, physical, biogeochemical, and ecological features of the Indian Ocean ***Oral Session - 1*** Convener: Lynnath Beckley, Marie-Alexandrine Sicre, N. V. Chalapathi Rao *Rapporteur/Coordinator: R Chandra Sekhar Naik*	Theme-5: Extreme events and their impacts on ecosystems and human populations ***Oral Session - 1*** Convener: Chari Pattiaratchi, Roxy Mathew Koll, M. Mohapatra *Rapporteur/Coordinator: Raam Balaji V*	Theme-4: Circulation and climate variability ***Oral Session - 1*** Convener: Helen Phillips, Amit Tandon, V. S. Prasad *Rapporteur/Coordinator: Bhagyashree Dash*	Theme-2: Boundary current dynamics, upwelling variability and ecosystem impacts ***Oral Session - 1*** Convener: P. N. Vinayachandran, Yukio Masumoto, Rasheed K *Rapporteur/Coordinator: Sneha Jha*
13:00-14:00	**Lunch Break**			
14:00-15:30	Theme-6: Unique geological, physical, biogeochemical, and ecological features of the Indian Ocean ***Oral Session - 2*** Convener: Lynnath Beckley, Marie-Alexandrine Sicre, N. V. Chalapathi Rao *Rapporteur/Coordinator: R Chandra Sekhar Naik*	Theme-5: Extreme events and their impacts on ecosystems and human populations ***Oral Session - 2*** Convener: Chari Pattiaratchi, Roxy Mathew Koll, M. Mohapatra	Theme-4: Circulation and climate variability ***Oral Session - 2*** Convener: Helen Phillips, Amit Tandon, V. S. Prasad *Rapporteur/Coordinator: Bhagyashree Dash*	Theme-2: Boundary current dynamics, upwelling variability and ecosystem impacts ***Oral Session - 2*** Convener: P. N. Vinayachandran, Yukio Masumoto, Rasheed K *Rapporteur/Coordinator: Sneha Jha*
15:30-16:00	**Refreshment Break / Poster**			
16:00-17:00	Theme-6: Unique geological, physical, biogeochemical, and ecological features of the Indian Ocean ***Flash Talk Session - 1*** Convener: Lynnath Beckley, Marie-Alexandrine Sicre, N. V. Chalapathi Rao *Rapporteur/Coordinator: R Chandra Sekhar Naik*	Theme-5: Extreme events and their impacts on ecosystems and human populations ***Flash Talk Session - 1*** Convener: Chari Pattiaratchi, Roxy Mathew Koll, M. Mohapatra *Rapporteur/Coordinator: Raam Balaji V*	Theme-4: Circulation and climate variability ***Flash Talk Session - 1*** Convener: Helen Phillips, Amit Tandon, V. S. Prasad *Rapporteur/Coordinator: Bhagyashree Dash*	Theme-2: Boundary current dynamics, upwelling variability and ecosystem impacts ***Flash Talk Session - 1*** Convener: P. N. Vinayachandran, Yukio Masumoto, Rasheed K *Rapporteur/Coordinator: Sneha Jha*
17:00-17:30	Popular Talk - 1 **Title: Ocean Technology for a Sustainable and Self Reliant Tomorrow** **Speaker: Dr Poornima Jalihal**			

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	Day-2: 02-December-2025 (Tuesday)			
09:30-11:00	**Plenary Session - 1 (Venue: Plenary Hall)** Chair: Prof. Eric Chassignet **Speakers: (i) Prof. P N Vinayachandran (ii) Prof. Amit Tandon (iii) Dr. Sinjae Yoo**			
11:00-11:30	**Refreshment Break / Poster**			
11:30-13:00	Theme-6: Unique geological, physical, biogeochemical, and ecological features of the Indian Ocean ***Oral Session - 3*** Convener: Lynnath Beckley, Marie-Alexandrine Sicre, N. V. Chalapathi Rao *Rapporteur/Coordinator: R Chandra Sekhar Naik*	Theme-5: Extreme events and their impacts on ecosystems and human populations ***Oral Session - 3*** Convener: Chari Pattiaratchi, Roxy Mathew Koll, M. Mohapatra *Rapporteur/Coordinator: Raam Balaji V*	Theme-4: Circulation and climate variability ***Oral Session - 3*** Convener: Helen Phillips, Amit Tandon, V. S. Prasad *Rapporteur/Coordinator: Bhagyashree Dash*	Theme-2: Boundary current dynamics, upwelling variability and ecosystem impacts ***Oral Session - 3*** Convener: P. N. Vinayachandran, Yukio Masumoto, Rasheed K *Rapporteur/Coordinator: Sneha Jha*
13:00-14:00	**Lunch Break**			
14:00-15:30	Theme-6: Unique geological, physical, biogeochemical, and ecological features of the Indian Ocean ***Oral Session - 4*** Convener: Lynnath Beckley, Marie-Alexandrine Sicre, N. V. Chalapathi Rao *Rapporteur/Coordinator: R Chandra Sekhar Naik*	Theme-5: Extreme events and their impacts on ecosystems and human populations ***Oral Session - 4*** Convener: Chari Pattiaratchi, Roxy Mathew Koll, M. Mohapatra *Rapporteur/Coordinator: Raam Balaji V*	Theme-4: Circulation and climate variability ***Oral Session - 4*** Convener: Helen Phillips, Amit Tandon, V. S. Prasad *Rapporteur/Coordinator: Bhagyashree Dash*	Theme-3: Monsoon variability and ecosystem response ***Oral Session - 1*** Convener: Raleigh Hood, Joaquim Goes, Suryachandra Rao *Rapporteur/Coordinator: Sherin V Raju*
15:30-16:00	**Refreshment Break / Poster**			
16:00-17:00	Theme-6: Unique geological, physical, biogeochemical, and ecological features of the Indian Ocean ***Flash Talk Session - 2*** Convener: Lynnath Beckley, Marie-Alexandrine Sicre, N. V. Chalapathi Rao *Rapporteur/Coordinator: R Chandra Sekhar Naik*	Theme-5: Extreme events and their impacts on ecosystems and human populations ***Flash Talk Session - 2*** Convener: Chari Pattiaratchi, Roxy Mathew Koll, M. Mohapatra *Rapporteur/Coordinator: Raam Balaji V*	Theme-4: Circulation and climate variability ***Flash Talk Session - 2*** Convener: Helen Phillips, Amit Tandon, V. S. Prasad *Rapporteur/Coordinator: Bhagyashree Dash*	Theme-3: Monsoon variability and ecosystem response ***Flash Talk Session - 1*** Convener: Raleigh Hood, Joaquim Goes, Suryachandra Rao *Rapporteur/Coordinator: Sherin V Raju*
17:00-17:30	Popular Talk - 2 (Venue: Plenary Hall) **Title: Indian Ocean Science, Culture, Livelihoods & Climate Change - An Indian Perspective** **Speaker: Dr S S C Shenoi**			
17:30-18:00	**Preparatory Break**			
18:00-19:00	**Cultural Program (Venue: Plenary Hall)**			
19:00-21:00	**Gala Dinner**			

Time (IST)	First Floor Plenary Hall	First Floor E-classroom	First Floor Training Room	Ground Floor Breakour Room
	Day-3: 03-December-2025 (Wednesday)			
09:30-11:00	**Plenary Session - 2 (Venue: Plenary Hall)** **Chair: Sudheer Joseph** **Speakers: (i) Prof. Lynnath Beckley (ii) Prof. Michael J Roberts (iii) Prof. Michael Landry**			
11:00-11:30	**Refreshment Break / Poster**			
11:30-13:00	Theme-6: Unique geological, physical, biogeochemical, and ecological features of the Indian Ocean ***Oral Session - 5*** Convener: Lynnath Beckley, Marie-Alexandrine Sicre, N. V. Chalapathi Rao *Rapporteur/Coordinator: R Chandra Sekhar Naik*	Theme-5: Extreme events and their impacts on ecosystems and human populations ***Oral Session - 5*** Convener: Chari Pattiaratchi, Roxy Mathew Koll, M. Mohapatra *Rapporteur/Coordinator: Raam Balaji V*	Theme-4: Circulation and climate variability ***Oral Session - 5*** Convener: Helen Phillips, Amit Tandon, V. S. Prasad *Rapporteur/Coordinator: Bhagyashree Dash*	Theme-3: Monsoon variability and ecosystem response ***Oral Session - 2*** Convener: Raleigh Hood, Joaquim Goes, Suryachandra Rao *Rapporteur/Coordinator: Sherin V Raju*
13:00-14:00	**Lunch Break**			
14:00-15:30	Theme-6: Unique geological, physical, biogeochemical, and ecological features of the Indian Ocean ***Oral Session - 6*** Convener: Lynnath Beckley, Marie-Alexandrine Sicre, N. V. Chalapathi Rao *Rapporteur/Coordinator: R Chandra Sekhar Naik*	Theme-5: Extreme events and their impacts on ecosystems and human populations ***Oral Session - 6*** Convener: Chari Pattiaratchi, Roxy Mathew Koll, M. Mohapatra *Rapporteur/Coordinator: Raam Balaji V*	Theme-4: Circulation and climate variability ***Oral Session - 6*** Convener: Helen Phillips, Amit Tandon, V. S. Prasad *Rapporteur/Coordinator: Bhagyashree Dash*	Theme-1: Human benefits and impacts ***Oral session - 1*** Convener: Convener: Halina T. Kobryn, Jerome Harlay, Sanitha S. Sivadas *Rapporteur/Coordinator: Sanjiba Kumar Baliarsingh*
15:30-16:00	**Refreshment Break / Poster**			
16:00-17:00	Theme-9: Indian Ocean seabed and habitat mapping ***Flsh Talk Session - 1*** Convener: Kaylee Smit, John Kurian *Rapporteur/Coordinator: Nandakumar K*	Theme-7: IIOE-2 contribution to sustainable development: toward the UN Decade of Ocean Science ***Flash Talk Session - 1*** Convener: Nick D'Adamo, T Srinivasa Kumar, Grinson George *Rapporteur/Coordinator: Dhanya M Lal*	Theme-8: Marginal seas of the Indian Ocean ***Flash Talk Session - 1*** Convener: Faiza Al-Yamani, Maryam Ghaemi, Harilal B Menon *Rapporteur/Coordinator: Asish K Sasidharan*	Theme-1: Human benefits and impacts ***Flash Talk Session - 1*** Convener: Convener: Halina T. Kobryn, Jerome Harlay, Sanitha S. Sivadas *Rapporteur/Coordinator: Sanjiba Kumar Baliarsingh*
17:00-17:30	Popular Talk - 3 (Venue: Plenary Hall) **Title: Space base Satellite Oceanography: Indian Perspective** **Speaker: Dr Prakash Chauhan**			

Time (IST)	First Floor Plenary Hall	First Floor E-classroom	First Floor Training Room	Ground Floor Breakour Room
	Day-4: 04-December-2025 (Thursday)			
09:30-11:00	**Industry Session: Technological innovation and capacity development for harnessing blue economy potential** **Venue: Plenary Hall** **Convener: Prof. Balaji Ramakrishnan and Dr Greg Cowie**			
11:00-11:30	**Refreshment Break / Poster**			
11:30-13:00	Theme-3: Monsoon variability and ecosystem response ***Oral Session - 3*** Convener: Raleigh Hood, Joaquim Goes, Suryachandra Rao *Rapporteur/Coordinator: Sherin V Raju*	Theme-7: IIOE-2 contribution to sustainable development: toward the UN Decade of Ocean Science ***Oral Session - 1*** Convener: Nick D'Adamo, T Srinivasa Kumar, Grinson George *Rapporteur/Coordinator: Dhanya M Lal*	Theme-8: Marginal seas of the Indian Ocean ***Oral Session - 1*** Convener: Faiza Al-Yamani, Maryam Ghaemi, Harilal B Menon *Rapporteur/Coordinator: Asish K Sasidharan*	Theme-1: Human benefits and impacts ***Oral session - 2*** Convener: Convener: Halina T. Kobryn, Jerome Harlay, Sanitha S. Sivadas *Rapporteur/Coordinator: Sanjiba Kumar Baliarsingh*
13:00-14:00	**Lunch Break**			
14:00-17:30	**Social Visit**			

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Speakers: (i) Prof. Raleigh Hood (ii) Dr. Srinivasa Kumar Tummala (iii) Dr. Wahid Moufaddal</td></tr>
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<tr><td>11:30-13:00</td><td>Theme-9: Indian Ocean seabed and habitat mapping
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Rapporteur/Coordinator: Nandakumar K</td><td>Theme-7: IIOE-2 contribution to sustainable development: toward the UN Decade of Ocean Science
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Convener: Convener: Nick D'Adamo, T Srinivasa Kumar, Grinson George
Rapporteur/Coordinator: Dhanya M Lal</td><td>Theme-8: Marginal seas of the Indian Ocean
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Convener: Convener: Faiza Al-Yamani, Maryam Ghaemi, Harilal B Menon
Rapporteur/Coordinator: Asish K Sasidharan</td><td>Theme-1: Human benefits and impacts
Oral session - 3
Convener: Halina T. Kobryn, Jerome Harlay, Sanitha S. Sivadas
Rapporteur/Coordinator: Sanjiba Kumar Baliarsingh</td></tr>
<tr><td>13:00-14:00</td><td colspan="4">Lunch Break</td></tr>
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Venue: E-classroom</td></tr>
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Key results from the Bay of Bengal Boundary Layer Experiment (BoBBLE)

Prof. P. N. Vinayachandran

Indian Institute of Science, Bangalore, Karnataka, India. 560012

E-mail: vinay@iisc.ac.in

Abstract

Key results from the Bay of Bengal Boundary Layer Experiment P.N. Vinayachandran. Adrian Matthews, & the BoBBLE Team The Bengal Boundary Layer Experiment (BoBBLE) is a joint project between Ministry of Earth Sciences, Govt. of India and Natural Environment Research Council, UK. The BoBBLE field programme was conducted during the summer monsoon of 2016 with the prime objective of producing new, high-quality, comprehensive observational data sets of ocean state and atmospheric fluxes through a dedicated field campaign in a key under-observed region, the southern Bay of Bengal. New results that emerged from the BoBBLE observational programme is summarised in this presentation. The BoBBLE cruise was conducted on board ORV Sindhu Sadhana (CSIR-NIO, Goa) during 23rd June – 24th July 2016. In the ocean, 148 CTD profiles, 930 underway-CTD (uCTD) profiles, 64 turbulence profiles, 37 radiometer profiles, 161 Argo profiles, and 915 glider profiles were measured. In addition, continuous monitoring was carried out using an autosal and ADCP. Atmospheric measurements were made using an automated weather station, an eddy covariance system and radiosonde profiling was carried out twice during every day. The in situ data set unravelled several physical and biogeochemical processes occurring in the southern Bay during summer monsoon. The key results (published in 30 journal papers) include formation and erosion of barrier layers, discovery of double diffusion, closing of the mixed layer heat budget using ground-breaking observational approach, dynamical control of chlorophyll profiles, CO_2 emission, and oxygenation of the OMZ by the Arabian Sea High Salinity Core.

Keywords: Bay of Bengal, BoBBLE, Cuise Data, Monsoon Current

From Bay of Bengal to Arabian Sea: Outcomes of a Decade+ of Scientific Partnerships in the Indian Ocean

Prof. Amit Tandon

DEOS/School for Marine Science and Technology, UMass Dartmouth

Email: atandon@umassd.edu

Abstract

Over the past twelve years, bilateral scientific collaborations (India-USA, with regional partners in Sri Lanka, Seychelles, Oman, Singapore and Maldives) have significantly advanced understanding of oceanic and atmospheric processes in the Indian Ocean, focusing on the Bay of Bengal (BoB) and Arabian Sea (AS). These collaborative campaigns—including research cruises aboard USA and Indian research vessels (2013–2025), and deployment of profiling instruments, gliders, drifters, and moorings—have revealed the crucial role of salinity stratification, mixed-layer variability, and mesoscale to submesoscale ocean features in shaping air–sea interactions.

In the BoB, intensive multinational fieldwork and coordinated modeling efforts (ASIRI, OMM, MISOBOB, EKAMSAT) addressed questions on freshwater-driven stratification, salinity fronts, spatial heterogeneity of mixing, diurnal warm layers, and variability in air–sea fluxes. Post-cruise analyses established critical links between upper-ocean structure and monsoon onset, cyclone modulation, and intraseasonal variability. These observations inspired the inclusion of key physical processes in coupled IITM "Monsoon Mission" models—mixed layer variability, ocean fronts, and diurnal cycles—which directly resulted in reduced precipitation bias and improved monsoon predictability.

Arabian Sea campaigns (NASCar, EKAMSAT) complemented these results, highlighting basin contrasts and cross-basin connectivity via glider lines near Sri Lanka, moored arrays, and studies of mixed-layer deepening and frontal activity. Joint analyses demonstrate how dynamic coupling between the Indian Ocean's eastern and western basins influences monsoon evolution and air-sea fluxes.

This sustained partnership has fostered capacity-building through training, joint analyses, and collaborative workshops, securing a legacy for future observations and modeling. Collectively, a decade-plus of high-resolution field observations has driven fundamental advances with tangible predictive benefits for Monsoon modeling. The talk will illustrate a few key science findings, their implications for the monsoon, and discuss outstanding open questions.

Keywords: India-USA, Bay of Bengal, Arabian Sea, air-sea fluxes, monsoon, modelling

Endorsed Project Number: IIOE2-EP54

Spatiotemporal Dynamics of Chlorophyll-a in the Indian Ocean: A Bi-Decadal Analysis of Seasonality and Trends

Dr. Sinjae Yoo

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Abstract

The Indian Ocean's ecosystems are governed by a strong, spatially heterogeneous seasonality driven by the monsoon system. To understand the varied ecosystem responses, this study classifies the Indian Ocean into distinct biogeochemical provinces. We analyzed monthly satellite data (Chlorophyll-a, SST, PAR from Aqua/MODIS) from 2003-2024 using a time-series clustering approach based on dynamic time warping (DTW), which accommodates temporal shifts and variable durations in seasonal cycles. Our classification identified seven subregions across the Indian Ocean, each with a distinctive seasonality in the timing and magnitude of chlorophyll-a peaks. Over the 22-year period, we observed complicated long-term trends, where a decrease in chlorophyll-a was observed only in a few subregions. This presentation will detail the chlorophyll-a dynamics of these seven subregions over the past two decades and explore the corresponding trends in SST and PAR that may be driving these changes.

Keywords: chlorophyll-a, long-term trend, seasonality

Endorsed Project Number: IIOE2-EP51

Revisiting 110°E during the IIOE-2: an overview

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Abstract

In the 1960s, during the first International Indian Ocean Expedition (IIOE), many countries made the initial explorations of this poorly understood ocean basin. Five decades later, in a warming Indian Ocean, the second IIOE commenced. As one of the contributions to this initiative, in May-June 2019, a multi-disciplinary team revisited the 110°E line off Western Australia with the RV Investigator. Notably, modern equipment, techniques and electronic technology had superseded most of the original methods employed during the first expedition. The 3,000 km transect was characterised by a strong latitudinal temperature gradient ranging from cool Sub-Antarctic Mode Water in the south to warm tropical surface waters derived from the Indonesian Throughflow in the north. We explored multi-decadal change in physical, chemical and biological properties of the water column, examined biogeochemistry, microbes, genomics, functional diversity, ecological processes and the pelagic food web from pico-plankton through to meso-pelagic fishes. The voyage also enabled measurements of bio-optical quantities and ground truthing of satellite remote sensing of ocean colour by quantifying algal pigments, as well as acoustic tracking of whales. A special issue of Deep-Sea Research II (2022) and many other papers have been published, and this talk will present highlights from a selection of these. The 110°E voyage has underscored the complex oceanography, biological diversity and trophic processes in the region. It has demonstrated a low nutrient ecosystem, dominated by recycling processes supporting picophytoplankton, small mixotrophic zooplankton, predatory copepods and mesopelagic fishes. Overall, the research reflects a stepwise improvement in the understanding of the pelagic ecosystem in the oligotrophic south-east Indian Ocean.

Keywords: South-east Indian Ocean, unique features, oceanography, biogeochemistry, ecology, change

Endorsed Project Number: IIOE2-EP06

WIOURI-Progress made towards a Climate Change Roadmap (2100) for marine ecosystems, fisheries and marine food security in WIO

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Abstract

This presentation reports on 10 years (2016-2025) of progress made in the flagship IIOE2 (International Indian Ocean Expedition II) special project called the Western Indian Ocean Upwelling Research Initiative (WIOURI). WIOURI comprises 9 designated ecosystems referred to as Regional Upwelling projects (RUPs). These include the Agulhas Current system, Mozambique Channel, Madagascar Ridge, Madagascar Bloom, East African Coastal Current, Chagos-Seychelles thermocline ridge, Somalia upwelling, Oman Upwelling and Mascarene Plateau. Studies have involved the use of ship surveys, ocean models, satellites and marine robotics. Topics ranged from ocean physics, biogeochemistry, plankton, trophic structures, fisheries and coastal communities. Historical performance (trends) of these ecosystems has been investigated. First generation model predictions suggest continued ocean warming with the first tipping point in terms of almost year-long MHWs around 2035. Results for each RUP have been published in Special Issues, the highlights of which will be presented. The new and final phase of the WIOURI project (2025-2030) involves developing forecasting projections of the WIO composition and performance of the ecosystems and fisheries to the end of the century using ocean-biogeochemical models developed in the EU (EDITO). The overall conclusion is WIO will continue warming with increases of 4-5°C certainly in the tropical regions by 2100 devasting much of the coastal reefs and fisheries.

Keywords: Regional Upwelling projects (RUPs), Agulhas Current system, Mozambique Channel, Madagascar Ridge, Madagascar Bloom, East African Coastal Current, Chagos-Seychelles thermocline ridge, Somalia upwelling, Oman Upwelling, Mascarene Plateau, coastal reefs and fisheries

Endorsed Project Number: IIOE2-EP04

Food webs supporting larvae of Southern Bluefin Tuna in their eastern Indian Ocean spawning region

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Abstract

Southern bluefin tuna (Thunnus maccoyii, SBT) range broadly in high latitudes of the southern hemisphere but spawn only in a small area of tropical waters in the eastern Indian Ocean, directly downstream of the Indonesian Throughflow (ITF). In January-March 2022 (peak spawning season), the BLOOFINZ (Bluefin Larvae in Oligotrophic Foodwebs, Investigations of Nutrients to Zooplankton) program conducted sampling and experimental studies in this poorly studied region to better understand biogeochemical and food web characteristics of the larval tuna habit and their potential vulnerabilities to climate change. This presentation will highlight key findings of the investigation relating to lower-level food web function: 1) a picophytoplankton-dominated nitrogen-recycling ecosystem of intermediate productivity; 2) balanced growth and grazing losses of phytoplankton; 3) nitrogen-fixation support for an unusually high ratio of export:productivity; and 4) enhanced food-web transfer efficiencies from mixotrophy and larval feeding selection of appendicularian prey. Despite warming and stronger water-column stratification, we found significantly improved conditions for larval SBT feeding and growth relative to a prior study more than 3 decades earlier. Our results illustrate that predictions of climate change impacts on higher level consumers in the Indian Ocean need to consider the complexities of pelagic food web interactions which do not necessarily maintain fixed relationships to the physical environment.

Keywords: larval tuna, productivity, nitrogen cycling, food webs, grazing, export, feeding selectivity, climate change

Endorsed Project Number: IIOE2-EP46

Future Perspective on the Second International Indian Ocean Expedition (IIOE-2): Science Plan Addendum 2026-2030

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Abstract

In response to a strong consensus in the Second International Indian Ocean Expedition (IIOE-2) community, an Addendum to the IIOE-2 Science Plan was drafted and submitted to the Scientific Committee on Oceanic Research (SCOR) last fall on behalf of the sponsors of IIOE-2, requesting continued support for the Expedition from 2026 to 2030. The Addendum was sent out for peer review with SCOR leading the process, subsequently revised following the reviewer comments, and submitted to SCOR for final consideration in June, 2025. The Addendum has been approved by all three sponsors of IIOE-2 (SCOR, IOC and IOGOOS), thus extending IIOE-2 for an additional 5 years. This presentation will provide an overview of the Addendum to the IIOE-2 Science Plan, thus providing a future perspective on IIOE-2.

The IIOE-2 Science Plan places considerable emphasis on the biogeochemical and ecological impacts of anthropogenic influences on the ocean and how these will, in turn, impact coastal marine environments and human populations. The plan also emphasizes the need for coastal monitoring, data sharing, scientific engagement of Indian Ocean rim countries, and capacity development. Despite this emphasis, most of the research that has been carried out to date in IIOE-2 has been focused on the open ocean, and additional effort needs to be focused on engagement of Indian Ocean rim countries and capacity development. Knowledge gaps and challenges articulated in the Addendum include: the need for more coastal monitoring and metadata sharing in exclusive economic zones (EEZs) of Indian Ocean rim nations; the need to engage with and promote marine spatial planning (MSP) efforts in the Indian Ocean; the need to increase scientific understanding and engagement of western Indian Ocean, the eastern Bay of Bengal and marginal seas research communities; and the need to increase capacity development efforts and promote early career scientists. The Addendum also highlights four new initiatives that will greatly facilitate addressing these needs: the Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) program; the Korea-US Indian Ocean Scientific Imperatives (KUDOS) program; the emerging Coastal Observations in a Box (COLaB) project; and a new Marginal Seas Research Initiative is proposed

Keywords: IIOE-2, Addendum, coastal monitoring, marine spatial planning, SIBER, KUDOS, COLaB

Ocean Decade Tsunami Programme: Advancing End-to-End Tsunami Early Warning and Mitigation through International Cooperation

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Abstract

Tsunamis are among the most destructive oceanic hazards, capable of impacting entire ocean basins within minutes to hours. The catastrophic Indian Ocean tsunami of 26 December 2004, which claimed over 230,000 lives, led to the establishment of coordinated regional tsunami warning systems under the mandate of UNESCOs Intergovernmental Oceanographic Commission (IOC). While significant progress has been made in the last two decades, challenges remain in improving forecast accuracy, reducing warning timelines, and ensuring community-level preparedness. The Ocean Decade Tsunami Programme (ODTP) endorsed by the IOC assembly in 2021 under the UN Decade of Ocean Science for Sustainable Development 2021-2030 (UN Ocean Decade) provides a global collaborative framework to enhance tsunami early warning and mitigation systems. The main objectives of the ODTP are (i) to develop the warning systems capability to issue actionable and timely tsunami warnings for tsunamis from all identified sources to 100% of coasts at risk and (ii) 100% of communities at risk to be prepared and resilient to tsunamis by 2030 through programmes like the UNESCO IOC Tsunami Ready Recognition Programme. The ODTP Research, Development and Implementation Plan (RDIP), prepared by the ODTP Scientific Committee and endorsed by the IOC Assembly at its 32nd session in June 2023, outlines pathways to achieve these goals through improved risk knowledge, detection and forecasting, warning dissemination, and preparedness. The plan also highlights capacity development needs, governance aspects and international cooperation. To date, over 25 actions have been endorsed under the Ocean Decade in support of the ODTP. These initiatives span real-time monitoring systems, tsunami modelling, community preparedness, submarine cable observatories, and integrated multi-hazard frameworks. This presentation will highlight ODTPs strategic vision, scientific priorities, and implementation pathways, inviting collaboration to co-design innovative solutions that secure coastal safety and resilience in the face of tsunami threats.

Keywords: Tsunami Preparedness, Tsunami Early Warning Systems, SMART, Ocean Decade Tsunami Programme, Risk Reduction, Community Resilience, Tsunami Ready Recognition Programme, Multi-Hazard Framework

The Marginal Seas of the Northwestern Indian Ocean: Drivers, Dynamics, and Sustainable Future

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Abstract

The Regional Organization for the Protection of the Marine Enviro (ROPME) Sea Area (RSA) is intrinsically connected to the Northwestern Indian Ocean through a suite of physical, biogeochemical, and ecological processes. These linkages include regional ocean circulation patterns, temperature and salinity exchanges, nutrient and sediment fluxes and ecosystem-level interactions shaped by the monsoon effects, phytoplankton variability, marine productivity and biological connectivity across the basin.

As a highly sensitive marginal sea, the RSA functions as both an environmental subsystem of the wider Indian Ocean and a natural laboratory for examining ecosystem responses to extreme conditions. Rapid coastal development, oil pollution, desalination brine discharge, marine litter and microplastics, combined with climate change, invasive species, and recurring harmful algal blooms, exert compounded pressure on the existing marine ecosystems. The RSA's pronounced temperature and salinity gradients, along with its high ecological tolerance thresholds, make it an instructive model for studying environmental change, cumulative stressors, and ecosystem resilience.

Despite the clear interdependencies between the RSA and the Northwestern Indian Ocean, integrated research addressing two-way influences, biogeochemical feedback, and shared environmental drivers remains limited. There is an urgent need to close this knowledge gap through integrated research and strengthened regional cooperation among ROPME and its Member States, IOCINDIO, and the IIOE-2 community. Advancing collaborative research will improve understanding of RSA–Indian Ocean connectivity and help translate scientific insights and data into effective policy action and sustainable management strategies.

This plenary lecture will present an overview of the RSA's unique oceanographic characteristics, the current state of its marine environment, and the most pressing environmental challenges and emerging issues. It will further explore oceanographic linkages with the Northwestern Indian Ocean and highlight key past and ongoing ROPME scientific initiatives. Finally, it will outline future research directions and opportunities for enhanced collaboration within the IIOE-2 & IOCINDIO frameworks

Keywords: ROPME, IOCINDIO, IIOE-2

THEME-1

HUMAN BENEFITS AND IMPACTS

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[ABS-06-0051]

A Regional Marine Spatial Planning Strategy for the Western Indian Ocean: A New IIOE-2 Initiative for Sustainable Ocean Governance

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Marine Spatial Planning (MSP) is intended to support sustainable ocean development and management, particularly in regions where marine ecosystems are under increasing pressure from human activities and climate change. In response to these pressures, and in alignment with new initiatives identified with the extension of the IIOE-2 program, the project to develop a regional MSP strategy for the Western Indian Ocean was endorsed in 2025. The project was initiated in 2020 after member states requested the United Nations Environment Programme (UNEP) Nairobi Convention to develop such a strategy, to support and guide their national MSP initiatives. The regional strategy represents a collective commitment by ten WIO countries to implement a harmonised, ecosystem-based approach to ocean governance in national waters and beyond in the high seas. The project emphasises regional-scale planning needs - such as shared fisheries, ecological connectivity, climate change impacts, and biodiversity beyond national jurisdiction - that transcend the capacity of individual countries. It supports knowledge integration, capacity development, and systems thinking to foster effective cross-boundary collaboration and policy coherence. This presentation outlines the process, framework, and early outcomes of the project, highlighting lessons from recent MSP pilot studies (e.g. the Northern Mozambique Channel, Algoa Bay in South Africa) and the development of technical guidelines and online training courses. By focusing on the intersection of science, policy, and regional cooperation, this project contributes to IIOE-2 Theme 1 (Human Impacts and benefits) and Theme 6 (Unique geological, physical, biogeochemical, and ecological features of the India Ocean), advancing both scientific understanding and practical mechanisms for sustainable ocean use in the WIO.

Keywords: Marine Spatial Planning (MSP), Transboundary collaboration, Ecosystem-based management, Regional ocean governance

IIOE-2 Endorsed Project No: IIOE2-EP56

ABS-01-0303]

Intra-Annual Shoreline Change and Beach Profile Variability on Either Side of Gopalpur Port: An Impact Assessment

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Coastal environments worldwide have observed increasing human interaction caused by changing infrastructure, with port construction being one of the main drivers of morphodynamic modification. Here, we examine the intra-annual variability of shoreline change and beach profiles on either side of Gopalpur Port, Odisha, India, to provide an understanding of its localised coastally-induced impacts. The study employs multi-temporal satellite imagery for seasonal variations from 2020 to 2024 along the coast. Shorelines were extracted using the semi-automated Normalised Difference Water Index (NDWI) and Modified NDWI (MNDWI), which were subsequently refined using Otsu thresholding and segmentation image processing. The tidal corrections, however, ensured the location was accurate and diminished positional errors derived from Archiving, Validation and Interpretation of Satellite Oceanographic data (AVISO), completely defining shoreline lines for analysis. Shoreline change analysis used metrics from the Linear Regression Rate (LRR), while the beach profile data quantified changes in volume of beach to understand the seasonal variability. Intra-annual variability of shoreline change rate due to surf zone dynamics and structure of breakwaters and associated Gopalpur Port have resulted in disturbance to alongshore sediment transport, causing yet to be explored distinguishable patterns of erosion to the updrift (north side) and accretion/stabilization to the downdrift (south side), Thus helping the inter-annual assessment to understand the coast's dynamic, seasonally specific, and multi-supply responses to the change in wave and sediment supply, which moves beyond static assessments. This will add a detailed characterisation of the impact of the port on coastal processes, which adds a level of complexity when interpreting coastal processes, the interaction of port structures, alongshore transport, wave energy and sediment supply, provides essential material for sustainable coastal zone management, and for future development planning and has the potential to support understanding in designing mitigation strategies associated with erosion and accretion issues over south Odisha coastal edge.

Keywords: MNDWI, NDWI, Tidal Correction, Beach Profile, Shoreline Change Rate.

IIOE-2 Endorsed Project No:

[ABS-06-0119]

Towards understanding the paradox associated with the rise in algal blooms of Noctiluca sp in coastal and offshore waters of India

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The recent intensification in the harmful algal blooms of *Noctiluca sp* in and around Indian waters has gained global attention. India has a coastline of approximately 7516 km with rich ecological diversity. Our analysis suggests this increase is presumably linked to changes in the silicate cycle due to reduction in sediment load in major rivers presumably due to damming effect. We observed low silicate concentrations (< 2 μmol) during monsoon and non-monsson seasons in offshore waters. Further, a comparison of historical data of major estuaries with recent measurements also delineates a reduction in silicate concentrations at least by one order. This is in line with the earlier published silicate budget, which show a reduction of silicate input in Indian waters. Our analysis suggests this depleting scenario is presumably fuelling ecosystem change from silicate-dependent diatom populations to more opportunistic *Noctiluca sp*. However, the increase in offshore waters in the northern Arabian Sea could be more complex. It is presumably linked to the declining strength of winter mixing aided by global warming. Our observation suggests that the formation of shallow mixed layers in the open ocean is restricting silicate recharge from deeper layers, thereby collapsing the winter blooms resulting in fast transition from diatom-driven community structure to more opportunistic *Noctiluca scintillans*. Our analysis clearly captures the complex interplay of socio-economic growth and feedback response of marine ecosystems; however, their implication in the ocean carbon budget, Indian fisheries, and the tourism sector remains to be thoroughly evaluated.

Keywords: Noctiluca scintillans; algal blooms; ecosystem; fisheries, Arabian Sea

IIOE-2 Endorsed Project No:

[ABS-01-0223]

Marine Invasive Species Spreads in the Indian Coastal Waters - Current Status

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Worldwide, the urgent issue of bio-invasions has arisen in Indian coastal waters, highlighting the effects of non-indigenous species on biodiversity and ecosystem services. Through a comprehensive review of over 139 articles, we identified 344 invasive species across 264 genera and 28 phyla, emphasising significant groups such as molluscs and crustaceans that thrive in new environments. Key pathways of invasion, including ballast water discharge and hull fouling from maritime activities, are examined, with particular focus on hotspots in Mumbai, Chennai, Visakhapatnam, Kochi, and Tuticorin. Notable invasive species, such as the Charru mussel *Mytella strigata* and Bryozoan *Amathia verticillata*, pose serious threats to the ecosystem, requiring urgent control measures. This study highlights critical research gaps and the need for systematic surveys of coastal regions, strict monitoring of shipping practices, and the development of up-to-date checklists for marine invasive species. By advocating for stronger regulatory frameworks and targeted research, this work aims to inform policy development to preserve marine biodiversity and protect local ecosystems in India.

Keywords: Invasive Alien Species; Ballas Water; Ship Hull; Charru mussel; Bryozoan; Biodiversity Impact; Control Measures

IIOE-2 Endorsed Project No:

[ABS-01-0181]

Plastics on the plate: Microplastic burden in Shellfish from the Arabian Sea

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Microplastics (MPs) are emerging contaminants of concern in marine ecosystems, with potential risks to food safety and human health. This study assessed MP contamination in seven edible shellfish species collected from Malpe Harbor, Karnataka. A total of 141 individuals were analyzed using visual, stereomicroscopic, and FTIR techniques. *Portunus pelagicus* exhibited the highest MP load, followed by *Perna viridis* and *Penaeus indicus*. Fibres and fragments were the most prevalent types, with MPs predominantly ranging from 1000â¿¿3000 Î¼m. Polymer analysis identified fishing and textile-related sources. The results raise concerns about MP exposure through seafood consumption and call for improved waste management and monitoring.

Keywords: Microplastic, shellfish, ecological risks, marine, emerging contaminant

IIOE-2 Endorsed Project No:

[ABS-01-0206]

Subterranean Estuaries: An Overlooked Route for Microplastics to Enter the Oceans

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The marine environment is increasingly threatened by microplastics (MPs) derived from riverine inputs, atmospheric transport, and surface runoff. These pathways are well recognised, yet the role of subterranean estuaries zones where freshwater mixes with seawater underground before discharging into the ocean, remains largely overlooked. Such systems are important biogeochemical filters, but their capacity to transport MPs to coastal waters is poorly understood. This study investigates the subterranean estuary of Malpe, southwestern India, to assess microplastic flux into the Arabian Sea via submarine groundwater discharge (SGD). Groundwater samples revealed an average MP concentration of 7.56 ± 6.45 particles/L, with microfibers (55.1%) dominating, particularly in the 1000-5000 µm size range. Polyethylene was the most abundant polymer (96.8%), reflecting widespread use of fishing nets and gear in the region. Estimated MP flux through SGD was 18.93 ± 10.25 particles/hour, demonstrating a continuous, though often unnoticed, contribution to coastal microplastic pollution. The findings underscore the importance of groundwater as a hidden conduit of MPs to marine ecosystems. Given that fishing and seafood consumption are central to coastal livelihoods in India- the world's third-largest fish-producing nation, such fluxes raise concerns for ecosystem health, food security, and human well-being. Persistent inputs of fibrous MPs not only threaten marine organisms but also increase the likelihood of trophic transfer into the human diet. To the best of our knowledge, this is the first comprehensive study quantifying microplastic transport via a subterranean estuary. Our results highlight the need to incorporate subterranean estuaries into global assessments of MP pollution sources. Recognising these hidden pathways is vital for developing monitoring frameworks and management strategies that safeguard fisheries, ecosystem services, and the millions of people who depend on the Indian Ocean for sustenance and livelihoods.

Keywords: Subterranean estuary, Submarine groundwater discharge, Microplastic flux, Interstitial water, Pore water

IIOE-2 Endorsed Project No:

[ABS-01-0185]

Concentration gradient of plastic debris larger than 500 µm detected across the Southwest Indian ocean

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Marine plastic pollution is increasing in the world's ocean, with the Indian Ocean understudied compared to the Pacific and Atlantic Oceans. This study investigates plastic pollution in the Southwest Indian Ocean, focusing on a size range from large debris to microplastics (> 500 µm). Using visual surveys and manta trawling, we assessed plastic concentrations, compositions, and polymer types across 19 oceanographic campaigns. A total of 11,438 litter items were identified, with over 70% consisting of plastics. Larger plastic debris was predominantly observed near Glorieuses Islands during visual surveys, while microplastics were more prevalent offshore, collected through manta trawling. We observed a gradient of increasing plastic concentrations along the 30°/33°S latitudes, from 40°E (macroplastics: 10 items/km²; microplastics: 1000 items/km²) to 65°E (macroplastics: 100 items/km²; microplastics: 100000 items/km²). The majority of plastic debris consisted of hard fragments, primarily polyethylene (45.7%) and polypropylene (26.7%). Our findings provide new insights into microplastic concentrations in offshore regions, highlight the significant degradation of plastic debris, and emphasize the need for further research to identify and map the Indian Ocean's garbage patch along these latitudes.

Keywords: Indian Ocean, Marine litter, Visual survey, Manta trawling, Microplastics.

IIOE-2 Endorsed Project No:

[ABS-01-0216]

Quantifying Inter-Annual Patterns of Macroplastic Pollution in Kavaratti and Agatti Beaches of Lakshadweep Archipelago, Indian Ocean

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Macroplastic pollution poses a significant threat to the ecological integrity of small island coastal ecosystems, in which these environments are particularly vulnerable to macroplastic contamination due to their geographical isolation, proximity to major oceanic current systems, and dependence on marine-based livelihoods, together facilitating both local and long-distance debris inputs. This study investigated the inter-annual variability of macroplastic debris on beaches during 2024 and 2025 across Kavaratti and Agatti beaches of the Lakshadweep archipelago. Systematic beach surveys carried out documented that predominant macroplastic types, including plastic fragments, thin sheet-like films (single-use bags and wrappers), ropes, and other discarded fishing gear, highlighting the pervasive influence of local anthropogenic activities and coastal tourism. Spatial and inter-annual variation in microplastic distribution patterns were quantified using standardised indices, including the Clean Coast Index (CCI), Plastic Pollution Load Index (PPLI) and Beach Debris Accumulation Index (BDAI), to assess pollution intensity and facilitate comparative analysis among sites. Observed year-to-year variations indicated higher macroplastic accumulation in 2025 compared to 2024, particularly in Kavaratti, where the prevalence of single-use and tourism-related plastics exhibited the need for responsible tourism practices. The findings highlight the role of monsoonal currents, tidal dynamics, and localised human pressures in driving macroplastic distribution, emphasizing the importance of sustained monitoring, targeted mitigation measures, and integrated coastal management to preserve the ecological resilience of island beach environments

Keywords: Kavaratti, Agatti, Beach, Plastic pollution, Spatial, Single-use plastics

IIOE-2 Endorsed Project No:

[ABS-01-0248]

Satellite-Based Nighttime Spatiotemporal Detection of IUU Fishing Activity in Indian Maritime Zones Using VIIRS-DNB Imagery: A Machine Learning Framework

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Illegal, Unreported, and Unregulated (IUU) fishing constitutes a significant global challenge, directly contributing to overfishing, marine habitat degradation, and a major threat to food security and the livelihoods of coastal communities. The persistent nature of these activities in large maritime zones makes traditional enforcement methods difficult and costly. This abstract presents a machine learning framework for the spatiotemporal detection of IUU fishing vessels in Indian Maritime Zones, using satellite-based nighttime imagery from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB). The research focuses on analysing the light signatures from fishing vessels at night, which can be distinguished from other maritime traffic and environmental phenomena using machine learning algorithms. By leveraging this unique dataset, the framework effectively identifies fishing patterns indicative of illegal activity, such as fishing in restricted zones or during closed seasons. This method provides a robust, scalable, cost-effective tool for monitoring vast oceanic areas. The findings demonstrate the capability of the system to map IUU hotspots, providing actionable intelligence to maritime enforcement agencies. The application of this technology offers a direct and tangible benefit to marine ecosystems by providing the means to combat overfishing and protect critical habitats from destructive practices. Ultimately, this research provides a crucial technological solution to address a core human impact on the marine environment, ensuring the sustainability of fisheries for present and future generations.

Keywords: IUU Fishing, Overfishing, Habitat Loss, Satellite Remote Sensing, VIIRS-DNB, Machine Learning, Indian Maritime Zones, Marine Conservation.

IIOE-2 Endorsed Project No:

[ABS-01-0090]

Impact of Ocean Acidification on Coastal Copepods. Implications for Futuristic Coastal Dynamics.

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Anthropogenic ocean acidification, resulting from increased atmospheric CO2 absorption by seawater, poses significant threats to marine ecosystems, particularly in coastal environments where pH reductions are expected to be more severe than in open oceans. Copepods represent a critical link between primary producers and higher trophic levels, yet their responses to the rapid decline in seawater pH expected by the century's end remain poorly constrainedâ¿¿especially in dynamic coastal regions. The current study quantifies how near-future pH scenarios affect the survival and population dynamics of the Pseudodiaptomus serricaudatus, a perennial coastal and estuarine copepod of the West Coast of India. Adult copepods were incubated at four target pH levels (8.10, 7.81, 7.51, 7.04), maintained by an automated COâ¿¿-bubbling system to study the mortality and population dynamics. Mortality was assessed every three days up to day 10; population stage composition was recorded on day 15. Mortality remained 23% at pH 8.10 (representing open-ocean conditions) but rose to 30% at pH 7.81 (present-day coastal average), 47% at pH 7.51 (projected late-21st-century coastal value), and 77% at pH 7.04 (extreme 23rd-century scenario). Population data revealed a decline in different life stages and a copepodites-to-nauplius (Co/N) ratio at lower pH values, indicating impaired development. The critical pH threshold for P. serricaudatus appeared to lie between 7.5-7.8, corresponding closely to current coastal conditions and near-future projections. These findings indicate that coastal copepod populations may already be experiencing sublethal stress, with potential demographic collapse occurring within decades rather than by century's end.

Keywords: Ocean Acidification, Copepods, Life-stages, Mortality, Coastal Dynamics.

IIOE-2 Endorsed Project No:

[ABS-01-0174]

Climatic Drivers and Oceanographic Factors Influencing Indian Oil Sardine Aggregation Along the West Coast of India

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A detailed assessment was carried out to examine the environmental factors influencing the aggregation patterns of Indian Oil Sardine (IOS) during 2023-2024 along Indiaâ¿¿s west coast, specifically across Kerala, Karnataka, and Goa. Building on earlier studies, this investigation utilized a more extensive spatio-temporal dataset to find out additional drivers affecting IOS aggregation behaviour. The results signified the critical influence of climate-related phenomena, particularly persistent marine heatwaves (MHWs) and ENSO phases, on sea surface temperature (SST) anomalies, which may have limited IOS movements. All observed aggregation events coincided with SST anomalies, with eight instances recording temperatures above 29Â°C and one exceeding 30Â°C. These conditions surpass the optimal SST range for IOS. Such elevated thermal regimes are likely to induce stress, disrupt physiological functions, and alter migratory patterns, potentially contributing to beach stranding incidents. Although broader offshore waters remained anomalously warm, certain nearshore regions provided temporary thermal relief due to factors like enhanced chlorophyll levels, relative marginal surface cooling from rainfall-induced mixing, and subsurface upwelling. Furthermore, the transition from El NiÃ±o to La NiÃ±a intensified regional oceanographic dynamics, contributing to increased sardine abundance along the Malabar coast. Coast-ward or alongshore-directed ocean currents and wind might have further influenced IOS movement toward the shoreline. This study identifies evolving climate variability and chlorophyll concentrations as emerging key drivers, alongside established factors such as SST, currents, and wind patterns.

Keywords: Indian Oil Sardine (IOS), Sea Surface Temperature (SST) Anomalies, Marine Heatwaves (MHWs), ENSO, Sardine Aggregation

IIOE-2 Endorsed Project No:

[ABS-01-0261]

An AI-Framework for Rapid Identification of Coastal and Endangered Species

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The accurate identification of coastal and endangered species is fundamental to understanding marine ecosystem health and guiding conservation policy, but traditional survey methods relying on expert knowledge are often a bottleneck for large-scale, rapid biodiversity assessment. To address this, we developed a novel AI-powered framework for real-time species identification, centered on a Convolutional Neural Network (CNN) optimized for deployment on accessible platforms. The model was trained on a comprehensive, annotated dataset featuring a wide range of marine and coastal fauna, and was enhanced with advanced data augmentation and transfer learning techniques to ensure robust performance under variable field conditions, such as underwater imaging and partial visibility. Achieving high accuracy, the framework provides instantaneous classifications, significantly improving the speed and accessibility of species identification compared to manual methods. This research validates the power of deploying advanced AI to bridge the gap between scientific data collection and real-time ecological monitoring, creating a powerful tool for researchers, conservationists, and citizen scientists to support the preservation of biodiversity within the Indian Ocean region and beyond.

Keywords: Species identification, AI-based analysis, coastal biodiversity, marine ecology, Convolutional Neural Networks (CNNs), citizen science, automated detection, conservation technology

IIOE-2 Endorsed Project No:

[ABS-01-0262]

Natural and Anthropogenic Controls on Jellyfish Swarming and stranding dynamics in Indian Coastal Waters

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Jellyfish strandings and aggregations have become increasingly common along the Indian coastline, yet the environmental and anthropogenic drivers remain poorly understood. This study presents a comprehensive synthesis of historical jellyfish occurrence records, including strandings and swarming events, and systematically analyzes their association with oceanographic, atmospheric, and coastal features. High-resolution Google Earth imagery was used to map and categorize coastal artificial structures including jetties, ports, fishing harbours, coastal bridges, breakwaters, rocky armours, fish culture structures, power plants, seaweed farms, and locations of stationary fishing gears operations while natural coastal features such as estuaries, bays, creek mouths, backwaters, lakes, mangroves, and coral reef zones were also compiled. This study revealed that species like Porpita porpita, Physalia physalis, and Acromitus flagellatus are frequently associated with artificial structures, particularly in close proximity to jetties, coastal bridges, breakwaters, and rocky armours. Among natural features, jellyfish occurrences were more commonly observed near estuaries, followed by creek mouths, bays, backwaters, and mangroves. Analysis of associated environmental factors showed that wind direction is a dominant driver of hydrozoan strandings, especially when aligned with coastward surface currents. Scyphozoan jellyfish strandings occurred under a wider range of conditions, influenced by wind, current, and coastal geomorphology. Aggregations were frequently associated with low-velocity current zones, often formed by mesoscale eddies or seasonal current reversals, etc. This multi-factorial approach highlights the combined influence of environmental forces and coastal infrastructure on jellyfish dynamics, offering insights for predicting future occurrences and informing coastal management practices.

Keywords: Jellyfish strandings; Jellyfish aggregations; Indian coast; Artificial coastal structures; Wind direction; Coastal topography

IIOE-2 Endorsed Project No:

[ABS-01-0150]

Spatial and Temporal Distribution of Polycyclic Aromatic Hydrocarbons (PAHs) in major creeks along the Kenyan coast

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Polycyclic Aromatic Hydrocarbons (PAHs) were analyzed in surface and core sediments from three major creeks along the Kenyan coast: Mwache, Tudor and Mida. The total concentration of the 16 priority PAHs in surface sediments ranged from 7.19 to 100.28 ng gâ□»Â^{1}. Alkylated PAHs, primarily methyl-phenanthrene, were also found in Mwache Creek varying from 1.06 to 5.56 ng gâ□»Â^{1}. Highest PAH levels were found in Mwache and Tudor peri-urban creeks, subject to high population density and anthropogenic activities, while the lowest levels in Mida creek reflect its status as a marine protected area and the slow pace urbanization in the region. 210Pb dating indicate that sediment cores provide a PAHs deposition history since the early 1900s at Mida and Mwache creeks but only from the 1980s for Tudor creek. Downcore total PAH concentrations ranged from 6.5 to 43.1 ng gâ□»Â^{1} in Mwache, 5.2 to 23.7 ng gâ□»Â^{1} in Tudor and from 1.5 to 10.0 ng gâ□»Â^{1} in Mida. The top core PAH values are consistent with mean PAH surface sediment concentrations at each site. Downcore profiles all show increased PAH accumulation in the recent decades with highest values in Mwache and Tudor Creeks. Positive Matrix Factorization (PMF) was used for PAH source apportionment. For surface sediments, gasoline engine emissions (33.86%) and biomass burning (33.11%) were major sources followed by diesel engine emission (16.71%) and petroleum products (16.24%). PMF applied to downcore PAH profiles at each site identify different local sources. In Mwache, petroleum PAHs, attributable to harbor activities, accounted for almost half of the variance (47%). In Tudor, gasoline engine emissions (31%) and oil (27%) prevailed, while at Mida, biomass burning (29%), diesel engine (27%) and gasoline engine (25%) emissions contributed at almost equal levels. In conclusion, this baseline study provides useful information of trends in urbanization and coastal ecosystems exposure for coastal water quality monitoring and mitigation strategies adapted to each site to beat coastal pollution.

Keywords: PAHs, contamination, coastal waters, Kenya sediments

IIOE-2 Endorsed Project No: IIOE2-EP55

[ABS-01-0132]

Comparative Pyrene Biodegradation Using Free and Coco Peat Immobilized Cells of Marine *Brevibacterium atlanticum*

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PAHs are widespread in aquatic environments and are major contributors to marine pollution. In the present study, a deep-sea bacteria *Brevibacterium atlanticum* was isolated from the depth of 1500Â m deep-sea sediment of Bay of Bengal was capable of degrading pyrene. The response of bacteria towards degradation for the free and immobilized cells was studied. An immobilization study was carried out using coco peat. The growth rate ofÂ *B. atlanticum* for free cells was significantly different from the growth for coco peat immobilized cells. The degradation percentage reached 83.4 and 91.2% for free and immobilized cells respectively within a retention period of 8Â days. The presence of 1, 2-Benzenedicarboxylic acid in GC-MS analysis and functional groups like carboxylic acid, aliphatic C-H group, C-N stretch of amide groups in FTIR confirmed the organism *B. atlanticum* follows phthalic acid degradation pathway. The enhanced biodegradation of pyrene in cocopeat-immobilized cells indicate the high potential of hydrocarbonoclastic cells immobilized agro-residues for bioremediation of hydrocarbon contaminated marine sites.

Keywords: biodegradation, immobilization, coco peat, free cells

IIOE-2 Endorsed Project No:

[ABS-01-0134]

Thermal priming and epigenetic changes improve heat-tolerance mechanisms of tropical seagrasses under warming ocean along Palk Bay region, southeast coast of India

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Seagrasses, a paraphyletic group of marine angiosperms, are experiencing accelerated global decline due to climate change and other anthropogenic pressures, with ocean warming being a major threat. Despite the ecological importance of seagrasses in blue carbon sequestration and coastal resilience, the mechanisms underlying thermal adaptation and acclimatization remain poorly understood. This study assessed the heat stress response of three tropical seagrasses - *Halodule pinifolia*, *Halophila ovalis*, and *Enhalus acoroides* for the first time through priming and epigenetic approaches. In the experiment, tropical seagrasses were subjected to two thermal regimes: priming (two heat treatments, 1st and 2nd) and non-priming (single extreme heat treatment) under a mesocosm facility. Key photo-physiological, morphological, and gene expression parameters (related to stress, photosynthesis, and methylation) were studied and compared to the control. Findings suggest that primed seagrasses exhibited enhanced thermal resilience with upregulated gene expression and species obtained thermal resilience were ranked in the order *E. acoroides* > *H. pinifolia* > *H. ovalis* than those in non-priming and control conditions respectively. Halophila ovalis showed the highest sensitivity to acute thermal stress, suggesting its limited capacity for thermal acclimation. The study provides first empirical evidence of priming-induced stress memory and epigenetic modulation in the topical seagrasses. Our findings underscore the seagrass adaptive potential of recurring heat exposure in enhancing resilience and offer crucial insights for climate-informed restoration strategies to conserve thermal sensitive seagrass like H. ovalis for long-term ecosystem stability and resilience under future warming scenarios.

Keywords: Climate Change, Ocean warming, Seagrasses, mesocosm, priming and epigenetics

IIOE-2 Endorsed Project No:

[ABS-01-0280]

Coastal Change Monitoring through Automated Shoreline Extraction on Google Earth Engine and validation with RTK GPS

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Coastal zones are dynamic environments constantly influenced by natural processes such as erosion, accretion, sea-level rise, and anthropogenic interventions. Monitoring shoreline dynamics is vital for effective coastal management, disaster preparedness, and sustainable development. India, with an originally reported coastline of 7,516 km, now spans 11,098 km when including island territories, highlighting the increasing extent and complexity of coastal monitoring requirements. Traditional shoreline mapping methods are often laborious, time-consuming, and constrained by data availability. Recent advances in cloud computing and remote sensing, particularly through the Google Earth Engine (GEE), have enabled efficient large-scale analysis of multi-temporal satellite imagery. This study presents an approach for the automatic extraction of shoreline changes using GEE, leveraging freely available Landsat and Sentinel datasets. Spectral indices such as the Normalized Difference Water Index (NDWI) and Modified NDWI were employed, followed by classification and edge-detection techniques to delineate the dynamic land, water interface. Multi-year analysis revealed significant spatial variations along India coastline, with erosion hotspots in eastern deltas and accretion zones along western coasts. Validation against high-resolution imagery demonstrated reliable accuracy of the automated method. The study confirms that GEE provides a scalable, and reproducible framework for shoreline change monitoring across vast Indian coastline. These insights are crucial for policymakers, researchers, and coastal planners to identify vulnerable areas, strengthen adaptation strategies, and ensure sustainable coastal development. Future enhancements could integrate higher-resolution imagery and machine learning models for improved shoreline detection accuracy.

Keywords: Remote Sensing, Coastal Monitoring, Shoreline changes detection, Google Earth Engine

IIOE-2 Endorsed Project No:

[ABS-01-0217]

Occurrence and Risk Analysis of Sedimentary Polycyclic Aromatic Hydrocarbons in Andrott and Kadmat Islands of Lakshadweep, Indian Ocean

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Polycyclic aromatic hydrocarbons (PAHs) are a class of persistent organic pollutants (POPs) of global concern due to their long environmental persistence, bioaccumulation potential, and toxic effects on aquatic organisms and human health. This study investigated the occurrence, spatial distribution, and potential sources of PAHs in coastal sediments of Andrott atoll and Kadmat island, representing highly and moderately populated islands, respectively, within the Lakshadweep archipelago. Surface sediment samples were systematically collected during 2024-2025 from selected sites across both islands. The 16 priority PAHs listed by the U.S. Environmental Protection Agency (EPA) were quantified using standard extraction protocols followed by gas chromatography-mass spectrometry (GC-MS) analysis. Concentrations exhibited significant spatial heterogeneity, reflecting the combined influence of local anthropogenic activities, including maritime transport, fishing, and coastal tourism, alongside natural inputs driven by oceanic currents. Diagnostic ratio and source apportionment analyses indicated a mixed origin, with both pyrolytic (combustion-derived) and petrogenic (petroleum-derived) sources contributing to contamination. Sediment quality assessments, benchmarked against internationally recognized threshold values, revealed moderate contamination, suggesting potential ecological risks. The study provides a baseline dataset for PAH pollution in Lakshadweep sediments and emphasizes the need for continuous monitoring and targeted management strategies to safeguard the fragile island coastal ecosystems.

Keywords: Hydrocarbons, Andrott, Kadmat, Chromatography, Persistent pollutants

IIOE-2 Endorsed Project No:

[ABS-01-0246]

Computational mining of Indian marine metagenomic data for novel antimicrobial peptides targeting ESKAPE pathogens

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The Indian Ocean is a cradle of immense microbial diversity, yet its potential for translational applications to address urgent human health challenges remains largely untapped. Antimicrobial resistance (AMR), driven by the limited efficacy of existing antibiotics against multidrug-resistant bacteria, especially the notorious ESKAPE pathogens, is among the most pressing global threats. Harnessing the power of marine microbiomes, our study explores the Indian Ocean as a frontier for the discovery of novel antimicrobial peptides (AMPs) with therapeutic promise. A total of five high-resolution shotgun metagenomic datasets, comprising 59 samples from diverse Indian marine habitats, including sediments, coral reefs, sponges, and seawater, were analyzed in search of potent therapeutic peptide targeting the outer membrane of ESKAPE pathogens. Quality-controlled reads were assembled with MEGAHIT, and small open reading frames were predicted using MetaProdigal, yielding a non-redundant peptide library. To identify high-confidence candidates, we employed a machine learning pipeline integrating six prediction tools i.e. AMPScanner v2, AMPLify, amPEPpy, AI4AMP, ampir, and APIN, where peptides consistently predicted across all tools were retained, reducing false positives. Biophysical filtering prioritizedPra cationic, amphipathic peptides with membrane-disruptive potential. AlphaFold3-generated 3D structures of top candidates were subjected to all-atoms molecular dynamics simulations in gram-negative membrane mimetic models. Our integrative pipeline identified 51,185 putative AMPs, with ten shortlisted for strong membrane-active features. Two lead peptides, c_AMP_1 and c_AMP_2, revealed distinct disruption mechanisms: c_AMP_1 remained surface-aligned in an Î±-helical conformation, destabilizing membranes via a carpet-like mechanism, while c_AMP_2 embedded into the bilayer, inducing curvature and thinning consistent with toroidal pore formation. Both peptides showed remarkable stability, with arginine and tryptophan residues acting as anchors for membrane perturbation. By bridging Indian Ocean microbial diversity with computational bioprospecting, this work highlights the translational potential of ocean science to combat AMR.

Keywords: antimicrobial resistance, antimicrobial peptides, machine learning, drug resistance, Indian ocean

IIOE-2 Endorsed Project No:

[ABS-01-0025]

Spatial Analysis of Blue Carbon Potential in the Mangrove Ecosystem at Muara Gembong Beach-Indonesia, as a Climate Change Mitigation Effort

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Blue carbon ecosystems-such as mangroves, seagrass beds, and coastal marshes-play a crucial role in naturally absorbing and storing carbon. Among them, mangroves are particularly effective due to their high carbon storage capacity, making their conservation vital in efforts to mitigate atmospheric carbon emissions. Muara Gembong, located in the northern part of Bekasi Regency and bordering Jakarta Bay, Indonesia, supports a mangrove ecosystem currently used by the local community for fisheries (ponds) and ecotourism. This study aims to evaluate the blue carbon storage potential of mangroves in the Muara Gembong coastal area. Using Sentinel-2 satelite imagery and the Mangrove Vegetation Index (MVI) algorithm (threshold range: 2.0 to 20), the assessment was conducted through ENVI and QGIS software. The analysis estimated a mangrove area of 776.40 hectares, with a total carbon stock of approximately 93,089 MgC (megagrams of carbon). These findings highlight the significant potential of Muara Gembongâ¿¿s mangrove ecosystem as a blue carbon sink and underscore the need to integrate its conservation into sustainable climate change mitigation strategies.

Keywords: Mangrove Ecosystem, Blue Carbon, Mangrove Conservation

IIOE-2 Endorsed Project No:

[ABS-04-0310]

Evaluation of GPM IMERG-derived diurnal precipitation over the Indian Ocean: A multi-faceted approach

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The vast tropical oceans, accounting for approximately 78% of global precipitation, are critically important for Earth's climate, yet in situ observations remain sparse, highlighting the crucial need for robust validation of global satellite precipitation products like the Integrated Multi-Satellite Retrievals for GPM (IMERG). This study reports a comprehensive validation of IMERG sub-daily estimates over the tropical Indian Ocean by utilizing the Research Moored Array for African-Asian-Australian Monsoon & Analysis and Prediction (RAMA) data. The comparison assesses skill using continuous metrics, including mean bias, Mean Absolute Error (MAE), Root Mean Square Error (RMSE), and correlation. Analysis of wet-day occurrence and intensity separation, examining wet-day frequency bias, and mean wet-day intensity is done. Categorical metrics such as Probability of Detection (POD), False Alarm Ratio (FAR), and Critical Success Index (CSI) are computed from contingency tables at various thresholds to evaluate event detection capabilities. A detailed distributional check, including Quantileâ¿¿Quantile (QQ) analysis and probability density comparisons, is done to understand the satellite rainfall products' ability to capture precipitation characteristics accurately. The performance of satellite estimates is checked in each season to account for temporal variability in performance.

Keywords: IMERG, Validation, Moored Buoys, RAMA, diurnal variation, In situ oceanic observations

IIOE-2 Endorsed Project No:

[ABS-01-0372]

Using Long Short Term Memory networks to predict daily-averaged sea level anomaly and surface currents

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Short-term forecasts of sea level anomalies (SLA) and surface currents are traditionally generated using ocean general circulation models. In this work, we introduce a univariate machine learning approach based on Long Short-Term Memory (LSTM) networks for predicting daily averaged SLA in the north Indian Ocean, with a lead time of three days, utilizing historical satellite altimetry observations at a spatial resolution of approximately 13 km. By considering SLA reanalysis products from advanced dynamical systems as benchmarks, our results reveal that the proposed model delivers superior predictive performance. The forecast errors remain below 0.04 m, and correlation values are consistently near unity, across most of the study region. Furthermore, surface currents predicted from the SLA forecasts, using geostrophic and Ekman balance relations, show comparable skill to state-of-the-art reanalyses when validated against both coastal and open ocean in-situ observations. When these predicted currents are treated as synthetic observations for data assimilation, the accuracy of subsurface current forecasts improves notablyâ¿¿correlations become statistically significant at the 99% confidence level across depths, and errors decrease by about 0.1 mÂ·sâ□»Â¹. Our study demonstrates that the short-term forecast of daily-averaged sea level and surface currents can be approached as a collection of localized low-dimensional independent univariate systems, leading to substantial reductions in computational demand. This framework highlights the potential of machine learning to reshape the landscape of operational ocean forecasting.

Keywords: Sea Level Prediction, Machine Learning, Neural Networks, LSTM

IIOE-2 Endorsed Project No:

[ABS-04-0340]

Influence of Subsurface Heat Storage on Coral Thermal Stress Across ENSO Phases in the Lakshadweep Sea

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Coral reef ecosystems are highly vulnerable to thermal stress, which often leads to widespread bleaching events. While surface temperature-based metrics such as Degree Heating Weeks (DHW) are commonly used to assess bleaching risk, subsurface heat storage within the upper ocean can significantly influence the persistence of thermal stress. Understanding the interaction between these components, particularly under climate variability drivers like the El NiÃ±oâ¿¿Southern Oscillation (ENSO), is essential for improving risk assessments. In this study, we investigate the relationship between DHW, maximum Sea Surface Temperature (SST), and upper 50 m Ocean Heat Content (OHC) in the Lakshadweep region over a 20-year period (2000â¿¿2020), focusing on their variability across ENSO phases. Results indicate that severe thermal stress (DHW > 4 Â°C-weeks) predominantly occurred during La NiÃ±a events, the cool phase of ENSO. On the other hand, El NiÃ±o years the warm phase of ENSO usually has high SST maxima but comparatively lower DHW values. Ongoing analysis of OHC anomalies suggests that prolonged subsurface heat accumulation may significantly influence the persistence of thermal stress during El NiÃ±o events, even when surface warming is short-lived. These findings demonstrate that DHW variability is not solely governed by SST maxima but is also modulated by subsurface thermal dynamics, which vary across ENSO phases. Understanding these interactions provides critical insights into the mechanisms driving coral heat stress and highlights the need to integrate subsurface ocean processes into predictive frameworks for coral reef resilience under a changing climate.

Keywords: Coral bleaching, Degree Heating Weeks (DHW), Sea Surface Temperature (SST), Ocean Heat Content (OHC), ENSO phases, La NiÃ±a, El NiÃ±o

IIOE-2 Endorsed Project No:

[ABS-04-0386]

Impacts of marine heat wave Versus Integrated Moisture Transport and Precipitation Variability over Bay of Bengal and Arabian Sea during Post-monsoon Season of (2005-2014) and (2015-2024)

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This study assesses the sensitivity of marine heat wave (MHW) intensity over the Bay of Bengal during post-monsoon season (Oct-Nov-Dec) of two decades 2005-2014 and 2015-2024 are considered. The MHW examines the contributions of linear sea surface temperature (SST) warming and record-breaking SSTs to extreme MHWs in 2005-2014 and 2015-2024. The MHW is defined by the high threshold due to the SST warming trend >â¿¿90th percentile threshold value as compared to the seasonal climatology. The MHW over Arabian Sea (AS) and Bay of Bengal (BoB) referred as MHWa and MHWb, which are more prominent in the AS than BoB. The duration of MHW covers entire AS whereas MHW confines over the central BoB region. The duration of MHWa and MHWb during OND season, > 30-days observed in recent decades (2015-2024) as compared to past decades (2004-2013). However, the frequencies of MHW events are significantly higher in BoB than AS. However, their duration MHWa and MHWb increases 16- and 13-days during 2015-2024, indicating a growing role of long-term warming in AS and BoB regions in recent decades. Therefore, the integrated moisture transport (IMT), convective, and large-scale precipitation during two decades (2005-2014) and (2015-2024) over the AS and BoB, are analyzed from ERA5 reanalysis. The role of sub-tropical easterly jets are also analyzed to understand the variability of spatial variability of precipitations and discussed in this paper.

Keywords: MHW,Arabian Sea (AS), Bay of Bengal (BoB)

IIOE-2 Endorsed Project No:

THEME-2

BOUNDARY CURRENT DYNAMICS, UPWELLING VARIABILITY AND ECOSYSTEM IMPACTS

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[ABS-02-0043]

Vertical Kelvin wave propagation produced by a subsurface ridge

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The vertical propagation of Coastal Trapped Waves (CTWs) due to subsurface ridges is explored with the help of linear numerical and analytical models. Results show that submerged ridges projecting from the shoreline can scatter a horizontally propagating single baroclinic mode Kelvin wave into both upward and downward propagating Kelvin wave (KW) beams, emanating from the ridge top. The semi-infinite shelf response to an incident single mode KW reveals alongshore dependence of the vertical structure in the form of multi-modal ridge-top KWs, suggesting that the width (alongshore extent) of the ridge is an important factor in determining the basin response past the ridge. We hypothesize that over narrow ridges (less than twice the Rossby radius of deformation on ridge-top), the trapped solutions at the edges of the ridges overlap and interact to transmit horizontally propagating energy into the surface layer of the downstream basin. At the same time narrow ridges result in a weaker subsurface peak in velocity next to the ridge top in the downstream basin. This decreases the amplitude of vertically propagating KW beams. The relative strengths of horizontally and vertically propagating KW modes are examined by using alongshore KW velocity profiles as a boundary condition near the ridge edge in the downstream basin. When the subsurface peaks in the vertical current profile are stronger, the basin response includes higher amplitudes of vertically propagating KW beams. Conversely, when the broader surface maximum is stronger, the horizontal energy propagation at the surface is higher.

Keywords: Kelvin Wave, Coastal Trapped Waves, Vertical Propogation

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[ABS-02-0237]

Effects of upwelling-driven acidification and deoxygenation on the dissolved inorganic carbon system over the southeastern Arabian Sea shelf

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Repeat measurements of inorganic carbon parameters for a year over two coastal transects (Kochi and Mangalore) from the southeastern Arabian Sea (SEAS) reveal significant acidification induced by the summer monsoon (June-September) upwelling that co-occurred with intense deoxygenation. High pH (oxygen) levels 8.096Â±0.073 (163Â±45.8 ÂµM) during the pre-upwelling period dropped sharply to 7.857Â±0.038 (21.6Â±19.2 ÂµM) when upwelled waters intruded onto the SEAS shelf. The inner shelf of Mangalore recorded anoxic/sulphidic conditions, while the same from Kochi remained hypoxic (17.47Â±6.5 ÂµM). Despite this, the pH variation between these regions was minimal (7.834Â±0.044 and 7.861Â±0.034, respectively). Upwelling of acidic waters onto the continental shelves drastically affected the carbonate system; the calcite (Î©Ca) and aragonite (Î©Ar) saturations of bottom waters during upwelling (2.45Â±0.23 and 1.61Â±0.15) dropped to nearly half their pre-upwelling levels (4.54Â±0.71 and 3.02Â±0.48). Î©Ca and Î©Ar reached as low as 2.5 and 1.5 in the nearshore waters when pCO2 exceeded 1000 Âµatm under intense redox conditions, which lasted for about 15 days. The duration of such conditions increased with increasing depth, persisted for around three months at the outer shelf, albeit the SEAS shelves never fell below their threshold value (Î©=1). The co-existence of oxygen-deficient conditions with changes in carbonate saturation levels and buffering capacity during the summer monsoon has severe implications for ecosystem functioning. Being an essential metabolite, oxygen deficiency harms functional macrobenthic diversity. However, the effects of acidification on non-calcifying organisms in the SEAS remain unknown, as they both co-exist, making it challenging to separate their effects, necessitating further attention.

Keywords: Upwelling, hypoxia, Inorganic carbon system, multiple stress, ecosystem impacts

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[ABS-02-0244]

Drivers of upwelling in the Eastern Arabian Sea: Role of eddies, wind and remote forcing

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Coastal upwelling is a major physical process in the Eastern Arabian Sea (EAS) basin, as it regulates the major fishery potential and biogeochemistry of the region. The dynamics of the upwelling process in response to prevailing monsoonal winds and remote forcing (coastal Kelvin and Rossby waves) along the EAS have been explored in detail in many studies using ship-borne in-situ and satellite/reanalysis data. This work discusses the causative factor responsible for initiating early (February-March) subsurface upwelling signals along the South Eastern Arabian Sea (SEAS), particularly in Kochi (10°N) and Mangalore (13°N). The coastal upwelling during May to October is heterogeneous in space and time due to the variation in forcing mechanisms and intensity. The upwelling mode of the Kelvin wave is formed due to local winds in Sri Lanka that reach EAS during the same period. The combined effect of monsoonal winds and the upwelling mode of the Kelvin wave triggers upwelling from May to October. Past studies explained the early subsurface upwelling in the SEAS due to remote forcing. Analysis of recent data along the EAS shows that the upsloping of subsurface isotherm in SEAS during February-March (late winter monsoon) is due to recurring cyclonic eddies and weakening of the downwelling mode of Kelvin wave. These observations ruled out the possibility of the influence of wind and remote forcing causing early upwelling (February/March) in SEAS. To summarise, the upwelling system in the EAS cannot be considered as a continuous process occurring from late winter to late summer periods, but can be identified as two different processes, one driven by eddies and weak remote forcing (Kelvin wave) during the late winter monsoon, and the other due to monsoonal winds and remote forcing during the summer monsoon.

Keywords: Upwelling, Eastern Arabian Sea, Wind, Remote forcing, Eddies

IIOE-2 Endorsed Project No:

[ABS-02-0075]

Interannual variability of the low-saline plume in the southeastern Arabian Sea

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The transport of low-salinity water from the Bay of Bengal into the Arabian Sea during boreal winter leads to the formation of low-salinity plumes and a barrier layer in the Southeastern Arabian Sea (SEAS), which is shown to influence the local air-sea interactions and the monsoon onset over India. This study investigates the interannual variability of this low-saline plume from 1988-2017. Analysis shows that during the enhanced plume years, the minimum salinity is observed in spring, with a low-salinity plume extending beyond 66°E. In contrast, non-plume years exhibit minimum salinity in January, two months earlier than climatology, and progressively increase subsequently. Equatorial forcing and the associated westward advection of salinity anomaly from the eastern Bay are found to be the main mechanisms driving the observed interannual variability. Notably, despite weaker (enhanced) freshwater intrusion, non-plume (plume) years exhibit a thicker (thinner) barrier layer in the SEAS during spring, induced by the stronger (weaker) west India coastal current in winter.

Keywords: Equatorial winds, Cross-basin transport, Barrier Layer, Salinity, Advection, SEAS

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[ABS-02-0279]

Implementation of River Runoff and Its Impacts on Salinity in a Regional Ocean Model for the North Indian Ocean Using MOM6

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The northern Indian Ocean is significantly affected by several major river systems that discharge into the Bay of Bengal and the Arabian Sea, delivering substantial amounts of freshwater, sediments, and nutrients. These inputs influence ocean salinity, circulation patterns, marine ecosystems, and regional climate. Ocean models that do not adequately represent the spatial and temporal variability of river discharge often exhibit salinity biases, particularly in the northern Bay of Bengal, where riverine input is most pronounced. In such models, the absence of river runoff generally results in higher-than-observed salinity levels. Accurately capturing salinity dynamics in ocean models is crucial for reliable predictions of oceanic and atmospheric processes in both the Bay of Bengal and the Arabian Sea. This study employs the Modular Ocean Model Version 6 (MOM6), which incorporates the Arbitrary-Lagrangian-Eulerian (ALE) remapping method for hybrid vertical coordinates, to simulate coastal and open-ocean dynamics along the Indian coast. The regional model domain spans from 32°E to 108°E and from 8°S to 30°N, covering areas strongly influenced by river discharge. Freshwater fluxes from 24 major rivers along the Indian coast are incorporated at surface grid points adjacent to land, enabling a more realistic representation of riverine impacts on salinity and circulation. MOM6 includes optional parameters to enhance vertical mixing at river input locations, as well as tunable settings such as the salinity restoration timescale, the maximum salinity difference for restoring, horizontal and vertical mixing coefficients, and tidal mixing parameterization. Initial simulations show that including river runoff significantly reduces the high salinity bias seen in models without runoff. However, a freshwater bias remains in the northern Bay of Bengal due to an underestimation of salinity in the model. The sensitivity of various model parameterizations on the salinity bias is investigated to improve the fidelity of the model simulations.

Keywords: River runoff, salinity simulation, MOM6, mixing, hybrid vertical coordinates

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[ABS-02-0055]

Heading south! Contrasting larval fish assemblages and taxonomic distinctness in the Agulhas and Leeuwin boundary current systems

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The Indian Ocean has unique boundary currents that flow poleward on both sides of the ocean basin adjacent to southern Africa and western Australia. Fish larvae in both boundary current systems have been independently investigated, but for the Agulhas Current system, this presentation provides the first analyses of seasonal ichthyoplankton assemblages. Early winter assemblages were compared across both the Agulhas and Leeuwin Current systems. Average Taxonomic Distinctness (Ave TD; relationship of every pair of species via levels in the Linnean classification tree) was calculated for each isobath and latitude sampled based on presence/ absence of fish taxa in each system. In the Agulhas Current system, *Scomber japonicus*, *Sardinops sagax* and *Etrumeus whiteheadi* were found to drive most of the differences between isobaths, being most abundant in shelf waters in all seasons. During summer, *Auxis rochei* differentiated mid-shelf and slope assemblages from other isobaths, and the families Myctophidae, Notosudidae and Gonostamatidae distinguished oceanic assemblages. In winter, the Leeuwin Current system was dominated by the myctophid genus Diaphus, *Sardinops sagax* and *Vinciguerria nimbaria*. The Ave TD of larval fish assemblages was similar for both the Agulhas Current (89.84± 0.85) and the Leeuwin Current (90.74 ± 0.99) systems. In both, oceanic assemblages tended to exhibit higher Ave TD, whilst it was similar across latitude for both oceanic and slope assemblages. Ave TD increased towards the south for Agulhas Current shelf assemblages but not for those of the Leeuwin Current. Overall, nMDS ordination showed larval fish assemblages from both current systems to be clearly delineated from each other. In terms of environmental factors, sea surface temperature, water depth and latitude returned the best correlations with larval fish assemblages from both sides of the Indian Ocean basin.

Keywords: Agulhas Current, Leeuwin Current, larval fish assemblages, Taxonomic Distinctness

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[ABS-02-0004]

The changes in La Niña induced summertime interannual variability of sea level anomaly along the western boundary of the Bay of Bengal

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In this study, interannual variability and associated dynamics of sea level anomaly (SLA) along the western boundary of the Bay of Bengal (WBoB) during the summer (June-September) seasons of La NiÃ±a years between 1998-2016 have been investigated using satellite observations and a linear, continuously stratified (LCS) model. To quantify interannual variability along WBoB, regions have been divided into three parts, which include northern (NBoB), central (CBoB), and southern (SBoB). Satellite observation shows negative interannual SLA at all three regions of WBoB during summertime La NiÃ±a years of 1998, 1999, and 2007, which became positive during summertime La NiÃ±a years of 2010, 2011, and 2016. The LCS model simulates reasonably well the observed interannual SLA variability along WBoB, depending on the forcing mechanisms and La NiÃ±a episode. Using dedicated boundary experiments on the LCS model, it has been observed that the interannual variability of SLA during summertime La NiÃ±a events is significantly dominated by remote forcing from the Equatorial Indian Ocean (EIO) and the interior BoB. The maximum dominant forcing for negative interannual SLA during summertime La NiÃ±a years of 1998 and 2007 originates from the EIO. However, negative interannual SLA during the summertime La NiÃ±a year of 1999 is mostly dominated by interannual SLA forced by the interior BoB. The LCS model also shows that positive interannual SLA during summertime La NiÃ±a years of 2010, 2011, and 2016 are significantly dominated by remote forcing from both the interior BoB and EIO via constructive interference.

Keywords: Satellite altimeter, Interannual sea level anomaly, Western boundary of Bay of Bengal, Linear wind-driven model, La NiÃ±a

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[ABS-02-0344]

Acoustic signatures and ecological patterns of sound scattering layers in a major upwelling system of the Indian Ocean

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Sound scattering layers (SSLs), composed primarily of micronekton, are a common feature of the global ocean but remain poorly studied in the Seychelles-Chagos Thermocline Ridge (SCTR), a major upwelling system in the southwest Indian Ocean. To investigate SSL characteristics in relation to environmental and biological conditions, we conducted a research expedition aboard the RV Isabu from May 25 to June 21, 2024. During the cruise, hydroacoustic measurements (18, 38, 70, 120, 200, and 333 kHz, EK80), oceanographic profiles (conductivity-temperature-depth probe, SBE 911plus), and zooplankton samples (multi-net, 1 m Ã¿ 1 m) were collected. Integration of these datasets revealed diverse SSL structures linked to the unique hydrographic properties of the SCTR and the distribution of zooplankton. These findings provide new insights into the ecological dynamics of SSLs in this key region of the Indian Ocean.

Keywords: Sound scattering layer, Seychelles-Chagos Thermocline Ridge, hydroacoustics, zooplankton, Indian Ocean, upwelling system

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[ABS-02-0332]

Drifter observations of surface currents from the Browse Basin, eastern Indian Ocean

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Drifting objects are the best proxy to elucidate the nature of the ocean surface currents. With the advancement of satellite tracked GPS, drifter observations offers a more comprehensive understanding of the spatial and temporal aspects of the ocean surface currents. North of Australia is a data sparse region from the oceanographers viewpoint. In the Browse Basin of Australia, The University of Western deployed over 150 surface drifters during 2019 to 2022. This data was used to examine the seasonality in Lagrangian characteristics of the Browse basin surface currents, in the light of the wind data from the Adele island meteorological station of the Bureau of Meteorology. This extensive deployment revealed that the prominent mean currents in the region during the first indigenous season, Mangala (December to January) was directed northeastward due to winds from the southwestward direction. For the Marrul (April), Wirralburu (May), Barrgana (June-August), Wirlburu (September) through Laja (October-November) the surface currents were directed in a westward direction following the southeasterly winds. Furthermore, our drifters could capture the high frequency to low frequency variabilities in the surface currents like tides, inertial currents and eddies, which were not always captured in the satellite observations. The drifters also revealed a region of higher mixing which is in agreement with the higher kinetic energy imagery from satellite data.

Keywords: surface currents, drifters, seasonality, eastern Indian Ocean

IIOE-2 Endorsed Project No:

[ABS-02-0065]

The Influence of Seabed morphology on the Flow-structure and Eddy variability in the Agulhas Current System: A modelling perspective

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The flow-topography interaction is a long-standing research challenge that has been investigated in several theoretical studies, laboratory experiments, modelling and direct measurements at sea. Yet, fundamental questions remain in desperate need of authoritative answers, and the subject is deemed unexplored. The southwest Indian Ocean hosts one of the most complex seafloor topographies of the worldâ¿¿s ocean, characterized by a chain of meridionally oriented plateaus and ridges, with rough structures at their summit and steep flanks that descend to deep ocean basins. Here flow-topography interaction is intense, resulting in flow-structures with different time and space-scales that affect the physical, chemical and biological responses and their coupling. Using the Coastal Regional Ocean Community (CROCO) model, a series of numerical simulations were performed primarily to investigate the dynamics of the southwest Indian Ocean Subtropical Gyres (SWAG). The simulations were forced at sea surface by hourly atmospheric interannual reanalysis fields ERA5, and lateral open boundaries from the Copernicus GLORYS12 reanalysis. At the seabed, bathymetry was derived from GEBCO2022. Several runs were performed at varying numerical grids of 1/4, 1/12, and 1/36. The model evaluations showed that SWAG accurately reproduced the oceanographic features and water mass properties in the greater Agulhas Current system. To assess the influence that the Madagascar Ridge â¿¿ one of the most prominent bathymetric features in the Agulhas system plays in modifying the flow-structure, volume transports, and mesoscale eddy characteristics, a sensitivity experiment was performed by flattening the Madagascar Ridge in the 1/12 simulation (SWAG12 Sensitivity). Direct comparisons between SWAG12 and SWAG12 sensitivity experiments allowed inferring and quantifying of the impact that the Madagascar Ridge exerts on the behavior of the main ocean currents and the overall gyre circulation patterns throughout the water column. Using a barotropic vorticity balance framework, we assessed the dynamic mechanisms responsible for the flow variability.

Keywords: Seafloor Topography, Ocean Ridges, Volume transport, Mesoscale eddies, Ocean Models, Barotropic Vorticity

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[ABS-02-0376]

Interaction between East India Coastal Current and eddies in Southwestern Bay of Bengal

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The ocean currents in the North Indian Ocean is driven by monsoon winds and hence exhibits seasonal reversal. Unlike the major oceanic basins, the coastal currents along the Indian coast exhibits seasonality and plays a major role in water mass exchange between the Arabian Sea and Bay of Bengal. The interaction with eddies further adds to its complexity. However, the information regarding the coastal currents are limited particularly the details off southwestern Bay of Bengal. An Argo GPS drifter that deployed along with the moored buoy off Chennai got detached during the cyclone Fengal, got trapped into the East India Coastal Current and started to move equator-ward during November 2024. While moving equatorward, the Argos GPS drifter got into a cyclonic eddy for a short period and continued its path until it joined the north equatorial current off Srilanka. The moored buoy observations exhibited the cyclonic structure in subsurface parameters and provided crucial information eddy characteristics. The satellite measurements of sea level anomaly and ocean currents further confirmed the track of cyclonic eddy which traversed a long distance form northern BoB to southwestern BoB, while carrying cooler and fresher water to open ocean and further down south. The present study provides crucial information of the East India Coastal Current during the winter season and its interaction with a cyclonic eddy.

Keywords: EICC, eddies, Bay of Bengal, Cyclone

IIOE-2 Endorsed Project No:

[ABS-02-0030]

Oceanic biophysical response to large-scale wind forcing: Observations from the R/V Mirai southwest of Sumatra in December 2017

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The water southwest of Sumatra is characterized by the seasonal and interannual occurrence of coastal upwelling, which drives biological variability and active fisheries. Although satellite observations show active biophysical variability at the surface, no observations of surface-subsurface physical and biogeochemical variations were available. Based on a field experiment southwest of Sumatra (4.2S, 101.5E) by the research vessel Mirai from 5 December 2017 to 1 January 2018, this study reports observational results for ocean temperature, salinity, nutrients, and biological variations. During the observation period, westerly winds dominated the eastern equatorial Indian Ocean, with northwesterly winds southwest of Sumatra. This wind forcing was unfavorable for local coastal upwelling. Time series of in situ observations indicated gradual shoaling of the thermocline from mid- to late December 2017. This thermocline displacement was significantly greater than the climatological variability and was attributed to the propagation of equatorial and coastal Kelvin waves in response to the appearance of easterly winds in the central equatorial Indian Ocean. Concurrent with thermocline shoaling, we observed active mixing at the top of the thermocline, upward transport of nutrients to the euphotic layer, and subsurface phytoplankton growth. These biophysical responses demonstrate that even if local wind forcing is unfavorable for coastal upwelling, remote wind forcing can affect the nutrient supply that supports biological activity off Sumatra through Kelvin wave propagation. These results will provide fundamental data for validating biophysical models of the eastern Indian Ocean.

Keywords: Coastal upwelling, Eastern Indian Ocean, Sumatra, Chlorophyll-a, Nitrate, Kelvin waves, R/V Mirai

IIOE-2 Endorsed Project No: IIOE2-EP36

[ABS-03-0363]

Precipitation Variability and Extremes over the Arabian Sea from Moored Buoy Observations and Satellite Estimates

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Global warming is intensifying the hydrological cycle, leading to significant changes in precipitation patterns through enhanced evaporation and greater atmospheric moisture-holding capacity. Understanding these changes is particularly important over the Indian Ocean, a key region that drives the Asian monsoon system and influences global climate variability. However, precipitation observations over the ocean remain sparse due to limited in-situ measurements, making satellite-based products the primary source of rainfall information. This study utilizes high-resolution (2-min) in-situ precipitation data collected from five moored met-ocean buoys deployed across the Arabian Sea from north to south during 2012-2024. These observations are used to investigate precipitation variability at monthly, seasonal, and annual scales. Spatial and temporal variations in rainfall intensity, frequency, and type are analyzed, with particular attention to their modulation by large-scale atmospheric phenomena and tropical cyclones. Buoy rainfall measurements are further employed to validate satellite-based IMERG precipitation estimates, enabling an assessment of their consistency and identification of biases. The role of thermodynamic processes, particularly the Clausius-Clapeyron relationship, is also examined to understand how warming influences precipitation extremes. The results highlight pronounced spatial and temporal variability in rainfall, strongly governed by monsoonal dynamics and extreme weather events. Validation demonstrates broad agreement between buoy and IMERG data, while also revealing discrepancies during intense precipitation episodes and transitional phases of the monsoon. The findings underscore the importance of sustained in-situ measurements for refining satellite retrieval algorithms and improving the reliability of precipitation datasets over oceanic regions. They also provide valuable insights for enhancing climate model simulations and strengthening regional monsoon prediction in the context of a warming climate.

Keywords: Precipitation, moored buoy data, IMERG data, seasonal variability, monsoon, tropical cyclones

IIOE-2 Endorsed Project No:

[ABS-02-0225]

A scientific examination of the link between Indian mackerel and sardines from the southwest coast of India: Are they actually related?

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Indian mackerel and sardines are the two important small pelagic fish species that support crucial marine capture fisheries along the southwest coast of India. Decoding the influence of the environmental drivers on their populations and potential interspecific relationships is critical for their sustainable management. This study examines the long-term relationship between the catches of Indian mackerel (MC) and sardines (SC) and various oceanic environmental parameters in the Malabar upwelling region and along the coasts of Karnataka (KA) and Kerala (KE), in the southeast Arabian Sea. The analysis reveals peculiar patterns for catches and conspicuous differences in the response of both species to environmental variables like rainfall, mixed layer depth, seawater temperature at the surface, and depth of 50 m. The study also explores their relationship with the productive frontal zones. These results imply that the population dynamics of the two species are mostly linked by their response to external forces, even if they inhabit the same ecosystem, and a substantial direct ecological relation between the two species may not be that exclusive. This study also demonstrates the importance of the response of commercially important small pelagic species to changes in their habitat to manage fisheries and ecosystems in highly productive coastal waters.

Keywords: Indian mackerel, sardines, small pelagic, southeast Arabian sea, environmental drivers, delayed environmental effects, correlation heatmaps, ecosystem-based approaches

IIOE-2 Endorsed Project No:

[ABS-02-0155]

Estimating Cross-Shore Flux along Indian Coast Using Observation and Model Data

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Cross-shelf exchanges have a ubiquitous influence on the blue economy. The exchanges between shelf seas and the open ocean are critical for global biogeochemical cycles, transporting nutrients, sediments, carbon, and heat that sustain more than 90% of the worlds fish catches and contribute to the oceans role as a major carbon sink. The variability and spatial distribution of cross-shore fluxes (CSflux) along the Indian shelf sea margin were investigated using Acoustic Doppler Current Profiler (ADCP) observations from 17 shelf and slope locations, complemented by a high-resolution (1/12°) ocean reanalysis (GLORYS). Using reanalysis data, CSflux was calculated along the 150 m isobath. ADCP data span 2008-2023, with continuous measurements available for 15 years at each location. The reanalysis product covers 1995-2020, and CSflux was calculated along the 150 m isobath of the Indian shelf seas. CSflux was computed by integrating daily averaged tide-residual cross-shore velocity. CSflux from reanalysis was evaluated against observations, showing close agreement in variability and standard deviation at most locations. Observed CSflux ranges from 3 to 17 m^2/s, representing 20-60% of alongshore fluxes, with slope values exceeding shelf values. These flux values are comparable to those reported for other global oceans. Four hotspots of CSflux are identified from reanalysis and observations: the northeastern coast (near Paradeep/Digha and Kakinada/Gopalpur), the southern tip (Kanyakumari), and the central west coast (Goa). Northeastern and Kanyakumari sites exhibit CSflux comparable to alongshore fluxes. Seasonal variability is strongest from November to March, with minima during the monsoon, except at Kanyakumari, Goa, and Kakinada, where monsoonal peaks occur. This study provides the first quantitative estimates of CSflux along the Indian shelf seas, highlighting key regions for targeted observation and their potential role in nutrient exchange, fisheries productivity, carbon sequestration, and coastalâ¿¿open ocean connectivity.

Keywords: Cross Shelf Exchanges, Cross Shelf Flux, Shelf Seas

IIOE-2 Endorsed Project No:

[ABS-02-0112]

Revitalizing and reinviforating EIOURI -- The 2026 Java upwelling multidisciplinary study cruise

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The Eastern Indian Ocean Upwelling Research Initiative (EIOURI) is one integral component of IIOE-2. Even the scientific importance and social relevance of the upwelling are widely recognized, the realization of EIOURI plan was not an easy job at all. The expected plan of the EIOURI were still largely uncompleted. The extension of IIOE-2 and the onging UN Ocean Decade bring new opportunities to revitalize EIOURI and recharge the community with new momentum. Here we propose a new opportunity of the proposed 2026 Java upwelling multidisciplinary study cruise onboard R/V Xiang Yang Hong 10 during her global ocean voyage. This in situ observation will be further complemented by the high resolution modeling study from University of Tokyo. Through this multilaterial joint effort, we call for the escientific inputs and regional cooperatoin to better shape the cruise science plan and analyze processes and mechanisms with the cruise data and model data, including the upwelling dynamics, air-sea interaction, physical-biological interaction, fishery impacts and the deep Jave trench exploration. The training at cruise especially for students and ECOP scientists will be included as one integral component.

Keywords: EIOURI, Java upwelling, multidisciplinary study, modeling study

IIOE-2 Endorsed Project No:

[ABS-02-0068]

Defining the SCTR depth in the Southwestern Tropical Indian Ocean: Review and Revisit

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The 20°C isotherm depth (D20) has been commonly used to represent the SCTR depth in the southwestern tropical Indian Ocean, mainly because of its simplicity and insufficient vertical resolution in both observation and modeling. Although D20 has been widely used, D20 does not always align with the physical thermocline defined as the maximum vertical temperature gradient. This discrepancy can lead to inaccuracies in understanding air-sea interaction dynamics and climate variability. In this study, we examine how well D20 and its variability are matched with those of the thermocline in the SCTR, by using CTD data obtained from six cruises of the RV ISABU from 2017 to 2023, as part of the project titled "Korea Indian Ocean Study (KIOS)", and reanalysis data (Global Ocean Reanalysis and Simulation Version 4 (GLORYS2V4) and Simple Ocean Data Assimilation version 3.15.2 (SODA3.15.2)). Sixteen CMIP6 model outputs were analyzed to determine future changes in the D20 and thermocline depth in the SCTR. We found that in the SCTR, D20 is generally deeper than the depth of the maximum vertical temperature gradient (Dtc). Dtc appears to be more aligned with the depth of the 24°C or 25°C isotherm. Future changes projected by CMIP5 models reveal that D20 tends to deepen in most of the tropical Indian Ocean at the end of the 21st century. In contrast, changes in thermocline depth (Dtc) show a spatially contrasting pattern in the tropics: shallowing in the eastern tropical Indian Ocean and deepening in the western tropical Indian Ocean, including the SCTR region.

Keywords: SCTR, Indican Ocean, thermocline depth, revisit

IIOE-2 Endorsed Project No: IIOE2-EP31

[ABS-06-0172]

Development of a High-Resolution Unstructured Coupled Ocean-Ecosystem Model for Simulating Coastal Dynamics over the Southeastern Arabian Sea Shelf

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Under the Ocean Modeling Mission of INCOIS, a high and flexible resolution hydrodynamic model based on the Finite Volume Community Ocean Model (FVCOM) has been configured to simulate coastal dynamics over the southeastern Arabian Sea shelf. The model's mesh, with resolutions ranging from 200m to 8km, was generated using blended bathymetry from SRTM 1-arcsecond topography, SRTM 15-arcsecond bathymetry, and detailed Vembanad Lake bathymetry provided by various government agencies. A 10-year climatological simulation was carried out to stabilize the physical model before initiating interannual simulations for the period 2017-2024. A comprehensive performance assessment was conducted using data from moored buoys (off Kochi and Kollam), in-situ measurements, and remote sensing observations. Model-simulated temperature and salinity showed good agreement with the water quality buoy off Kochi (R^2 = 0.92 and 0.65, RMSE = 1.13°C and 0.91 PSU), the Kollam buoy (R^2 = 0.92, RMSE = 0.84 °C), satellite observations (R^2 = 0.87 - 0.93, RMSE = 0.54 - 1.04 °C), and in-situ CTD measurements (R^2 = 0.80, RMSE = 1.75°C). At 46 m depth at the ADCP location, the U-component of currents had correlation and RMSE values of 0.53 and 0.15 m/s, respectively, while the V-component recorded values of 0.43 and 0.16 m/s. Current patterns from the model were consistent with buoy observations and ADCP measurements, indicating realistic subsurface current structures. The model also captured key physical processes, including southwest monsoon-driven upwelling and seasonal current reversals along the Kerala coast. Following the performance evaluation, the model was coupled with the European Regional Seas Ecosystem Model (ERSEM), a well-established, lower-trophic-level marine food web and biogeochemical cycling model, via the Framework for Aquatic Biogeochemical Models (FABM) coupler. The climatological coupled model run is in progress, and an assessment of the biogeochemical state of the southeastern Arabian Sea shelf has yet to be undertaken.

Keywords: Southeastern Arabian Sea, FVCOM, Ocean Currents, Biogeochemical State.

IIOE-2 Endorsed Project No:

[ABS-02-0078]

Characteristics of Mesoscale Eddies in the South Indian Ocean and Their Implications for the Redistribution of Heat and Salt in the Basin

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We examined the eddy dynamics in the south Indian Ocean (30-120°E, 55-5°S), using AVISO 1/8° resolution data for the period 1993-2023. Eddy concentrations are higher south of 45°S, and off the west coast of Australia, which gradually decreases to the west. Additionally, the number of anticyclonic eddies are slightly higher than the number of cyclonic eddies. There exists a distinct seasonal cycle for the eddy generation in this area, with an increase in the number of eddy generation from April to August (southern hemisphere winter), which then decreases towards summer. The average eddy radius is less during July-October, when maximum eddy generation occurs, and it gradually grows in radius, with the maximum observed during December-March. The average eddy amplitude is lower during May-September and it increases towards December. In addition, the average lifetime, radius and amplitude of cyclonic eddies are higher than those of anticyclonic eddies. Eddies with a radius greater than 100 km are generally found north of 30°S. Eddies with higher amplitude values are concentrated off the west coast of Australia, and along a narrow band in the southern region. Moreover, the majority of the eddies having amplitudes greater than 10 cm are cyclonic. The cyclonic eddies generated in the eastern basin tend to propagate southwards, while anticyclonic eddies tend to propagate northwards. Additionally, a greater number of cyclonic eddies persists for longer duration compared to anticyclonic eddies, with all of them originating off the west coast of Australia, and six of these even lasted for more than 4 years. By utilising MOM6 simulations, the study further investigates the role of these mesoscale eddies in transporting heat and salt within the basin and towards the north Indian Ocean, and its contribution to the region's warming.

Keywords: South Indian Ocean, Mesoscale eddies, Heat transport, MOM6

IIOE-2 Endorsed Project No:

[ABS-02-0151]

Austral Autumn Surface CO_2 in the Western Indian Ocean and Relationship with the Indian Ocean Dipole (IOD)

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The Indian Ocean plays a crucial role in global carbon cycling, yet the seasonal and climate-driven variability in air-sea CO_2 exchange remains poorly understood. We investigated surface fugacity of CO_2 (fCO_2sea) and associated CO_2 air-sea fluxes in the western Indian Ocean during austral autumn (April-June) in 2019, 2023, 2024, and 2025. The western Indian Ocean generally acted as a CO_2 sink, except in the northern region (<10°S; Seychelles-Chagos Thermocline Ridge, SCTR) during negative Indian Ocean Dipole (nIOD) years, with fluxes ranging from 0.2 to 0.7 mol m^{-2} yr^{-1}. Thermal effects on fCO2sea were strongest in 2025 (the warmest year), while non-thermal effects dominated in the SCTR region. During nIOD years (2023, 2025), enhanced subsurface upwelling in the SCTR region increased surface CO_2 concentrations, producing positive non-thermal effect anomalies, higher fCO_2sea, and weaker CO_2 uptake. In contrast, during positive IOD years (2019, 2024), suppressed upwelling generated negative non-thermal anomalies, lower fCO_2sea, and stronger CO_2 uptake. These results highlight the relationship between IOD phases and CO_2 dynamics in the SCTR region.

Keywords: surface fCO_2, CO_2 flux, western Indian Ocean, SCTR, IOD

IIOE-2 Endorsed Project No: IIOE2-EP51

[ABS-02-0173]

Impacts of rising atmospheric CO_2 concentrations and climate variability on air-sea CO_2 fluxes in the Arabian Sea between 1980 and 2018

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The Arabian Sea (AS) acts as a net source of CO_2 to the atmosphere primarily due to summer upwelling of deep, carbon-rich waters along the coastlines of Somalia and Oman. Recent environmental changes, such as rising atmospheric CO_2 concentrations, rapid warming, and changing summer monsoon winds, may affect air-sea CO2 fluxes in the region. However, our understanding of the long-term variability of these fluxes and its drivers remains limited. To address this gap, we use an eddy-resolving model of the Indian Ocean to assess the evolution of air-sea CO_2 fluxes from 1980 to 2018 and explore the mechanisms underlying their long-term variations. Our analysis indicates a decline in AS carbon emissions to the atmosphere, estimated at 0.06± 0.05 PgC/yr, decreasing at a rate of -7% per decade over the study period. This decline primarily stems from rising anthropogenic CO_2 concentrations, resulting in a -13% reduction in outgassing per decade, partially offset by climate warming, which enhances outgassing at a rate of +6% per decade. The influence of warming and climate variability on CO_2 emissions is notably pronounced in the Arabian Gulf and the region off the coast of Somalia. In the former, rapid warming driven by enhanced downward radiation and weakened surface winds has intensified CO_2 emissions, resulting in a 40% increase in outgassing by the late 2010s compared to the early 1980s. In the latter, the decline in CO_2 outgassing driven by rising atmospheric CO_2 concentrations is counterbalanced by enhanced upwelling. These findings underscore the importance of local climatic factors, such as changes in winds and radiative forcing, in modulating the evolution of air-sea CO_2 fluxes at regional scales and highlight the necessity of improving their representation in climate models.

Keywords: Arabian Sea Upwelling, carbon cycle, climate change

IIOE-2 Endorsed Project No:

[ABS-02-0067]

Influence of climate-driven thermocline variability on vertical distribution of mesozooplankton in the western Indian Ocean

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The Seychelles-Chagos Thermocline Ridge (SCTR) in the western Indian Ocean is a major open-ocean upwelling region with notable interannual variability. To understand annual differences in mesozooplankton vertical distribution around the SCTR, we collected mesozooplankton at five discrete depths (from surface to 1,000 m) at the inner (08°S, 65°E) and outer (02°S, 65°E) stations of the SCTR during May-June 2023 and June 2024. Hydro-climate parameters, including the Indian Ocean Dipole (IOD) index and thermocline depth (20 ^{0} isotherm depth, D20), were evaluated as proxies for physical forcing. Mesozooplankton communities were mostly concentrated within the surface mixed layer and thermocline depth. Integrated abundances (0-1,000 m) at the inner station of the SCTR declined sharply from 2,072 inds./m3 in 2023 to 158 inds./m3 in 2024 (13.1-fold), and those at the outer station of the SCTR also decreased from 975 inds./m3 to 665 inds./m3 (1.5-fold). Mesozooplankton communities were categorized into five vertical distribution types: (1) surface dwellers, (2) surface-thermocline migrants, (3) thermocline dwellers, (4) sub-thermocline dwellers, and (5) diel vertical migrants. At the inner station of the SCTR, the proportion of surface dwellers decreased (2023: 84%, 2024: 18%), but that of surface-thermocline migrants (2023: 12%, 2024: 40%) and thermocline dwellers increased (2023: 3%, 2024: 40%), as D20 deepened from 48 to 72 m, coinciding with the transition of the IOD index from negative (-0.6 to -0.1) in 2023 to positive (+0.5 to +0.7) in 2024. At the outer station of the SCTR in 2024, the proportion of surface dwellers (2023: 29%, 2024: 52%) and surface-thermocline migrants increased (2023: 20%, 2024: 37%), but that of thermocline dwellers declined (2023: 48%, 2024: 9%) compared with 2023. Overall, the differences in the thermocline depth, the related changes in vertical distribution of mesozooplankton communities and the shift from negative to positive IOD phases between the inner and outer stations of the SCTR imply that climate-driven variability may influence the significant interannual shift in the depth-related characteristics of mesozooplankton communities in the western Indian Ocean.

Keywords: mesozooplankton, seychelles-chagos thermocline ridge, cilmate variability

IIOE-2 Endorsed Project No: IIOE2-EP51

[ABS-02-0345]

One-year dynamics of sound scattering layers in the central Seychelles Chagos Thermocline Ridge, Indian Ocean

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Covering about 20% of the world's ocean surface, the Indian Ocean strongly influences climate-ocean interactions and supports diverse marine life. One of its major upwelling regions, the Seychelles-Chagos Thermocline Ridge (SCTR) in the southwest Indian Ocean, is notable for its high biological productivity. Sound scattering layers (SSLs), composed mainly of micronekton, are ubiquitous in the global ocean and play a key role in marine ecosystems. In the Indian Ocean, SSLs exhibit distinct dynamics; however, their long-term temporal characteristics remain poorly understood in the SCTR. To investigate the temporal variability of SSLs, including diel vertical migration, over a one-year period in this region, an Acoustic Zooplankton Fish Profiler (ASL, Canada) was moored at 65°E, 8°S from June 2024 to April 2025. Acoustic backscatter at 38 and 120 kHz was recorded to depths of 360 m, and a temperature-depth sensor (DST centi-TD, Star-Oddi, Iceland) was also deployed. Together, these long-term acoustic and environmental observations provide critical insights into the temporal dynamics of SSLs in the SCTR.

Keywords: Sound scattering layer; temporal dynamics; Seychelles-Chagos Thermocline Ridge; Long-term acoustic monitoring

IIOE-2 Endorsed Project No: IIOE2-EP52

[ABS-02-0337]

Integrating Satellite Derived Oceanographic Parameters with Species Specific Catch and Fishing Effort (2018- 2023) for the west coast of India

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The interaction between fish distribution and oceanographic conditions has consistently influenced the fish species present in the waters off the west coast of India, especially during the biologically abundant post-monsoon season. In this study, important pelagic fish (Oil Sardine, Lesser Sardine, Anchovies, Indian Mackerel and Horse Mackerel) and environmental variables from 2018 to 2023 were examined, including upwelling indices, sea surface temperatures (SST), sea surface salinity (SSS), surface currents, and Chlorophyll-a concentrations. Focus was paid to the role of the West India Coastal Current (WICC), which has seasonal reversals and influences nutrient transport, salinity gradients and dispersal of larvae along the coast. To understand the seasonal and inter-annual variations in fish landings for the west coast of Indian states from Gujarat to Kerala, we devised a multi-source dataset framework which included Global Fishing Watch effort maps, fish landing data from CMFRI reports, satellite-derived Chlorophyll from ocean colour datasets, Copernicus ocean reanalysis for currents magnitude (vectors) and Optimum Interpolation Sea Surface Temperature (OISST) for temperature. This study improves prior knowledge of the distinct and predictable habitat preferences of the species on the fishing ground and the climate impacts on the ecosystem, which in turn facilitates planning for sustainable fisheries. Such results, in turn, augment planning for regional economic development, potential fishing zone (PFZ) optimisation, and sustainable fisheries management

Keywords: Oil Sardines, Indian Mackerel, sea surface temperature, Potential fishing Zone, West Indian Coastal Current, Optimum Interpolation Sea Surface Temperature, west coast of India.

IIOE-2 Endorsed Project No:

[ABS-02-0146]

Vulnerability of Coastal Mangrove Ecosystems to Environmental Stressors: A Case Study of Manus Island, Papua New Guinea

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The responses of mangroves to local oceanographic conditions, especially in remote regions, remain poorly understood. This study focuses on Manus Island, located north of Australia in Papua New Guinea, where local upwelling may influence mangrove health. Using NASA's MODIS satellite data processed with Google Earth Engine, we analyzed the Normalized Difference Vegetation Index (NDVI) to assess mangrove greenness and vitality from 2007 to 2020. We also examined key climate variables, including temperature, rainfall, and soil moisture, to identify drivers of observed changes. Our results reveal a significant increase in mangrove greenness over the 14-year period (R^2 0.75, $p<0.01$), with the area of change measuring 1.51 $km^{2.}$ Notably, warmer temperatures correlate with enhanced mangrove growth, suggesting that regional warming may have a positive effect on these ecosystems. In contrast, precipitation and soil moisture showed minimal influence, likely due to tidal dominance in water supply. While direct measurements of ocean currents and upwelling were not conducted, the sustained greening trend indicates a degree of resilience, potentially supported by oceanographic conditions mitigating terrestrial climate impacts. Importantly, no widespread declines in mangrove health were detected, indicating relative ecosystem stability. This work provides a critical baseline for future integrated research essential for developing effective conservation strategies under ongoing climate change

Keywords: Coastal Mangrove Ecosystems, Papua New Guinea, MODIS satellite data, Google Earth Engine, Normalized Difference Vegetation Index (NDVI)

IIOE-2 Endorsed Project No:

THEME-3

MONSOON VARIABILITY AND ECOSYSTEM RESPONSE

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[ABS-03-0110]

Ocean preconditioning the Asian-Australian monsoon onset

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The Asian monsoon region is characterized by the abrupt onset, i.e. the quick dry-wet transition in days. The classic theory emphasizes the elevated heating effect of the Tibetan Plateau in boreal spring. However, three Asian monsoon components (Indian monsoon, Bay of Bengal monsoon and South China Sea monsoon) do not onset simultaneously, but with the surprising sequence of Bay of Bengal, South China Sea and India. With the microwave satellite such as TRMM and the Indian Ocean Observing System (IndOOS), the sea surface temperature (SST) data clearly reveals that the ocean preconditions the monsoon onset. SST reach the annual peak before the monsoon onset, which helps trigger the monsoon onset through attracting the intra-seasonal oscillation (ISO) into the region. The extension into Australian monsoon onset reaffirms the validity of the present conceptual model. This provides the physical basis for the challenging prediction of monsoon onset, its inter-annual variations and the associated marine heatwave disasters.

Keywords: monsoon onset, SST, precondition, intraseasonal oscillation, ocean-atmosphere interaction

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[ABS-03-0312

Air-sea interaction processes and mixed-layer Heat budget in the Arabian Sea during the northward Propagating summer Monsoon Intraseasonal Oscillation (MISO)

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The northward propagating organized convective activity on 20-60-day timescale from the equatorial Indian Ocean (EIO) is a striking phenomenon during the Indian Summer Monsoon. This phenomenon is usually referred to as the summer monsoon intraseasonal oscillation (MISO), and it predominantly determines the active and suppressed spells of the Indian Summer Monsoon, with rainfall anomalies extending from the Arabian Sea to the western Pacific. However, the representation of MISO in the coupled models used for seasonal and extended-range prediction is still challenging. Hence, it is imperative to understand the factors that modulate them in different oceanic basins. In this study, we used a combination of in-situ, reanalysis, and field campaign data to understand the air-sea interaction processes and factors that modulate the sea surface temperature variability associated with MISO using mixed-layer heat budget analysis. It was found that net surface heat flux and vertical processes play a predominant role in determining sea surface temperature during the active phase of MISO. Conversely, the sea surface temperature state during the suppressed phase is predominantly controlled by net surface heat flux alone. In addition, the relative importance of diapycnal mixing to determine the sea surface temperature variability during the different phases of MISO is also quantified.

Keywords: Air-Sea Interaction, Monsoon Intraseasonal Oscillation

IIOE-2 Endorsed Project No: IIOE2-EP54

[ABS-03-0313]

Moist Static Energy Budgets and Propagation Characteristics of Indian Summer Monsoon Intraseasonal Oscillations

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The Indian Summer Monsoon (ISM) is crucial for agriculture and water resources across South Asia, with one of its dominant modes of variability occurring on intraseasonal timescales (20-70 days). These intraseasonal oscillations (ISO) manifest as alternating active and break phases of rainfall and are marked by the coherent northward propagation of convection from the equatorial Indian Ocean (EIO) to the Himalayan foothills. Previous studies have examined the characteristics of ISO and suggested links between the state of central India (CI) during break phases and the subsequent strength of active phases. However, the thermodynamic and dynamic processes governing ISO initiation and propagation remain less well understood. In particular, the relative contributions of moist static energy (MSE) budget components to the ISO lifecycle have not been systematically quantified. In this study, we first analyze the spatiotemporal evolution of ISO events, with emphasis on their inception over the EIO and subsequent northward propagation. Using Multichannel Singular Spectrum Analysis (MSSA), ISO signals are isolated from 25 years of IMERG rainfall and atmospheric data. Eastern EIO convective events are categorized based on simultaneous rainfall anomalies over CI. Results show that of 77 EIO convective initiations, 26 exhibit stronger and slower northward propagation when CI experiences a strong dry anomaly at the time of onset. To investigate the energetic drivers of these differences, we apply an MSE budget framework using ERA5 reanalysis. The analysis evaluates the roles of horizontal and vertical advection, surface turbulent fluxes (latent and sensible heat), and radiative heating during active and break phases of ISO. Our findings suggest a strong connection between ISO propagation speed and MSE budget components, particularly under suppressed CI conditions. These results provide new insights into the energetics of monsoon intraseasonal variability and have implications for improving extended-range prediction systems.

Keywords: Indian monsoon variability; intraseasonal oscillation; moist static energy budget

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[ABS-03-0211]

Role of Northeastward propagating Intra Seasonal Oscillation over Arabian Sea in triggering Indian summer monsoon onset

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Indian summer monsoon onset over Kerala is vital for Indian economy. In this study we investigate the prevailing conditions involved before monsoon onset over Arabian Sea (AS) with the ERA-interim reanalysis data for the period of 1982-2013. A pentad composite analysis has been done to reveal the background circulation changes and association among Sea surface temperature, Convective instability and Convection before monsoon onset over AS. It has been observed that a little zone of higher SST during the pre-monsoon period i.e. before 40 days at western equatorial Indian Ocean around 55Ë¿E can be considered as a prelude to monsoon onset. This SST increases in dimension and can be seen moving in northeast direction from western AS from day -40 to day 0. Prior to summer monsoon onset, the higher SST increases the surface equivalent temperature (Î¸e), which establishes the meridional asymmetry of the atmospheric convective instability over AS. This instability leads to the North Eastward propagating Intraseasonal oscillation (NEISO, a second episode of Northward Propagating ISO during pre-monsoon season, making its first intense episode over BOB) at southwestern AS on day -15. That means, from April to May, the convection over tropical Indian Ocean forms in two episodes. In the first Episode, it moves towards the BOB and on day -35 it occupies the south BOB and decays afterwards. In the second Episode it starts near Somalia coast on day -15 in the south western Arabian sea i.e. over Somalia coast between 50^0-55^0E, 5^0-10^0 N. The NEISO convection increases in intensity and moves northeastward passing through the Kerala latitudes on day 0 with the pillar support of low-level jet (LLJ) and triggers the onset over Kerala The results distinctly illustrate the phase-locked relationship among the persistent sea surface warming over the AS, the NEISO convection and the established low level westerlies.

Keywords: Monsoon Onset, Sea Surface Temperature, Convective Instability, NEISO Convection, Low Level jet.

IIOE-2 Endorsed Project No:

[ABS-03-0016]

Atmospheric conditions on the west coast of India during the dry and wet spells event in July 2024

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The western coast of the Indian peninsula experiences intense rainfall during the summer monsoon months (June-September), and some regions record seasonal totals exceeding 250 cm. Variations in atmospheric conditions during the monsoons active and break spells significantly influence water availability, agriculture, and related sectors. However, the physical mechanisms governing atmospheric structure and variability during these transitional phases are still not fully understood. To address this gap, we examine the thermodynamic evolution of the atmosphere using high-resolution radiosonde observations collected in July 2024 during a dedicated field campaign over the southeastern Arabian Sea. These observations were conducted at a fixed time-series location (11.25°N, 72.53°E), where both active and break phases of the monsoon were captured. To complement as well as extend our analysis, we also utilize simulations from the IITM model and ERA5 reanalysis data to explore the broader-scale thermodynamic and dynamical context. Our findings indicate a clear rise in SST and a drop in precipitation during break spells, while the opposite feature occurs during active phases. Vertically integrated moist static energy exhibits a declining trend during the onset of break conditions and begins to increase again as the monsoon transitions into an active phase. This variation is closely linked with prominent intensification of zonal wind speeds along with decreases in mid-tropospheric relative humidity, which decrease sharply during breaks. Analyzing further reveals that rainfall strongly relates to vertically integrated moisture content across different monsoon phases. The modulation of MSE is predominantly driven by moisture processes, with horizontal moisture advection playing a critical role in shaping its divergence. Elevated MSE values during active periods correspond with enhanced convective activity and rainfall, whereas suppressed MSE during breaks contributes to reduced precipitation. This study provides a detailed assessment of the atmospheric moisture and energy budgets and highlights the contrasting mechanisms during transitional phases.

Keywords: Moist static energy (MSE), Active and break spells, ISM

IIOE-2 Endorsed Project No:

[ABS-03-0215]

The causes of the difference in marine heat wave conditions during the summers of 2019 and 2020 in the Northern Bay of Bengal

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Time series measurements of the high-resolution vertical profiles of temperature, salinity, current velocity and surface meteorological parameters from a moored buoy at 17.8°N, 89.5°E in the northern Bay of Bengal (BoB) are used to document differences in the marine heatwaves (MHW) conditions between summer (defined as June to September) 2019 and 2020 and its plausible connection with northward propagating monsoon intraseasonal oscillation (MISO). It was found that the summer of 2020 exhibited significantly warmer SST anomalies in the northern BoB with magnitudes exceeding 1°C north of 15°N, compared to the near climatological state in 2019. Consequently, MHW metrics reveal a moderate and persistent MHW state in the summer of 2020, in contrast to the sporadic and weak MHW conditions in 2019. In the summer of 2019, the northern BoB experienced progressive cooling, modulated by the sequential occurrence of MISO events without a significant break period between the events. Despite a similar number of MISO activities in 2020, seasonal cooling was absent, leading to persistent MHW conditions with a peak magnitude in August 2020. A mixed-layer heat budget analysis using flux mooring data indicates that the enhanced net shortwave radiation (NSW) was the primary factor responsible for the MHW in 2020. The westward extension of an anomalous anticyclone over the northwestern Pacific into the BoB reduced cloud cover, thereby increasing NSW heating at the ocean surface in 2020. This mechanism weakened MISO-driven cooling, allowing SST to remain anomalously warm in 2020, along with a prolonged break between the events.

Keywords: Bay of Bengal, Monsoon intraseasonal oscillation, Marine heatwaves, Mixed layer heat budget

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[ABS-03-0358]

Study of Variability of Air-Sea Interaction in the Western Arabian Sea between Excess and Deficient Monsoon Composite Years

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The Somalian jet drives the strong Somalian current in the western Arabian Sea along the Somalian coast. The Great Whirl is a feature of this coastal current eddy structure. In these eddies, spatially, the SSTs differ by a magnitude of 3° C within a distance of around 200 km. These differences cause a distinguished characteristics of air-sea interaction processes within the area spanning these eddy structures. Using the ICOADS ship dataset, analysis of characteristics of the air-sea interaction processes show a clear variability between excess monsoon years and deficient monsoon years. The surplus monsoon years composite and deficient monsoon years composite of meridional profiles (along 57° E in the WAS region) of variables like, SST, meridional wind speed at 10m, air temperature at 10m, sea-air temperature difference, surface layer stability, potential vorticity tendency and other oceanographic variables show a clear difference exhibiting a high inter-annual variability of air-sea interaction in this region.

Keywords: inter-annual variability, excess and deficient monsoon years, air-sea interaction, western Arabian Sea

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[ABS-03-0295]

Strategies of ensemble based coupled data assimilation for improved weather and short-term climate predictions

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Early prediction of sub-seasonal to inter-annual variations in Indian summer monsoon rainfall has multifaceted benefits (e.g., agriculture, economy, etc.). Hence any significant improvement in the prediction skill could be highly appreciated. The Ocean and Atmosphere observations have increased tremendously during recent decades due to satellites and improved observational networks. Incorporating the accurate state of the Earth system's components as the best initial conditions to the prediction model is imperative in minimizing forecast errors. Targeting a seamless prediction system, an ensemble-based flow-dependent coupled data assimilation system is developed for Climate Forecast System version 2 (CFSv2), namely the Indian Institute of Tropical Meteorology, University of Maryland- Weakly Coupled Analysis (IWCA). The quality of IWCA coupled analysis over other state of the art coupled and uncoupled analysis is reported in this study. Further the sensitivity of seasonal prediction (June to September) of Indian monsoon to initial state from two variants of coupled data assimilation (CDA) products, viz. the Climate Forecast System (CFS) Reanalysis (CFSR) and IWCA is explored in this study. The IWCA implements the local ensemble transform Kalman filter and incorporates theoretically advanced features of flow-dependency and ensemble-based analysis compared to CFSR. The CFS version-2 predictions using IWCA simulate the large-scale monsoon features, and convection centers well, and improve prediction skills compared to CFSR predictions. The enhanced analysis quality and Ocean-Atmospheric cross-domain equilibrium in IWCA reduce initial shocks in springtime predictions. Further, the sustained ensemble consistency aided to simulate the variability better and improved the seasonal predictions. The study strongly advocates the adaptation of advanced CDA methods for seasonal monsoon and probable seamless predictions.

Keywords: Coupled data assimilation, Ensemble methods, Kalman Filter, monsoon prediction

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[ABS-03-0020]

Role of ocean dynamics in connecting the North Indian Ocean variability with the Arctic Ocean

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In this study, a numerical model simulation has been performed to understand the role of the Arctic Ocean (AO) on upper ocean variability of the North Indian Ocean (NIO) at various time scales from intraseasonal to seasonal, interannual, and decadal. A global Modular Ocean Model of version 5 with Sea Ice Simulator (MOMSIS) has been used for this study with a horizontal resolution of 25 km x 25 km in longitude-latitude direction and 50 vertical levels. The role of AO on NIO variability has been quantified using a model experiment in which the year-to-year atmospheric forcing in the Arctic regions of the MOMSIS has been replaced with its climatology values so that the impact of the recent increase in Arctic ocean warming can be estimated globally. The model simulation showed that the role of ocean dynamics is prominent through the Atlantic Ocean pathway compared to the Pacific Ocean. The connection of NIO with AO through the Atlantic Ocean also signifies the role of the Southern Ocean in it. The preliminary result also showed that the impact of AO on NIO is dominant on ocean current variability compared to Sea Surface Temperature (SST) and Sea Level Anomaly (SLA) due to the dominance of ocean vertical processes. Also, the role of AO on NIO increases at decadal time scales compared to intraseasonal due to significant remote forcing impact via ocean circulations. Due to AO and NIO pathways via the Southern Ocean, the strong impact of AO has been observed in the equatorial Indian Ocean Bay of Bengal, and the Arabian Sea. This study shows that the recent significant warming in the AO has a significant impact on ocean physics and monsoon variability in the NIO via ocean pathways.

Keywords: North Indian Ocean, Arctic Ocean, Ocean dynamics, Remote Forcing, Upper Ocean variability, Monsoon variability

IIOE-2 Endorsed Project No:

[ABS-03-0035]

Variability in the secondary nitrite maxima in the central Arabian Sea: Summer (2017 - 2018) Vs. Winter monsoon (2019)

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The secondary nitrite maxima (SNM), expanding up to several hundred meters, are a typical feature that develops in the subsurface waters of most of the Oxygen Deficient Zones (ODZs) in the global oceans. SNM indicates nitrogen loss that occurs under severe oxygen deficiency, when the denitrifying microbes utilize oxygen via a dissimilatory nitrate reduction pathway by reducing nitrate (NO_3^-) to nitrite (NO_2^-). Hence, within the core ODZs where denitrification occurs, oxygen levels vary inversely with nitrite concentrations and linearly with nitrate levels. Monitoring the formation of SNM is important to understand nitrogen loss, which may impact primary productivity. In the Arabian Sea, one of the intense and persistent ODZs is found on its eastern side, which is spatially decoupled from the high-productivity regions. In this basin, monsoon strength is a key factor affecting primary productivity, ODZs, as well as associated features like the distribution of SNM. Here we present the variability in SNM along the central Arabian Sea (64°E, 11 °N -21°N) during two consecutive summer monsoon (Aug 2017 and Aug 2018) and winter monsoon (Dec 2019) seasons. Significant difference in monsoon onset and intensity was reflected in most of the physicochemical and biological processes, including the SNM. During summer monsoon, the SNM was expanded between 200-400 m, and the core was mostly present between 13 -17°N, with the highest nitrite level (>5 µM) seen in 2018 (200 m; 14°N). Within the two summer monsoons, the highest nitrite concentration was observed in 2018. Contrarily, during winter, the SNM was shrunken and the maximum nitrite value was lower (3 µM; 300 m; 16 °N) compared to summer (4-5 µM). These variabilities were correlated in terms of space, nitrate, and oxygen levels with monsoon intensity and onset, which largely impacts organic matter transport to sustain the ODZs.

Keywords: Monsoon, Oxygen, Indian ocean, Nitrite, Nitrate, Organic matter

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[ABS-03-0330]

An Ecosystem in Flux - The Arabian Sea in a Warming World

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The Arabian Sea's monsoon-driven ecosystem has undergone profound transformations since the Joint Global Ocean Flux Studies (JGOFS) program of the mid-1990s, with many changes linked to the growing influence of climate variability. Since 1998, summer coastal upwelling has intensified, while winter convective mixing has weakened, driving biomass increases and a major shift in the winter-time microbial community from diatom dominance to widespread blooms of the mixoplankton, *Noctiluca scintillans*. In contrast, the inter-monsoon periods, traditionally characterized by weak winds, acute oligotrophy, and low productivity, remain comparatively understudied. Emerging evidence, however, points to increasing cyclonic activity during these transitional phases, with satellite observations revealing phytoplankton biomass increases comparable to those seen in summer upwelling seasons. Such ecosystem transitions have far-reaching consequences for food-web dynamics, biogeochemical cycling, and the sustainability of coastal fisheries. Yet, contemporary studies remain sparse, and key questions about the Arabian Sea's evolving productivity states, from oligotrophic to mesotrophic to eutrophic, are unanswered. Here, we integrate satellite observations, coupled physical-biological model outputs, and targeted shipboard measurements to assess the present state of the Arabian Sea ecosystem, highlight emerging trends, and identify critical challenges and opportunities for future research.

Keywords: Climate Change, Ecosystem Change, Monsoons

IIOE-2 Endorsed Project No:

[ABS-03-0175]

Defining Seasonal-Spatial Ranges and Trends of Marine Water Quality Parameters in the Indian Coastal waters

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Understanding the seasonal and spatial variability of marine water quality is essential for assessing ecosystem health, tracking anthropogenic changes, and guiding sustainable coastal management. This study presents a comprehensive analysis of long-term datasets (1965 to 2024), including shipboard observations, field campaigns, and sustained time-series records, to examine key water quality parameters across India's coastal waters. The parameters analyzed include chlorophyll-a, dissolved oxygen (DO), pH, dissolved inorganic carbon (DIC), and major inorganic macronutrients such as nitrate, nitrite, phosphate, silicate, and ammonium. The analysis reveals distinct seasonal and regional patterns shaped by monsoonal cycles, freshwater influx, upwelling zones, and increasing anthropogenic pressures. Elevated chlorophyll-a and nutrient levels along the west coast during the southwest monsoon are linked to strong upwelling, while the east coast experiences nutrient enrichment from the river discharge. A marked increase in nitrogen-based nutrients over the past two decades, approximately two times higher on both the coasts, indicates growing eutrophication risks and more frequent algal bloom events. Seasonal hypoxia in the eastern Arabian Sea points to rising deoxygenation stress. These changes collectively highlight emerging ecological vulnerabilities. By establishing baseline ranges and identifying environmental hotspots, though constrained by data availability and location coverage, this study provides a valuable reference for tracking ongoing/future changes. The findings support the development of predictive tools, inform marine spatial planning efforts, and guide policy frameworks aimed at improving water quality monitoring and enhancing coastal ecosystem resilience.

Keywords: Nutrients; Hypoxia; Pollution; Bay of Bengal; Arabian Sea

IIOE-2 Endorsed Project No:

[ABS-03-0294]

Coastal upwelling and river influx shape mesozooplankton communities along the central west coast of India (off Goa) during the southwest monsoon

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Zooplankton, being highly responsive to environmental variability, serve as vital indicators of ecological conditions in marine ecosystems. This study examines the impact of hydrographical changes on the mesozooplankton (0.2 - 2 mm) community in the coastal waters of Goa (central west coast of India) during the southwest monsoon (SWM). Mesozooplankton samples were collected during two contrasting seasons, SWM (Sep. 2022; n=4) and northeast monsoon (NEM; Dec. 2022; n=4). Abundance and biovolume were quantified using a FlowCAM imaging system, while temperature and salinity profiles were measured with a portable CTD sensor. The water column during the SWM was characterized by a thick, low-salinity (avg. 26.2 ± 1.3 PSU) nearshore layer and high-salinity offshore waters (avg. 33.3 ± 0.9 PSU). In contrast, during the NEM, salinity remained uniformly high across all sites (avg.34.2 ± 0.37 PSU). Mean abundance was higher during the SWM (avg. 1485 ± 1007 ind./m^3) than the NEM (avg. 961 ± 455 ind./m^3), but the greater variability during the SWM suggested a less stable population. During the SWM, abundance was higher in the low-salinity location (1727 ind./m^3), lowest at the frontal zone (283 ind./m^3), and gradually increased offshore (up to 2399 ind./m^3). Whereas during the NEM, abundance remained relatively stable up to the third location (avg. 732 Â± 136 ind./m^3) before declining at the offshore station (111 ind./m^3). Low-salinity waters were dominated by calanoid copepods, particularly *Acartia sp*., and cladocera (*Penilia sp*.), whereas *Corycaeus sp*., siphonophora, and *Evadne sp* dominated in high-salinity offshore waters. In contrast, the NEM showed relatively uniform salinity and a more consistent zooplankton community. The peculiar coastal-to-offshore distribution observed during the SWM can be attributed to the co-occurrence of coastal upwelling and river influx. These processes enhanced nutrient availability and created strong density gradients, driving greater variability in zooplankton distribution across nearshore waters.

Keywords: zooplankton; river influx; upwelling; stratification; southwest monsoon; central eastern Arabian Sea

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[ABS-03-0318]

Modelling the impact of climate change on the Inland Fisheries sector in the Brahmaputra Basin

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The fishery sector is an important contributor to the economic development of India. India ranks second in fisheries and aquaculture production, with around 8% share globally. The Brahmaputra River, which is one of the largest rivers, along with its tributaries, supports about 217 species of fish, making it one of India's most biologically productive inland water systems. The Brahmaputra River supports millions of people in northeast India through fishing and aquaculture, especially in the state of Assam. In 2023-24, the state alone achieved a fish production level of 4.74 lakh metric tons and contributed ~155.55 billion to the state's Gross State Domestic Product (GSDP). However, this sector faces various ecological and structural challenges. Increased rainfall variability, rising annual mean temperature, and frequent flooding are the key climatic changes that disrupt fish breeding cycles and reduce the water quality. In addition to this, overfishing, pollution, and unsustainable practices further degrade fish habitats and biodiversity. These combined factors have led to a significant decline in fish stocks. To address these challenges, this paper presents a data-driven modeling and simulation framework to quantify the effects of climatic and environmental variables on inland fish production in the Brahmaputra basin. By integrating the historical time-series data of fish landings with the required variables, the model aims to forecast the fishery outcomes under multiple scenarios. The results are intended to support the adoption of sustainable fishing practices and guide the development of context-specific policy interventions to meet the increasing demands of fish production. The combined model will thus offer a more complete solution by merging ecological, climatic, and acoustic variables to safeguard biodiversity and support resilient livelihoods in the region.

Keywords: Blue economy, Brahmaputra basin, modelling and Simulation

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[ABS-03-0100]

Seasonally Restricted Distribution of Wedge-tailed Shearwaters (Ardenna pacifica) within Sri Lanka's Exclusive Economic Zone

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Sri Lanka's Exclusive Economic Zone (EEZ; 77.85 °E, 2.11 °N) spans in ~500,000km^2 in the Northern Indian Ocean is nearly eight times the country's land area, remains poorly studied despite its rich seabird diversity. We used the Wedge-tailed Shearwater (Ardenna pacifica) a common non-breeding pelagic seabird in the region, to assess its use of the Sri Lankan EEZ as a wintering site within the tropical Indian Ocean. Occurrence data from GLS-tagged individuals (n = 7) deployed between 2007 and 2015 yielded 528 locations inside the EEZ, which were analysed here. Tags were fitted at five colonies spanning ~17° of latitude-from the Seychelles to RÃ©union and Round Island (~20-21° S)â¿¿an average straight-line distance of ~4,000 km (range 3,500-4,500 km) from Sri Lanka. All birds repeatedly entered the EEZ between April and August, with peak use in May-June, coinciding with the formation of the Sri Lankan Dome, triggered by wind curl associated with the onset of the southwest monsoon. This window aligns with austral autumn,winter for the southwest-Indian-Ocean breeding populations and coincides with the southwest-monsoon upwelling off Sri Lanka, indicating a persistent, seasonally restricted exploitation of the EEZ's productivity pulse. These findings represent the first comprehensive mapping of a pelagic seabird habitat within Sri Lanka's EEZ and underscore the critical importance of conservation planning in this sensitive marine environment.

Keywords: Indian Ocean, Marine Spatial Planning, Pelagic Seabirds, Wedge-tailed Shearwater, GLS Tagging, Sri Lankan Dome, Sri Lanka

IIOE-2 Endorsed Project No:

[ABS-03-0296]

Multiproxy reconstruction of Late Quaternary climatic variability from the sediments of the western Bay of Bengal

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The Bay of Bengal (BoB), is significantly influenced by climate variables and natural climate forcing mechanisms and receives precipitation from the Indian Summer Monsoon (ISM) and North East Monsoon (NEM). This coupled with the fluvial discharges of sediments and water from both Himalayan and peninsular rivers have a major stake on the geochemical processes of the nearby regions. Considering the unique geoenvironmental features of the BoB and its connections to global climate forcings, the present study aims to unravel the paleoclimate and paleoceanographic variability, using a chronologically dated 2.90m long sediment core retrieved from the western BoB. Sediment deposition occurred in a tranquil and low-energy setting, with a relatively slow sedimentation rate during 4515 ka and last 8 ka, in contrast to 15-8 ka interval. The core site received organic carbon from both terrestrial C4 plants and marine sources, with a predominance of terrestrially sourced C4 plants during 45-15 ka. The multiproxy analysis indicated stronger ISM during 4528 ka and 144 ka, interspersed with a period of weakened monsoon. Nonetheless, between 2514 ka and the last 4 ka, there was an increase in calcareous productivity, which is attributed to a decrease in the ISM and poor fresh water stratification over the BoB. In contrast, the strengthened ISM during the period of 144 ka led to increased freshwater inflows, resulting in significant freshwater stratification in the western BoB, which subsequently hindered calcareous in-situ productivity. Based on the Principal Component Analysis, two dominant processes, i.e. terrigenous sediment input and oceanographic processes, had a strong bearing on the geochemical variability at the core location. The provenance of sediments was prominently from the Deccan basaltic and the Archean crystalline rocks in the hinterlands. This study underlines that the millennial-scale hydroclimate changes in the BoB are significantly linked with the regional and global climate dynamics.

Keywords: Sediment, Indian Summer Monsoon, Bay of Bengal, Paleoclimate, Productivity

IIOE-2 Endorsed Project No:

[ABS-06-0224]

Understanding Particulate Organic Carbon Variability in the Arabian Sea Using Satellite and In-situ Observations

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Particulate Organic Carbon (POC) plays a crucial role in the ocean's carbon cycle by acting as a key mechanism for the long-term sequestration of atmospheric CO_2, thus influencing global carbon storage and mitigating climate change. The distribution and dynamics of POC in the ocean are vital for understanding carbon fluxes and ecosystem health. This study investigates the spatial and temporal variability of POC in the Arabian Sea by integrating in-situ data from bio-Argo floats and satellite-derived data from MODIS-Aqua. The bio-Argo data, covering the period from 2015 to 2023, provided detailed measurements of POC concentration, derived from backscattering, and were compared with satellite-derived estimates, revealing a strong linear correlation ($R^2 = 0.79$). The spatial distribution of POC showed significant seasonal variability, with elevated concentrations along the coastlines of Somalia and Kochi during the southwest monsoon (June-September) due to upwelling-induced nutrient influx, which enhanced primary productivity. Conversely, peak POC concentrations were observed in the northern Arabian Sea during the northeast monsoon (February-March), driven by winter convective mixing. The POC:chl-a ratio revealed interesting seasonal trends, showing higher ratios in the open ocean during the southwest monsoon and lower ratios in the coastal waters, where phytoplankton concentrations were elevated due to nutrient enrichment from upwelling. Additionally, vertical profiling from bio-Argo floats identified a secondary POC concentration maximum between 200-400 meters, associated with low oxygen and nitrate levels, indicating active denitrification processes in the oxygen minimum zone (OMZ). The study highlights the value of combining satellite and in-situ data to provide high-resolution insights into the spatial and temporal dynamics of POC.

Keywords: Particulate Organic Carbon, Arabian Sea, bio-Argo, Satellite.

IIOE-2 Endorsed Project No:

[ABS-03-0053]

Multidecadal to Centennial Variability in ENSO-Indian Monsoon Coupling Since 850 CE: Insights from Coupled Model Simulations and Paleo Data Assimilation

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The El Niño thern Oscillation (ENSO) exerts a dominant influence on Indian Summer Monsoon (ISM) variability at interannual scales. However, this teleconnection exhibits substantial multidecadal fluctuations, with indications of weakening in recent decades. Understanding the mechanisms underlying such non-stationarity remains critical for predicting monsoon behavior. The limited temporal span of instrumental records constrains our ability to assess the drivers of long-term ENSO ISM variability. To address this, we leverage both paleoclimate reconstructions and simulations from the Community Earth System Model- Last Millennium Ensemble (CESM-LME). Our analysis of 31-year running correlations between ENSO and ISM rainfall over the last millennium reveals significant correlation in ~55% of the period, highlighting episodic and non-stationary coupling. We investigate whether this variability stems from external forcings or internal dynamics. While ensemble simulations under various forcings (volcanic, solar, orbital, LULC, and GHG) show some influence on ISM-ENSO coherence, we find no systematic linkage between any single forcing and the breakdown or strengthening of the teleconnection, suggesting a dominant role for internal variability. To further explore internal drivers, we classify monsoon years based on ENSO phase and ISM anomaly into compound event types (e.g., El Niño + drought, La Niña + excess). Composite analysis of SST, SLP, and wind anomalies reveals distinct ocean-atmosphere patterns associated with each event type. For example, droughts during neutral ENSO phases exhibit diminished El Niño -like warming in the tropical Pacific, accompanied by North Atlantic cooling, a weak positive PDO-like pattern, and warming in the western Indian Ocean. These findings highlight that ISM variability even during ENSO-neutral years can be modulated by far-field SST anomalies and internal ocean-atmosphere dynamics. Our results underscore the complex, internally modulated nature of ENSO-ISM coupling and provide new insights into Indian monsoon variability on multidecadal to centennial timescales.

Keywords: Indian Summer Monsoon, El Niño Southern Oscillation, ENSO-ISM Correlation, Teleconnection Variability, Paleoclimate Reconstructions, Model Simulations

IIOE-2 Endorsed Project No:

[ABS-06-0276]

Comparative study on wave characteristics off east and west coast of India using wave rider buoys

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The wave climate along the Indian coastline exhibits strong regional contrasts due to the differing oceanographic and meteorological conditions of the Arabian Sea (west coast) and the Bay of Bengal (east coast). In this study, in situ observations from the network of directional wave rider buoys operated by the Indian National Centre for Ocean Information Services (INCOIS) and the National Institute of Ocean Technology (NIOT) are analyzed to assess significant wave height (Hs), mean wave period (Tm), and mean wave direction (Î¸) over multiple years. Results indicate that the west coast is dominated by monsoon-driven swell, with Hs typically ranging from 0.5-1.5 m during the fair-weather season and increasing to 3.0-4.5 m during the Southwest monsoon (June-September). Mean wave periods exceed 8-12 s in monsoon months, reflecting the influence of long-period swells propagating from the Southern Indian Ocean. In contrast, the east coast exhibits lower background wave energy (Hs ~0.5-1.0 m in fair-weather months) but is punctuated by extreme events during tropical cyclones, where Hs can exceed 6-8 m with associated shorter-period wind-sea components (6-9 s). Wave direction along the west coast is consistently southwesterly during the monsoon, while the east coast displays a broader directional spread influenced by both seasonal winds and cyclone tracks. The comparative analysis highlights the sustained energetic monsoon regime of the Arabian Sea versus the episodic but extreme cyclone-driven wave climate of the Bay of Bengal. These findings, based on long-term buoy records from the INCOIS/NIOT network, provide critical inputs for coastal vulnerability assessment, shoreline management, and the design of marine and offshore infrastructure along the Indian coastline.

Keywords: Wave climate, Indian coastline, Arabian Sea, Bay of Bengal, Directional wave rider buoys, Significant wave height (Hs), Mean wave period (Tm), Coastal vulnerability

IIOE-2 Endorsed Project No:

[ABS-06-0266]

Spatial and Seasonal Variability of Air-Sea CO_2 Fluxes along the Southern Bay of Bengal from In-Situ Observations

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Coastal oceans are increasingly recognized as dynamic zones of carbon exchange, yet the processes governing air-sea CO_2 fluxes in the North Indian Ocean remain poorly constrained. In this study, we present in-situ measurements collected along the southeastern coast of India (Bay of Bengal) for the year 2024. Sampling campaigns were conducted at key coastal sites-Pazhayar, Marakanam, and Pondicherry, where parameters such as pCO_2, Dissolved Inorganic Carbon (DIC), Total Alkalinity, temperature, and salinity were systematically measured. The observations reveal distinct spatial and seasonal variations in CO_2 fluxes. The Pazhayar coastal waters predominantly acted as a net CO_2 source, whereas Marakanam exhibited consistent uptake, functioning as a sink. Pondicherry displayed intermediate and variable behavior. These patterns reflect the combined influence of monsoonal forcing, freshwater influx, stratification, and biological activity on carbonate chemistry and gas exchange. The results underscore the value of in-situ observations for capturing short-term and localized flux variability, which often remains unresolved by satellite approaches. Establishing such baseline assessments is essential for constraining regional carbon budgets and improving our understanding of the coastal oceans role in regulating atmospheric CO_2.

Keywords: Air-sea CO_2 exchange, Coastal carbon fluxes, In-situ measurements, Bay of Bengal

IIOE-2 Endorsed Project No:

[ABS-03-0219]

Seasonal Dynamics of Inorganic Macronutrients in the Coastal Waters off Paradip, Bay of Bengal

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This study examines the seasonal and spatial patterns of key inorganic macronutrients, as well as their stoichiometry in the coastal waters off Paradip, western Bay of Bengal. Sampling was conducted across three stations during post-monsoon, pre-monsoon, and monsoon seasons between January 2024 and July 2025 to assess nutrient fluxes, limitation patterns, and implications for primary productivity. Nitrate and nitrite concentrations peaked during the monsoon, driven by enhanced riverine discharge, whereas pre-monsoon values were minimal due to phytoplankton uptake. Ammonium exhibited elevated concentrations in the post-monsoon, linked to organic matter decomposition, but remained low during pre-monsoon. Phosphate followed a contrasting pattern, with high monsoonal levels from agricultural runoff and minimal pre-monsoon concentrations, while post-monsoon subsurface maxima suggested regeneration from sinking detritus. Silicate concentrations were markedly high during the monsoon, reflecting terrestrial input, and depleted during dry seasons due to diatom uptake. Nutrient stoichiometry revealed strong seasonal shifts: phosphorus limitation dominated offshore during pre- and monsoon periods, silicate limitation prevailed in post-monsoon surface waters, and nitrogen limitation emerged nearshore in pre-monsoon. Chlorophyll-a distribution further reflected these dynamics, with post-monsoon higher magnitude linked to favourable nutrient ratios, while monsoon phytoplankton growth was restricted by light limitation despite nutrient enrichment. Overall, the outcomes highlight the interplay of hydrological forcing, nutrient regeneration, and stoichiometric balance in regulating primary productivity and ecosystem functioning in this dynamic coastal system.

Keywords: Nutrient Stoichiometry; Monsoon; Phytoplankton; Chlorophyll-a; Mahanadi

IIOE-2 Endorsed Project No:

[ABS-06-0270]

Monsoon-Driven Variability in Nutrients and Chlorophyll-a: A Time-Series Study from the Eastern Arabian Sea

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This study presents the outcome of the Indo-US joint program Enhancing knowledge of the Arabian sea marine environment through science and advanced training, under which a 10-days time-series observation was conducted in the Eastern Arabian Sea (EAS) from July 1 to July 10, 2024, during the monsoon period, to investigate the influence of monsoon-driven processes on water column variability and to examine the spatial variability and controlling factors of nutrient and chlorophyll biogeochemistry. During the study period in the EAS, higher salinity was consistently observed in the upper 0-150 m depth. The water column exhibited thermal stratification throughout the period, with temperature gradients ranging from 5 to 7°C between the upper 50-120 m depth. Dissolved Oxygen (DO) concentrations were significantly lower below 75 m depth across the entire study period. On the first day of the time-series study, higher surface chlorophyll-a concentrations were observed, coinciding with lower surface temperatures compared to subsequent days. Throughout most of the study period, chlorophyll-a concentrations in the upper 25 m of the water column remained low, with a prominent subsurface chlorophyll maximum (0.5-0.7 mg m^{-3}) consistently observed between 25 and 50 m depth. This subsurface chlorophyll maximum was associated with a corresponding nitrite maximum. Elevated concentrations of nitrate, phosphate, and silicate were observed below 75 m depth. In contrast, high nitrite concentrations were detected around 50 m depth in the subsurface layer of the EAS, likely due to the advection of upwelled waters from the western parts. Nitrite concentrations showed a positive correlation with chlorophyll-a, whereas nitrate, silicate, and phosphate exhibited negative correlations. The findings of this study are highly beneficial, as they provide extensive information on temporal variability in the eastern Arabian Sea.

Keywords: Arabian Sea; Mixing; Chlorophyll-a; Nutrient; EKAMSAT

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[ABS-06-0267]

Impact of Satellite Chl-a and Other Physical Parameters on Deriving Reliable Export Production Estimates over Indian Ocean

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The Indian Ocean has productive coastal upwelling systems characterized by phytoplankton blooms both in summer and winter. In this study, the daily (or 3-daily) surface ocean Chl-a parameter is utilised for the calculation of compensation depth (Zc). The Ocean Tracer Transport Model is forced using GFDL MOM-4 data and reanalysed chlorophyll data and the results were compared over the Indian Ocean region. A comparison shows an increase in compensation depth during ON and DJF, with maximum depth in the southern Indian Ocean. Model run using reanalysed chlorophyll shows deeper compensation depth than that using GFDL chlorophyll. In the reanalysis data, the compensation depth maxima occurs closer to Madagascar, whereas in GFDL the maxima is situated south of the Southern Indian Ocean (for the months of DJF and ON). There is a clear overestimation of the compensation depth (larger mean value) in the run forced with reanalysed chlorophyll data as compared to GFDL. In addition, new production and export production values have also been analysed.

Keywords: Indian Ocean, ocean biogeochemistry, Oceansat-III

IIOE-2 Endorsed Project No:

[ABS-06-0080]

Decadal variability in ocean-atmospheric interaction and its implications on primary productivity in the central Arabian Sea

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The Arabian Sea, one of the oceanic regions with the highest primary productivity, which varies annually influenced by semi-annual reversal of the monsoon winds, affecting its physical and biogeochemical properties. This basin also receives a significant amount of atmospheric dust that supports phytoplankton growth. The Arabian Sea is warming faster than any other ocean, and its impacts are not well understood. Long-term ocean observation is crucial for monitoring these changes, as they may impact ecosystem functioning and carbon cycling. This study uses high-resolution satellite data on Chl-a, winds, SST, AOD, and dust deposition, combined with reanalysis mixed-layer depth estimates, to identify factors that influence surface water productivity and upper-ocean processes. This study analyzes twenty years of satellite data considering aerosol optical depth (AOD), Chl-a concentration, wind speed (WS), and sea surface temperature (SST) during summer and winter monsoons covering the area between 62°E to 66°E and 18°N to 22°N for Northern Arabian Sea (NAS) and 62°E to 66°E and 9°N to 15°N for Southern Arabian Sea (SAS). The results revealed a significantly higher spatial variability in Chl-a, SST, and AOD in the NAS compared to the SAS. In NAS, Chl-a shows average values > 1 mg m-3, and in the SAS, it was < 0.5 mg m^{-3}. The findings also show SST trends increase over decades in summer without any significant trends in winter. Conversely, AOD exhibits a notable increase in winter, but not in summer. Other factors, such as wind velocity and upwelling intensity, are also explored to understand the interplay between all these factors. Despite higher SSTs over the past two decades, Chl-a concentration has not changed significantly. We hypothesize that increased SST may reduce nutrient supply due to enhanced stratification, although atmospheric deposition could help compensate for some nutrient deficits. Further analyses are in progress.

Keywords: Productivity; Temperature; Aerosol optical depth; Atmospheric forcing; North Indian Ocean

IIOE-2 Endorsed Project No:

[ABS-06-0198]

Contrasting Productivity Regimes of the Arabian Sea and Bay of Bengal: Perspective from Depth-resolved CbPM Modeling

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Understanding the contrasting productivity regimes of the Arabian Sea (AS) and Bay of Bengal (BoB) is critical for improving biogeochemical modeling and carbon cycling estimates in the Northern Indian Ocean. In this study, the Carbon-based Productivity Model (CbPM) was implemented locally at 4 km spatial resolution, using satellite-derived chlorophyll and backscatter data along with high-resolution physical and biogeochemical inputs including HYCOM mixed layer depth (MLD), ROMS-Fennel nitracline depth, and MODIS ocean color products. Monthly Net Primary Productivity (NPP) from June 2023 to May 2024 was estimated by vertically integrating up to the euphotic depth (Zeu), providing a depth-resolved characterization of primary productivity drivers across seasons and regions. The results reveal distinct basin-scale differences in the mechanisms regulating NPP. The AS exhibited strong seasonal variability, with elevated productivity during the pre monsoon and post-monsoon months driven by coastal upwelling and convective mixing nutrient entrainment. In contrast, the BoB showed comparatively lower seasonal variations, but maintained moderate and consistent productivity, particularly during stratified periods. This sustained productivity in BoB is linked to a better vertical alignment of the chlorophyll layer, higher euphotic depth and nitracline depth than MLD, although stratification restricts deep mixing but retains phytoplankton in light-favorable conditions. These findings demonstrate that surface chlorophyll alone is insufficient to capture productivity variability, and that vertical coupling between light, nutrients, and biomass plays a dominant role. The depth-aware, high-resolution CbPM framework employed here provides a good representation of primary production and offers insight into regional responses of ocean productivity to seasonal forcing in the northern Indian Ocean.

Keywords: Primary Productivity, northern indian ocean, biogeochemistry, CbPM

IIOE-2 Endorsed Project No:

[ABS-03-0176]

Decadal Trends in Phytoplankton Biomass and Size Structure with a Focus on Diatoms in the Western Bay of Bengal

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This study examines the seasonal and spatial variability of chlorophyll-a (chl-a) concentrations, diatom distributions, and phytoplankton size classes (PSCs) in the coastal waters off Gopalpur and Visakhapatnam, located along the western Bay of Bengal. Using MODIS-Aqua satellite data from 2003 to 2024, monthly climatologies of chl-a, diatom pixel counts, and PSCs (micro-, nano-, and picophytoplankton) were generated. The analysis revealed bimodal peaks in chl-a concentrations during the pre-southwest (March & April) and post-southwest (September &October) monsoon seasons along both locations. Gopalpur, influenced by the Rushikulya River and relatively lower anthropogenic pressure, exhibited higher chl-a and more frequent algal bloom events, predominantly dominated by diatoms. In contrast, Visakhapatnam, despite experiencing strong upwelling, lacked recurrent bloom reports, likely due to limited freshwater input and port-associated material flux. Seasonal variation in PSCs showed dominance of microphytoplankton during post-southwest monsoon periods, with picophytoplankton prevailing during the peak monsoon season due to increased turbidity. Spatially, microphytoplankton dominated nearshore regions, while picophytoplankton were more prevalent in offshore. The East India Coastal Current (EICC) and upwelling processes emerged as key physical drivers influencing phytoplankton biomass distribution and bloom timing. Cyclonic events and monsoonal dynamics also modulated nutrient availability, further impacting bloom development. While satellite-based observations offer broad-scale insights, they face limitations under high turbidity and cloud cover. This study underscores the need for integrated bloom monitoring that combines satellite data with in situ measurements and modeling approaches.

Keywords: Algal Blooms, Chlorophyll-a, Ocean Colour, MODIS-Aqua, Monsoon

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[ABS-03-0200]

Diatom-Diazotroph Associations (DDAs): A Potential Source of New Nitrogen in the Arabian Sea During the Southwest Monsoon

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Diatom-diazotroph associations (DDAs) are ubiquitous in the tropical and subtropical oceans. Although the mixed layer of the open ocean generally remains nitrogen-limited year-round, DDAs are predominantly found during the summer monsoon (SM) in the Eastern Arabian Sea (EAS). Globally, DDAs peak between June and September, though the drivers behind this seasonal pattern are not well established. Our observations indicated that during this period, sea surface temperatures (SSTs) rise in the Pacific and Atlantic but slightly decline in the Arabian Sea (AS). Nevertheless, SSTs across all these regions converge to ~25-28°C, creating a uniform thermal environment that likely supports the global occurrence of DDAs between June-September. During this period, we studied the variability of DDAs in the euphotic zone (0-80 m) along the eastern Arabian Sea (68°E, 8°N-21°N) over two consecutive summer monsoons (July 2020 and July 2021). Our results revealed that the Arabian Sea's mixed layers remain oligotrophic and serve as a hotspot for DDAs. During the SM-2020, DDAs were mostly found in moribund stages of *Richelia-Rhizosolenia* (R-R) and *Climacodium-Crocosphaera* (C-C), associated with elevated temperatures (>28°C). In contrast, the SM-2021 observed healthier DDAs R-R, *Hemiaulus-Richelia* (H-R), and C-C associations occurring at lower temperatures (<28°C). The higher abundance of DDA in the EAS, particularly in the NEAS is likely driven by excess phosphate and high silicate concentrations, increased aeolian dust deposition and availability of iron, and relatively lower temperatures compared southeastern AS. *Climacodium-Crocosphaera*, found across all latitudes, suggests that iron availability may play a key role in DDAs distribution in the EAS. Our estimated N_2 fixation rates, based on heterocyst abundance, ranged from 6 to 103µmol N_2 m^2d^{-1} in the EAS, suggesting a substantial input of new nitrogen which is previously unaccounted in the regional N_2 fixation budgets in the EAS.

Keywords: Diatom-diazotrophs, Global oceans, N_2 fixation, summer monsoon, Eastern Arabian Sea

IIOE-2 Endorsed Project No:

[ABS-03-0257]

Influence of Hydrographic Forcing on Phytoplankton Morphology and Community Structure along the Central West Coast of India

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This study investigates the relationship between environmental parameters and the abundance and morphology of phytoplankton along the central west coast of India. Monthly samplings were conducted over six months (December 2023; January-April 2024; and September 2024) from multiple coastal stations with discrete depth sampling. Regarding phytoplankton shape, a total of 18 classes were identified (based on taxonomic data) and grouped into two categories as simple and complex. The simple category consisted of a single basic geometry, whereas the complex category was formed by a combination of two or more basic geometries. The analysis revealed that complex morphological shapes were more prevalent under low-salinity conditions, with their abundance increasing notably during periods influenced by monsoonal rainfall and river influx. The dominant shapes found were Prism on elliptic base girdle view (eg: *Chaetoceros sp., Eucampia sp.*), Cylinder + 2 half spheres (eg: *Skeletonema sp.*), Prism on parallelogram base (eg: *Nitzschia sp., Pseudonitzschia sp., Pleurosigma sp.*). The seasonal trend was also observed among the complex shapes, decreasing from north-east monsoon (174255 ± 85199 cells/L) to pre-monsoon (60750± 48649 cells/L) and again increased during south west monsoon (508684 ± 42979 cells/L). Irrespective of seasons, among the simple shapes, centric diatoms accounted for 75.1% and pennate diatoms for 24.8%, whereas in the complex shapes, centric diatoms comprised 82.9% and pennate diatoms 17.1%. Additionally, complex morphological shapes showed a strong negative correlation with salinity ($n = 90$; $r^2 = 0.76$, $p < 0.001$), indicating a greater affinity for low-salinity waters. The total abundance was largely contributed by complex-shaped phytoplankton, suggesting that these taxa dominate bloom conditions under reduced salinity regimes. Our study shows the combined influence of hydrographic forcing and morphological traits in shaping phytoplankton community structure in coastal water.

Keywords: Phytoplankton morphology, Centric diatoms, Complex shapes, Salinity, Monsoon

IIOE-2 Endorsed Project No:

[ABS-03-0209]

Hydrobiological Responses to Seasonal Forcing in Coastal Waters off Paradip, Bay of Bengal

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This study investigates the hydrobiological response to seasonal forcing through an integrated approach, combining vertical water column profiling with multivariate statistical analysis of various environmental parameters in the coastal waters off Paradip, western Bay of Bengal. The high-resolution vertical profiles of temperature, salinity, chlorophyll-a (chl-a), turbidity, and dissolved oxygen were recorded from January 2024 to July 2025 at three stations located up to 23km from the coast. Seasonal changes were significantly observed in the surface and subsurface during the study period. During the pre-monsoon, elevated sea surface temperature (SST) and salinity indicated a limited freshwater input, and resultant thermal stratification with relatively reduced dissolved oxygen (DO) concentration. Subsurface waters exhibited stable salinity, and a positive correlation between turbidity and chl-a indicated enhanced biological productivity. Despite low freshwater influx, the anthropogenic material flux sometimes influenced the turbidity of this region during this season. By the onset of monsoon, a strong riverine freshwater influx disrupted stratification and reduced light availability, leading to suppressed phytoplankton growth. Although a peculiar phenomenon of phytoplankton was found in the transitional station, where the sub-surface chl-a maximum was observed with concentrations exceeding 8 mg m^{-3}. During the post-monsoon, SST was found to be the lowest of all time, and the salinity began to recover. The increase in DO and turbidity was attributed to biological processes. Non-metric multidimensional scaling (NMDS) ordination and correlation matrices revealed that Station-1 is primarily a physically dominated system, with turbulence and terrestrially-sourced sediments contributing to high turbidity and reduced biological activity. Station-2 serves as a transitional mixing zone, influenced by both coastal and offshore processes, while Station-3 represents a biologically dominated system where phytoplankton are tightly coupled with physical conditions. This study highlights the effectiveness of combining physical profiling with multivariate techniques to provide a comprehensive understanding hydrobiological forcing of a coastal region.

Keywords: Hydrobiology; Monsoon; Chlorophyll-a; Multivariate Analysis; Mahanadi

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[ABS-03-0210]

Seasonal Variability of Algal Size Classes in the Coastal Waters off Paradip, Bay of Bengal

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Phytoplankton communities in tropical coastal ecosystems exhibit strong seasonal variability driven by monsoonal forcing and nutrient dynamics. This study investigates the seasonal distribution of phytoplankton size classes (micro, nano, and picophytoplankton) in coastal waters off Paradip, western Bay of Bengal, using both in situ and satellite data. Results reveal marked seasonal shifts in community composition. During the pre-monsoon, phytoplankton biomass was low, with pico and nanophytoplankton thriving under stratified, nutrient-limited conditions, although localized nutrient inputs occasionally favoured microphytoplankton. The monsoon season was characterized by enhanced riverine inputs, strong vertical mixing, and nutrient enrichment, leading to a pronounced bloom dominated by microphytoplankton (particularly diatoms), alongside elevated nano and picophytoplankton. In the post-monsoon period, phytoplankton biomass concentrations declined, with pico and nanophytoplankton emerging as the dominant groups under oligotrophic, re-stratified conditions. Comparisons of satellite and in situ phytoplankton biomass indicated seasonal discrepancies, with satellite underestimation during pre-monsoon and overestimation during monsoon due to turbidity and cloud interference. Overall, the findings highlight the dynamic seasonal partitioning of algal size classes and their ecological significance in sustaining coastal productivity in the Bay of Bengal.

Keywords: Chlorophyll-a; MODISA; Monsoon; Mahanadi; Nutrient

IIOE-2 Endorsed Project No:

[ABS-03-0250]

Ecosystem Trophic States vis-Ã -vis Algal Community Structure in a Tropical Estuary

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This study investigates the influence of tidal and diurnal variations on phytoplankton community structure and trophic status in the Mahanadi estuary, which connects to the Bay of Bengal on the east coast of India. Recognising phytoplankton as sensitive indicators of ecosystem health, this study assessed their spatial and temporal dynamics in relation to environmental parameters such as salinity, nutrients, suspended matter, and chlorophyll-a. Field surveys were conducted during high and low tides at estuarine and freshwater stations with distinct salinity regimes. A total of 44 and 77 phytoplankton species were recorded at the upstream (E1) and downstream (E2) stations, respectively, with Bacillariophyta being the dominant group across all conditions. Diversity indices indicated subtle variations between tides and diurnal cycles, with species richness generally higher during high tides and daytime. Canonical Correspondence Analysis revealed phytoplankton groups responded distinctly to hydro-biological variables such as suspended matter, Salinity, Total Nitrate (TN), and Total Phosphate (TP). Trophic State Index (TSI) values indicated mesotrophic to eutrophic conditions, driven by nutrient enrichment likely from anthropogenic sources. The presence of organic pollutant indicators (bloom-forming and harmful algal species) like *Pseudonitzschia pungens, Nitzschia* sp., *Cyclotella* sp., *Anabaena sp., Scenedesmus sp., Ankistrodesmus sp., Oscillatoria sp., Merismopedia sp. and Microcystis aeruginosa*, underscores the ecological stress in the system. Overall, the study highlights strong tidal-diurnal coupling in shaping phytoplankton assemblages and establishes the utility of integrated biological and physicochemical indicators for assessing estuarine water quality.

Keywords: Mahanadi Estuary, Trophic State Index, Estuarine Ecology, Tidal Influence, Bay of Bengal

IIOE-2 Endorsed Project No:

[ABS-03-0044]

Influence of Tidal and Seasonal Forcing on Hydroecological Conditions and Plankton Assemblages in the Baleswar Estuary

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Studying the dynamic plankton community of the coastal regions is important for understanding the trophic interaction of the aquatic ecosystems. However, these coastal regions are less explored Which is why this study intends to investigate the community structure as well as the drivers of phytoplankton in these tropical coastal regions. We have collected high-resolution (Hourly) data on phytoplankton, zooplankton and environmental parameters from two different locations in the Baleswar estuary by considering spatial gradients in salinity, tide and ecological dynamics. These data were collected during two different seasons, winter (December) and pre-monsoon (March) to capture the hydroecological variations associated with seasonal transitions in the estuary. Our study has found that tidal fluctuations strongly influence salinity, turbidity and nutrient availability in the estuary with salinity peaking during flood tides and nutrients (specifically nitrite and silicate) peaking during ebb tides. Diatoms were the dominant phytoplankton group in both locations and seasons. However, dominant species varied along locations and seasons. Taxa of *Coscinodiscus* was found dominant in estuary while taxa of *Ditylum* and *Chaetoceros* were found dominant further upstream in the river. The number of micronutrients was found to be the major drivers. Zooplankton was also found to play a vital role in shaping the phytoplankton community structure. Our study affirms that phytoplankton dynamics in the coastal regions are influenced by nutrients that are controlled by the tidal cycle.

Keywords: Baleswar Estuary, Plankton Dynamics, Tidal Cycle, Seasonal Variation, Nutrient Enrichment, Phytoplankton Community, Ecohydrology, Tropical Estuary, Salinity Gradient, Environmental Parameters

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[ABS-06-0242]

Thermal front dynamics and their role in identifying Potential Fishing Zone (PFZ) hotspots along the southwest coast of India

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This study investigates the spatiotemporal variability of thermal front (TF) frequency and its ecological significance along the southwest coast of India from 2020 to 2023. High-resolution AVHRR (1 km) satellite-derived sea surface temperature (SST) data were analyzed using the Cayula-Cornillon Algorithm (CCA), implemented through the Marine Geospatial Ecology Tools (MGET) in the GeoEco Python package. TFs were identified as regions with SST gradients exceeding 0.3°C per pixel. Results reveal persistent TF activity, particularly in defined hotspot zones influenced by mesoscale eddies, coastal upwelling, and stratification. Seasonally, TF frequency peaked during winter, declined in summer, and was lowest during the southwest monsoon due to cloud cover, freshwater influx, and enhanced wind-driven mixing, which led to thermal homogenization. Post-monsoon months showed partial reactivation of frontal activity. Statistical analysis indicated a moderate positive correlation between TF density and chlorophyll-a concentration ($r = 0.35$), and total fish catch ($r = 0.28$), suggesting that TFs serve as proxies for biologically productive and fish-rich waters. These findings underscore the utility of TF detection in delineating Potential Fishing Zones (PFZs) and support its application in sustainable fisheries and marine spatial planning. This research demonstrates the relevance of remote sensing-based front detection as a valuable tool in ecosystem-based fishery management in the eastern Arabian Sea, with broader implications for PFZ forecasting and marine resource conservation.

Keywords: Thermal Fronts; Thermal Front Frequency; Thermal Front Density; Remote Sensing; PFZ Hotspot

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[ABS-03-0383]

Stagnation of atmospheric circulation leads to historically prolonged extreme rainfall event over northwestern India in August 2024

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Northwestern India (NWI) received anomalously heavy rainfall from August 21-30, 2024, despite the monsoon being in a break phase. This study reveals how mid-latitude dynamics triggered this unusual event. Using reanalysis, we perform a moisture budget analysis and Local Wave Activity (LWA) diagnostics and find that the enhanced mid-tropospheric baroclinic instability greater than 1.1 per day (1.34 Ï¿) peaked during August 13-17 in the North Atlantic, 7-10 days before the NWI rainfall event. This instability fueled the north Atlantic westerly jet and reinforced an "Î©" shaped blocking high over the Ural Mountains ("Ural block") that developed over August 21-22. This block initiated a wave train that propagated eastward with increasing amplitude over subsequent days. The downstream distorted Rossby waves broke, triggering a pronounced Caspian Sea trough that deepened by August 25-26, strengthening a subtropical jet streak north of the Tibetan Plateau, with maximum geostrophic wind speeds exceeding 120 m/s. The NWI was in the jet streak's right entrance region, where upper-level divergence and compensatory upward motion intensified a low-pressure system that had been steered northwestward into the region. Despite monsoon break conditions, the elevated mid-tropospheric humidity allowed sustained deep convection, which combined with the quasigeostrophic ascent arising from the jet streak entrance region, led to extreme rainfall over NWI. Our analysis provides a case study showing the importance of the growing influence of mid-latitude circulation changes traceable to alterations in the North Atlantic for Indian Monsoon variability. The physical linkages demonstrated here may be crucial for improving monsoon behaviour in changing climate.

Keywords: Local Wave Activity,Tibetan Plateau,atmospheric circulation

IIOE-2 Endorsed Project No:

THEME-4

CIRCULATION, CLIMATE VARIABILITY AND CHANGE

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[ABS-04-0064]

Unexpected temperature trends in plankton growth and grazing along a 110°E transect in the eastern Indian Ocean

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With mid- to low-latitude waters of the Indian Ocean (IO) warming faster than other major oceans, many questions can be raised about the potential impacts of increasing temperature on IO productivity and food webs. Most models predict a significant decline in intermediate consumers like zooplankton due to the combined effects of reduced nutrient input, enhanced metabolism, and phytoplankton size shifts that reduce availability to larger gragers. On R/V Investigator cruise IN2019V03 (May-June 2019), we investigated phytoplankton production, growth and grazing processes along the historic IIOE 110°E transect from 39.5 to 11.5°S in the eastern IO. Stations spanned a 14°C gradient in mean euphotic zone temperature from temperate and subtropical to tropical water masses. Production and grazing were strongly coupled over the transect and balanced on average. Increasing growth conditions (light and temperature) were mainly manifest as more rapid biomass turnover and mesozooplankton biomass accumulation, which was elevated by 3 fold in the warmest tropical waters. Biomass-normalized grazing of mesozooplankton also increased 6 fold over the transect, showing a strong temperature relationship (r2 = 0.87) that exceeded expected temperature effects on gut turnover and metabolic rates. Such results are explained by recent findings of enhanced food web efficiencies due to widespread mixotrophy and appendicularian-facilitated grazing pathways in the tropical water mass. Our results highlight the importance of using natural gradients of adapted complex communities like the eastern IO as natural laboratories for observation and hypothesis testing relating to the likely directions of climate change impacts.

Keywords: climate change, zooplankton, growth, grazing, food web efficiency

IIOE-2 Endorsed Project No: IIOE2-EP06

[ABS-04-0077]

Reduced Ventilation of Southeast Indian Ocean Water Masses revealed by Repeat Hydrography Along 110°E (1963-2019)

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The South Indian Ocean (SIO) plays a critical role in global climate through its contribution to the global meridional overturning circulation. Two repeat full-depth hydrographic sections along 110°E (1963 vs. 2019) reveal substantial changes in Subtropical Water (STW), Subantarctic Mode Water (SAMW), and Antarctic Intermediate Water (AAIW)â key watermasses in the upper cell of the overturning circulationâ over 56 years. STW has warmed and become saltier along isopycnals, while SAMW and upper AAIW have cooled and freshened, primarily through spice (along-isopycnal) changes, pointing to salinity-driven processes from their source regions. In contrast, lower AAIW shows warming and salinification, suggesting temperature-driven variability. The thickening of SAMW and AAIW layers, combined with increased apparent oxygen utilization (AOU), nitrate, and phosphate, indicates reduced ventilation and potential circulation changes. These property shifts imply a slowdown in overturning circulation and altered nutrient cycling, consistent with anthropogenic climate change impacts.

Keywords: overturning circulation, watermass change, ventilation, nutrients, hydrographic data, climate change impacts

IIOE-2 Endorsed Project No: IIOE2-EP06

[ABS-04-0066]

Krill assemblages influenced by currents, eddies and fronts along the 110 °E meridian in the eastern Indian Ocean

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Krill (euphausiids) are widespread across the Indian Ocean and are important contributors to marine food webs, nutrient cycling and carbon sequestration. In May-June 2019, krill were investigated from temperate to tropical waters along the 110°E meridian, originally surveyed during the first International Indian Ocean Expedition (IIOE). A total of 28 species of tropical, subtropical and temperate krill were identified from day and night vertical hauls using an Indian Ocean Standard Net between 11.5°S and 39.5°S. Species richness and abundances were generally higher in warmer tropical waters, with the exception of the high abundance of Thysanoessa gregaria (4240 ind/1000 m3) in the cooler waters south of the Subtropical Front. The occurrence of the Pacific Ocean species, Euphausia pacifica/nana, was likely facilitated by the Indonesian Throughflow, and the occurrence of the typically coastal Pseudeuphausia latifrons was likely a result of the westward propagation of Leeuwin Current eddies. A repeat of the 110°E meridian also allows for a rare opportunity to compare krill assemblages over 50 years apart, examining how species occurrence, life stages and preferred distributions have differed since the first IIOE. In the context of krill zoogeography across the entire basin, this recent 110°E study improves our knowledge of range extensions and species richness in the eastern Indian Ocean.

Keywords: Euphausiacae, Oceanography, Water masses, Zooplankton, Zoogeography, Sea surface temperature

IIOE-2 Endorsed Project No: IIOE2-EP06

[ABS-04-0098]

Observations of surface currents and inter-connectivity in the Indian Ocean west of Mascarene Plateau: an IIOE-2 (Project IIOE2-EP49) / Monaco Explorations Indian Ocean Expedition collaboration

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Connectivity in the SW Indian Ocean was studied by tracking 18 sea surface drifters (SSD) and 4 SVP drifters during the 2022 Monaco Explorations Indian Ocean Expedition (ME-IOE), endorsed as IIOE2-EP49. The SSD types used originate from the University of Western Australia and have also been deployed in the NW IO. They add to traditional drifter techniques (e.g. SVPs which track currents at 15 m depth) as cost effective and easy to deploy trackers of currents in the upper ~50 cm. Deployments ran from Mauritius to Aldabra Atoll to Seychelles and then along Mascarene Plateau back to Mauritius, comprising a cluster west of Aldabra Atoll, a set around Saya de Malha Bank, and others at various locations along the circuit. Circulation features observed included the South Equatorial Current (SEC), South Equatorial Countercurrent, East African Coastal Current, Northeast Madagascar Current, Southeast Madagascar Current, eastward retroflexions, Indian Ocean Countercurrent and mesoscale eddies in the Mozambique Channel. On passing over Mascarene Plateau, the SEC characteristically diverged laterally into north-westward, westward and south-westward offshoot cores, with these further diverging on approaching coasts. Tracks of up to 9000 km / 10 months were observed. Connectivity ranged from weeks to a few months between high biodiversity areas such as the Mascarene Plateau, East African coastal zone and islands and atolls between. Westward movements between Aldabra and east Africa (Tanzanian coast) were found to be < 4 weeks, at mean speeds of ~ 0.3-0.5 ms^{-1} with maximum speeds ~1.3 ms-1. This work complements other connectivity studies of the region, providing insights on the potential for biological propagule transport and ecological connectivity between potential source and recruitment zones, and on transport potential for anthropogenically derived materials such as debris (e.g. plastics) and toxicants (e.g. oil). These insights are relevant to biodiversity conservation, environmental and natural resource management interests.

Keywords: Northwest Indian Ocean, biological and physical connectivity, surface currents, satellite tracked sea surface drifters, Monaco Explorations Indian Ocean Expedition

IIOE-2 Endorsed Project No: IIOE2-EP49

[ABS-04-0148]

The multi-year negative Indian Ocean Dipole of 2021-2022

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During 2021 and 2022, the Indian Ocean experienced persistent negative Indian Ocean Dipole (nIOD) conditions, with the 2022 event being the strongest on record. The Dipole Mode Index remained negative from the summer of 2021 through early winter 2022- an unprecedented 19-month duration- marking the first documented multi-year nIOD. This event co-occurred with the triple-dip La Niña of 2020-2022. In this study, we investigate the mechanisms underpinning this prolonged nIOD. Beginning in summer 2021, the tropical Indian Ocean (TIO) experienced dominant westerly wind anomalies that persisted until the end of 2022, accompanied by a record number and duration of westerly wind bursts (WWBs). These anomalous westerlies were supported by the prevailing La Niña state and enhanced convection over the eastern TIO associated with tropical intraseasonal oscillations. WWBs occurring outside their climatological peak months, along with strong westerly anomalies, altered the strength of zonal currents and Wyrtki jets in the TIO. The resulting heat and mass redistribution deepened the thermocline in the eastern TIO, sustaining the nIOD. Anomalous westerly activity in spring 2022 acted as a bridge between the two nIOD phases, extending the event's duration to record length. This multi-year nIOD mitigated the potential for excess Indian summer monsoon rainfall by offsetting the monsoon-favourable modulation of the Walker circulation with anomalous subsidence over India, driven by nIOD-induced changes in the regional Hadley circulation.

Keywords: Wyrtki jets, negative Indian Ocean Dipole, Triple-dip La Nina, Indian Monsoon

IIOE-2 Endorsed Project No: -

[ABS-04-0166]

Towards an integrated MOM6 framework for seamless Regional & Global Forecasting at INCOIS

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Accurate operational ocean forecasting demands dynamically consistent simulations across scales to capture basin-scale circulation, mesoscale variability, and coastal processes. In the northern Indian Ocean (NIO), where monsoon-driven currents interact with energetic eddies and narrow boundary flows, high-resolution modeling is critical. We present a new integrated Modular Ocean Model version 6 (MOM6) framework developed at the Indian National Centre for Ocean Information Services (INCOIS) to provide seamless global-to-regional prediction capabilities for the Indian Ocean. The system couples a global 1/12° tripolar MOM6 configuration with a nested 1/36° (~3 km) high-resolution regional NIO model spanning 32°E-108°E and 8°S- 30°N, with open boundaries to the south and east. The MOM6 core employs the Arbitrary-Lagrangian-Eulerian (ALE) method for hybrid vertical coordinates, enabling improved representation of fine-scale processes and non-linear regions such as the western Arabian Sea. Validation against satellite observations, in situ measurements, and reanalyses demonstrates that both the global and regional configurations realistically represent seasonal SST, salinity, SLA, and major current systems, including the Somali Current, East India Coastal Current, and Equatorial Jets. Across the tropical basin, mean SST bias is less than 0.5 °C, with correlation coefficients exceeding 0.85 for SST and SLA. The high-resolution (1/36°) regional configuration significantly enhances the simulation of coastal currents along the east and west coasts of India, particularly at sub-inertial and intraseasonal timescales, and improves the depiction of intraseasonal eddy variability in the western Arabian Sea and Bay of Bengal. Enhanced open-boundary formulations reduce systematic biases along the southwestern boundary, improving dynamical coherence across the basin. This framework establishes the basis for a next-generation operational ocean prediction system for the Indian Ocean, supporting applications from short-term forecasts to climate-scale projections.

Keywords: MOM6, High-resolution ocean circulation modeling, mesoscale dynamics

IIOE-2 Endorsed Project No: -

[ABS-04-0073]

Tracking Arabian Sea High-Salinity Water Intrusion into the Bay of Bengal and its Interannual Variability: Insights from Ocean Glider Observations and modelling

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A large amount of river discharge and a net freshwater surface flux make the upper water column of the Bay of Bengal (BoB) fresher. The intrusion of high-salinity water from the Arabian Sea (commonly referred to as the Arabian Sea High-Salinity Water mass; ASHSW) into the BoB during summer monsoon plays a key role in maintaining the salinity balance of the basin. However, the pathway of the intrusion of ASHSW into the BoB and its seasonal distribution is not clear. Repeated Ocean glider transects in the BoB under the Deep Ocean Mission, along with existing observations, provided a rare opportunity to document the presence of ASHSW along the entire latitudinal stretch of the basin. Additionally, a Lagrangian particle tracking model is used to augment the observational findings to understand further the intrusion pathway of this ASHSW mass and its subsequent distribution over the basin. We show that the ASHSW intrusion into the BoB predominantly occurs through the southcentral BoB between 85 °E-88 °E during the early phase of the summer monsoon. Once the water mass crosses 10°N, the pathway becomes chaotic and can be traced in the northern part of the Bay in winter. Notably, this pathway shows a strong interannual variability, with the least intrusion observed during Indian Ocean dipole years.

Keywords: Arabian sea high Salinity Water, Ocean glider, langrangian particle tracking, Interannual variability

IIOE-2 Endorsed Project No: -

[ABS-04-0081]

Subsurface Cooling and Freshening in the South Indian Ocean: Distribution, Variability, and Climate Implications

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The Indian Ocean has experienced rapid surface warming in recent decades, yet the subsurface shows significant basin-scale cooling and freshening during the Argo era. These anomalies display strong spatial contrasts across the South Indian Ocean (SIO), differing between the eastern and western regions of the SIO, suggesting distinct formation mechanisms and propagation pathways. Analysis of Argo observations indicates that long-term cooling and freshening in both regions are primarily driven by spice (along-isopycnal) changes, while heave (vertical displacement of isopycnals) contributes mainly to smaller-scale variability linked to ENSO and the Indian Ocean Dipole. Freshening accounts for much of the cooling along isopycnals, underscoring the dominant role of salinity in shaping subsurface thermal trends. Both eastern and western SIO anomalies likely originate from multiple source regions, reflecting complex interactions between water mass formation and climate variability. We discuss possible mechanisms underlying spice- and heave-driven changes and propose potential pathways for anomaly propagation across the SIO. These findings highlight the importance of understanding multiple sources and pathways of subsurface changes and their connections to climate variability.

Keywords: South Indian Ocean, spice and heave, water mass

IIOE-2 Endorsed Project No: -

[ABS-04-0334]

Sustained observations along the Australian sector of the eastern Indian Ocean usingocean gliders

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Oceanographic observations has been traditionally undertaken using ships but the emergence of autonomous ocean gliders have provided an alternative measurement platform to acquire high spatial and temporal resolution data even during periods of extreme weather conditions. These data sets enable researchers to discover physical processes as well as document the natural variability of the ocean and coastal ecosystems. The Australian Integrated Marine Observation System (IMOS) ocean glider facility has been in operation since 2017 and have completed more than 400 glider missions around Australia with ~40% deployed along the west Australian coast in the eastern Indian Ocean. Discovery of Dense Shelf Water Transport (DSWT), or underwater rivers, where higher density water is transported along the sea bed across the continental shelf around Australia is one of the major scientific highlights. Also time series spanning more than 16 years allows for the documentation of the inter-annual variability in surface and sub-surface ocean parameters (temperature, salinity, chlorophyll etc), particularly through ENSO cycles.

Keywords: ocean gliders, eastern Indian Ocean, dense shelf water transport, inter-annual variability, ENSO

IIOE-2 Endorsed Project No: IIOE2-EP08

[ABS-04-0191]

Rising Frequency of Yangtze River Floods Linked to Shifts in the Indian Ocean Wave Characteristics

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In recent decades, particularly since the 1990s, the frequency of flood events in the Yangtze River Basin has increased significantly. This rise in hydroclimatic extremes is closely linked to enhanced variability at the quasi-biennial (QB) timescale. In this study, using sea surface height (SSH) and thermocline depth data from the ORAS5 reanalysis and the EN4 observational analysis, we demonstrate that the increased QB variability in East Asian summer monsoon rainfall over the Yangtze River Basin is strongly coupled with intensified QB-scale wave dynamics in the Indian Ocean. We present strong evidence of fundamental changes in the characteristics of baroclinic waves in the tropical Indian Ocean in recent decades. We find that the mean phase speed of westward-propagating tropical Rossby waves has increased, along with their overall variance. These shifts are likely associated with changes in oceanic circulation and large-scale atmospheric forcing. Our findings highlight that evolving Indian Ocean wave dynamics is a key contributor to the amplification of monsoon variability and the associated hydrological extremes over East Asia.

Keywords: Yangtze River Discharge, Quasi-biennial,Tropical Rossby Waves

IIOE-2 Endorsed Project No: IIOE2-EP51

[ABS-04-0368]

Analysis of Seasonal and Interannual Variability of Surface Currents in the Northern Indian Ocean Using in-situ and Satellite products.

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Understanding ocean currents in the Indian Ocean is vital for forecasting, assessing climate varia-bility, and modelling regional circulation. Circulation in this basin is strongly influenced by mon-soonal winds, which drive seasonal reversals of surface currents. In this study, we integrate in situ Acoustic Doppler Current Profiler (ADCP) measurements from a moored buoy deployed in the southern Arabian Sea for the period 2012 to 2020. The in-situ measurements are also utilized for validating satellite-derived currents from OSCAR, and numerical outputs from the GLORYS12V1 reanalysis model, and to assess seasonal and interannual variability of surface currents. Seasonal summaries from GLORYS show circulation patterns across the basin in summer, winter, spring, and fall, providing context for point-based observations. To reduce spikes in variability, 30-day moving averages of current speeds from buoy measurements, OSCAR, and GLORYS were analysed for 2012-2020. The ADCP recorded stronger magnitudes and fluctuations, while OSCAR and GLORYS often underestimated speeds, especially during the northeast (winter) monsoon. De-spite these differences, all three datasets captured the seasonal cycle and directional reversals with minor phase offsets. To address directional variability, in-situ current speeds from 2019 were analysed with vectors superimposed on the time series to show the evolution of current direction and magnitude. De-composing ADCP currents into zonal (u) and meridional (v) components improved dataset agreement, with OSCAR and GLORYS aligning more closely with ADCP than in speed-only compar agreement, with OSCAR and GLORYS aligning more closely with ADCP than in speed-only comparisons i-sons. Significant deviations are being analysed to determine the influence of various meteorologi-cal conditions and upper ocean dynamics. These findings highlight the critical role of long-term in situ ADCP observations in validating sat-ellite and reanalysis data in the Indian Ocean. Such integrated approaches are crucial for maintain-ing ocean observing systems, improving seasonal forecasting, and understanding regional climate variability amidst changing conditions

Keywords: Indian Ocean, ADCP, OSCAR, GLORYS, monsoon currents, surface circulation, validation

IIOE-2 Endorsed Project No: -

[ABS-04-0059]

Heat content distribution in the southeastern Indian Ocean during the hiatus period

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It has been known that there exists decadal variability in the upper ocean heat content in the eastern Indian Ocean. During the hiatus period in the first decade of the 21th century, the southeastern Indian Ocean (SEIO) experienced unprecedented warming in the upper layer temperature as a part of decadal variability. Horizontal distribution of the temperature trend during the hiatus period indicates the wide area of positive value in the southeastern Indian Ocean. Several studies have identified possible causes for this heat content increase during the hiatus period: one is the enhanced Indonesian throughflow and another is the local wind forcing over the Indian Ocean as well as the remote influence from the Pacific Ocean. However, detailed processes and mechanisms causing the temperature trend distribution within the SEIO have not been revealed yet. In this study, as the first step toward better understanding of processes and mechanisms responsible for the temperature trend distribution within the SEIO, a heat budget analysis focusing on the hiatus period is conducted by using an OGCM output. Heat budget analysis is applied to several key areas in the SEIO, where large increase of the heat content is observed. In one of these areas away from the western Australia, in which the large temperature trend can be seen only during the hiatus period, the meridional heat convergence is a significant component for the heat accumulation. This meridional advection is caused by the anomalous southward current at the norther face of the region. In the presentation, the cause of that anomalous southward current and the quantitative analysis of the contribution of mesoscale eddies for the heat content variability in the SEIO will be discussed.

Keywords: hiatus period, heat content distribution

IIOE-2 Endorsed Project No: -

[ABS-04-0011]

The potential impacts of long-term changes in the tropical exports of oxygen and nutrients on ecology: a case study

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Our oceans are changing, and the second International Indian Ocean Expedition (IIOE2) provided a significant opportunity to observe large scale physical, chemical and biological changes some 60 years after the original Expedition. Here we compare observations in 2019 with those made in 1963 along 110°E. Our comparison focuses on changes in the upper 500m with their implications for ocean productivity. We report a general increase in temperature and an increase in salinity at mid latitudes. There is strong evidence of more 24 Ï¿t water at ~100m extending from the tropics to at least 25.5°S possibly associated with the increased tropical precipitation and strengthened Indonesian Throughflow. Important for regional ecology this water has lower concentrations of oxygen and increased nitrate. The intensification of this layer within the euphotic zone is hypothesized to support increasing primary and secondary production along 110°E and the west coast of Australia. Based on other reports of decreasing dissolved oxygen at relatively shallow depths, and its likely transport poleward from the tropics, we hypothesize the potential for a widespread increase in primary production across the subtropics.

Keywords: climate, temperature, salinity, oxygen, nutrients, plankton, IIOE-2

IIOE-2 Endorsed Project No: IIOE2-EP06

[ABS-04-0239]

Tracing the Abyssal Water Pathways in the Indian Ocean

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Antarctic-origin abyssal waters occupy a significant volume of the Indian Ocean and play a critical role in ocean circulation and ventilation. Yet, they remain understudied, with no direct measurements of the abyssal upwelling. In our work, we employ a high-resolution Regional Ocean Modelling System (ROMS), along with reanalysis and ocean observation datasets, to investigate the transport and pathways of abyssal waters entering the Indian Ocean (IO) from the Southern Ocean. We show that our model accurately simulates the dense, terrain-following flows, and we find that the abyssal water enters the IO through three distinct pathways, steered by seafloor topography. Major upwelling occurs at key hotspots mainly along continental boundaries and narrow fracture zones, where approximately 75% of the abyssal water entering the IO returns to the upper ocean. This study provides the first model-based quantification of both the meridional and vertical abyssal volume fluxes in the Indian Ocean, identifying key boundary processes and upwelling hotspots that control the basin-wide circulation.

Keywords: bottom-water; upwelling; abyssal flows

IIOE-2 Endorsed Project No: -

[ABS-04-0002]

The difference between simulating sea level and currents: An illustration from the western Bay of Bengal

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It is commonly observed that models tend to simulate sea level much better than currents, particularly the currents at intraseasonal periods or below the near-surface layer of the ocean. We illustrate the reasons for this difficulty that models have in simulating the currents, even as they are able to simulate the sea level with numerical experiments designed to simulate the observed East India Coastal Current (EICC). Mukherjee et al (2018) used two numerical models (resolution 0.1 ° Ã¿ 0.1 Â°), an oceanic general circulation model (OGCM) called Modular Ocean Model, and a simpler, linear, continuously stratified (LCS) model, to simulate the observed EICC. Their simulations were better, as is generally observed, at simulating the sea level than at simulating the currents. A stratification experiment with the LCS model shows that changing the background stratification from the Equatorial Indian Ocean (EIO) to the Bay of Bengal (BoB) leads to a stronger surface EICC owing to strong coupling of higher-order vertical modes with wind forcing for the BoB profiles. This assessment is important owing to a limitation of the LCS model: the background density profile is invariant in space and time. An experiment with six different background density profiles in the LCS model shows that the stratification in the EIO and BoB leads to significantly different structures for the vertical normal modes. The change in stratification from EIO to BoB leads to a stronger EICC for the BoB stratifications compared to the EIO stratifications, and this increase in magnitude of the surface current is seen for both locally and remotely forced components. Furthermore, the high-order modes (5â¿¿10) contribute significantly to the locally forced EICC, but the remotely forced component is weakly affected by these modes. These high-order modes, which lead to energy propagating down into the ocean in the form of beams, are important only for the current and do not contribute significantly to the sea level. The high-order modes, which the OGCMs struggle to simulate, are not important for the sea level, but contribute significantly to the current, particularly in the intraseasonal band.

Keywords: Western Bay of Bengal, Sea level, North Indian Ocean, Ocean Model, Vertical modes

IIOE-2 Endorsed Project No: -

[ABS-04-0111]

Decadal variability of Sea Surface Temperatures in the Western Indian Ocean over the Common Era

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Long-term Sea Surface Temperature (SST) records in the Indian Ocean are very few hindering our understanding of decadal to multi-decadal climate variability in the region. Here, we present the first SST reconstruction obtained in the western Indian Ocean, resolving decadal variability over the last 2000 years (Common Era). Our data show strong multi-decadal oscillations between 27.2 and 28.2°C and a 1°C warming since 1800 AD. Several cold periods are identified after the major volcanic eruptions of the last millennium, e.g. the Samalas, Kuwae, and Tambora. The more pronounced and persistent coldness associated with the Kuwae and Tambora eruptions likely reflects an amplification effect due to their concomitance with solar minima. Comparison with the extratropical temperature reconstruction of Moberg et al. (2005) reveals a delayed return to pre-eruption temperatures in the extratropics as compared to the tropics that is imputable to feedbacks mechanisms due to sea ice. Our results also evidence a two-phase Medieval Climate Anomaly (MCA) with a first colder interval (900-1050 AD) followed by a rapid transition into a second warmer interval (1050-1250 AD) each reflecting different ENSO phases. Wavelet analysis of the 2000-year SST signal demonstrates a strong remote influence of ENSO and coherency with the Laguna Pallcacocha ENSO record, Ecuador. Cold surface time spans of the last millennium, e.g. the Early MCA and those triggered by volcanic forcing, were associated with prolonged La Niña like conditions in the Eastern Equatorial Pacific.

Keywords: SST, proxy reconstruction, Common Era, ENSO

IIOE-2 Endorsed Project No: IIOE2-EP55

[ABS-04-0088]

Latitudinal patterns of deep chlorophyll maxima (DCM) and their bio-optical response to climate forcing in the north to south Indian Ocean

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The deep chlorophyll maximum (DCM) in the Indian Ocean exhibits distinct latitudinal patterns shaped by regional physical processes and bio-optical conditions. This study utilizes hyperspectral radiometric (Satlantic) profiles of backscattering and chlorophyll-a fluorescence collected during three expeditions-SS356 (February-March 2017), SWTIO (June 2014), and the Indian Scientific Expedition to the Southern Ocean (January-February 2018) covering the northeastern Arabian Sea, Southwestern Tropical Indian Ocean (including the Equatorial and Southern Indian Ocean), and the Indian sector of the Southern Ocean (ISSO). Two types of DCMs were identified from vertical profiles of chlorophyll-a and backscattering at 650 nm: deep acclimation maxima (DAM), driven by photoacclimation, and deep biomass maxima (DBM), representing true biomass accumulation. The study examines how salinity and temperature-driven stratification influences DCM characteristics across contrasting oceanic regimes. In the North Indian Ocean (NIO), strong salinity stratification from less-riverine input, and higher optical active substances, and productivity, results in a shallow DCM (~30-50m). The Equatorial Indian Ocean (EIO) shows a weaker and more variable DCM (~50-70m), shaped by dynamic forcings. In comparison, the SWTIO region exhibits stronger stratification, lower sea level anomaly, higher precipitation, a more stable mixed layer, and elevated buoyancy frequency, with DBM dominant, whereas DAM prevails in the EIO. In the Southern Ocean, the DCM deepens (~80-120m) under oligotrophic conditions and strong light limitation. Across frontal zones such as the Subtropical Front (STF) and Subantarctic Front (SAF), eddy-driven mixing and nutrient supply enhance the DCM, while in the Polar Front (PF), freshwater stratification and deep convection modify phytoplankton community structure. These findings highlight that climate-driven ocean warming and surface freshening are likely to significantly alter phytoplankton vertical distribution and community composition across the Indian Ocean, with major implications for biogeochemical cycles and carbon export.

Keywords: Stratification; Winds and eddies; Sea ice extent; Bio-optical properties; Hyperspectral radiometer.

IIOE-2 Endorsed Project No: -

[ABS-04-0227]

Future Plausible Changes in Surface pCO_2 over the Bay of Bengal from Regionally Downscaled High-Resolution Models

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The Bay of Bengal (BoB), the world's largest bay in the northeastern Indian Ocean, shows marked north-south contrasts driven mainly by river discharge, influencing salinity, pCO_2, and biological productivity. This study examines the drivers controlling seasonal pCO_2 distribution in the BoB using high-resolution, regionally downscaled simulations from the Regional Ocean Modelling System (ROMS). We also examine the relative influence of pCO_2 drivers in controlling its long-term variability by analyzing the northern and southern BoB separately for historical (HF; 1995-2014) and far-future (FF; 2080-2100) periods. Model results show that temperature is the dominant driver of seasonal pCO_2 variability in both HF and FF. In the northern BoB, temperature contributes to a decrease in pCO_2 variability during December-February (DJF) and an increase during the remaining seasons. Whereas in southern BoB, the temperature drives a decrease in pCO_2 variability during DJF and June-September (JJAS) seasons, while contributing to an increase in the other seasons. Freshwater flux emerges as the dominant driver of pCO_2 reduction during October-November (ON), particularly in the northern BoB, with contributions of ~ 9 µatm in HF and ~ 25 µatm in FF. The contribution of DIC is negligible in HF but becomes a significant driver (>15 µatm) in FF during DJF. Conversely, during March-May (MAM) in the northern BoB, the DIC contribution shifts from driving an increase (+4 µatm) in HF to a decrease (~8 µatm) in FF. In the southern BoB, the contribution of TA doubles in HF to FF. For long-term trends, DIC is the primary contributor to pCO_2 changes, followed by temperature, in both periods. However, in FF, DIC contribution decreases by ~15% while TA contribution increases from ~ -10% to 1% in both the regions from HF to FF. This enhancement of TA alters the carbonate buffering capacity of the basin.

Keywords: Bay of Bengal, pCO_2, river discharge

IIOE-2 Endorsed Project No: -

[ABS-04-0087]

Marine Carbon Dioxide Removal (mCDR) in the Indian Seas: Current Understanding, Regional Opportunities, and Future Directions

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As the global community confronts the escalating threat of climate change driven by anthropogenic greenhouse gas emission, carbon dioxide removal (CDR) has emerged as an essential strategy to complement emissions reductions and achieve net-zero goals. Marine Carbon Dioxide Removal (mCDR), which leverages the ocean's natural carbon uptake processes, is gaining increasing attention for its vast sequestration potential. Despite the ocean absorbing a significant quantum of anthropogenic CO_2 emissions, rising emissions are outpacing its natural buffering capacity. This paper synthesizes current understanding of mCDR approaches, including biotic (e.g., seaweed cultivation, ocean fertilization), abiotic (e.g., ocean alkalinity enhancement), and physical (e.g., artificial upwelling and downwelling) techniques, and evaluates their applicability to the Indian Seas, a region characterized by unique monsoon-driven dynamics, stratified biogeochemistry, and large CO_2 outgassing. Drawing upon observational programs, model simulations, and ecosystem-specific assessments, the study highlights opportunities for regionally adapted mCDR deployment, such as macroalgal farming, mangrove restoration, and pilot-scale alkalinity enhancement in semi-enclosed coastal systems. It also discusses technical, ecological, and governance challenges, including monitoring uncertainties, regulatory gaps, and community engagement needs. Strategic recommendations are offered to integrate mCDR into India's climate policy, blue economy goals, and international climate commitments. Ultimately, the paper argues for India's leadership in shaping inclusive, evidence-based marine climate solutions while ensuring environmental integrity, social equity, and scientific transparency in mCDR development and deployment.

Keywords: Marine CO2 Removal, Indian seas, Blue Carbon, Seaweed Farming, Ocean Alkalinity, Artificial Upwelling-Downwelling, Climate Mitigation.

IIOE-2 Endorsed Project No: -

[ABS-06-0226]

Satellite Seascapes, Signatures and Habitat Clues of Marine Mammal Distribution and Phytoplankton Assemblages in Indian waters

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Cetacean distribution and habitat preferences in Indian waters remain poorly understood, particularly in relation to dynamic oceanographic and optical conditions. Recent increases in sightings and strandings along the southwest coast of India, especially during the southwest monsoon, raise concerns about how monsoon-driven upwelling, phytoplankton blooms, and fisheries dynamics influence cetacean movement. These seasonal processes alter ocean optical properties, creating dynamic and spatially distinct seascapes. This study uses normalized satellite Remote Sensing Reflectance (Rrs) across six wavelengths (412-670 nm) from 2021 to 2023 to derive optical seascapes. A Fuzzy C-Means classification identified five distinct optical classes, mapped seasonally. We propose a synoptic framework integrating these optical seascapes with cetacean sighting records to evaluate whether specific water types, shaped by processes such as upwelling, chlorophyll blooms, or sediment plumes, correlate with cetacean distribution, foraging, or migration. Preliminary results indicate recurrent cetacean activity along the southwest coast aligns with turbid-green Case-2 waters (Classes 3-5), characteristic of high productivity. These waters are linked with monsoon-driven upwelling, Noctiluca blooms, small pelagic fish aggregations, and whale migratory pathways in the Arabian Sea. Spatio-temporal analyses of reflectance spectra and chlorophyll-a support this, with localized blooms in October 2023 showing concentrations up to 15 mg/m^3 and a distinct 560 nm signature. Additionally, Ekman transport-induced upwelling (June-September) followed by fall intermonsoon conditions (October-November) appears to influence coastal whale migrations. Our findings highlight the potential of optical classification to identify ecologically significant regions for marine mammals in Indian waters. Linking satellite-derived water colour data with marine megafauna ecology offers a novel, large-scale approach to inform conservation planning and support ecosystem-based management under a changing climate.

Keywords: Seascapes, Optical properties, Clustering, Marine Mammals, Migration, Indian waters

IIOE-2 Endorsed Project No: -

[ABS-04-0179]

Climate-driven seasonal surface pCO_2 amplification in the Indian Ocean: Insights from a machine learning-based improved data product

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The increase in atmospheric CO_2 impacts the seasonal variability of the inorganic carbon in the global oceans. However, in the Indian Ocean (IO), the quantification of seasonal amplification of surface pCO_2 and its drivers has not yet been explored. In this study, we use a machine learning (ML) approach to correct the biases in high-resolution (1/12°) surface pCO_2 simulations from the INCOIS-BIO-ROMS model (pCO_2model) over the period 1980-2019. We train the ML model using the differences between observed surface pCO_2 (pCO_2obs) from SOCAT and the Indian Scientific Expeditions and modeled pCO_2 to generate the spatio-temporal pCO_2 deviants (pCO_2obs-pCO_2model). The climatology of these deviations is then added back to the original model output, which results in an improved pCO_2 data product. To study the strengthening of pCO_2 seasonality using this improved pCO_2 product, we first create a climatology of the first (1980-89) and fourth (2010-2019) decades. We find seasonal amplification of pCO_2 between the first and fourth decades in each of the sub-regions (Arabian Sea (AS), Bay of Bengal (BoB), Equatorial Indian Ocean (EIO), and Southern tropical Indian Ocean (SIO)) of the IO. The maximum seasonal amplification is found in the SIO (5.20±0.15 µatm), while the minimum amplification is found in the AS (2.56±0.43 µatm). The amplification of the thermal component (driven by temperature) of the pCO_2 seasonality primarily drives the seasonal amplification. The amplitude of the bio-physical (driven by biological and physical ocean characteristics except temperature) component also contributes to the seasonal amplification of pCO_2 in all sub-regions except AS. Although AS shows minimum pCO2 amplification, the amplification of the thermal component is maximum in AS (8.3±0.30 µatm), and is opposed by the attenuation of the bio-physical component (-3.86±0.35 µatm). This attenuation of the bio-physical component could be attributed to enhanced stratification due to the increased ocean warming.

Keywords: Machine Learning, Climate Change, pCO2, seasonal amplification

IIOE-2 Endorsed Project No: -

[ABS-04-0286]

Ocean observations imputation using Machine Learning Algorithms

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Ocean observations are essential for understanding the marine environment, from short-term processes to long-term climate change studies. They are fundamental for monitoring phenomena such as sea-level rise, ocean warming, ecosystem variability, etc. While surface observations have increased since the advent of remote sensing, subsurface oceanic processes can only be studied reliably using in-situ measurements and model simulations. Ocean reanalysis products are a valuable source for studying subsurface features. High-quality independent observational data are required for the validation of ocean reanalysis products. However, gaps in observational data hinder the reliability of reanalysis products. In this study, we address these challenges by applying machine learning (ML) algorithms to fill data gaps in observed oceanic currents. We use daily surface and sub-surface current observations from 12 OMNI buoys across the North Indian Ocean during 2011-2024. Since remote sensing techniques cannot directly measure total surface currents, we utilize analysis products such as OSCAR and the Copernicus Marine Service (CMS) Glob Current dataset to supplement observations as training data. We first evaluate OSCAR and CMS surface current speeds against OMNI buoy measurements and then use CMS current as predictors. We train to reconstruct missing OMNI buoy current speed data from 2011 to 2022. Further, we use 2023-2024 buoy observations for the validation. Independent evaluation statistics show that the ML algorithm performs very well in estimating the daily current variability. This approach demonstrates the potential of ML-based imputation for enhancing the completeness and reliability of long-term oceanographic datasets, thereby improving studies of climate variability and ocean processes.

Keywords: Observations, Gap filling, Machine Learning, Climate change

IIOE-2 Endorsed Project No: -

[ABS-04-0165]

Observed Temperature Variability in the Abyssal Depths of the North Indian Ocean and its Dynamical Mechanisms.

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The temperature variability of the sea surface and the upper water column has been studied extensively over the last few decades owing to the availability of satellite observations and other in-situ measurements. However, our understanding of deep ocean temperature variabilities beyond the upper 2000 m remained limited owing to the lack of in-situ observations from the deeper parts of the ocean. This study investigates the deep ocean temperature variability in the north Indian Ocean using in-situ temperature observations during 2018-2022 at a depth of 2 km, 3 km, and 4 km in the Arabian Sea at 15°N, 68.8°E as part of the OMNI buoy network. At all these depths, distinct events of synchronised intraseasonal variability in the periodic band of 30-110 days are observed, albeit the energy decreases rapidly with depth. A similar events of intraseasonal temperature undulation is also observed in the in-situ bottom pressure recorders (BPRs) deployed in the northcentral Arabian Sea (20.80°N, 65.34°E) and in the southern Bay of Bengal (13.47°N, 88.99°E). This indicates that the abyssal depth of the north Indian Ocean experiences significant temperature variabilities, which remained completely undocumented till now. Lag-correlation analysis between the observed temperature at depths and altimeter data indicates that the signals originating in the central equatorial Indian Ocean propagate along the equator as high-order baroclinic modes of Kelvin waves and subsequently reflected Rossby waves cause the undulation in deeper isotherms. A specific property of these deeper undulations shows a large meridional scale extending until the northern limit of the BoB, but a very short zonal length scale of 200-300 km, indicating the influence of smaller lengthscale modes in the deeper part of the ocean. In conclusion, this study shows the interactions of deep ocean dynamics with upper oceanic processes and highlights the smaller correlation length scale in the deeper ocean.

Keywords: Deep Ocean Variability, Iterseasonal Variability, Equtorial Forcing, Indian

IIOE-2 Endorsed Project No: -

[ABS-04-0158]

Heat and Salt Transport in the Indian Ocean by the Indonesian Throughflow

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The Indonesian Throughflow (ITF) is an important oceanic current that carries warm, fresh, low-latitude Pacific Ocean water to the Indian Ocean. This mean flow of warm, fresh water, along with its variability, profoundly impacts the heat and freshwater budgets in the Indian Ocean, with significant consequences for regional weather and climate. After entering the Indian Ocean, it moves with the South Equatorial Current (SEC) and then splits into two components upon reaching Madagascar. The southern part exits to the Atlantic Ocean through the Agulhas Current system, while the northern section flows as the East African Coastal Current (EACC). Some portion of the ITF upwells in the Chagos-Seychelles Thermocline Ridge, and the remaining flow crosses the equator at the subsurface. Finally, it emerges at the surface in the North Indian Ocean upwelling regions (e.g., Somali, Oman) due to monsoon-driven winds, and then again crosses the equator southward. Although we have a fair understanding of the ITF's spreading in the Indian Ocean, we do not yet know how heat and salt change as it moves into different parts of the basin. To address this, we use a mass-conserving Lagrangian parcel-tracing algorithm with data from a 1/12 degree ocean hindcast simulation. At the conference, I will present the results from the currently running Lagrangian simulation.

Keywords: Indonesian throughflow, Heat and Salt transport, Lagrangian Parcel tracing

IIOE-2 Endorsed Project No: -

[ABS-04-0290]

Impact of vertical resolutions in a global ocean general circulation model

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Vertical resolution in an ocean general circulation model (OGCM) significantly impacts the model's ability to accurately represent ocean processes and their influence on climate and other phenomena. Higher vertical resolution leads to better representation of water masses, stratification, and vertical mixing, which can reduce biases in key variables like sea surface temperature (SST) and improve the simulation of ocean currents and heat transport. In this study, we show the global ocean model simulations with two different vertical resolutions but the same horizontal resolution. Two identical experiments were performed with CORE-II atmospheric forcing with cold starts using WOA23 temperature and salinity initialization. The meridional resolution is 1-4° between 10°S and10°N, gradually increasing to 1/2° poleward of 30 °S and 30 °N. Zonal resolution is a uniform 1/2° in both experiments. We used 40 layers in the vertical and bottom depth of approximately 4.5 km in both experiments. However, in one experiment we used 21 layers in the upper 200 m, and the first level at 5 m, and in another experiment we used 31 layers in the upper 200 m with uniform 1 m resolution in the upper 10 m with the first layer at 0.5 m. The results show significant improvement in the thermocline depth temperature when compared with EN4 observations in the higher vertical resolution experiment, as compared to coarse vertical resolution simulation. The sea surface temperature (SST) fronts are more notable, with a very prominent instability wave signature in the equatorial Pacific Ocean in the higher vertical resolution simulation compared to the coarse vertical resolution simulation.

Keywords: Ocean Model, Thermocline depth, Sea Surface Temperature

IIOE-2 Endorsed Project No: -

[ABS-04-0338]

Future Storm Surge Risks under Climate Change: Insights from Historical and Synthetic Cyclone Scenarios along the Indian Coasts

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This study investigates storm surges and associated coastal inundation along the east and west coasts of India, regions highly vulnerable to extreme weather events. Using historical cyclone tracks from the past five decades, together with synthetic tracks projected for the next 50 years, a comprehensive assessment of storm surge risk has been carried out. The ADCIRC model is employed to simulate surge heights and inundation under both historical and future cyclone scenarios, explicitly accounting for the influence of climate variability and long-term climate change on cyclone intensity and trajectories. Composite analyses highlight spatial patterns of surge characteristics across diverse coastal settings, thereby identifying hotspot regions of vulnerability. The results indicate a significant shift in coastal risk distribution under future climate scenarios: low-risk zones are drastically reduced, while high-risk zones expand substantially. Moderate-risk zones also increase considerably, underscoring the enhanced exposure of coastal communities and ecosystems. These outcomes emphasize that future storm surge impacts will be more widespread and severe, demanding improved coastal adaptation and mitigation strategies. The novelty of this work lies in its integrated framework, which combines historical cyclone behavior with climate-projected scenarios to understand the evolving nature of storm surges in the Indian Ocean region. The findings are directly relevant to disaster risk reduction, operational surge forecasting, and coastal management, while advancing scientific understanding of the links between circulation changes, climate variability, and extreme coastal events. They provide a scientific basis for preparedness strategies to safeguard ecosystems, infrastructure, and coastal populations against climate-driven hazards.

Keywords: Storm surge; Coastal inundation; ADCIRC model; Cyclone climatology; Climate change; Indian coasts; Extreme events; Disaster risk reduction

IIOE-2 Endorsed Project No: -

[ABS-04-0366]

Numerical Investigation of the Interaction between Coastal and Open Ocean Waters in the Prydz Bay Region of the Indian Sector of the Southern Ocean

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The Prydz Bay region of East Antarctica plays a critical role in the global ocean system. It holds the fourth largest source of Antarctic Bottom Water (AABW), significantly influencing the meridional overturning circulation and, in turn, the global climate. Prydz Bay also contains East Antarctica's largest ice shelf, the Amery Ice Shelf (AIS), along with the neighbouring West Ice Shelf (WIS). These ice shelves affect the stability and mass balance of a large part of the Antarctic ice sheet. Their melting has a profound impact on the thermohaline structure of the region. Additionally, the exchange of heat, mass, and momentum between the coastal and open ocean waters shapes water mass properties and coastal processes within Prydz Bay. In recent decades, sea ice variability and its decline are transitioning Antarctic coastal waters into an increasingly unpredictable regime. A realistic ocean-sea ice-ice shelf coupled numerical model, based on the Regional Ocean Modelling System (ROMS), is employed to investigate the coastal ocean processes in the Prydz Bay region of the Indian Sector of the Southern Ocean. The model configuration includes the major icebergs D-15A and D-15B to capture fine-scale features that shape the thermohaline structure of Prydz Bay. Following a 10-year model spin-up using 2019 forcing, a one-year simulation for 2019 successfully reproduced key oceanic and cryospheric features, including the Antarctic Slope Current, Prydz Bay gyre, sea ice production and variability, surface mixing, and basal melting of the ice shelf. These results offer valuable insights into the oceanic processes that regulate ice shelf vulnerability from the subshelf regime.

Keywords: Southern Ocean, Meridional Overturning Circulation, Regional Ocean Modelling System, Prydz Bay, Ice shelf, sea ice, Indian Sector of the Southern Ocean (ISSO)

IIOE-2 Endorsed Project No: -

[ABS-04-0369]

Characteristics of Ocean Heat Content in the Northern Indian Ocean and its Long-Term Variability

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Global warming has led to a significant variability in the upper ocean thermal structure. As one of the first attempts to study the Upper Ocean Heat Content in the Northern Indian Ocean, the present study utilizes insitu observations from Ocean Moored buoy Network for Northern Indian Ocean (OMNI) for the period 2014 to 2024 and monthly mean data of Ocean Heat Content for the period 1960-2024, obtained from the European Centre for Medium-Range Weather Forecasts ECMWF Ocean Reanalysis System 5 (ORAS5) for basin-wide analysis. The SST analysis has been carried out using the International Comprehensive Ocean-Atmosphere Data Set (ICOADS). The time evolution of the calculated OHC from the insitu observations at 10-30 m showed a bi-modal distribution with primary and secondary peaks in May and October, respectively, while the primary and secondary minima were in January and August, showing a close correspondence with incoming solar radiation. The OHC variation at 50-500 m appeared to exhibit intra-seasonal to inter-annual variation. The long-term analysis of ORAS5 OHC in the Arabian Sea, averaged over 40-78°E, 5-25°N from 1960 to 2024, reveals that at 0-300 m, the OHC shows an increasing trend of 4.7 - 1013 J/m2 from 1960 to 2007 and a greater warming trend from 2007 with 44.4 - 1013 J/m2 from 2007 to 2024. At 0-700 m, between 1960 and 2009, shows a decreasing trend of -3.3 - 1013 J/m2 and a rapid warming trend of the basin is observed from 2009, showing 81.9 - 1013 J/m2. The OHC in the Bay of Bengal, averaged over 78-100°E, 5-25°N for the same period, reveals a similar, but an increased warming trend. SST and OHC were correlated with multiple anthropogenic and environmental drivers and the spatial variability of OHC has also been analyzed in the study.

Keywords: Upper Ocean Heat Content, OMNI Buoy, Seasonal-interannual variability, Arabian Sea, Bay of Bengal, ORAS5

IIOE-2 Endorsed Project No: -

[ABS-04-0084]

Southern Indian Ocean Warming Accelerated by Shifts in Inter-Basin Heat Transport

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The Indian Ocean has experienced rapid warming over recent decades, though this warming has been spatially non-uniform. Notably, the Southern Indian Ocean (SIO; 5°S-35°S) cooled until the late 20th century before undergoing an abrupt warming. Previous studies attributed this recent warming primarily to increased Indonesian Throughflow (ITF) during the global surface warming hiatus (1998-2010). Our analysis, however, reveals that despite a strong decadal variability and a declining ITF trend over the past decade, the SIO upper ocean has continued to accumulate heat at a rate of 0.65 (Â±0.02) Ã¿ 10Â²Â² J/decade. We propose that the enhanced ITF during the hiatus initiated the SIO warming, which in turn weakened the Mascarene High and decoupled it from Southern Ocean atmospheric variability. This led to an asymmetric poleward shift of the subtropical gyres between the Indian and Pacific Oceans, allowing increased Tasman inflow to compensate for the weakened ITF in recent years. The resulting heat accumulation in the SIO further weakened the Mascarene High and reduced the Agulhas outflow by approximately 3 Sv/decade, reinforcing a positive feedback loop that sustained the warming of the upper SIO.

Keywords: Indian Ocean warming, Sub-surface heat content, Indonesian throughflow, Tasman leakage

IIOE-2 Endorsed Project No: -

[ABS-04-0138]

Oceanic influence on large-scale atmospheric convection during co-occurring La Niña and negative IOD events

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This study explores the influence of co-occurring La Niña and negative Indian Ocean Dipole (nIOD) on atmospheric convection and rainfall over South Asia, focusing on the often-overlooked role of oceanic subsurface processes. Using observed and reanalysis datasets, we find that the interaction of strong equatorial Pacific easterly wind anomalies during La Niña and equatorial westerly wind anomalies during nIOD results in convergence over the eastern Equatorial Indian Ocean (EIO). This convergence deepens the thermocline and warms sea surface temperatures (SST), intensifying the Indian Ocean equatorial Walker cell with anomalous rising motion over the eastern EIO and subsidence over the western EIO. The subsidence over the western EIO promotes divergence, enhancing northward moisture transport and southerly winds over the northern Arabian Sea. Simultaneously, a westward shift of the Western Pacific Subtropical High (WPSH) induces low-level easterly winds over the Indo-Gangetic Plain. The interaction between nIOD-induced southerlies and WPSH-induced easterlies over the northern Arabian Sea further deepens the thermocline and warms SST over the north Arabian Sea. Ekman pumping from wind stress curl also contributes to this warming. These conditions create a favorable environment for sustained convection and enhanced rainfall over north-west India and adjoining areas. Our findings suggest that recent extreme rainfall events in northwest India and Pakistan are linked to the combined influence of La Niña and nIOD. Climate model projections indicate potential intensification of ENSO and IOD under global warming, which can amplify their combined effects and increase the risk of extreme precipitation events over South Asia.

Keywords: Atmospheric convection, Monsoon, Climate modelling, Ocean subsurface, La Niña, Indian Ocean Dipole

IIOE-2 Endorsed Project No: -

[ABS-04-0240]

Impact of the Atlantic Zonal Mode on ocean surface waves in the tropical Indo-West Pacific during boreal summer

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Ocean surface waves, which are gravity waves primarily driven by surface winds, significantly influence air-sea interactions, coastal ecology, and marine operations. Tropical climate variability is shaped by ocean-atmosphere coupled modes such as the El Niño- Southern Oscillation (ENSO), and the Indian Ocean Dipole (IOD), which also influence ocean surface waves through changes in surface winds. This study examines the impact of the Atlantic Zonal Mode (AZM), a less-studied climate driver, on the interannual variability of ocean surface waves in the tropical Indo-West Pacific. A warm AZM induces surface wind anomalies that oppose the climatological winds. As a result, it reduces the wind sea by 0.2-0.3 m in the South China Sea (SCS), and by 0.1-0.2 m each in the Bay of Bengal (BoB) and the Philippine Sea (PS), causing an apparent domination of Southern Ocean swells in the Arabian Sea. It is substantiated by consistent changes in the mean wave period and energy flux into waves. A warm AZM can favour marine operations in the BoB, SCS, and PS. On the contrary, a cold AZM is not observed to cause any statistically significant change in the wave activity during the analysis period, highlighting an asymmetric impact of the AZM, the reasons for which require further investigation using wave model sensitivity experiments. Given the future projections of a weakening Atlantic cold tongue under global warming, effects of warm AZM events may intensify, potentially leading to further reductions in tropical Indo-West Pacific wave activity. These findings highlight the importance of incorporating AZM impacts in wave climate assessments.

Keywords: Atlantic Zonal Mode, Ocean waves, Marine Operations, Indian Ocean, South China Sea

IIOE-2 Endorsed Project No:

[ABS-04-0271]

Weakening of interannual-to-decadal Sea Surface Temperature Variability of the South Indian Ocean: role of internal variability vs forced response

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Sea surface temperature (SST) variability in the Indian Ocean in the low-frequency (interannual-decadal) timescale is most pronounced in the subtropical South Indian Ocean (STIO; 15ºS-40ºS). Using a high-resolution global model simulation, we investigate the role of atmospheric forcing and the internal oceanic variability in the observed decline in the low-frequency variability in this region. Observations for the period 1965-2021 suggest a significant shift in the magnitude of low-frequency SST variability in the early 1990s, with a rapid decrease across the STIO, particularly in the central-western basin, except for the eastern basin off the west and northwest Australian coasts, where an increase is detected. After the early 2010s, a revival of SST variability is noted. We show that weakening of surface wind variability played a key role in causing the observed shift in the SST variability in the early 1990s. The heat convergence/divergence within the basin associated with lateral advection also contributes significantly. Dominant climate modes, which explain ~71% of the SST variability in the basin, do not explain the shifts. The external climate forcings, however, likely contribute to the observed weakening. The instability embedded in the large-scale Rossby waves that propagate across the south subtropical Indian Ocean can also significantly contribute to the low-frequency SST variability at the local scale, but owing to its smaller scale, it is unlikely to influence the large-scale observed SST variabilities of this region. Our results highlight that the external climate forcings and the associated change in cross-basin connections are the critical parameters that should be considered for this region's interannual/decadal prediction system.

Keywords: Climate variability, External forcing, Inter-basin connections, Air-sea intercations

IIOE-2 Endorsed Project No:

[ABS-04-0297]

Impact of humidity and wind forcing in an Indian Ocean Regional model simulation

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Bulk formulas are widely used to estimate turbulent surface fluxes over global oceans for weather forecasting, climate models, ocean models, and the generation of observed global surface flux data sets. These formulas parameterize turbulent fluxes using near-surface atmospheric and oceanic state variables, but their computation is subject to large uncertainties arising from errors in input meteorological variables and algorithm types. Stand-alone forced ocean models typically use near-surface atmospheric variables from reanalysis or corrected reanalysis products. Since sea surface temperature (SST) is strongly influenced by air-sea flux exchanges, especially net heat flux, accurate computation of turbulent fluxes is essential to capture realistic seasonal, intra-seasonal, and interannual SST variability in the Indian Ocean. This study evaluates the sensitivity of a nested regional Indian Ocean model to near-surface humidity and wind forcing. Two sets of experiments were performed. In the first, CORE-II interannual atmospheric forcing fields were used as a control, while near-surface humidity was replaced with OAFlux data; six-year simulations (2000-2006) showed significant improvements in mean and daily SST variations when compared with TRMM Microwave Imager observations. In the second, CORE-II winds were replaced with QuikSCAT satellite wind fields; four-year simulations (2003-2006) demonstrated substantial improvements in both SST and surface current simulations, with reduced root mean square errors over the equatorial Indian Ocean. Together, these results highlight the critical role of improved near-surface humidity and wind forcing in enhancing flux computations and in better reproducing SST and circulation features in the north Indian Ocean.

Keywords: Indian Ocean, Ocean modeling, near surface humidity, wind forcing

Endorsed project: -

[ABS-04-0390]

Seasonal Variability of Wave States and Their Influence on Air–Sea Fluxes in the Northern Indian Ocean

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The Northern Indian Ocean (NIO) exhibits pronounced intra-seasonal and seasonal variability in sea surface temperature (SST), air–sea fluxes, and wave dynamics. Recent studies (e.g., Sauvage et al., 2023; Raj et al., 2025) have demonstrated that mixed sea states and wind–wave misalignment can significantly alter air–sea momentum exchange, suggesting that conventional bulk flux formulations may not always be applicable under such conditions. These processes may, in turn, influence SST and upper-ocean thermal structure, particularly in regions with strong thermal, vorticity, and stratification gradients such as the Arabian Sea mini-warm pool. To investigate the spatiotemporal characteristics of wave states in the NIO, we analyze long-term OMNI mooring records from the Arabian Sea together with observations from a fleet of autonomous wave gliders deployed in the Bay of Bengal during the 2024 EKAMSAT field campaign. The results reveal that mixed sea states—combinations of locally generated wind waves and remotely generated swell—and wind–wave misalignment are persistent features across seasons. Comparisons with state-of-the-art wave reanalyses indicate that these features are systematically underrepresented, particularly during the Spring Intermonsoon and Southwest Monsoon periods. Given that mixed-sea conditions often violate the wave–wind equilibrium assumption embedded in the COARE flux algorithm, we assess the sensitivity of air–sea fluxes and the upper-ocean thermal structure of the NIO mini–warm pool (characteristic of the Spring Intermonsoon) to alternative parameterizations proposed by Sauvage et al. (2023). The analysis highlights the strong coupling between wave state and upper-ocean thermodynamics in the NIO, underscoring their implications for sub-seasonal to seasonal monsoon prediction.

IIOE-2 Endorsed Project No: -

[ABS-04-0347]

Observed characteristics and interannual variability of Indonesian Throughflow Water in the southwestern Indian Ocean

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The Indonesian Throughflow (ITF) transports low-salinity, oxygen-depleted, and silicate-rich waters from the Pacific to the Indian Ocean, playing a crucial role in global ocean circulation and regional climate dynamics. While modification of Indonesian Throughflow Water (ITW) during its westward advection has been hypothesized, direct observations of ITW at thermocline depths in the Southwestern Indian Ocean (SWIO) are limited. This study investigates the persistence and variability of ITW in the SWIO (61°-67°E, 5°N-27°S) . Using CTD (Conductivity-Temperature Depth) profiles and discrete water samples collected during six research cruises from 2017-2025, we analyzed temperature, salinity, dissolved oxygen, and silicate along with spiciness anomalies to identify and track the presence of ITW. We identified a distinct ITW layer between 100-300 m depth, characterized by absolute salinity of 35.25 ± 0.08 g/kg, conservative temperature of 15.13 ± 0.36 °C, dissolved oxygen of 101.52 ± 10.90 Î¼mol/kg, and silicate of 19.05 ± 2.61 Î¼mol/kg. ITW was distributed between 15°S-8°S within the South Equatorial Current, showing slight interannual variations in its position and extent. During 2018-2019, we observed a remarkable northward shift of the entire ITW structure by ~3° latitude (from 15-11°S to 8-10°S), concurrent with a similar northward shift of Indian Ocean Subtropical Underwater (IOSTUW) boundaries. This northward shift of ITW and IOSTUW was coincident with anomalously high IOSTUW subduction rates reported in recent studies. These findings demonstrate that ITW, though modified by mixing during westward transport, retains its distinctive water mass signatures far into the western Indian Ocean and responds sensitively to large-scale climate forcing through thermocline-scale water mass interactions. These results have important implications for understanding circulation at thermocline depths, tropical-subtropical exchange processes, and subsurface indicators of basin-scale climate variability in the Indian Ocean.

Keywords: Indonesian Throughflow (ITF), Indonesian Throughflow Water (ITW), Seychelles-Chagos Thermocline Ridge (SCTR), Indian Ocean Subtropical Underwater (IOSTUW), thermocline, ocean circulation

IIOE-2 Endorsed Project No: -

[ABS-04-0180]

Quantifying Future Air Temperature and Precipitation Changes Over the Indian Ocean With Bias-Corrected CMIP6 Models

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Systematic biases inherent in global Earth System Models (ESMs) significantly constrain their ability to accurately simulate regional-scale ocean-atmosphere processes at regional scale. Consequently, projections of key climate variables such as near-surface air temperature (T2M) and precipitation (PR) from Coupled Model Intercomparison Project Phase 6 (CMIP6) models are associated with considerable uncertainties. This study rigorously evaluates the performance of five widely employed bias-correction techniques against two reanalysis datasets. Among these methods, Quantile Mapping (QM) and Time-varying Delta (TVD) exhibit superior skill, with TVD demonstrating marginally enhanced performance. To further optimize correction, an ensemble technique (ETQM), integrating QM and TVD, is conceptualized and applied. ETQM is utilized to correct biases in T2M and PR from three CMIP6 models over the Indian Ocean domain. During the historical period (1980-2014), ETQM effectively reduces upper T2M extremes by approximately 1.5-4.5% and substantially attenuates the persistent positive bias in PR extremes over the west-central Indian Ocean by 30-40%. In future climate scenarios, the corrected upper T2M extremes decline by 4.0-5.0%, while the variance in T2M anomalies decreases by 4.0-7.0% in the near-term (2015-2040), escalating to 16.0-22.0% by the end of the century (2071-2100). Although the variance in PR anomalies exhibits notable changes following bias-correction, its projected temporal evolution remains largely unaltered. Overall, the bias correction framework suggests a relatively cooler future compared to CMIP6 outputs. These bias-adjusted datasets offer enhanced reliability for climate change studies in the Indian Ocean region.

Keywords: Bias-Correction, CMIP6, Quantile Mapping, Indian Ocean Region

IIOE-2 Endorsed Project No: -

[ABS-04-0213]

Indian Ocean Acidification Under Future Climate Scenarios: Bias-Corrected CMIP6 Model Projections

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This study examines projected changes in the Indian Ocean (IO) acidification using bias-corrected surface pH simulations from Coupled Model Intercomparison Project Phase 6 (CMIP6) outputs. Surface pH datasets from three CMIP6 models were bias-corrected using two observation-based reconstructed datasets, CMEMS-LSCE-FFNN and OceanSODA. The resulting bias-corrected multi-model ensemble dataset, which we name BEM_pH (1985-2100), showed a significant reduction in bias by about 84% Â± 8% during the historical period (1985-2014). The June to September season (JJAS) of the historical period shows the lowest pH values (<8.05) over the western Arabian Sea (AS) and the highest pH values (>8.1) over the southern IO. The bias-corrected future projections indicate a continuous decline in the IO surface pH (increase in [H+]) across all scenarios, with estimated relative change of 2.13% ± 0.11% (60.61% ± 4.06%) for SSP5-8.5, 1.43% ± 0.07% (31.24% ± 1.91%) for SSP2-4.5, and 0.93% ± 0.045% (18.95% ± 1.05%) for SSP1-2.6. During the historical and future periods under the SSP5-8.5 and SSP2-4.5, the southern IO and the eastern Bay of Bengal (BoB) regions exhibit the highest decline (rise) in pH ([H+]). The analysed seasonal amplification between the far-future (2071-2100) and the historical periods is most pronounced in the BoB (143.24%) and the southern IO region (121.05%) under high-emission scenarios. We further observe a prolonged seasonal extreme ocean acidification over the AS and central IO in the far-future period, which may pose a serious risk to marine ecosystems, biodiversity, and regional fisheries.

Keywords: Indian Ocean, pH, CMIP6, Uncertainty, Ocean acidification

IIOE-2 Endorsed Project No: -

[ABS-04-0339]

Climate Variability over the North Indian Ocean: Insights from Observations and Satellite Datasets

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The climate variability over the North Indian Ocean has been examined using long-term weather observations recorded in the meteorological logbooks of the Indian Voluntary Observing Fleet (IVOF), along with additional weather reports from ships operating within India's area of responsibility and transmitted by other WMO member states. These historical datasets have been systematically compared and validated against the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) as well as recent satellite-derived products. To assess long-term changes, the climatology has been constructed and analyzed for three standard climatological periods: 1971-2000, 1981-2010, and 1991-2020. The analysis reveals that although the overall spatial and temporal climatological patterns have largely remained similar, significant differences in several key atmospheric and oceanic parameters are evident across the successive climatological periods. These differences highlight notable variability and shifts in atmospheric and oceanic parameters. In particular, the most recent climatology (1991-2020) indicates pronounced changes in both oceanic and atmospheric conditions compared to earlier baselines, pointing toward a robust signal of climate variability and potential long-term trends over the North Indian Ocean. The study documents these changes and cross-validation with other datasets (e.g., ICOADS and satellite observations). The variability and changes in oceanic and atmospheric parameters over the North Indian Ocean, together with their validation and inter-comparison, will be presented in detail.

Keywords: Indian Ocean, Climate variability, Intercomparison

IIOE-2 Endorsed Project No: -

[ABS-04-0021]

Evaluation of hydrographic features in the Tropical Indian Ocean from CMIP and OMIP2 models

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Coupled Model Intercomparison Project (CMIP) and Ocean Model Intercomparison Project phase 2 (OMIP2) models from the 6th phase of the CMIP group were used in the current study to represent the annual mean biases of hydrographic features. The OMIP2 models are ocean-only simulations, while the CMIP models are coupled ocean-atmosphere-land-sea ice simulations. These models are assessed against the observations in the Tropical Indian Ocean (TIO). This study identified that many of the models from both CMIP and OMIP2 exhibited cold and warm temperature biases at the surface (0-100m) and subsurface (100-300m) on an annual scale, respectively. Overall, the CMIP models were observed to have larger biases than the OMIP2 models. Also, strong positive biases of salinity were identified in the south-eastern Arabian Sea (AS) and the western Bay of Bengal than in other regions of TIO. In addition, a deeper thermocline was identified in the northern AS and Seychelles-Chagos Thermocline Ridge region in CMIP and OMIP2 models compared to observations, which was predominant in the CMIP models than in the OMIP2 models. This deeper thermocline is associated with subsurface warm temperature biases. Brunt-Väisälä frequency revealed weaker stratification from surface to 100 m with a peak at 80m. Further, vertical shear currents revealed strong shear bias at the top 40m, that can result in vertical mixing, which is chiefly accountable for the biases of temperatures and salinities. The heat and salt transport analysis at different straits in the TIO suggested positive northward and negative southward transport. The positive transport occurred during the post-monsoon and while negative transport occurred during other seasons. SST-based upwelling index analysis revealed strong upwelling signals during summer months in all individual models for all regions. However, strengthened upwelling has been identified in the CMIP models than in OMIP2 models due to strong winds over the upwelling regions.

Keywords: Temperature, Salinity, CMIP models, Heat and Salt transport, wind speed, upwelling.

IIOE-2 Endorsed Project No: -

[ABS-04-0157]

The Prediction Skill of Indian Ocean Dipole Mode in DCPP-CMIP6 Decadal Hindcast Models

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Indian Ocean dipole (IOD) mode events are the most fascinated interannual ocean-atmosphere phenomenon in the tropical Indian Ocean. The zonal contrast of tropical ocean conditions foists enormous unfavorable impacts on the regional weather and climate. However, the predictability of IOD events is limited to only a season in advance which poses a huge socioeconomic loss in the affected regions. We explore the DCPP-CMIP6 decadal hindcast models for their predictability of IOD events at different years after their initialization. Two CMIP6 models viz., CanESM5 and NorCPM1 (to some extent) have quite significant predictability of IOD events even after eight to ten years of initialization. We anatomize these two models to probe the features that significantly impact the IOD predictability. Customized version of model components, refined ocean-atmosphere coupler and sophisticated data assimilation system are the major attributes to their skill for IOD predictability. It is evident from CanESM5 simulations that Southern Ocean provides notable signals through Antarctic circumpolar currents that propagates to tropical Indian Ocean and influence the IOD events.

Keywords: Indian Ocean, dipole mode events, CMIP6 decadal hindcast, IOD prediction

IIOE-2 Endorsed Project No: -

[ABS-04-0263]

Impact of Climate Variability on Phytoplankton Dynamics in the Indian Ocean

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The Indian Ocean basin, particularly its western sector, is among the most biologically productive tropical ocean regions, driven by strong monsoon dynamics and basin-scale mesoscale processes. However, this productivity is increasingly threatened by rapid surface warming, which has reduced phytoplankton abundance by up to 20% in recent decades. To better understand the climate controls on biological variability, we analyzed two decades (2000-2024) of satellite-derived chlorophyll a (Chl-a), sea surface temperature (SST), and sea level anomaly (SLA) data, focusing on the influence of the Indian Ocean Dipole (IOD) and El Niño-Southern Oscillation (ENSO). Time series and Hovmöller analyses highlight substantial seasonal and interannual Chl-a variability, particularly in the western Indian Ocean during the summer monsoon. Cross-correlation and variance decomposition reveal that, over the long term, both ENSO and IOD significantly modulate productivity, but their relative roles have shifted. ENSO emerged as the dominant driver across most basins, explaining up to 75-80% of Chl-a variance in 2023 (e.g., Somali and Mascarene basins). In contrast, the IOD's contribution weakened markedly (from 33.4% to 6.6% in the Central Indian Ocean), though it remained influential in the Bay of Bengal. A high positive ENSO-IOD correlation in 2023 ($r = 0.94$) amplified shared climatic forcing, altered lead-lag relationships, and intensified chlorophyll variability beyond the effect of either mode alone. Our findings underscore that analyzing long-term Chl-a variability while characterizing ENSO-IOD interactions at basin and regional scales strengthens understanding of how climate-driven physical processes regulate phytoplankton dynamics. This integrative perspective is critical for forecasting ecosystem responses and guiding sustainable marine resource management under accelerating climate variability and change.

Keywords: Ocean productivity, Climate change, IOD, ENSO, Ocean Physical processes, SLA, SST

IIOE-2 Endorsed Project No: -

[ABS-04-0274]

Rising Sea Surface Temperatures in the Arabian Sea: A Driver for Increased Tropical Cyclone Activity

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The rapid increase in sea surface temperature (SST), along with global warming, influences the marine ecosystem adversely. It also influences the frequency and occurrence of tropical cyclones over the Indian Ocean. The Arabian Sea, historically less active in the occurrence of tropical cyclones as compared to the Bay of Bengal, has witnessed a notable increase in cyclone frequency and intensity in recent decades. A comprehensive analysis of the change in SST over the Arabian Sea in connection with the occurrence of cyclones is presented in this study. The sea surface temperature time series data during the period 1979-2024 from the global atmospheric reanalysis ERA-5 by the European Centre for Medium-Range Weather Forecasts (ECMWF) are used for this study. The collected daily average SST data have a spatial resolution of ~0.25° longitude ~0.25° latitude. The historical cyclone data are collected over the period of 1979 to 2024 from the Indian Meteorological Department (IMD)- eAtlas. A study analysing Sea Surface Temperature (SST) data found that the number of days the SST exceeded the cyclone genesis threshold of 26.5°C has significantly increased in the Arabian Sea. The analysis compared two periods: the First Ten Years (FTY) from 1979 to 1988 and the Last Ten Years (LTY) from 2015 to 2024. The total number of days SST exceeds the threshold in FTY and LTY is represented in Figure 1. The change in percentage of SST above threshold in the FTY and LTY is analysed. The results show that the north-west Arabian Sea, north-east Arabian Sea, west-central Arabian Sea and south-west Arabian Sea show a significant increase in SST, which is above the threshold considered in the study. The total number of days with SST above the threshold rose from 389 days in the FTY to 740 days in the LTY.

Keywords: Arabian Sea, Cyclone, Sea surface temperature

IIOE-2 Endorsed Project No: -

[ABS-04-0356]

Interannual Variability of Temperature in Kongsfjorden and Role of Large-Scale Atmospheric Fluxes

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Amidst rapid Arctic amplification, quantifying the relative contributions of Atlantic Water advection and large-scale atmospheric forcing to interannual water temperature variability in Svalbard fjords remains an open question. We analyze monthly hydrographic observations from long-term moorings in Kongsfjorden (2006-2021) to examine temperature variability. Depth-averaged monthly anomalies reveal a significant warming trend of 0.058 °C/year ($p < 0.05$). This trend is not uniform across seasons; the strongest occurs in autumn (SON), with an increase of 0.094 °C/year ($p < 0.05$), followed by summer (JJA) at 0.058 °C/year ($p < 0.05$). The winter (DJF) trend is weaker at 0.069 °C/year ($p > 0.05$) but exceeds the summer rate. Overall, the mooring data show pronounced interannual variability, with an annual standard deviation of 0.662 °C. The summer of 2010 stands out as the coldest in the 15-year record, with anomalies of ~2.632 °C (July), ~2.508 °C (August), and ~2.394 °C (June), defining the 2010 Summer Cold Event. This was followed by the 2011 Winter Cold Event, with strong anomalies in February (~2.284 °C) and January (~2.259 °C). To investigate the drivers of this variability, we examined ERA5 reanalysis data. The analysis shows a two-month lag between fjord temperature anomalies and surface air temperature over the adjacent shelf (78-80° N, 10-15° E), with $r = 0.647$ ($p < 0.05$), suggesting a strong atmospheric influence on fjord thermal variability. Both cold events coincided with anomalous sensible heat fluxes, highlighting the role of large-scale atmospheric changes in shaping fjord thermal structure. Our study demonstrates that although Atlantic Water advection is the dominant driver of fjord temperature variability, large-scale atmospheric circulation also exerts significant control on water column temperatures in Svalbard fjords at interannual timescales.

Keywords: Kongsfjorden, Interannual temperature variability, Atmospheric forcing

IIOE-2 Endorsed Project No: -

[ABS-06-0235]

Refining Ocean Surface Roughness Parameterization Using Eddy Covariance Flux Observations in the Bay of Bengal

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Accurate representation of air-sea flux transfer is crucial for achieving realistic simulations in weather and climate models. At the air-sea interface, momentum flux (Ï¿, or wind stress), act as a drag on the air-sea coupled interface, driving surface waves and ocean currents. A thorough understanding of this momentum transfer is fundamental to accurately represent wind-wave interactions. A key component in modelling these complex interactions is the roughness length (z0) at the sea surface which is influenced by both the sea-state and the wind speed. However, many widely-used parameterizations, often rooted in the Charnock relation, are based primarily on wind speed and assume a constant state of wave development. This approach is inadequate for complex marine environments, as it fails to fully capture the variability introduced by diverse wind-wave conditions, particularly the distinct and often opposing effects of locally generated wind-seas and remotely generated swells. This study utilized high-resolution eddy covariance (EC) flux data over a period of 16 months, collected from a mooring deployed in the Bay of Bengal to study effect of sea-state on the z0. Various z0 parameterizations were then validated against parameterized outputs from COARE 3.6 and other established parameterizations, across different wind speed and sea state regimes. Results reveal significant underestimation of wind stress by COARE 3.6, especially under low to moderate wind conditions and mature sea states (up to ~12% in counter swells and ~7% in along and cross swells). These findings highlight the limitations of wind-based parameterizations and MOST assumptions in dynamic marine environments. Based on these findings study propose a new z0 parameterization, taking into account the locally generated wind-seas and remotely generated swells and its combined effect on sea-state. The parameterization is then tested and validated extensively under diverse sea-states. This research strongly advocates for a shift towards integrated air-sea-wave interaction schemes, holding profound implications for enhancing the accuracy of coupled ocean models and reanalysis systems, especially in data-sparse, monsoon-influenced regions like the Bay of Bengal.

Keywords: Eddy-covariance method, Wind stress, Wind-wave interaction, roughness length parameterisation

IIOE-2 Endorsed Project No:

[ABS-04-0357]

Long-term Variability of Water Vapor over the Tropical Indian Ocean and Its Relationship to Climate Variability

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Precipitable water vapor has shown an increasing trend in the Indian Ocean over the last 30 years. However, the linear trend varies depending on the region, season, and analysis period, which is associated with interannual to decadal variability of water vapor. This study examines the long-term variability of water vapor in the tropical Indian Ocean by analyzing 60 years of ERA5 total column water vapor (TCWV) data. The results show that TCWV variability exhibits two major modes: (1) a dipole mode, characterized by opposite signs of anomalies between the western and eastern regions, associated with the Indian Ocean Dipole (IOD) and the El Niño Southern Oscillation (ENSO); and (2) a trend mode, which is stronger in the eastern region and linked to the Indian Ocean Basin Mode. Discussions on the relationship between the two dominant modes and climate variability will be presented, including a plausible influence of the strong positive phases of the IOD and ENSO in 2023.

Keywords: Indian Ocean, Water Vapor, Indian Ocean Dipole, ENSO, Indian Ocean Basin Mode

IIOE-2 Endorsed Project No:

[ABS-04-0101]

Long-Term variability of surface Chlorophyll in the North Indian Ocean: Role of Ocean-Atmosphere Forcings

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Surface chlorophyll a concentration (Chl-a) in the North Indian Ocean (NIO) exhibits substantial spatial and temporal variability, driven by a complex interplay of oceanic and atmospheric processes. This study investigates the long-term variability in Chl-a across different upwelling and winter cooling regions of the NIO, using satellite-derived Chl-a data spanning from 1997 to 2024, in conjunction with oceanographic and atmospheric reanalysis products. The NIO is divided into five subzones based on coastal upwelling and winter cooling - North Arabian Sea (NAS), South Eastern Arabian Sea (SEAS), Somalia Upwelling Region (SUR), Oman Upwelling Region (OUR), and Sri Lanka Dome Region (SDR). Seasonal and inter-annual variabilities in Chl-a was analyzed in relation to key physical drivers such as sea surface temperature (SST), thermocline depth (D26), upper ocean stratification, wind stress curl, and Ekman pumping velocity. SST exhibits a semi-annual seasonal cycle, peaking in Apr-Jun and Oct-Nov, and reaching minima during Jan-Feb and Aug. Long-term (1960-2024) trends indicate a statistically significant warming in SST across all regions, with the most rapid increases observed in SDR (0.0119°C/year) and SEAS (0.0093°C/year), while the lowest SST trend was observed in SUR (0.0051°C/year), followed by OUR(0.0067°C/year). Long-term wind speed showed an overall increasing trend in all the sub domains except in NAS and SEAS. However, post 1997, all regions showed declining trend. Chlorophyll-a concentrations display strong seasonal variability, with maxima during the southwest monsoon (Jun-Sept) and minima during pre-monsoon months (Mar-May). From 1997 to 2024, declining trends in chlorophyll-a were observed in NAS, SUR, and OUR, with NAS showing the steepest decline. In contrast, SEAS and SDR showed increasing trends in chlorophyll a, possibly associated with changing monsoonal winds and increasing ocean stratification under a warming climate. These findings enhance our understanding of biophysical coupling and provide insight into the potential impacts of climate variability productivity and economically vital region.

Keywords: Chlorophyll, North Indian Ocean, Ocean warming, Wind, Upwelling

IIOE-2 Endorsed Project No:

[ABS-04-0037]

Variability of thermocline currents on the continental slope in the eastern Arabian Sea

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We present an analysis of the variability of sub-surface, essentially thermocline, currents on the continental slope in the eastern Arabian Sea, i.e., off the Indian west coast. This analysis is based on data from ADCP (acoustic Doppler current profiler) measurements; the near-surface (roughly top 200 m) currents have been described earlier (Amol et al. 2014, Chaudhuri et al. 2021), but the thermocline currents have not been analysed yet. We show that the thermocline currents from these ADCPs present a challenge owing to periodic data gaps that were not seen in the near-surface currents. Inspection of the data shows that these gaps occur during the night, i.e., from dusk to dawn, and they follow a diurnal cycle, suggesting a link to the diel vertical migration (DVM) of zooplankton. These gaps are more prominent at ADCP moorings located within the oxygen minimum zone (OMZ) in the eastern Arabian Sea (EAS). For moorings outside the OMZ, such as Kanyakumari or Okha, these periodic gaps are absent, pointing to the OMZ's role in reducing the zooplankton population in the thermocline and thus limiting the backscatter signal necessary for viable ADCP measurements. Our analysis focuses on sub-inertial currents. To ensure reliable interpretation of thermocline variability at these timescales, gap-filling methods were carefully optimised. The objective was to preserve the spectral characteristics at longer periods while avoiding artificial high-frequency noise caused by the Gibbs phenomenon. We applied a robust approach (Mukhopadhyay et al. 2020) that combines cubic spline interpolation with grafting techniques. Comparison of wavelet spectra before and after gap-filling reveals minor discrepancies at shorter periods, but overall consistency in power trends and intensities at longer periods. The gap-filled records provide a remarkable data set of currents. A brief description of the variability of the sub-inertial thermocline currents will be presented.

Keywords: ADCP, Diel Vertical Migration, Oxygen Minimum Zone, Wavelet, Thermocline currents

IIOE-2 Endorsed Project No:

[ABS-04-0115]

An Assessment of Projected Changes in SST, Rainfall, Winds, and Sea Level over the Indian Ocean under 2Â°C and 3Â°C Global Warming Thresholds Using CMIP6

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This study investigates how the Indian Ocean climate system responds to global warming thresholds of 2°C and 3°C above pre-industrial levels, using a 10-member ensemble of CMIP6 models under SSP2-4.5 and SSP5-8.5 scenarios. The Indian Ocean is identified as one of the fastest-warming ocean basins, with multi-model mean sea surface temperature (SST) increases of about 1.5°C and 2.2°C at the respective global warming levels. Warming is spatially uneven, with a marked west-east SST gradient that weakens the Indian Ocean Walker Circulation and shifts convective activity poleward. Precipitation changes closely follow SST anomalies, showing strong spatial and seasonal variation. Rainfall is projected to increase over the western Indian Ocean, the northern Bay of Bengal, and much of the Indian subcontinent during the summer (JJAS) and post-monsoon (ONDJ) seasons, while the southeastern Indian Ocean is expected to dry. These changes result from both increased moisture availability and dynamic circulation shifts, such as reduced ascent in the eastern basin, potentially impacting water resources, agriculture, and monsoon reliability. Sea surface height (SSH) projections suggest a dipole-like redistribution, with rising sea levels in the northern Arabian Sea and declines in the southeast, driven by thermal expansion, wind stress changes, and circulation shifts. Surface wind stress is projected to weaken for southwest monsoon winds and strengthen for equatorial easterlies, altering Ekman transport and reinforcing upper-ocean warming through air-sea feedbacks. Despite individual model biases, the ensemble mean captures observed historical trends reasonably well, increasing confidence in these projections. The study underscores the need for high-resolution regional modeling and targeted adaptation planning, especially for Indian Ocean rim nations vulnerable to climate and sea level changes.

Keywords: Indian Ocean, climate change, CMIP6, sea surface temperature, sea level rise, wind stress, precipitation, global warming thresholds, climate projections, climate feedback

IIOE-2 Endorsed Project No: -

[ABS-04-0153]

On the relative roles of mesoscale eddies and Kelvin wave propagation in governing the tracer balance over the Bay of Bengal.

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The Bay of Bengal is a semi-enclosed water body with complex climatic, hydrographic, and biogeochemical significance in the north-eastern Indian Ocean. The freshwater intake from neighbouring rivers and intense stratification, shallow mixed layer, and seasonal current reversals make this basin a critical region to monitor and analyse. The advancement of the South Asian monsoon, heat and salinity distributions and air-sea interactions make them unique. The Oceanic transports, such as volume, heat and salt, influence the upper ocean stratification, exchange of air-sea fluxes and intra-seasonal variability. This work employs a high-resolution ocean reanalysis product to quantify the spatiotemporal variability of these transports in the Bay of Bengal. The daily temperature, salinity, Sea Surface Height (SSH), zonal and meridional currents over the study region are obtained from global ocean physics reanalysis in Copernicus Marine Environment Monitoring Service (CMEMS), having 1/12° horizontal resolution. Using these datasets, the latitudinal variability of transport from the northern to southern Bay of Bengal over the years was estimated. Subsequently, the underlying factors for spatiotemporal variability in the transport were studied. The poleward propagation of equatorial coastal Kelvin waves along the boundaries of the Bay of Bengal imparts significant variations in sea level heights and current structures, especially the EICC and its reversals. These alter the transport structures in different aspects. The contribution of prevalent mesoscale eddies over the Western rim of the Bay of Bengal in modulating the transport structures is investigated based on the eddy kinetic energy distributions. The relative roles of eddies, Kelvin waves, the EICC, remote equatorial forcing and the local wind stress curl in governing the BOB's heat, salt, and volume transport varying with interannual climate modes were investigated. Identifying the key factors is essential in comprehending climate feedback in the region and the changes in biogeochemical cycles, especially under global climate-change scenarios.

Keywords: Ocean transports, Mesoscale eddies, Kelvin waves, EICC

IIOE-2 Endorsed Project No: -

[ABS-04-0159]

Understanding the Role of Dominant Variabilities in Surface Heat Fluxes in Shaping the Sea Surface Temperature Over Bay of Bengal

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The variability of sea surface temperature (SST) in the Bay of Bengal (BoB) is strongly influenced by surface latent heat flux (LHF), sensible heat flux (SHF), outgoing longwave radiation (OLR), and incoming shortwave radiation (ISR). Continuous wavelet spectrum analysis reveals two dominant variabilities with two distinct periods, 128-250 days and 260-512 days, which are evident in the surface heat fluxes in both northern and southern BoB, as obtained from daily interannual data. These dominant modes exert a significant influence on SST. A Butter-width filter is applied to isolate the dominant variabilities in both the surface heat fluxes and SST. Lead-lag correlation analysis is then used to determine the phase differences between a given variability in SST and the corresponding variability in the surface heat fluxes. This is followed by a partial correlation (PC) analysis between SST and surface heat flux, revealing notable linkages between the two and offering valuable insights into their underlying causes and feedback mechanisms. Two distinct sets of sensitivity experiments were conducted to investigate the impact of each profound temporal variability in surface heat fluxes on SST. This study presents a novel framework for isolating the relationship between various surface heat flux variabilities and SST.

Keywords: Sea Surface Temperature, Surface Heat Fluxes, Continuous wavelet spectrum, Butter-width filter, Lead-lag correlation, Partial Correlation

IIOE-2 Endorsed Project No:

[ABS-04-0269]

Identifying the relationship between Tropical Easterly Jet and Tropical Cyclones using Reanalysis data sets and CMIP6 models

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Indian Summer Monsoon (ISM) consists of several elements that are inter-linked. Any change in one element will reflect on the other and finally on the rainfall characteristics. Tropical Easterly Jet is one of the elements that directly affects Indian Summer monsoon. Tropical easterly jet is the strong easterly flow which is seen at about 15-16 km in the upper troposphere having speeds <-30m/s. This easterly jet occurs due to the differential heating between Tibetan plateau and the Indian Ocean. Strong easterlies in the upper level and westerlies in the lower level induces strong vertical shear. Vertical shear of TEJ over B.O.B exhibit a clear annual cycle. Shear associated with TEJ and its relationship with the occurrence of tropical cyclones is investigated using ERA5 reanalysis datasets for the period from 1959 to 2023. Tropical cyclones over B.O.B for the same period are used for study. This study reveals a negative relationship between Tropical cyclone occurrence and TEJ intensity. These changes can be attributed to global warming which results in increase in the tropospheric temperatures. Further, CMIP6 models are used to study the future projections of TEJ and possible TC occurrence. This study focuses to find out the relationship between TEJ/TCS in the present decade and explores its future projection.

Keywords: Keywords: Indian Summer Monsoon, Tropical Easterly Jet, Tropical cyclone, Bay of Bengal, CMIP6.

IIOE-2 Endorsed Project No:

[ABS-04-0343]

Extreme warming events in the East Antarctic: Drivers, impacts, and climate significance

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Antarctic heatwaves are extreme events sustained over several days, characterized by temperatures that exceed specific threshold values or rank among the most intense in the historical record, causing major impacts on sea ice, ocean atmosphere interactions, and the cryospheric ecosystem. This study focuses on the extreme warming events observed during the austral summer of 2022 and investigates the underlying atmospheric drivers. To analyze these events, we combine observations from Automatic Weather Stations (AWS), satellite-based measurements, and ERA5 reanalysis data. The analysis emphasizes spatial and temporal variations in key atmospheric circulation variables, including mean sea level pressure (MSLP), wind patterns, surface air temperature (SAT), and sea ice concentration (SIC), over the Indian Ocean Sector of the Southern Ocean. During the summer of 2022, East Antarctica experienced record-breaking temperature anomalies, with the Relay AWS reporting SAT values more than 13.4°C above climatological mean. These extreme temperatures were strongly linked to the repeated intrusion of atmospheric rivers (ARs), with a long, narrow corridors of moisture originating in the midlatitudes. The occurrence of heatwaves was primarily driven by the increasing frequency of ARs, which were associated with anomalous cyclonic activity, reduced MSLP, and poleward advection of warm air. In addition to synoptic-scale systems, broader climate drivers also contributed to the formation and intensity of these ARs. These included variability in the Amundsen Sea Low, fluctuations in the Southern Annular Mode (SAM), dynamics of the polar vortex, and upper-ocean warming. Episodes of atmospheric blocking and extratropical storm activity further amplified the persistence of these events. Together, these interacting processes shaped the occurrence of extreme temperature anomalies in Antarctica during 2022, accelerating sea ice decline and intensifying climate-related impacts across the region.

Keywords: Marine Heatwaves, Extreme temperatures, ERA5, Southern Ocean, East Antarctic

IIOE-2 Endorsed Project No: -

[ABS-04-0379]

Investigating the Change and Variability in the Indian Ocean Meridional Overturning Circulation

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The Indian Ocean Meridional Overturning Circulation (IMOC) is a key part of the global thermohaline circulation, regulating heat transport, ocean-atmosphere interactions, and long-term climate variability. Yet, compared to other basins, its dynamics remain less well understood, particularly across seasonal to multi-decadal timescales. This study investigates the structure, variability, and long-term changes of the Shallow (SMOC) and Deep (DMOC) Meridional Overturning Circulation using multiple ocean reanalysis products (ECCOv4r4, ORAS4, ORAS5, SODA3.15.2, CGLORS, GLORYS2v4) and coupled climate model simulations (CMIP6 and SMILE). Results show distinct seasonal patterns, with monsoon-driven reversals in the Subtropical Cell (STC) and Cross-Equatorial Cell (CEC). Both cells exhibit strong interannual to decadal variability, including a weakening trend during 1992-2000 linked to zonal wind stress. Over 80% of reanalysis products agree on these features. The STC, between 5°S-20°S, remains anticlockwise year-round, confined to the upper 400 m, and upwells to the Seychelles Dome thermocline ridge. The CEC, linking both hemispheres, upwells to ~10°N off Somalia, reverses from December-March, and is anticlockwise otherwise. A clockwise subtropical gyre near 20°S and a northward-flowing equatorial roll between 5°S-5°N are also identified. For the DMOC, reanalysis products consistently show two overturning cells: an anticlockwise cell south of 20°S and a clockwise cell near 10°S during boreal winter, both reversing in summer. While CMIP6 models underestimate SMOC features due to weaker wind stress, they reproduce DMOC structures with ~80% multi-model mean agreement. A comparison between 1980-1989 and 2005-2014 highlights significant changes in IMOC strength. These results advance understanding of IMOC variability and its role in Indian Ocean warming, sea-level rise, and ecosystem impacts.

Keywords: Meridional Overturning Circulation

IIOE-2 Endorsed Project No: -

[ABS-04-0107]

Deciphering the dynamic link between upwelling in the North Indian Ocean and the changing climate

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Abstract Upwelling in the North Indian Ocean is a key driver of marine productivity and regional climate interactions, yet its long-term variability and underlying mechanisms remain underexamined. This study explores changes in upwelling patterns over the past three decades (1994-2024), using high-resolution reanalysis datasets (ERA5, ORAS5, HERMES) along with key oceanic and atmospheric variables such as sea surface and subsurface temperature, sea level anomaly, wind, and chlorophyll-a. A multi-parameter approach is applied to identify upwelling zones and track their evolution through vertical temperature structure and surface signals. The role of the Indian Ocean Dipole (IOD), captured via the Dipole Mode Index (DMI), is also investigated to assess its potential influence on these changes. Preliminary results suggest emerging spatial patterns and seasonality shifts, hinting at a more complex coupling between ocean dynamics and climate variability than previously recognized. These findings offer new perspectives on the sensitivity of Indian Ocean upwelling systems to a changing climate.

Keywords: upwelling, climate, Indian Ocean Dipole.

IIOE-2 Endorsed Project No: -

[ABS-04-0201]

Impact of the extreme Indian Ocean Dipole events on the Cold Pool characteristics over the Southern Bay of Bengal

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The southern Bay of Bengal is characterized by the presence of a mini-cold pool during the summer monsoon. Several studies have reported that the sea surface temperature (SST) remains below 28°C within this pool and plays a crucial role in regulating convection, air-sea heat exchange, and monsoon onset and active-break cycles. In the present study, the impact of extreme Indian Ocean Dipole (IOD) on the maintenance and evolution of the mini-cold pool is investigated using satellite-derived and high-resolution ocean-atmosphere reanalysis products for the period 1996-2024. The temporal evolution of the Dipole Mode Index (DMI) was compared with SST anomalies over the southern Bay of Bengal cold pool (83°E-90°E, 4°N-10°N) to assess co-variability with positive and negative IOD phases through threshold-based classification. Analysis suggests that positive IOD phases are generally associated with above-average SST anomalies, reflecting warmer conditions during strong events (e.g., 1997-98, 2019, 2021-24). Conversely, negative IOD phases correspond to below-average anomalies, with pronounced cooling observed during prolonged events (e.g., 2002-07, 2015-19). Strong, prolonged phases produce more consistent SST anomalies, while shorter events exhibit higher variability within the cold-pool region. Atmospheric forcing parameters were analysed using the European Centre for Medium-Range Weather Forecasts fifth-generation reanalysis (ERA5) for the study period. Cold pool events during the last decade were further examined to discern the role of extreme IOD phases and the associated variability in the generation, evolution, and decay of such events. This event-wise analysis highlights that the magnitude of SST response depends on both the strength and duration of IOD events and the variability in atmospheric forcing and air-sea exchange processes. Understanding the causative factors of the southern Bay of Bengal cold pool is essential for improving regional climate prediction, anticipating extreme weather events, and assessing marine ecosystem responses in the northern Indian Ocean.

Keywords: Southern Bay of Bengal, Mini-cold pool, summer monsoon, Convection, Air-sea heat exchange, Monsoon onset, active-break cycles, Indian Ocean Dipole (IOD), Dipole Mode Index (DMI), Atmospheric forcing

IIOE-2 Endorsed Project No: -

[ABS-04-0212]

Upper oceanic processes driving sea surface temperature variability in the Southwestern Tropical Indian Ocean: An ocean-reanalysis study

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The southwestern tropical Indian Ocean is characterized by the presence of warmer sea surface temperature throughout the annual cycle which plays a significant role in the progression of the Indian summer monsoon system and the overall atmospheric circulation in the northern hemisphere. SST variability over this thermocline ridge have found to be serving a critical role in regional climate, air-sea interaction, and marine ecosystems. Previous studies have primarily linked SST changes in this region to local processes such as surface flux anomalies and upwelling, or to remote forcing from tropical modes like El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). However, the impact of Indian Ocean basin-wide warming as well as the contribution of other large-scale climate drivers, including the Southern Annular Mode (SAM) in governing the SST variability and associated air-sea interaction processes remain to be better understood. The impact of marine heatwave events over this region in the recent decades also needs to be better understood. This study aims to investigate the upper-oceanic mechanisms influencing SST variability in the southwestern tropical Indian Ocean across seasonal to interannual timescales. Using an eddy resolving ocean as well as atmospheric reanalysis data and available observational datasets, the mixed-layer processes governing the SST variability over the study region is investigated. A quantitative evaluation on the role of ambient atmospheric conditions and remote forcing is studied. The statistical linkages between SST anomalies and major climate indices will be explored and the event-based analysis of high SST anomalies will be discussed. The findings are expected to provide important implications to the relative importance of local and remote drivers of upper oceanic thermohaline properties and improve understanding of factors controlling SST variability in this climatically significant region

Keywords: Marine heatwaves, Sea surface temperature(sst) variability, Southern Annular Mode(SAM), Southern Tropical Indian Ocean, air-sea interaction,

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[ABS-06-0163]

Decadal Trends in Small Pelagic Fisheries Along the Malabar Coast: Ocean Climate Linkages

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Small pelagic fishes play a vital ecological and economic role in marine ecosystems. Among the small pelagic, oil sardine (*Sardinella longiceps*) and Indian mackerel (R*astrelliger kanagurta*) are the most commercially important species, collectively contributing the highest share to India's total marine fishery landings. The southwestern coastal states of Kerala and Karnataka, situated in the Malabar upwelling zone, are key fishing grounds for these species. This study analyses decadal trends (1985-2023) in their landings, highlighting interspecific variability and links to environmental drivers. The key environmental parameters known to influence small pelagic fishes were selected, including sea surface temperature anomalies (SSA), chlorophyll-a concentration, precipitation, upwelling intensity, and large-scale climatic indices such as El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). These variables were extracted for both the Kerala and Karnataka coasts from satellite/model-simulated data to evaluate their impact on the two species. The results support the hypothesis of an alternating dominance pattern between these two species, influenced by environmental conditions and climate indices. Despite partially overlapping ecological niches, oil sardine and Indian mackerel exhibit different feeding behaviours. Oil sardine which are diatom-feeding planktivores and Indian mackerel, which are opportunistic feeders, both showed a negative relation with ENSO and the IOD, as their catches declined with increasing index values. Upwelling was found to have a positive effect on oil sardine abundance. However, during years of relatively weak upwelling when sardine landings declined Indian mackerel catches often increased, indicating a compensatory mechanism and alternating cycle between the two species. Additionally, SSA and precipitation patterns also influenced interannual fluctuations in landings across both states. This study underscores the importance of environmental and climatic drivers in shaping decadal shifts in small pelagic fisheries and emphasizes the need to consider interspecific dynamics in developing sustainable fishery management strategies.

Keywords: Species shift, ENSO, Upwelling, Oil sardine, Indian mackerel

IIOE-2 Endorsed Project No: -

[ABS-04-0385]

Changing Ocean-Atmosphere Interactions Governing Bay of Bengal Cyclones: A Multi-Parameter Assessment

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The Bay of Bengal (BoB) is one of the most cyclone-prone regions, where storm development is strongly controlled by variations in atmospheric and oceanic conditions across different seasons and years. This study examines how the precursors to tropical cyclogenesis over the BoB have evolved during 1980-2023, using ERA5 reanalysis data along with best-track tropical cyclone records. A set of critical parameters-sea surface temperature (SST), vertical wind shear (200-850hPa), mid-level humidity (850-500hPa), mean sea level pressure (MSLP), and low-level vorticity (850â¿¯hPa)â¿¿are analyzed to capture their spatial, seasonal, and temporal variability. Our analysis reveals pronounced warming of SSTs in the central and eastern BoB after 2000, accompanied by a decline in MSLP and a strengthening of cyclonic vorticity during the monsoon and post-monsoon seasons. Increasing wind shear during the monsoon appears to act as a limiting factor for cyclone growth, while mid-level humidity shows modest yet consistent reductions, particularly in the post-monsoon phase. A machine-learning-based attribution (Random Forest regression combined with partial correlations) highlights SST and low-level vorticity as the most influential predictors of seasonal cyclone frequency, followed by MSLP, with wind shear exerting seasonally dependent positive or negative impacts. Network correlations further underscore the interplay between thermodynamic and dynamical drivers of cyclogenesis. Overall, this multi-decadal assessment provides clear evidence that climate-driven shifts are altering the cyclone-conducive environment in the BoB. The findings not only have direct implications for cyclone prediction and disaster preparedness but also serve as a diagnostic framework adaptable to other cyclone basins globally.

Keywords: Tropical Cyclones, Bay of Bengal, Climatology

IIOE-2 Endorsed Project No: -

[ABS-04-0389]

Deep Learning for Sea Surface Temperature Prediction in the Indian Ocean: A Comparative Study Using 1D-CNN, LSTM, and CNN-LSTM Architectures

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Anthropogenic activities had led to major climate changes, causing the oceans to warm rapidly. Subsequently, there is a need for accurate prediction of sea surface temperature (SST). The dynamic Indian Ocean climate, weather and marine ecology is significantly affected by SST changes. In this study, hourly and daily SST data, specifically from 15 and 7 RAMA stations (1m deep) respectively, at different parts of Indian Ocean is utilized to forecast SST using three deep learning techniques; 1D Convolutional Neural Network (1D-CNN), Long Short-Term Memory (LSTM) network, and Hybrid 1DCNN-LSTM network. The SST data obtained from RAMA buoy is trained using a sliding window method and model performance is evaluated based on evaluation matrices like Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and Mean Absolute error (MAE). The results indicated that LSTM outperforms 1D-CNN at most sites, consistently achieving lower MSE, RMSE and MAE. The findings also revealed that in places where SST shifts significantly, the hybrid 1DCNN-LSTM model often competes with or does better than LSTM in MAE. Distinctive physical phenomena like equatorial jets, thermohaline stratification, monsoon, Indian Ocean Bipolar (IOD) and El Niño -Southern Oscillation (ENSO) bring about geographical difference in performance. Hence, the study illustrates how deep learning frameworks make better SST predictions in complex ocean basins and thereby aids in anticipating climate change.

Keywords: Ocean warming; Sea Surface Temperature; Machine learning; 1D-CNN; LSTM; 1DCNN-LSTM

IIOE-2 Endorsed Project No: -

[ABS-04-0301]

Contrasting Pacific and Indian Ocean Trade Wind Responses to the Interdecadal Pacific Oscillation

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Trade winds are winds that predominantly blow from the east in the tropical region. These winds play a vital role in maintaining Earth's climate balance by redistributing heat and driving ocean currents. They also influence the precipitation pattern of the tropics. Seasonal shifts in the convergence zones of trade winds contribute to the development of the monsoon systems. Understanding the changes in trade winds due to climate change is crucial for predicting future climate scenarios and assessing their potential impacts on different parts of the world. This study investigates the underlying causes of trade wind variability in the Indian and Pacific oceans. We define a trade wind area for each season for both northerly and southerly wind regimes, based on the consistency of wind speed and direction. From the wind strength in these regions, we construct a trade wind index, which represents the interannual variability of trade winds for each season and ocean basin. Unlike the tropical Pacific, which is dominated year-round by easterly trade winds, the tropical Indian Ocean exhibits strong seasonality, with annual mean westerlies influenced by the boreal summer monsoon circulation. We found that trade wind indices of the Indian and Pacific oceans show strong correlation with the Interdecadal Pacific Oscillation (IPO). Indian Ocean trade winds, including the monsoon winds, show a positive correlation (0.61 for JJA) whereas Pacific ocean trade winds show a negative correlation. The correlation of Pacific trade winds with the IPO can be explained by the changes in zonal pressure gradient due to the IPO. We further examine how Indian Ocean trade winds are influenced by Pacific decadal variability through the associated changes in sea level pressure and sea surface temperature.

Keywords: Trade wind, pacific decadal variability, monsoon winds, climate change

IIOE-2 Endorsed Project No: -

[ABS-04-0327]

Influence of the extreme Indian Ocean Dipole on the equatorial Indian Ocean circulation

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The Equatorial Indian Ocean (EIO) plays an active role in global and regional climate change through ocean-atmosphere-coupled processes and acts as a base for many global and regional climate and weather patterns. An extreme positive Indian Ocean Dipole (IOD) event occurred in the 2019 boreal autumn, which has induced severe climate impacts around the Indian Ocean region. The ADCP observed high-frequency currents reveal that there is a strong eastward subsurface current at a depth of 50m - 150m persisting from fall 2019 to spring 2020 which is abnormal to a normal condition. Here, observational data, together with the simulations from an ocean model used to identify the processes responsible for the abnormally strong subsurface currents in the EIO during 2019/2020. The Modular Ocean Model (MOM) ocean model shows anomalous strong westward flow in the surface and strong eastward flow in the subsurface at a depth of 50m ~150m depth consistent with the observation with a good correlation. The surface westward flow during the fall of 2019 was induced by the easterlies driven by a strong positive IOD. However, the subsurface strong eastward flow persisted in the following winter and spring of 2020 after its peak with two-fold stronger and deeper than the pIOD composites. The sensitivity experiments from a linear and continuously stratified (LCS) model reveal that an abnormal westerly wind anomaly in the western EIO is responsible for these high-magnitude subsurface currents. An anomalous westerly wind burst in the western EIO in early June generated an eastward propagating downwelling Kelvin wave, which reflected from the eastern boundary as a downwelling Rossby wave with a westward phase propagation to the western EIO. Our analysis suggests that the equatorial wave dynamics and wind anomalies on the western EIO play a dominant role in the development of an extreme IOD.

Keywords: Zonal current, Wyrtki Jets, Indian Ocean Dipole, equatorial waves, observations

IIOE-2 Endorsed Project No: -

[ABS-04-0122]

Southern Ocean Climate Dynamics: Observations, Modelling, and Future Projections

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This study investigates the dynamics of the Southern Ocean (SO) climate system, focusing on sea surface temperature (SST), sea surface salinity (SSS), and wind stress (WS), along with their impact on the Antarctic Circumpolar Current (ACC). Using outputs from selected CMIP6 climate models, we analyze seasonal variability and long-term trends in these key variables. The results reveal pronounced seasonal cycles across the SO. During austral summer, SST increases to 4-8°C between 50°-55°S, while remaining below ~2°C in the Weddell and Ross Seas. In winter, widespread cooling reduces SST across the SO to below ~2°C. SSS peaks during early summer and late winter (34-34.8 psu), largely due to brine rejection from sea ice formation. Wind stress shows persistent maxima (0.30-0.35 Nm^2) over the eastern SO, associated with strong westerlies driving the ACC. Long-term trends indicate general warming across the SO, with model-dependent variations. ACCESS simulates the highest SST rise (1-2°C), while FGOALS shows minimal change (<0.5°C). SSS changes vary, with some models indicating freshening and others salinification. An increase in WS, especially in the Pacific sector, is evident across all models. The Weddell and Ross Seas emerge as key regions, exhibiting consistently low SST and high SSS, highlighting their role in deep and bottom water formation. These physical changes have major implications for global ocean circulation and climate regulation. While CMIP6 models show consistent spatial patterns, inter-model differences stress the need for model refinement and validation with observations. Understanding these dynamics is vital for improving future climate projections and addressing the Southern Ocean's response to climate change.

Keywords: Climate change; Antarctica circumpolar current; weather prediction; sea surface temperature; salinity changes

IIOE-2 Endorsed Project No: -

[ABS-04-0319]

Role of the Indonesian Throughflow in Modulating Indian Ocean SST and Monsoon Rainfall Variability

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The Indonesian Throughflow (ITF) plays a crucial role in the global overturning circulation, acting as a low-latitude conduit for warm, fresh Pacific waters to flow into the southern Indian Ocean (SIO). The South eastern Indian Ocean is the main region which is affected immediately by pacific warm water. SST skewness over ITF region shows the positive skewness in post-monsoon and winter seasons, reflecting its sensitivity to ENSO-induced warming and over Arabian Sea experiences persistent negative skewness during summer and summer monsoon due to upwelling, while the southern Indian Ocean(SIO) exhibits positive skewness linked to subtropical gyres and IOD variability. The anomalous cooling occurred over ITF during monsoon season in El Niño and PIOD years, while anomalous warming observed during pre monsoon season in El Niño years and post monsoon season in PIOD years. Heat transport anomalies differ between El Niño and PIOD years, with El Niño showing dipole patterns and PIOD exhibiting predominantly positive fluxes. Importantly, post-monsoon ITF SST anomalies have a stronger and more persistent influence on SSTs in the AS and SIO, suggesting oceanic and atmospheric feedback that modulate regional climate. The high magnitude westward moving winds (3-6.5m/s) over ITF region will transport warm water to South-eastern Indian Ocean during post monsoon season and transport cold water in monsoon season. The high magnitude westward moving winds (3-6.5 m/s) over ITF region will transport warm water to South-eastern Indian Ocean during post monsoon season and transport cold water in monsoon season. SSTs in the ITF region correlate positively with Indian summer monsoon rainfall (ISMR), especially over central India, reinforcing the ITF's critical role in Indo-Pacific climate dynamics and seasonal predictability.

Keywords: Climate Variability, Indian Ocean Dipole, Ocean Heat Content, Sea Surface Temperature

IIOE-2 Endorsed Project No: -

THEME-5

EXTREME EVENTS AND THEIR IMPACTS ON ECOSYSTEMS AND HUMAN POPULATIONS

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[ABS-05-0284]

Development of AI/ML driven Rip Current Forecasting System for Indian beaches

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Rip currents pose a major threat to residents as well as tourists visiting coastal areas, responsible for a significant amount of worldwide drownings each year. Traditional empirical models often fail to capture nonlinear interactions among oceanographic parameters, thus falling short in predicting rip currents accurately. This paper presents the development of a machine learning-driven rip current prediction system, 'Safe Beach' implemented at the Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC), Indian Space Research Organization (ISRO). The system utilizes a two-stage approach: detection followed by prediction. Rip currents are first identified via a computer-vision object detection model, YOLO-V11, applied to Timex imagery from public video sources as well as Video Beach Monitoring Stations (VBMS). These detections are stored to create a rip current database, that is used to train a stacked ensemble learning framework for the prediction stage. This ensemble framework integrates various approaches & algorithms, including Random Forest, Gradient Boosting, XGBoost, and Support Vector Machines, with a meta-learner for final prediction. Input parameters include significant wave height, wave period, wave direction, spectral directional spread (from satellite-assimilated WaveWatch III model), and predicted tidal elevation. The system is currently issuing experimental forecasts at 175 Indian beach locations, providing predicted nearshore wave parameters such as breaker height, surf similarity, and breaker angle, along with rip current risk levels. The YOLO-V11 model shows around 90% precision in detection, while the ensemble model demonstrates over 85% prediction accuracy along with reduced false positives compared to traditional methods. Implemented in Python, the system operates autonomously, ingesting daily WaveWatch III outputs and generating five-day rip current forecasts at six-hour intervals. Safe Beach is accessible at https://www.mosdac.gov.in/safebeach. It supports coastal management, lifeguards, and public advisories, demonstrating the potential of AI and ML in operational coastal hazard forecasting and making an impactful contribution to public safety.

Keywords: Rip Currents, Forecasting, Machine Learning, Modelling

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[ABS-05-0349]

SAMUDRA: A User-Centric Platform for Multi-Hazard Ocean Service Delivery and Decision Support

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Effective management of ocean-related hazards demands timely, reliable, and accessible services that enable informed decision-making for a wide range of stakeholders, from disaster managers to coastal communities. To address this critical need, the Indian National Centre for Ocean Information Services (INCOIS) has developed SAMUDRA (Smart Access to Marine Users for ocean Data Resources and Advisories), a next-generation user-centric geospatial platform for multi-hazard ocean service delivery and decision support. SAMUDRA integrates and disseminates advisories on tsunamis, storm surges, high waves, swell surges, high currents, and ocean state forecasts through a single, interactive interface. Beyond hazard services, it also supports ecosystem-based applications such as Potential Fishing Zone (PFZ) advisories and Marine Heat Wave monitoring, providing direct benefits to fishing communities and coastal livelihoods. The platform is founded on a service delivery philosophy, offering intuitive access to real-time observations, advanced model forecasts, impact-based advisories, and interactive geospatial visualizations. Information Technology plays a central role in SAMUDRA, with its architecture leveraging high-performance computing, scalable databases, modern geospatial frameworks, cloud-ready APIs, and secure web and mobile delivery channels. By integrating satellite observations, in situ networks, and numerical model outputs with robust ICT infrastructure, SAMUDRA ensures that critical information is processed, visualized, and disseminated with minimal latency. By connecting ocean science, decision support, and ICT innovation, SAMUDRA helps disaster managers, maritime operators, and coastal communities respond better during emergencies. Its modular and interoperable design aligns with global best practices and contributes to the objectives of the UN Decade of Ocean Science for Sustainable Development. The platform demonstrates how advances in ICT-enabled ocean services can enhance preparedness, reduce risks, and support sustainable and resilient coastal societies.

Keywords: SAMUDRA; Decision Support Systems; Multi-Hazard Ocean Services; Information Technology; Geospatial Visualization; Disaster Risk Reduction; Coastal Communities

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[ABS-05-0282]

A state-of-the-art digital ecosystem for Supporting Multi-Hazard Coastal Resilience, the Blue Economy and Sustainable Ocean Planning

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Oceans are central to climate regulation, food security, maritime transport, and coastal development, yet they also pose risks such as tsunamis, storm surges, and sea-level rise. Understanding and predicting ocean behaviour is essential for safeguarding lives, livelihoods, infrastructure, and economies. This demands sustained ocean observations, systematic data, focused research, modelling, and forecasting - underpinned by state-of-the-art digital infrastructure, capacity development, and global cooperation - to generate services that support end-to-end ocean value chains for diverse stakeholders. The Indian National Centre for Ocean Information Services (INCOIS), under the Ministry of Earth Sciences (MoES), delivers operational services including potential fishing zone advisories, harmful algal bloom alerts, coral bleaching and marine heatwave forecasts, ocean state predictions, and early warnings for tsunamis, storm surges, high waves, sea-level rise, and oil spills. The Intergovernmental Oceanographic Commission (IOC-UNESCO), mandated to foster international cooperation in marine science, ocean observations, services, early warning systems, and capacity development, also coordinates the UN Ocean Decade. It facilitates transformative, cross-sectoral collaboration to advance integrated ocean knowledge and support sustainable development. INCOIS works closely with the IOC in facilitating the co-design, co-development, and co-delivery of ocean science solutions in the Indian Ocean region through its roles as Tsunami Service Provider, Decade Collaborative Centre, Regional Oceanographic Data Centre, Specialized Training Centre, UNESCO Category 2 Centre, Secretariat for IOGOOS, International Project Office for IIOE-2, and Indian Seas node under the OceanPredict DCC's India Seas Node. The powerful digital ecosystem at INCOIS, integrating Synergistic Ocean observations, Prediction and Services (SynOPS) Facility, Tarang HPC, SAMUDRA web/mobile apps, Common Alerting Protocol (CAP), and immersive learning platforms, enables seamless acquisition, analysis, visualization, generation and dissemination of ocean services, and capacity development. It supports multi-hazard coastal resilience, the blue economy, and sustainable ocean planning, while serving as a scalable precursor to the Digital Twin of the Ocean.

Keywords: Tsunami Early Warning, Multi-Hazard Coastal Resilience, Operational Oceanography, Ocean Value Chain, Digital Twin, Blue Economy, SynOPS, SAMUDRA, Digital Ecosystem, High Performance Computing, Ocean Decade

IIOE-2 Endorsed Project No: -

[ABS-05-0333]

A range of physical processes contribute to non-tidal residual water levels

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Storm surges (non-tidal water level) are a hazard, which result in coastal inundation, erosion, and possible loss of lives and is usually defined as the difference between the observed water level and the predicted tide. But there are many different physical processes that contribute to storm surge. Tropical storms (cyclones, hurricanes, typhoons) are among the most energetic forcing agents for the coastal ocean. Physical processes that influence the non-tidal water level associated with storms systems can persists for up to 14 days, beginning 3-4 days prior to storm landfall and ceasing up to 10 days after landfall. There is an additional contribution due to the influence of surface gravity waves (wave set-up). The storms also generate long waves with periods in the order of hours to days, which influence the water levels and currents both locally and many thousands of kilometres away. The components of a storm surge include: (1) forerunner, an increase in the mean water level up to several days prior to storm landfall; (2) meteotsunami; (3) continental shelf seiches; (4) edge waves with periods of ~six hours, that move both directions along the coast; and, (5) continental shelf waves, which propagate in a single direction with the coast on their left (right) in the southern (northern) hemisphere, with the restoring force being the Coriolis force. In this presentation, we use field measurements and numerical modelling from Western Australia (North West Shelf and south-west) to identify these processes and define their contribution to the storm surge.

Keywords: storm surge, forerunner, meteotsunami, coastally trapped waves

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[ABS-05-0135]

Giant Submarine Landslides Offshore Eastern India: Insights into Past Events and Implications for Future Hazards

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Giant submarine landslides are rare but high-impact extreme events that can reshape continental margins, generate tsunamis, and disrupt marine ecosystems. This study identifies previously unrecognized Pliocene-Pleistocene fossil mass transport complexes (MTCs) in the Godavari Basin, offshore Andhra Pradesh, India, among the largest slope failure events documented along the eastern Indian margin. Interpretation of a regional grid of two-dimensional (2D) seismic data reveals two major failures (MTC I and II), each comprising headwall, translational, and toe domains. MTC I spans 20,400 km² with a runout of ~200 km, and MTC II covers 32,000 km² with a runout of ~285 km, indicating high-mobility, long-runout emplacement. Extensional fault blocks are observed upslope and toe-thrust structures downslope, reflecting linked extensional-compressional deformation. Both events were likely triggered by rapid delta progradation, growth faulting, and overpressure in underlying shales. These findings demonstrate that similar geological and sedimentary conditions persist in the modern Bay of Bengal, implying a non-negligible risk of future large-scale failures. Understanding the triggers, magnitudes, and recurrence potential of such events is critical for geohazard assessment, tsunami preparedness, and safeguarding vulnerable coastal populations and marine ecosystems across the Indian Ocean region.

Keywords: Submarine landslide, continental slope failure, growth faulting, marine geohazards, Godavari Basin, Bay of Bengal

IIOE-2 Endorsed Project No: -

[ABS-05-0285]

Indian Ocean Tsunami Warning and Mitigation System: Two Decades of Progress and Future Directions

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Established in 2005 under UNESCO's Intergovernmental Oceanographic Commission (IOC) after the 2004 tsunami, the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) is coordinated by the Intergovernmental Coordination Group (ICG/IOTWMS). It includes 27 Member States and Territories, supported by Tsunami Service Providers (TSPs) in Australia, India, and Indonesia. These TSPs provide threat information to National Tsunami Warning Centres (NTWCs), which issue national alerts. Over two decades, IOTWMS has evolved into a robust, interoperable system built on three pillars: Risk Assessment and Reduction; Detection, Warning and Dissemination; and Awareness and Response. Key achievements include improved hazard assessments, expanded seismic and sea-level monitoring, 24/7 NTWC operations, initial implementation of the UNESCO-IOC Tsunami Ready Programme in India and Indonesia, regular regional training workshops, and biennial Indian Ocean Wave exercises. Capacity assessments in 2005, 2018, and 2024 have guided progress. The 2024 survey of 22 Member States showed significant advances in hazard assessments, national policies, and community preparedness. However, gaps remain in upstream warning systems, non-seismic detection, real-time data sharing, last-mile communication, community-level SOPs, and evacuation planning. Additional challenges include limited dissemination systems, lack of integration with broader multi-hazard frameworks, funding constraints, and the need for expanded training. The IOTWMS work plan addresses these gaps while aligning with the UN Ocean Decade Tsunami Programme and the Early Warnings for All initiative. It emphasizes inclusive, technology-enabled, multi-hazard approaches, with special attention to the needs of Small Island Developing States (SIDS) and Least Developed Countries (LDCs). Multilateral cooperation among Member States, regional bodies, and international partners remains central to governance, innovation, and capacity building, and will be vital as IOTWMS enters its next phase.

Keywords: Indian Ocean, Tsunami Warning System, Risk Assessment, Early Warning Dissemination, Community Preparedness, Tsunami Ready Programme, Multilateral Cooperation, Multi-Hazard Framework, UN Ocean Decade

IIOE-2 Endorsed Project No: -

[ABS-05-0381]

Seismological Network of India: RTSMN for Tsunamigenic Earthquake Detection: A Review Two Decades after the Indian Ocean Tsunami

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Following the 2004 Indian Ocean tsunami, the Indian Tsunami Early Warning Centre (ITEWC) was rapidly established at INCOIS to provide essential real-time tsunami monitoring and advisory services across the Indian Ocean region. This study offers a systematic operational analysis of ITEWC, with a focus on the key performance metrics of the Real-Time Seismological Monitoring Network (RTSMN), as developed and maintained by the National Centre for Seismology (NCS) over the past two decades. Drawing on comprehensive seismic event catalogues' including ISC-GEM, USGS, NCS, and INCOIS, this research evaluates detection capabilities for earthquake events, comparing magnitude, location, and depth accuracy across international and national databases. The comparative analysis shows that integration of the RTSMN, with its network of seventeen broadband stations and additional regional inputs, enables the detection of low-magnitude earthquakes (down to approximately 3.4 Mw), a threshold unmatched by global systems alone. Seismic catalogue mapping and spatial clustering assessment illustrate improved accuracy and completeness for regional seismic monitoring, especially in geologically complex or densely populated Indian coastal zones. Application of network simulation tools such as NetMoD demonstrates further potential for optimizing station deployment and enhancing monitoring effectiveness. The ITEWC's operational protocols ensure rapid notification: detection of tsunamigenic earthquakes occurs within 5-6 minutes, and tsunami advisories are issued in less than 10 minutes to all stakeholders throughout the Indian Ocean rim. This operational synergy between INCOIS and NCS offers a regional paradigm for earthquake and tsunami risk management. The research discusses the evolution of earthquake source parameter estimation, network detection thresholds, and spatial coverage limitations, proposing future directions for enhancing detection sensitivity and advisory reliability. The findings demonstrate reductions in false alarm rates and improvements in community safety, establishing the Indian system as a reference model for global tsunami early warning efforts.

Keywords: ITEWC, Real-Time Seismological Monitoring Network, tsunamigenic potential, source parameters, tsunami early warning

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[ABS-05-0070]

Causative mechanisms of coastal flooding due to Kallakkadal events along the southwest coast of India

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Sudden coastal flooding events known as kallakkkadal affect the southwest coast of India without any apparent local weather triggers, often catching communities off guard. These events are primarily driven by long-period ocean swells originating in the Southern Ocean, which travel vast distances to reach the Indian coastline. This study investigates the hydrodynamic mechanisms behind three Kallakkadal events by linking atmospheric conditions in the Southern Hemisphere with nearshore wave processes. Cut-Off Low systems forming south of 30°S were identified as the primary drivers, generating strong, sustained winds over large fetches that produced energetic swell waves. Using WAVEWATCH III and XBeach models, we simulate the swell propagation and its transformation into infragravity waves, which play a central role in wave setup and coastal inundation. The most severe flooding was observed when IGWs amplified and broke nearshore, especially over gently sloping bathymetry, enhancing wave setup and flood intensity. This combined modelling approach helps trace the complete pathway from atmospheric disturbance to coastal flooding, offering insights into the dynamics of Kallakkadal events.

Keywords: Kallakkadal, Cut Off Low, Swells, Infragravity waves

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[ABS-05-0128]

On the Role of Sri Lankan Land Mass in Safeguarding the South-Eastern Coast of India from Southern Ocean Swell Attacks

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Observations, modelling, and reports show that the west coast of India bordering the Arabian Sea is prone to long-period swells generated in the Southern Indian Ocean. Although these swells also propagate into the Bay of Bengal, they are not predominant in the southeast coastal parts of India. Analyses of data from wave rider buoy observations which are deployed off the coast of Kollam (located in the southwest coast of India) and Pondicherry (located in the southeast coast of India) for the year 2019 suggest that 96% of the events of long-period swells which are seen in the Kollam buoy data are not reaching Pondicherry. Using the WAVEWATCH III 6.07 model, focused experiments are carried out to show that the Sri Lankan Land Mass (SLLM), situated in the south-east part of the Indian peninsula effectively blocks the long-period swell waves from the Southern Ocean to reach the south-east coast of India. Our analysis shows that in the absence of SLLM, the destructive Southern Ocean swells can reach Indian southeast coast, including the areas north of Sri Lanka until mid-Andhra Pradesh.

Keywords: Southern Ocean swells, Sri Lanka, Indian east coast, long-period swells, WAVEWATCH III, wave rider buoys

IIOE-2 Endorsed Project No: -

[ABS-05-0131]

Monsoon High Wave-Induced Coastal Inundation Along the Kerala Coast: A Coupled Wave-Hydrodynamic Modelling Approach

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The southwest coast of India, particularly Kerala, is highly vulnerable to coastal inundation during the southwest monsoon. Persistent high-energy wave conditions driven by strong monsoonal winds often coincide with elevated tidal phases, leading to flooding across low-lying coastal regions. Accurate prediction of such events requires a coupled wave-hydrodynamic modelling framework capable of resolving nonlinear wave-tide interactions and terrain-driven flood propagation. This study employs a fully coupled ADCIRC+SWAN (ADCSWAN) model to simulate monsoon wave-driven coastal flooding. Wave boundary conditions from WAVEWATCH III are provided to SWAN to incorporate remotely generated monsoonal high waves and swells into the coupled ADCSWAN model domain. ADCIRC simulates hydrodynamic processes, while SWAN resolves the nearshore wave dynamics. The model is configured on an unstructured inundation mesh developed from high-resolution (100 m) merged bathymetric and topographic datasets generated by INCOIS. High-resolution wind (0.1° spatial, 3-hourly temporal) and sea-level pressure data from ECMWF are used to force the coupled model. To further refine the flood extents, head-loss downscaling was applied using a 5 m resolution DEM based on Airborne Laser Terrain Mapping (ALTM) data. Hindcast simulations were performed for a recent monsoon high wave-induced inundation event along the Kerala coast. Model performance was evaluated using tide gauge observations, waverider buoy data, and field-surveyed inundation extents. The results demonstrate good agreement with observations and underscore the dominant influence of wave setup and wave-tide interactions in determining inundation characteristics. This coupled modelling framework offers a reliable tool for understanding and forecasting monsoon wave-induced coastal flooding. It supports the development of operational early warning systems and enhances risk management strategies for the climate-sensitive coastal regions.

Keywords: Southwest Monsoon, Monsoon High Waves, Coastal Inundation, SWAN+ADCIRC, WAVEWATCH III, Head-Loss Downscaling.

IIOE-2 Endorsed Project No: -

[ABS-05-0015]

Recent Reduction in the Frequency and Intensity of Rapid Intensification of the Tropical Cyclones over the West Coast of the Bay of Bengal during October-December

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The densely populated west coast of the Bay of Bengal (BoB) is susceptible to Tropical cyclones (TCs) landfall during the post-monsoon season (October-December). Climatologically, post-monsoon TCs over the BoB undergo rapid intensification (RI) when they approach the west coast of the BoB. Analysis of post-monsoon TC data over the BoB during the last three decades (1993-2024) depicts a notable reduction in the frequency and intensity of RI events, such that the proportion of TC undergoing RI decreased from 55% during the first period (1993-2003) to 30% in the second period (2004-2014) and further to 22% in the third period (2015-2024). Multiple RI events occurred in 25% of cases during the first period, but such cases were absent during the recent period. In addition, the maximum increase in wind speed associated with RI often exceeded 50-75 kt in the first period, whereas in the recent period, it never exceeded 40 kt. It was found that a reduction in absolute vorticity intensity and a decrease in potential intensity within 300 km over the west coast of the BoB are primarily responsible for the decrease in RI frequency over the BoB during the recent period. Our analysis based on the Genesis Potential Index (GPI) indicates that the reduction in the RI cases in the BoB in the recent period is part of the decadal modulation of GPI over the BoB, which is primarily determined by the combined effect of Pacific Decadal Oscillation and Atlantic Multi-decadal Oscillation.

Keywords: Tropical Cyclone (TC), Genesis Potential Index (GPI), Rapid Intensification (RI)

IIOE-2 Endorsed Project No: -

[ABS-05-0072]

Impact of tropical cyclone generated swell on the Indian coasts and Islands

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The present study is focusing on the swells propagated from the tropical cyclone (TC) Freddy which is the long-lived cyclone and traversed the entire Indian Ocean propagating westwards in February 2023. The intensification and prolonged duration of severe TCs are anticipated to increase, making them a greater threat under future climate conditions. While swells are not the most intense wave conditions, these low frequency swells produce high wave conditions leading to coastal hazards, hence understanding the TC trends and the effect along the coastlines is crucial. The experimental runs are done using unstructured WAVEWATCH III (WW3) with a varying grid resolution of 1km-10km, from the coastlines to the offshore region respectively which was nested with a global multigrid WW3. We did three experimental runs (1) with wind forcing along the cyclone track only, to understand the propagation pattern and the intensity along the coasts. (2) wind forcing below the cyclone tracks from the Southern Ocean (SO) only in order to differentiate the effect of SO swells (3) wind forcing along the entire region. The propagation pattern reveals that swells from a large-scale cyclone such as TC Freddy, which covered the entire IO, were able to reach distant shores including India, the Gulf coast, and eastern Africa. As the swells reach the North Indian Ocean (NIO) coast, they lose up to 80% of their energy, with only low energy levels making landfall; further analysis of wave power density (WPD) along the coast shows that southern coastal regions and islands are likely to be significantly affected in similar scenarios. In summary the study emphasizes on the swell propagation pattern and the degree of impact during a similar situation, which will help us to provide coastal protection strategies during subsequent events.

Keywords: Unstructured WW3

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[ABS-05-0202]

Impact of Approach Angle of Cyclones Remal and Dana on Storm Surges and Inundation in Coastal Bay of Bengal

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The unique configuration and funnel-shaped nature of the Bay of Bengal stand as an area of increased vulnerability, particularly due to storm surge impacts. Among several factors, the approach angle of the tropical cyclone significantly influences surge height variations. This study simulates several surges and associated inundation for cyclones Remal and Dana that affected the Bay of Bengal regions in 2024, by varying the position and angle of their tracks while considering both tides and waves using a tightly coupled SWAN+ADCIRC model. For surge simulating purposes, 18 idealized radiating straight-line tracks originating from the landfall point with an increment angle of 10° have been plotted, taking into consideration real bathymetry data from GEBCO, a 15-arc second gridded bathymetry dataset. The atmospheric forcing required for running the SWAN+ADCIRC model has been derived from the Holland10 model. The combined effects of surge, tide, and wave interactions, along with cyclonic landfall location at different angles, influence the peak water levels. Since Cyclone Remal attained higher wind speeds (~28m/s), lower MSLP (~976 hPa), and higher SST (31.5°C-32.7°C) compared to Cyclone Dana, which had wind speeds of 24.65m/s, MSLP of 985.51 hPa, and SSTs around 30.3°Câ--30.9°C, the maximum water elevation at the landfall locations affected by Cyclone Remal (4-4.5m) is also higher than that of Cyclone Dana (2.4-2.5m). For Cyclone Remal, a progressive increase in surge height is observed after 100°, peaking at 140°-150°, while no noticeable variation in surge height with approach angle is observed for Cyclone Dana, mainly due to its weaker intensity. Although overall water elevation is heavily influenced by tidal variations, approach angle, and bathymetry, the cyclone's strength is a key factor that regulates surge height.

Keywords: SWAN+ADCIRC, Remal, Dana, Bay of Bengal

IIOE-2 Endorsed Project No: -

[ABS-05-0056]

Downscaling Sea Surface Temperature for Extreme Events with Residual Corrective Neural Networks

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The large-scale oceanic and atmospheric forecasts provided by global climate models lack sufficient resolution to accurately capture the response of the coastal ocean. Dynamical downscaling is computationally prohibitive, especially when applied to the large coastlines, like Western Australia and to many climate ensembles. Therefore, this work presents a statistical downscaling of sea surface temperature (SST) from the seasonal coupled ocean-atmosphere forecast system (ACCESS-S2) that is based on machine learning techniques. This study introduces a novel methodology that combines a convolutional neural network called U-Net, known for its ability to effectively capture spatial features, for coarse-scale predictions with a residual corrective neural network (RCNN) that iteratively refines these predictions toward high-resolution SST. The target high-resolution SST fields are obtained from the Regional Ocean Modeling System (ROMS). The RCNN incorporates dynamically adjusted residual corrections proportional to residual scales, ensuring stable and multi-scale refinement. Through iterative residual corrections, the model shifts its focus from coarse corrections in early steps to fine-grained refinements in later steps, capturing both broad trends and localized features, such as eddies and fronts. The developed framework efficiently downscales the SST along the west coast of Australia. A specific case study involving the 2011 marine heatwave event shows that the RCNN can sharpen the SST predictions of ACCESS-S2 and determine temperature anomalies during the heatwave efficiently. By applying the developed framework, this work achieves a balance between computational efficiency and the accuracy required for capturing local oceanic variations, ultimately improving forecasting capabilities for coastal management and marine ecosystem studies.

Keywords: Sea Surface Temperature, Statistical Downscaling, Marine Heatwaves, Extreme Events, Residual Corrective Neural Network

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[ABS-05-0060]

Surface cooling in the Arabian Sea driven by near-inertial wave-induced mixing during a tropical cyclone

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Temperature observations from a deep-ocean mooring located along the track of cyclone Nanauk revealed an abrupt surface cooling that persisted for over twenty days during. Mooring observation of currents showed strong near-inertial currents in the mixed layer and elevated shear at its base throughout this cooling period. To investigate the role of near-inertial-driven vertical mixing on surface cooling, we utilized a one-dimensional Price-Weller-Pinkel (PWP) mixing model and a high-resolution (2 km) three-dimensional Regional Ocean Modelling System (ROMS) model. Various sensitivity experiments are performed using the mixing model to understand the role of near-inertial waves in SST cooling. A part of long-term cooling was explained by shear-driven mixing induced by near-inertial waves in the mixed layer. The spatial variability of this cooling and the potential influence of near-inertial waves is further analysed using ROMS model simulations. The prolonged cooling was observed over the wide region in the eastern Arabian Sea associated with the cyclone. The strong near-inertial kinetic energy due to the cyclone winds induces elevated shear at the base of the mixed layer, which leads to the prolonged cooling at the surface. Our study shows that the increased cyclone activity in the Arabian Sea during the recent years may have a significant influence on SST variability in the region in a short time scale. This may have a significant influence on the local climate system in this region.

Keywords: near-inertial waves, cyclone, SST, ROMS, PWP model

IIOE-2 Endorsed Project No: -

[ABS-05-0133]

Increase in the intense cyclones in the Arabian Sea during the last decade and its reasons and characteristics

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In the present study, decadal variability of the North Indian Ocean (NIO) cyclone characteristics and the reasons led to it are unraveled. Importantly, during the recent decade (2014-2023), the frequency of intense TCs over the Arabian Sea has increased remarkably compared to the previous decade (2004-2013), while such an increase is not seen in the BOB. In the NIO, positive anomaly of air temperature (~1°C) and specific humidity (~1 g kg-1), and an increase in the sea surface temperature anomaly (SSTA) of ~0.55°C during the last four decades were observed. The AS (BOB) shows stronger (weaker) subsurface warming throughout the 0-150 m (100 m) layer, with anomalies surpassing 0.4°C (>0.1°C). In the recent decade, very high positive moisture loading (ML), low vertical wind shear, high positive vorticity, and strong positive anomaly (2-8 x1010 KJ cm-2) in the ocean heat content (OHC) were observed in the NIO. Such decadal variabilities are more visible in the AS than BOB. An important result from the present study is that the AS showed a substantial increase in GPI (genesis potential index) of ~ 13-fold during the recent decade, largely driven by changes in the relative humidity. In contrast, the Bay of Bengal showed only a minor increase in it over the same period. Variability studies on GPI, SST, mid-level moisture, and wind shear reveals that the conduciveness for TC genesis and intensification has an increasing trend over the last four decades, notably in the last decade. By considering ESCS Tauktae as a typical TC case, a methodology was coined based on linear and multiple regression analyses and quantified the prevalent role of ocean and/or atmosphere on the genesis and intensification which was continued as a knowledge gap for long.

Keywords: Decadal variability, Tropical Cyclones, Northern Indian Ocean, Genesis Potential Index, ENSO, Arabian Sea

IIOE-2 Endorsed Project No: -

[ABS-05-0208]

Impact of sea level rise on storm surges due to futuristic cyclone tracks along North coast of Bay of Bengal

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This study examines the impact of future shoreline changes on storm surges in the northern Bay of Bengal. The study utilizes the cyclone tracks of super cyclone Amphan and cyclones Bulbul, Fani and Yaas and synthetic tracks are generated for the next 50 years to project a future scenario of the could be affected areas due to these extreme events. Due to global warming from high industrial carbon emissions, sea levels are rising, leading to continuous changes in the shape and position of coastlines, which is of great concern. Based on data from 'CMIP6' (Coupled Model Intercomparison Project) up to 2050, the average sea level rise in our study region is found to be approximately 0.35 cm per year. The future bathymetry profile of the study area, required as an input for the surge simulation, has been computed using this data from CMIP6. Storm surges can be modeled using a state-of-the-art hydrodynamic model called 'ADCIRC' (Advanced Circulation). Simulations of super cyclone Amphan and cyclone Bulbul, using a high-performance computing system with 144 cores, incorporating the future bathymetry with sea level changes, show surge height increases of about 0.4-0.6m and 0.2-0.5m, respectively. TCWiSE (Tropical Cyclone Wind Statistical Estimation Tool) is used to generate the synthetic tracks, which considers the average number of storms per year in the region of interest, with data on wind speed, forward speed, and other factors. Results indicate that global warming increases maximum cyclone wind speeds by about 10 m/s. Additionally, there is a significant change in the number of cyclone tracks compared to historical data for the West Bengal and Odisha regions. The present study will benefit the future planning for the coastal zone management.

Keywords: CMIP6, ADCIRC, TCWiSE, Tropical Cyclone

IIOE-2 Endorsed Project No: -

[ABS-05-0273]

Air-Sea interactions linked to Tropical Cyclones in the Bay of Bengal with special emphasis on oceanic meso-scale Eddies.

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The Bay of Bengal (BoB) is an active region for the formation of the Tropical Cyclones (TCs) and accounts for about 6% of the global annual total number of tropical storms. In this study, we have conducted an Ocean Mixed Layer Heat budget analysis for distinct TCs over Bay of Bengal. Further we have examined the coherence between distinct ocean mixed layer budget terms and Genesis Potential Parameter (GPP) especially over warm and cold core eddies. Through this analysis, we found that the net heat flux and entrainment terms have high correlations with GPP, with correlation coefficient value of magnitude 0.42 and 0.68 respectively and among all the parameters reported, the entrainment has highest correlation of magnitude 0.68 with GPP. It is interesting to mention that unlike the warm-core eddies the prior response (5 days before the passage of cyclone) between mixed layer terms and GPP is not observed for the case of cold-core eddies. Also, the magnitude of correlation between distinct terms of mixed layer heat budget analysis and GPP is relatively less for cold-core eddies, compared to the warm-core eddies. A notable feature for warm-core eddies is that the net latent heat flux dominates in influencing GPP among the terms that determines net surface heat flux, however, such dominance of net heat flux is not observed for cold core eddies, which infers that the cold core eddy regions are relatively less influential in determining/impacting cyclone life cycle, compared to the warm core eddy regions. As the latent heat flux is the major pathway between the energy exchanges from ocean to atmosphere, during active cyclone period. Further we have reported the air-sea interactions w.r.t. Viyaru cyclone as case-study. The present study could be beneficial in improving the TC models for better prediction.

Keywords: Tropical Cyclones, Bay of Bengal, Mixed layer heat budget, Cyclogenesis, Meso-scale Eddies, Air-Sea interaction

IIOE-2 Endorsed Project No: -

[ABS-05-0302]

Satellite-Based Analysis of Rainfall Structure in Rapidly Intensifying Tropical Cyclone Dana: Insights from GPM IMERG and DPR Observations

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Tropical Cyclone Dana (October 19-25, 2025) was a high-impact post-monsoon system over the Bay of Bengal that underwent rapid intensification (RI) between 23 and 24 October, with satellite-estimated wind speeds increasing by over 30 kt within 24 hours. The cyclone followed an anomalously long 1780 km track nearly twice the post-monsoon climatological mean with a slow translation speed of 10.8 km/h and a prolonged landfall duration (~9 hours). Dana affected over 4.1 million people across 14 districts in Odisha and West Bengal, causing estimated economic losses of ~616 crore [1]. This study integrates Global Precipitation Measurement (GPM) Integrated Multi-satellitE Retrievals (IMERG) (21-25 October) and Dual-frequency Precipitation Radar (DPR) (22 and 25 October) data to analyze Dana's precipitation evolution from genesis to dissipation. IMERG provided continuous high-resolution mapping of rainfall during key lifecycle phases. DPR snapshots enabled detailed vertical profiling of convective organization and inner-core structure. Results from IMERG show the gradual strengthening and gathering of convective activity with increased precipitation around the TC center during the rapid intensification period. DPR data showed a shift from mostly shallow rain (less than 8 km high) with the majority stratiform precipitation type during the early stage to deep convective clouds (over 12 km high) forming a symmetric eyewall. The precipitation characteristics showed a strong leaning towards the northwest quadrant at landfall, with near-surface rainfall reaching above 170 mm/hr due to vertical wind shear and the TC movement. This multi-sensor analysis highlights how satellite data help us understand cyclone intensification and rainfall risks in the Bay of Bengal.

Keywords: Rapid Intensification, Inner-Core Convective Organization, GPM IMERG and DPR Synergy, Azimuthal Precipitation Asymmetry, Extreme Precipitation, Human Vulnerability.

IIOE-2 Endorsed Project No: -

[ABS-05-0316]

Interpretable Machine Learning for Tropical Cyclone Genesis and Track Prediction over the Bay of Bengal

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Forecasting the onset and path of tropical cyclones remains a substantial hurdle in operational meteorology, particularly over the Bay of Bengal (BoB), where storms often develop quickly and impact densely populated coastlines. The present research investigates the use of three distinct machine learning (ML) models, viz. Random Forest, Support Vector Machine, and Neural Network-to anticipate both the formation and movement of tropical cyclones at lead times of 24, 36, 60, and 84 hours. Initial detection of tropical disturbances is achieved using a refined Kalman Filter approach, with relevant atmospheric and oceanic parameters extracted from reanalysis data. The ML models exhibit strong classification performance in identifying developing systems. At 24- and 36-hour lead times, the F1-score approaches 0.90, and remains robust (~0.86) at longer forecasts of 60 and 84 hours. In addition to genesis prediction, storm trajectories are estimated by predicting the future positions of disturbances, yielding accurate displacement forecasts over all tested lead times. To improve interpretability, SHapley Additive exPlanations (SHAP) are applied to evaluate the role of individual predictors. It is well established that, CAPE emerges as the most influential variable, with wind shear and mid-level vorticity also playing important roles in both genesis and track prediction. To illustrate practical utility, a case study of Cyclone Titli is presented, where we have shown role of distinct cyclogenesis parameters in affecting both the probability of genesis and projected track. The present results enhance transparency, making ML outputs more accessible for forecasters. The study also discusses key challenges such as data imbalance and generalization across seasons and recommends combining ML with physical modeling to further improve reliability. Overall, the results support the integration of interpretable ML frameworks into tropical cyclone forecasting over the BoB.

Keywords: ML, tropical cyclones, Bay of Bengal, ocean and atmosphere data

IIOE-2 Endorsed Project No: -

[ABS-05-0320]

Warming Indian Ocean spinning more cyclones: A case study from 2019

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Tropical cyclones occur twice in the North Indian Ocean (NIO) - during spring-summer and fall-winter transitions. In recent years, there has been a noticeable increase in cyclone activity across the NIO, which has been linked to climate warming. The year 2019 was particularly remarkable, producing eight cyclones that ranged in intensity from cyclonic storms to super cyclones. Of these, five cyclones formed in the Arabian Sea (AS) and three in the Bay of Bengal (BoB). This was an unprecedented event for two key reasons - the total number of cyclones in the AS was the highest since 1960, and significantly out-numbered those in the BoB. An analysis of long-term ocean-atmosphere parameters revealed that in 2019, the ocean and atmospheric conditions aligned to create favourable dynamic and thermodynamic environments necessary for cyclone formation. Observations from satellite and in situ data showed significant variability in the upper ocean's physical and biogeochemical responses to the cyclones. The cyclone-induced changes in the AS such as surface cooling, increased chlorophyll biomass, enhanced primary productivity, and elevated CO2 outgassing were much more pronounced than those in the BoB. This contrasting response was attributed to differences in upper ocean stratification and wind stress curl between the two basins. Specifically, reduced upper ocean stability and stronger wind-driven Ekman suction in the AS in 2019 contributed to the more intense oceanic response. Two major atmospheric and oceanic contributors to the formation of five cyclones in the AS during 2019 were the highest mid-tropospheric relative humidity and the second-highest upper ocean heat content recorded since 2000. The anomalously high cyclone activity in the NIO in 2019 was driven by a combination of factors, rapid warming of the western Indian Ocean, a strong Indian Ocean Dipole (IOD) event, and changes in the Walker circulation associated with the IOD.

Keywords: Tropical cyclone, Sea surface temperature, Relative humidity, wind, chlorophyll a, Carbon dioxide

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[ABS-05-0017]

Last Decade's (2014-23) Unprecidented Spatio-temporal variability in Cyclone's Accumulated Energy, Power Dissipation Index and Track Density in the Northern Indian Ocean

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The present study explores the variability in tropical cyclone (TC) characteristics, including frequency, intensity, trajectory, energy and duration over the Arabian Sea (AS) and the Bay of Bengal (BOB) during the pre-monsoon and post-monsoon seasons from 1984 to 2023. In general, the analysis indicates a notable increase in the occurrence of intense cyclones over the AS, while a decline is observed in the BOB. During the recent decade (2014-2023), the frequency of intense TCs (VSCS, ESCS & SUCS) over the Arabian Sea has increased 3 fold in the pre-monsoon and 8 fold in the post-monsoon compared to the previous decade (2004-2013), while the post monsoon mild TCs (CS & SCS) declined to half in number with no change in the frequency of pre-monsoon TCs. Over the Bay of Bengal, intense pre- and post-monsoon TCs rose by just 33% and there is even a decrease in mild TCs during both the pre- and post-monsoon periods. Trends in cyclone energy indicators, such as the power dissipation index (PDI) and accumulated cyclone energy (ACE), show an increasing trend in the AS (closer to the coast) and a decreasing trend in the northern BoB (however, an increasing in the southern west part). The Genesis Potential Index (GPI) shows strong correlations with ACE (PDI) during the AS pre-monsoon with 0.61(0.57) and post-monsoon with 0.62(0.55) seasons. Further analysis shows that spatial trends in GPI, low-level vorticity, VWS, TCHP, thermal instability, and RH mainly drive cyclone genesis and intensification during the post-monsoon (pre-monsoon) over the AS (BOB). Increased cyclone intensity over post-monsoon AS in the recent decade is linked to high GPI, RH, TCHP, and subsurface ocean warming. Global warming in the wake of climate change seen to intensify the conditions favoring cyclone development, leading to more frequent and powerful storms with shifting trajectories.

Keywords: Tropical Cyclones (TC), Northern Indian Ocean (NIO), Genesis Potential Index (GPI), Accumulated cyclone energy (ACE), Tropical cyclone heat potential (TCHP), Potential destructive index (PDI)

IIOE-2 Endorsed Project No: -

[ABS-05-0254]

From Ocean to Coast: Upper-Ocean and Coastal Water Level Response to Cyclone Hamoon in the Bay of Bengal

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Tropical cyclones significantly affect upper-ocean structure and coastal water levels. This study examines the evolution of sea surface temperature (SST), sea surface height anomaly (SSHA), depth of the 26°C isotherm (D26), tropical cyclone heat potential (TCHP), ocean heat content (OHC), 0-100 m Salinity, Sea Surface salinity (SSS) and temperature before, during and after Cyclone Hamoon (October 2023) in the Bay of Bengal, in relation to the Genesis Potential Index (GPI) derived from atmospheric and oceanic parameters. Changes in upper-ocean stratification and cyclone translation speed were also analyzed to understand air-sea interaction processes. Satellite and reanalysis datasets were combined with tide gauge observations from Paradeep, Gopalpur and Garden Reach (used as a control site). Results reveal SST cooling, reduced TCHP and OHC and a shoaling of D26 during the cyclone's peak intensity. Stratification weakened markedly along the cyclone track, coinciding with a decrease in translation speed, which enhanced the oceanic response. Tide gauge records at the affected sites captured positive anomalies that coincided closely with the cyclone's landfall. These findings highlight the coupled ocean-coast response to Cyclone Hamoon and emphasize the value of integrating tide gauge observations with upper-ocean diagnostics for improved cyclone impact assessment.

Keywords: Keywords: Tropical cyclone, Bay of Bengal, Genesis Potential Index (GPI), Sea surface temperature (SST), Sea surface height anomaly (SSHA), Tropical cyclone heat potential (TCHP) and Tide gauge observations.

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[ABS-05-0256]

Influence of WRF Find Forcings on Simulated Ocean Waves during ESCS Biparjoy (2023) over the Arabian Sea

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This study investigates the performance of a high-resolution wave modelling framework during the lifecycle of the Extremely Severe Cyclonic Storm (ESCS) Biparjoy (June 2023) using three different wind forcing datasets: the Weather Research and Forecasting model (WRF), the European Centre for Medium-Range Weather Forecasts (ECMWF), and the National Centre for Medium Range Weather Forecasting (NCMRWF). Surface winds were validated against buoy observations and Oceansat-3 scatterometer data, showing that WRF most effectively represented the cyclone's intensity and temporal evolution, particularly during peak wind events. The Simulating WAves Nearshore (SWAN) model, driven independently by each wind dataset, was assessed against Wave Rider buoy records and multi-mission satellite altimeter measurements. Time-series and spatial analyses indicated that all three models reproduced both calm and storm conditions reasonably well, with WRF exhibiting improved accuracy in coastal areas and better sensitivity under extreme conditions. Although ECMWF slightly outperformed at certain open-ocean locations, WRF consistently achieved stronger correlations and lower RMSE in nearshore regions, attributed to its finer spatial and temporal resolution. Altimeter-based validation further underscored the reliability of WRF-driven forecasts, especially for significant wave heights exceeding 4 m. These results emphasize the advantage of high-resolution regional wind models such as WRF in enhancing wave forecasting during tropical cyclones and support their application in operational coastal hazard management.

Keywords: WRF, SWAN model, Scatterometer winds, Wave Rider buoy, Satellite altimeter, Significant wave height

IIOE-2 Endorsed Project No: -

[ABS-05-0258]

The Evaluation of Carnot Efficiency in Cyclones over the Arabian Sea: Decadal Trends and the Role of Eliassen-Palm Flux in recent decades

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Tropical cyclones are natural heat engines, powered by the latent heat released from the ocean. This study investigates the changes in the Carnot efficiency of cyclones over the Arabian Sea from 1991 to 2020, with a focus on the impact of climate change and decadal variability. The study calculates the theoretical maximum efficiency of energy conversion using sea surface temperature (SST) and upper atmospheric temperature data for each decade, applying the Carnot efficiency formula. To understand the underlying atmospheric dynamics, the Eliassen-Palm (EP) flux is incorporated to examine energy and momentum transport in the cyclone systems. The EP flux is used to assess how the vertical energy flux and momentum transport between the ocean surface and upper atmosphere have evolved, affecting the intensity and efficiency of cyclones over time. The results show an increase in Carnot efficiency, reflecting rising SSTs and potentially more efficient energy conversion in stronger cyclones. This analysis offers insights into how climate change has impacted both the thermodynamic efficiency of cyclones with implications for regional climate patterns in the Arabian Sea.

Keywords: Carnot efficiency, Eliassen-Palm flux, Arabian Sea, Climate change

IIOE-2 Endorsed Project No: -

[ABS-05-0130]

Unravelling the Role of Tropical Cyclone and Marine Heatwave on a Jellyfish Beaching Event in the Bay of Bengal

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The escalating impacts of global warming and climate change pose significant threats to the stability of marine ecosystems. This study investigates a large-scale jellyfish stranding event that occurred along the northwestern Bay of Bengal, specifically at Puri, a recognized Blue Flag beach. The stranded species was taxonomically identified as *Netrostoma spp*. The event followed the landfall of Extremely Severe Cyclonic Storm Mocha in May 2023. Using met-oceanic multi-parameter analysis, this study investigates the combined influence of extreme events, specifically a marine heatwave (MHW) and Tropical Cyclone Mocha, on the aggregation and transport of jellyfish. The occurrence of a persistent MHW during the month leading up to the stranding likely created favourable thermal conditions that supported rapid jellyfish growth and population expansion in the region. Concurrently, sustained mesoscale ocean features, including cyclonic and anticyclonic eddies, are found to have contributed to biological productivity and nutrient enrichment near thermal fronts, further supporting jellyfish proliferation. During the cyclone''s approach and landfall, strong cross-shore wind and current-induced divergence led to significant surface water transport toward the coastline, effectively driving the jellyfish stranding toward the beach. This event highlights the interconnected influence of ocean warming and extreme weather on marine ecological disruptions. By examining the physical-biological linkages underpinning this stranding, the study underscores the growing ecological consequences of compound events like MHWs and tropical cyclones in a warming climate, offering important implications for coastal ecosystem monitoring and marine hazard preparedness.

Keywords: Tropical cyclone; Marine Heatwave; Jellyfish; Mesoscale eddies; Bay of Bengal

IIOE-2 Endorsed Project No: -

[ABS-05-0190]

Subsurface Drivers and Teleconnections of Marine Heatwaves in the Seychelles-Chagos Thermocline Ridge

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Marine heatwaves (MHWs), extended periods of unusually warm sea surface temperatures are intensifying globally under climate change, cascading impacts on marine ecosystems and regional climate. This study investigates the characteristics and drivers of MHWs in the Seychelles-Chagos Thermocline Ridge (SCTR; 50° to 75°E, 5° to 12°S), an important open-ocean upwelling zone in the southwestern tropical Indian Ocean. Analysis of daily optimum interpolated SST data (1982 to 2024) identifies 98 MHW events and shows a marked increase (3 days per year) in annual MHW days. K-means clustering of event duration and intensity reveals three distinct types with differing thermocline dynamics: long-lived, intense events (Cluster 1, 9%) linked to rapid thermocline shoaling and strong subsurface warming; short-lived, weak events (Cluster 2, 52%) driven mainly by surface heat flux anomalies; and moderate events (Cluster 3, 39%) characterized by subsurface heat buildup and pronounced upper-ocean stratification. Thermocline shoaling emerges as a key mechanism facilitating vertical heat emergence and MHW initiation. Notably, Cluster 1 events coincide with enhanced rainfall over southern India and East Asia, indicating far-reaching atmospheric teleconnections. These results underscore the importance of incorporating subsurface processes into MHW monitoring, particularly in upwelling systems such as the SCTR.

Keywords: Marine Heatwaves, Extreme Rainfall, Seychelles-Chagos Thermocline Ridge, Clustering

IIOE-2 Endorsed Project No: IIOE2-EP20

[ABS-05-0220]

Rapid climate downscaling using deep learning to inform climate vulnerability assessment of a marine World Heritage Area in the Indian Ocean

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To help evaluate climate vulnerability of marine values of the Ningaloo Coast World Heritage Area and the Ningaloo Marine Park, five best performing CMIP6 climate models for the Australian Region [Grose et al., 2023] have been chosen to produce high resolution climate projections of sea-surface temperature (SST) using machine learning, which is capable of rapidly downscaling climate models for different Shared Socioeconomic Pathways (SSPs) to inform a range of likely outcomes. First, biases in SST from these climate models were assessed and corrections made using 30 years of satellite SST observations [Skirving et al., 2020] using a quantile delta mapping method [Cannon et al., 2015]. The analysis shows all five models to have a warm bias in SST of ~1°C. A deep learning model was then trained to downscale the SST projections from 100 km resolution to 10 km using the Australian BlueLink OFAM model simulations [Cyriac et al., 2025]. The downscaled ensemble mean of the five climate models at 10 km resolution show that SST at the Ningaloo Coast of the study region is projected to warm by about 0.5°C under a global warming level (GWL) of 1.5°C, increasing to ~1°C under a GWL of 2°C. At a GWL of 3°C, the warming would exceed 1.5°C. As global warming levels (GWL) approach 3°C, the degree heating week (DHW), a measure of cumulative heat stress, is projected to increase substantially. This increase is a major concern because higher DHW values are directly linked to a greater risk of severe coral bleaching and widespread mortality. On the other hand, sea level along the west coast of Australia will remain slightly below the current level under the high emission scenario (RCP8.5) by the end of 21st century, with likely very little change under a moderate emission scenario [Zhang et al, 2017].

Keywords: climate downscaling, deep learning, climate vulnerability, world heritage areas

IIOE-2 Endorsed Project No: -

[ABS-05-0108]

The challenge of disasters to the coastal communities: A case study of two states in India

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The frequency of tropical cyclones in the Bay of Bengal and Arabian Sea has increased in the last ten years. In the Bay of Bengal, compared to 1990-2010 and 2010-2023, there is an increased occurrence of depression, inducing more occurrences of the 'red alert' category than orange or yellow, in the past decade. Whereas in the Arabian Sea, comparing 1982-2002 and 2001-2019, the severe category of cyclones has increased by 150 per cent. The Arabian Sea is not prone to frequent tropical cyclones like the Bay of Bengal. However, this trend is changing with increased cyclone activity in the past five years. In this circumstance, the most impact has been on the livelihoods of the coastal communities that rely on fishing, small-scale businesses, aquaculture, and agriculture. They face critical challenges such as displacement, livelihood threats, and health risks. The measures taken by Tamil Nadu and Kerala governments include disaster management plans, cyclone shelters, monsoon preparedness and response, early warning systems and relief activities. However, lack in relief, urban planning and mitigation of coastal health. At the policy level, updating ICZM maps, measures to reduce rapid urbanisation, sustainable fishing and protection of coastal ecosystems are absent. The paper will first analyse the major coastal disasters and the impact of anomalies on the local communities of the two states during 2015 and 2025. Second, to understand the adaptation measures of the coastal communities. Third, analyse the effectiveness of the coastal governance measures of the Tamil Nadu and Kerala governments. Lastly, draw lessons within states in India (Odisha and Assam) and from other IOR states (Singapore, Australia and France) for better coastal management. The study will lead to policy recommendations for better coastal governance strategies.

Keywords: Anomalies, fatalities, adaptation, governance, lessons within IOR

IIOE-2 Endorsed Project No: -

[ABS-05-0156]

Occupational Hazards and Safety Preparedness among Small-scale Motorised Fishers of Southernmost Coasts of India

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Millions depend on marine fisheries for their livelihoods, with small-scale fishers particularly reliant on these resources for their income, food security, and way of life. However, climate change driven extreme weather events increasingly threaten their life by intensifying the hazards associated with this occupation. The present study examines the occupational hazards and use of safety devices among small-scale motorised fishers in the southernmost coastal region of India based on primary data collected from 253 respondents. The study employed Relative Importance Index (RII) to assess fishers' perceived impact across different hazard categories and analysed adoption rates to examine the usage patterns of available life-saving devices. The findings indicate environmental hazards (0.80) such as heavy rain, cyclones, heavy currents, and high tides have the greatest impact on fishers compared to psychological (0.70), vessel-related (0.69), health (0.64), ergonomic (0.63), and biological/chemical hazards (0.50), emphasising the severe threat posed by extreme events whose frequency and occurrence are far more difficult to prevent. GPS (87.75%), mobile phones (84.19%), VHF radio (67.98%), and AIS (20.16%) are the primary life-safety gadgets predominantly used by fishers, while other essential safety devices such as life jackets (3.56%), life buoys (2.37%), and fire extinguishers (1.98%) remain underutilized despite awareness of safety measures. This indicates that fishers are prioritizing communication and navigation tools over vital safety measures, thereby increasing their risk at sea. Addressing these gaps requires strict enforcement of safety protocols, along with enhanced awareness, training, and regular inspections during the registration and renewal process of fishing vessels, to safeguard the lives and livelihoods of fishers facing rising extreme weather events.

Keywords: Extreme weather events, Occupational hazards, Marine fisheries, Life-Saving Devices

IIOE-2 Endorsed Project No: -

[ABS-05-0222]

Effect of episodic event cyclonic storm â¿¿Dayeâ¿ on the microzooplankton community structure in the north-eastern coastal waters of India: A spatial and temporal comparison.

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The Cyclonic storm (CS) Daye, which made landfall on the northern Andhra Pradesh coast, India, during the summer monsoon (SM) season of 2018, had a pronounced effect on the physico-chemical conditions as well as the biological community (especially the microzooplankton) in the affected region. In this study, we have analysed the effect of the cyclone on the microzooplankton population in a regional (spatial scale) by comparing the microzooplankton community structure across three study zones with varying levels of cyclone impact (High, moderate, least) during SM 2018, and on an inter-annual basis (temporal scale) by comparing the microzooplankton community structure across three summer seasons (2018, 2019 and 2021) in the same region (Andhra Pradesh). The study region, highly impacted by CS Daye, witnessed distinct environmental parameter changes such as lower sea water temperature, lower chlorophyll a concentration, high salinity and changes in nutrient concentrations. The average abundance of microzooplankton (MCZ) was reduced in the post-cyclone high-impact region stations. When comparing MCZ community structure on a temporal scale, it was observed that the overall MCZ abundance was much lower in SM 2018 (the year of the cyclone) compared to the other two years (SM 2019 and SM 2021) when there was no cyclone at that time. Indicator species analysis was performed, which revealed the ciliate species *Epiplocyloides ralumensis* and the copepod nauplii stage III as indicator species in both the temporal as well as spatial analyses. Considering both scales of comparison, it can be inferred that the environmental factors in the Andhra Pradesh region during SM 2018 showed noticeable effects of the meteorological phenomenon, which in turn brought about changes in the biological parameters (the MCZ community structure).

Keywords: marine plankton, protist, Bay of Bengal, Indian Ocean, cyclone impact

IIOE-2 Endorsed Project No: -

[ABS-05-0326]

Vulnerability and risk assessment of coastal hazards in India: Insights from bibliometric analysis and systematic review

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Coastal systems, often exposed to multiple hazards have been identified to be at risk. Although assessment processes of comprehending the risk and vulnerability level have guided only limited action, these remain valuable tools for an 'objective' means to identify targeted areas focusing on 'particularly' vulnerable. A holistic understanding of how these assessments are conceptualised and operationalised is necessary to understand the challenges that hinder effective translation of the results into actionable decisions. The study combines two complementary methods' bibliometric analysis and systematic review' to synthesise the literature on risk and vulnerability assessment. Bibliometric analysis was used to analyse trends in publication, author and journal information, hotspot themes and their co-occurrence. A systematic literature review was done to gather specific insights on the regions of study, type of hazards studied, scale of reporting, methods and tools used, indicators used, gaps identified, policy analysis and the reported usability of the outputs. We reviewed 178 studies published between 2000 and 2024. The results report (1) nearly twofold growth in studies in the last 5 years as compared to the previous decade; (2) majority of research focused on the eastern coastal states; (3) half of the reviewed studies focused on risk or vulnerability due to multiple hazards (4) indicator-based assessments were the most commonly used method (63 %); (5) biogeophysical indicators were more commonly investigated than socioeconomic and (6) the administrative level of reporting majorly focussed on villages (37.9 %). The study also reports vagueness in definitions and conceptual frameworks. Further, most of the studies implicitly emphasised assisting in policy formulation but often failed to explicitly address the specific type or stage of the policy process. In conclusion, this study provides a comprehensive overview of the current knowledge on risk and vulnerability assessment for natural hazards in the coastal regions of India.

Keywords: Coastal hazard, Risk, Vulnerability, Socioeconomic

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[ABS-05-0012]

Impact of Noctiluca Bloom on Microzooplankton Community Structure in a Tropical Estuary (Udyavara, Karnataka)

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This study investigates the impact of a Noctiluca bloom on the community structure of microzooplankton in the Udyavara estuary, Karnataka, India, in November 2020. The Udyavara estuary, a dynamic coastal ecosystem, is periodically affected by harmful algal blooms, including those of Noctiluca. In this study, we measured parameters such as pH, salinity, dissolved oxygen (DO), biological oxygen demand (BOD), chlorophyll pigments (Chl a, b, c), total suspended solids (TSS), particulate inorganic matter (PIM), particulate organic matter (POM), and nutrient levels (nitrite, nitrate, phosphate, silicate, ammonia) across three stations: one experiencing a bloom and two without. Results from the bloom-affected station revealed elevated pH (7.350-7.410) and salinity (30.8 ppt) levels, with notably lower silicate concentrations (0.55-1.91 µgL-1) and reduced chlorophyll a (0.109-0.110 mg m^{-3}), reflecting disrupted nutrient dynamics and a decline in phytoplankton diversity. The microzooplankton community at the bloom site was dominated by Noctiluca ($0.9 * 10^5$ - $4.6 * 10^5$ No L^{-1}), leading to a significant reduction in other taxa such as tintinnids and dinoflagellates, which were nearly absent or present in very low densities ($0.4 * 10^3$ No L^{-1}). Other dinoflagellates showed a similar pattern, with higher numbers in stations unaffected by the bloom. In contrast, non-bloom stations exhibited more balanced ecological conditions, with higher chlorophyll-a levels (0.252-0.445 mg m^{-3}) and a more diverse microzooplankton community, including various species of rotifers, nauplii, tintinnids, and other dinoflagellates. These findings indicate that Noctiluca blooms significantly alter the microzooplankton community structure affecting the estuarine ecosystem's overall trophic dynamics and nutrient cycling. This study underscores the need for continuous monitoring and management strategies to mitigate the impacts of such blooms on coastal marine ecosystems.

Keywords: Noctiluca bloom, Community structure, Microzooplankton

IIOE-2 Endorsed Project No: -

[ABS-05-0275]

Tropical Cyclone Heat Potential Variability and Model Validation in the Northern Indian Ocean: Insights from Observations and Recent Extreme Events

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Accurate estimation of Tropical Cyclone Heat Potential (TCHP) is crucial for predicting the intensity of tropical cyclones (TCs) in the Northern Indian Ocean (NIO). This study validates TCHP estimates from three ocean models' the Regional Ocean Modeling System (ROMS), the Hybrid Coordinate Ocean Model (HYCOM), and the Global Ocean Data Assimilation System (GODAS) using in-situ observations from OMNI buoys and Argo floats. The integration of these datasets provides a comprehensive validation framework, addressing the limitations of relying solely on satellite-derived SST. Seasonal comparison improves understanding of each model's strengths using both OMNI buoy and Argo observations. In the first evaluation phase (January 2023-May 2024) comparison of ROMS and GODAS TCHP estimates, while the second phase (June-December 2024) compares ROMS and HYCOM with available observations. Results show that GODAS generally captures seasonal variability and absolute TCHP values more accurately, especially in the Arabian Sea, while ROMS demonstrates some skill in resolving fine-scale variability during transitional periods. HYCOM, assessed in the latter phase, exhibited improved consistency and closer alignment with in-situ observations, owing to its hybrid vertical coordinate system and assimilation capabilities. In addition to this, case studies of two cyclones-Biparjoy (June 2023, Arabian Sea) and Michaung (December 2023, Bay of Bengal) were analyzed to assess TCHP variability during extreme events. Statistical evaluation (RMSE, bias, correlation) revealed basin-specific behavior, with GODAS accurately representing cyclone-induced TCHP variations. Both cyclones showed a decline in TCHP after passage, consistent with oceanic mixing and upwelling. Challenges remain in reproducing TCHP variations in the highly stratified Bay of Bengal, underscoring the need to integrate in-situ observations for improved estimation and forecasts. As all models exhibit errors across regions and seasons, refinement is essential. This validation and event-based analysis highlights TCHP's operational role in cyclone prediction, monitoring, and risk preparedness in the NIO.

Keywords: TCHP, HYCOM, GODAS, ROMS, Argo, OMNI Buoy, Biparjoy, Michaung.

IIOE-2 Endorsed Project No: -

[ABS-05-0387]

Impact of Data assimilation in the Indian ocean wave forecasting system

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The Indian Ocean Wave Forecasting System (IOWFS), established at INCOIS, provides operational forecasts of wave fields and associated advisories, alerts, and warnings. The system employs the WAVEWATCHIII model with assimilation of significant wave height from satellite altimeters and in-situ measurements from wave rider and met-ocean buoys. A comprehensive validation was undertaken for the Indian Ocean for a period of two years from 2022-2024, with emphasis on seasonal variability across the Pre-monsoon, Monsoon, and Post-monsoon periods, as well as high swell and cyclone conditions. Comparative analyses of data-assimilated and free-run wave parameters were performed using in-situ observations (wave rider buoy, moored buoy and wave drifters). Results demonstrate significant improvements in predictive skill with assimilation, particularly during extreme events. The longer memory of swell in the assimilated model improves forecast skill during extreme swell events, thereby supporting swell surge early warnings. This study advocates the importance of wave data assimilation for the improvement of wave forecast in the Indian Ocean. By evaluating the accuracy of wave forecasts, this study supports more reliable coastal warnings and greater safety in the coastal regions of India.

Keywords: Wave forecasting, Swell surges, Data assimilation

IIOE-2 Endorsed Project No: -

[ABS-05-0003]

Impacts of Climate Induced Extreme Events on Ecosystems and Human Population in India: Necessary Mitigation Measures and Appropriate Adaptation Strategies Neede

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In India, climate induced extreme events have disastrous effects on vulnerable populations, leading to loss of life, damage to property and infrastructure, habitat destruction and severe economic damage and financial burdens in addition to major health crisis situations. These extreme events will also have severe ecosystem consequences that include coral bleaching, ocean acidification, harmful algal blooms, and deoxygenation. The occurrence of these events ranges spatially from local to basin scales and temporally from days to climatic scales. The Indian Ocean region is particularly susceptible to these extreme events, because of its unique oceanic and atmospheric circulation patterns, geomorphology and the large populations living in the coastal regions making them particularly vulnerable. Climate change is surely creating grounds for newer and more severe risks in India. Further, there are complex interrelationships and feedbacks between human driving forces and impacts, on the one hand, and climate-and sea level-induced changes and effects on the other. The ecosystems may undergo further stress from competing multi-usage demands, while having to retain their functional diversity and resilience in the face of global environmental change. Increase in the Ocean water temperature due to climate change could also adversely affect local flora and fauna of coastal areas, coral reefs, mangroves, as well as the biological equilibrium of marine life. Hence, in India, there is an urgent and imminent need to combat climate change and protect the Ocean, biodiversity and eco systems through various measures. This paper briefly discusses the adverse impacts of Climate Change on human populations, coastal and marine eco systems of India and the necessary mitigation measures and appropriate adaptation strategies needed to be taken for ensuring sustainable development.

Keywords: Coastal and Marine Ecosystems, Biodiversity, Human Health, Climate Change, Global warming, Disaster Risk Reduction and Environment Governance

IIOE-2 Endorsed Project No: -

[ABS-05-0380]

Decision Support System for Tsunami Early Warning in the Indian Ocean: Framework, Operational Procedures

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In response to the catastrophic December 26, 2004 Boxing Day tsunami, the Government of India established a comprehensive Indian Ocean Tsunami Early Warning System to monitor and forecast tsunami events, enhancing coastal safety across the nation. The Indian Tsunami Early Warning Centre (ITEWC), operational at the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, has provided continuous tsunami monitoring and advisories since October 15, 2007, serving as a critical safeguard for India's extensive 11,000 km coastline, which remains highly vulnerable to seismic tsunamis, cyclones, and related hazards. The 2004 disaster revealed profound gaps in both infrastructure and preparedness, accentuating the urgent need for robust early warning mechanisms and community engagement. Central to the Indian warning system is the Decision Support System (DSS) at ITEWC. The DSS integrates real-time data from various sensors and automatically issues alerts and advisories according to preset decision rules, leveraging seismic parameters, numerical tsunami models, and water level observations. Advisories are generated and disseminated in near real-time, classified under four threat levels'warning, alert, watch, and no threat, as per National Disaster Management Authority (NDMA) guidelines. Notably, coastal areas within 60 minutes of tsunami wave travel time from a seismic source receive automatic warnings based solely on earthquake data, while regions beyond this threshold are initially placed under watch, upgraded only after confirmation via water level instruments. This operational protocol is fortified by UNESCO-IOC's tripartite Indian Ocean Tsunami Warning and Mitigation System (IOTWMS), which advocates interconnected hazard assessment, timely dissemination, and preparedness. The ITEWC's advanced DSS framework and SOPs collectively elevate tsunami resilience, serving as a model for global coastal risk management. This paper critically examines the DSS, operational workflows, and forecasting advancements that underpin India's reinforced approach to tsunami risk reduction and community safety.

Keywords: Tsunami Early Warning, Decision Support System, Standard Operating Procedure, Tsunami Travel Time, Tsunami Resilience

IIOE-2 Endorsed Project No: -

[ABS-05-0382]

Integrated GNSS Source Parameter Estimation and Real-time Tsunami Modeling for Enhanced Early Warning in the Andaman and Nicobar Archipelago

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A comprehensive Global Navigation Satellite System (GNSS) and Strong Motion Accelerometer (SMA) network comprising 35 stations has been deployed across the Andaman and Nicobar Islands to monitor coseismic displacements arising from tsunamigenic earthquakes. This study introduces a robust methodology for rapid estimation of earthquake source parameters using advanced GNSS data processing coupled with real-time tsunami hazard assessment. The proposed approach utilizes moment tensor inversion, leveraging preprocessed GNSS time series (North/South, East/West, Up/Down) alongside station coordinates and pre-event noise characteristics from all monitoring stations. Green's functions are computed with region-specific multi-layered crustal velocity models, enabling accurate integrations for moment tensor solutions. By performing multiple centroid-based inversions and selecting optimal results through systematic misfit analysis, this methodology ensures precise parameter determination. Tsunami inundation is modeled in real-time using advanced numerical codes, achieving complete tsunami propagation and inundation simulations within five minutes for extended scenarios. Evacuation modeling is carried out for key vulnerable locations, such as Port Blair and Car Nicobar, across varied earthquake scenarios. Results emphasize the pivotal role of network station density and spatial distribution in effectively retrieving fault geometry, particularly fault length, strike, and slip. However, fine-tuning is warranted to improve the network's ability to estimate dip angle, depth, and fault width. The integrated workflow combining rapid seismic source parameter determination with real-time tsunami modeling and evacuation simulation establishes a comprehensive operational framework for tsunami early warning systems. The study recommends the adoption of this rapid moment tensor inversion methodology integrated with real-time tsunami impact modeling and evacuation exercises at the Indian Tsunami Early Warning Centre. Implementation of this approach will substantially enhance the effectiveness and timeliness of operational tsunami warning and response services for both the Andaman and Nicobar archipelago and the broader Indian coastline.

Keywords: GNSS, Tsunami Early Warning, TUNAMI, ADCIRC, evacuation

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[ABS-05-0308]

Seasonal Inhomogeneity in the Upper Ocean Thermodynamics of the Bay of Bengal to Influence the Air-Sea Interactions

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The air-sea interactions in the Bay of Bengal (BoB) are crucial as it produces a large number of tropical cyclones over the region. Moreover, the low-pressure systems over the BoB have a strong seasonal dominance. The complex upper ocean thermodynamics and mixing of the BoB have most significant influence on the air-sea interactions. This study analyzed the long-term (1982-2022) trend in the upper ocean thermodynamics and mixing using available observational and reanalysis data products which can potentially influence the air-sea exchange. Specifically, the analysis looked in to the upper ocean processes to control its feedback to the atmosphere during pre- and post-Indian Summer Monsoon (ISM) when the maximum tropical cyclones occur (23% and 66%, respectively). The results show that the surface as well as mixed layer temperature have an increasing trend during both pre- and post-ISM. But interestingly the subsurface temperature has a faster increasing rate in post-ISM (0.56°C) than pre-ISM (0.5°C) over the analysis period possibly owing to high (~15 m) barrier layer thickness. Although pre-ISM always has a deeper 26°C isotherm compared to post-ISM, the deepening (~10-15 m) of the 26°C isotherm from year 2001 onwards in both seasons might have a positive response on the increased tropical cyclone intensity during the same time. The ocean heat content and cyclone heat potential show faster increasing rate in post-ISM compared to pre-ISM. The outgoing heat fluxes over the BOB depict an easr-west variation in the post-ISM, while the variation is north-south in pre-ISM similar to the seasonal spatial pattern of cyclonic activities. Overall, the study provides a better understanding on the seasonal inhomogeneous behaviour of the upper ocean thermodynamic processes to influence the air-sea interactions and associated atmospheric extreme events.

Keywords: Bay of Bengal, Upper ocean thermodynamics, Mixed layer, Air-sea interactions, Tropical cyclone.

IIOE-2 Endorsed Project No: -

[ABS-05-0317]

Role of physical oceanographic parameters in impacting the cyclogenesis over Indian Ocean

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Tropical cyclones form over tropical regions in both hemispheres (the Northern and Southern Indian Oceans). Till now, sea surface temperature (SST) is known as the only important parameter for cyclogenesis from an oceanic point of view. Oceanic Rossby and Kelvin waves are the factors that control the variability of different parameters. The Indian Ocean produces a lot of cyclogenesis each year, which have wide social and economic impacts on the Indian subcontinent. The objective of this work is to understand different physical oceanographic parameters and their impacts on tropical cyclones in the tropical Indian Ocean. In the northern Indian Ocean, downwelling kelvin waves (dKw) manipulate the thermal structure of the ocean by affecting the thermocline depth. Due to dKw propagation, the thermocline depth increases, warms up the sea surface, and increases the oceanic heat content. It impacts the sea surface salinity (SSS) as well, which eventually drives the density to change. Both warm SST and high oceanic heat content induce cyclogenesis, though SSS does not have too much importance in cyclogenesis. A positive sea level anomaly (SLA), which is mainly influenced by downwelling Rossby waves (dRw), influences cyclogenesis by deepening the thermocline depth from October to December. The Rossby wave pattern is not clearly visible in sea surface temperature, but during August and September, a coastal kelvin wave is propagating, which is influencing cyclogenesis, We found that in the southern Indian Ocean Westward, propagating dRw significantly controls different oceanic parameters and eventually controls the cyclogenesis over this region. Further, the impact of different oceanic parameters on cyclogenesis over Bay of Bengal is reported in this study.

Keywords: Tropical Cyclone, Kelvin waves, Rossby waves, Bay of Bengal, ocean and atmosphere data

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[ABS-05-0336]

Improving Marine Weather Services through Verification of NWP Surface Wind Forecasts in the Indian Ocean

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This study evaluates the performance of surface wind forecasts from multiple operational Numerical Weather Prediction (NWP) models and their Multi-Model Ensemble. The assessment focuses on the Indian Ocean for the period 2023-2025, using a wide range of reference datasets including in-situ observations from moored buoys and ships, satellite-derived winds, and model analyses over the Indian domain. The verification highlights systematic strengths and weaknesses across the models while demonstrating the added value of the MME in improving forecast reliability. By integrating in-situ, satellite, and analysis datasets, the study provides a basin-scale assessment of forecast skill. These findings are directly relevant for marine weather services, where accurate near-surface wind forecasts are critical for issuing timely warnings to fishermen, ensuring safe navigation of ships, optimizing port operations, and safeguarding lives and property at sea. The results underscore the importance of multi-source validation in strengthening operational forecasting capacity across the Indian Ocean region. The verification indicates that most models show a positive bias of about 1-2 m/s against buoy observations, while ASCAT winds suggest slight underestimation in high-wind regimes. Ship data, although less reliable for wind speed due to overestimation, remains valuable for assessing wind direction. The MME reduces systematic errors by nearly 20-30%, enhancing forecast reliability.

Keywords: NWP, MME, Forecast verification; Indian Ocean; Buoy and ship observations; Satellite-derived winds (ASCAT); Marine weather services

IIOE-2 Endorsed Project No: -

[ABS-05-0373]

Some characteristics of rapidly intensifying tropical cyclones over the North Indian Ocean

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A tropical cyclone (TC) is a devastating coastal hazard developing over the north Indian Ocean (NIO) causing loss of lives & properties and affecting the ecosystem. Hence, it is very essential to accurately monitor and predict the genesis, track, intensity, landfall processes and adverse weather associated with TCs impacting the NIO, coastal states and the shoreline eco-system. Though, there has been significant improvement in prediction of track, intensity and landfall processes leading to 40-50% improvement in forecast accuracy in recent decade, still predicting intensity, especially the rapid intensification (RI) is a challenge. Over the North Atlantic Ocean, the RI has been defined as the change in intensity by at least 30 kt in 24 hours period and it corresponds to 95th percentile. Currently, over the NIO also same formula is used. Thus, a study has been undertaken to find out the salient characteristics of RI of TCs over the NIO based on the best track data of IMD over the period of 35 years (1990-2024). Study shows that over the NIO, 30 kt RI corresponds to 90th percentile, indicating that RI is more frequent over the NIO compared to North Atlantic Ocean. All such cases satisfying the 90th percentile of intensity change are analysed further to find out associated dynamic and thermodynamic features. Most of the extremely severe TCs (maximum sustained wind speed (90 kt) show RI over the NIO. Results indicate that RI over NIO is associated with deep convection triggered by low level relative vorticity & convergence, upper-level divergence supported by anticyclonic flow and thus low vertical wind shear of horizontal wind, higher ocean heat content based on ERA5 and CIMSS products analysis.

Keywords: Rapid intensification, tropical cyclones, North Indian Ocean

IIOE-2 Endorsed Project No: -

[ABS-05-0374]

Subsurface Structure of the Marine Heatwaves in the Bay of Bengal

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Marine Heatwaves (MHWs) in the Bay of Bengal (BoB) are becoming more frequent and intense under climate change, with major ecological and climatic implications. Using NOAA OISST (1991-2020) and Argo float profiles, this study examined 2018 MHW events with focus on two subregions: Region 1 (14°N-16°N; 88°E-90°E, high intensity) and Region 2 (6°N-8°N; 88°E-90°E, low intensity). Hovmöller analyses revealed strong MHWs between 8°N-18°N during March, May, and October, propagating west-east, with prolonged March-June events linked to solar heating and shorter October events influenced by rainfall and runoff. Vertical structure showed Region 1 characterized by high SSTs (up to 32 Â°C), deeper thermocline, strong stratification, and shallow MLDs, favoring persistent MHWs, while Region 2 exhibited weaker stratification, deeper MLDs (~74 m in June), and stronger vertical mixing, limiting intensity. Isotherm analysis indicated deeper d20 (~157 m) and stratified subsurface structure in Region 1 versus shallower, more stable profiles in Region 2. T-S diagrams confirmed freshwater-driven stratification in Region 1 and salinity-controlled mixing in Region 2. Collectively, results show that MHW intensity and persistence in the BoB are strongly regulated by subsurface structure, freshwater fluxes, and vertical mixing, with unusual June 2018 events linked to monsoon breaks and enhanced insolation. Multi-year analyses are needed to assess interannual variability and the roles of ENSO, IOD, and monsoon extremes in modulating MHWs.

Keywords: Marine Heatwaves (MHWs), Thermocline, Mixed Layer Depth (MLD), Stratification, Vertical mixing

IIOE-2 Endorsed Project No: -

[ABS-05-0375]

Identification and estimation of microplastics in the marine sample using FTIR analysis

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Plastics dumped into environment get degraded into small particles. The small plastic pieces with diameter less than 5mm are termed as Microplastics. Microplastics in seawater are harmful to both human health and marine ecosystem. Due to the growing concern regarding the environmental impact of plastic pollution, identification and quantification of Microplastics in seawater are examined in the study. Samples are collected from coastal waters adjacent to Ennore. The collected marine sample was investigated for the presence of plastics using FTIR analysis. The standard curves were given as an input to identify and classify the type of plastic available in the sample. The study identified different types of plastics from the collected sample includes Polypropylene (PP), Polyethylene (PE), High Density Polyethylene Terephthalates (HDPET), Low Density Polyethylene Terephthalates (LDPET), Polystyrene (PS), Teflon (TF), and Nylon (NL). This alarming trend underscores the pervasive characteristics of plastic pollution. It also highlights the crucial necessity for regular environmental assessment and the application of impactful mitigation solutions to reduce the global challenge.

Keywords: Microplastics, Polyethylene terephthalate, polyethylene, polypropylene, Fourier Transform Infrared spectroscopy

IIOE-2 Endorsed Project No: -

[ABS-05-0161]

Simulation of Storm Surge and Coastal Vulnerability Assessment over the Coastal Belt of West Bengal and Odisha using the high resolution CROCO ocean model

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Coastal zones are highly hazard-prone, ecologically sensitive, biologically productive, and geomorphologically dynamic, particularly when influenced by tidal surges and cyclones. These regions are particularly susceptible to extreme events, including storm surges, high tides, and waves. The coastal strip of the Bay of Bengal, particularly the head Bay area, is prone to these hazards because of its low-lying land, large river drainage systems, tidal creeks, mudflats, and barrier islands. The presence of shallow bathymetry, significant tidal ranges, and a densely populated coastline increases the potential for flooding and inundation due to storm surges. To examine regional ocean seasonal variability and the vertical structure of the water column, a high-resolution (925 m) regional ocean modeling system (CROCO) was run for an area along the eastern coast of West Bengal and Odisha. The model was initially run with climatological data to establish baseline seasonal and vertical patterns. Subsequent experiments used customized wind stress forcings to simulate cyclonic and severe cyclonic conditions, allowing assessment of the ocean's dynamic response and associated coastal impacts in the West Bengal and Odisha regions. The model generated estimates of monthly volumetric flow for these areas, and analysis identified regions along the coastal zone affected under cyclone and severe cyclone forcing scenarios, offering information on locations most exposed to significant water influx and inundation.

Keywords: Tides, Storm Surge, Inundation, Ocean Modelling, Cyclone Impact, Coastal Vulnerability, CROCO

IIOE-2 Endorsed Project No: -

[ABS-05-0247]

Intensified Coral Bleaching Events During Marine Heatwaves In the Andaman and Nicobar Coral Reef Region

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Abstract: Marine heatwaves (MHWs) prolonged periods of unusually high sea surface temperatures are intensifying with global climate change and pose a growing threat to marine ecosystems. Coral reefs in the Indian region of the North Indian Ocean are particularly vulnerable, with major bleaching episodes observed in recent decades. This study investigates the link between extreme MHWs and coral bleaching events in 2010, 2016, and 2024, focusing specifically on coral reef regions in the Andaman and Nicobar Islands. Our objective was to identify a combination of thermal stress criteria that would capture the most severe MHWs in this region and encompass all known bleaching-associated events. Using satellite-derived sea surface temperature anomalies, we analysed the spatial extent, intensity, and ecological consequences of these heatwaves. The results reveal a strong relationship between high-intensity MHWs and widespread coral bleaching, influenced by regional oceanographic conditions, cumulative thermal stress, and coral species' resilience. This research provides critical insights into the vulnerability of Indian coral reef ecosystems and underscores the urgent need for region-specific conservation strategies and climate adaptation measures to enhance reef resilience and ensure the survival of these ecosystems in a rapidly warming ocean.

Keywords: Andaman and Nicobar, coral bleaching, Indian Coral Reefs, Marine heatwaves, Mass coral bleaching, Sea surface temperature

IIOE-2 Endorsed Project No: -

[ABS-06-0188]

Linking cyclone induced physical forcing to sources of POM and phytoplankton community shifts in the Arabian sea

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The influence of Cyclone Biparjoy (June 2023) on particulate organic matter (POM) and its isotopic signatures (Î´Â¹Â³C, Î´Â¹âµN) was investigated along the EKAMSAT pilot track (11.69°S-12.53°N; 66.59°W-67.87°E) in the Arabian Sea. The cyclone-induced high wind speeds, strong wind stress curl, and surface cooling enhanced upwelling of nutrient-rich subsurface waters, resulting in elevated chlorophyll-a (Chl-a) concentrations and a diatom-dominated bloom were observed. Mixed layer depth (MLD) was shallower in the cyclone region (~38 m) and deeper in the warm pool (~65 m). The C: N molar ratios (6.42±2.7) close to the canonical Redfield ratio (6.63), indicating predominantly in-situ production in Cyclone zone. POC concentrations were (higher 7.31±3.77 µM in the cyclonic area) (lower 5.22±1.79 µM in warm pool) revealed noticeable difference. In the cyclone zone, higher Î´Â¹Â³CPOC (22.8±1.25°) and Î´Â¹âµNPN (6.05±1.48°) values corresponded to a microplankton dominated community (66-98% of phytoplankton biomass) in the mixed layer, whereas the warm pool showed lower Î´Â¹Â³CPOC (25.11±1.66) and Î´Â¹âµNPN (4.88±1.22) values associated with pico-plankton dominance (67-77%). Nanoplankton contributed 18-22.2% in the cyclone zone and 7.5-20% in the warm pool. In the cyclone impacted region, deep nitrate inputs high production, while Î´Â¹âµNPN > 7° in POM between 75-200 m depth indicated the utilization of denitrified nitrogen. The PN isotopic signatures suggest source of nitrogen is lateral advected subsurface nutrients from the western Arabian Sea. This significant impact of cyclone on POM, changes the export flux pathways in the eastern Arabian sea.

Keywords: Arabian sea, Biparjoy cyclone, Particulate organic matter, nutrients, phytoplankton

IIOE-2 Endorsed Project No: -

[ABS-06-0039]

Marine Heat Waves: Reason for Cyclogenesis in the Arabian Sea (2013-2022)

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In recent years, it has been observed that the number of cyclones in the Arabian Sea have increased. Though there are many studies on the cyclogenesis of the Cyclones and the factors that lead to the formation of cyclone, one factor that is being studied in this project is of the Marine Heat Wave. The project aims to study the relation between the Marine heat wave events that occur in the Arabian sea and the duration at the time when cyclones have taken place in the Arabian sea in those coordinates and dates. Various studies have been taken on Marine heat waves and its effects on Marine Life, Bay of Bengal, Cyclogenesis of Amphan. This project aims to compare the data taken from NOAA OI SST day mean data for the last ten years from 2013 to 2022 and calculate and filter out the marine heat wave events occurred in each coordinate of the Arabian Sea with the resolution of 1X1 deg in the latitude and longitude and compare the events with the date of occurrence of a particular cyclone in these last ten years along with its coordinates and also the date on which the lowest expected pressure was observed along with its coordinate. Though there are various other scope related to this study, this project aims to find the relation as mentioned aforesaid. Python script has been used extensively for the generation of output, plots, graphs and desired result.

Keywords: Marine Heat Waves, Arabian Sea, Cyclones

IIOE-2 Endorsed Project No: -

[ABS-05-0079]

High Impact Weather Events over the Indian Subcontinent: Meteorological Diagnosis and Socio-Ecological Consequences

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The increasing frequency and intensity of extreme weather events such as tropical cyclones, heavy rainfall episodes, prolonged droughts, and heatwaves are observed manifestations of a warming climate and evolving atmospheric dynamics. These events not only challenge the limits of forecasting systems but also lead to disruptions across natural ecosystems and human settlements. Rapid intensification of cyclones, unseasonal rainfall, and shifting monsoon patterns have led to habitat loss, change in ecosystem, and increased vulnerability of agricultural and coastal communities. This study aims to examine selected extreme weather events over the Indian subcontinent, with a focus on their synoptic/ mesoscale characteristics and correlate them with observed ecological degradation and socio-economic impacts. The paper highlights the importance of high-resolution Numerical Weather Prediction (NWP), ensemble forecasting, and improved early warning dissemination in mitigating the consequences of such events. Emphasis is placed on the role of meteorological services in not just predicting extreme phenomena, but also in supporting coordination for disaster managements and climate adaptation strategies. The findings highlight an integrated approach where meteorology informs both ecological resilience and human preparedness.

Keywords: Importance of high-resolution Numerical Weather Prediction (NWP), ensemble forecasting, and improved early warning dissemination in mitigating the consequences of high impact weather events.

IIOE-2 Endorsed Project No: -

[ABS-05-0031]

Sea surface wave during extreme weather in the coastal water off Mumbai

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Under the current scenario of weather and climate, coastal deformation has been identified as one of the prime stressors globally. The resultant sea surface disturbance generated by wind-sea and swell is a standalone factor that drastically impacts the coastal deformation on a short scale, especially during extreme weather, like cyclones. In the Arabian Sea, the frequency as well as intensity of cyclone formation are quite countable over time. The cyclone Tauktae is one of the extremely severe cyclonic storms that affected most of the coastal belt from Kerala to Gujarat along the west coast of India during 14-19 May 2021. The capital city, Mumbai, is one of the threatened zones affected significantly. Based on the in-situ observation through a wave rider buoy deployed at 10 m water depth off Versova, the half-hourly spectral density characteristics revealed that the usual significant wave height (Hsig) varied up to 1.2 m, while the maximum wave height (Hmax) was 2.8 m, which intensified to 4.7 m and 7.4 m, respectively, during Tauktae. During the cyclone phase, the waves were propagating coast at the directional bandwidth of 202.5-265.8°, having the peak period of 4-11.76 s with an average of 9.39 s. Concurrently, the half-hourly wave energy and power were rapidly raised up to 28.24*103 J/m2 and 84.76 kW/m, which is 15 and 19 times the normal sea performance in the coastal water off Mumbai. This belt is a low-lying area, and the backshore zone can be identified very sparsely. Based on the real-time sea surface wave observation, this study illustrates a high degree of vulnerability at the Mumbai coast, especially during such kinds of extreme weather conditions. Hence, a functioning early warning system is cost-effective, and issuing warnings well in advance will be highly beneficial to society.

Keywords: Cyclone Tauktae, Coastal Wave, Wave Energy, Wave Power, Coastal stressor

IIOE-2 Endorsed Project No: -

[ABS-05-0196]

Sea Surface Temperature Rise and Marine Heatwave Intensification Over Coral Reefs in the Indian Ocean

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Coral reefs are among the most diverse ecosystems globally but are increasingly threatened by rising ocean temperatures. In the North Indian Ocean, reefs remain critically understudied, with scarce long-term monitoring and limited recent coral cover data. To address this gap, we examine long-term sea surface temperature (SST) trends and marine heatwave (MHW) patterns across five key reef regions: the Andaman and Nicobar Islands, the Lakshadweep Islands, the Western Coast, the Gulf of Mannar, and the Gulf of Kutch. We analyze three SST datasets- HadISST (reconstructed), ERA5 (reanalysis), and OISST (satellite observations) to assess summertime SST trends over different periods. HadISST (123 years) revealed the lowest warming trend per decade, ERA5 (84 years) showed a higher rise, while OISST (43 years) indicated the steepest increase, highlighting accelerated recent warming linked to anthropogenic climate change. Regionally, the Gulf of Mannar showed the lowest warming trend, while the Gulf of Kutch exhibited the highest. Notably, HadISST recorded a 1.26 °C rise in the Gulf of Kutch over 123 years. MHW analysis revealed dataset-dependent differences, with ERA5 recording fewer MHW days annually than OISST. Using OISST, the Andaman and Nicobar Islands showed the greatest increase in MHW days per decade. Across all regions, the mean number of MHW days during 2015-2024 was 144.4 days in ERA5 and 203.6 days in OISST, suggesting a near semi-permanent MHW state in recent years. Our results highlight the urgency of sustained monitoring of North Indian Ocean coral reefs, as warming and intensifying MHWs increasingly threaten reef health and resilience.

Keywords: Coral reefs, North Indian Ocean, Sea Surface Temperature (SST), Marine Heatwaves (MHWs), Climate change, Anthropogenic warming, Andaman and Nicobar Islands

IIOE-2 Endorsed Project No: -

[ABS-05-0205]

Hydrodynamic Traps Amplify Coral Reef Decline in the Lakshadweep Archipelago

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The 2024 global marine heatwave triggered widespread coral bleaching across the Lakshadweep Archipelago, leading to extensive reef degradation and ecological change. This study investigates the environmental drivers of bleaching and their cascading impacts on reef ecosystems and associated human communities. Field surveys conducted in May 2025 across multiple islands, including inhabited and uninhabited sites, revealed strong contrasts in ecological responses. In Kavaratti, restricted lagoon flushing and elevated turbidity promoted post-bleaching algal overgrowth, while other islands with more dynamic circulation displayed greater resilience and maintained coral-algae balance. Hyperspectral radiometer measurements highlighted pigment-related shifts in reef reflectance, while chlorophyll-a and SST patterns corroborated local vulnerability to thermal stress and nutrient retention. By integrating in-situ and satellite observations, this study demonstrates how hydrodynamic restriction and nutrient retention intensify bleaching impacts and shape post-disturbance reef states. The findings provide a framework for assessing reef vulnerability in small island systems and highlight critical processes that should inform long-term monitoring, ecosystem management, and climate adaptation strategies.

Keywords: Coral bleaching, Marine heatwaves, Reef resilience, Algal overgrowth, Lakshadweep Archipelago

IIOE-2 Endorsed Project No: -

[ABS-05-0314]

Extreme Weather-Induced Environmental Changes and Their Impact on Marine Biogeochemistry in the Northern Bay of Bengal

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The Northern Bay of Bengal (NBoB), a cyclone-prone region of the global ocean, experiences extreme weather conditions that radically alter biogeochemical processes through intense vertical mixing, nutrient redistribution, and phytoplankton biomass changes. This study discusses the spatio-temporal distribution of nitrate (NO-), phosphate (PO-), silicate (Si), dissolved iron (dFe), and chlorophyll-a (Chl-a) due to three recent cyclones -post-monsoon Sitrang (2022), post-monsoon Hamoon (2023), and pre-monsoon Mocha (2023) from daily datasets of the Copernicus Marine Service in five hydrographic regions. Statistical comparison of the pre-, during-, and post-cyclone seasons reveals that post-monsoon events triggered abrupt Chl-a peaks of 3-4 days' duration before declining with winter transitions, while pre-monsoon conditions created gradual build-ups lasting into the monsoon. PO- and Si traced similar seasonal trajectories, while NO- and dFe built up progressively into the monsoon but dropped dramatically at landfall. Comparative analysis identifies NO- as the dominant regulator of cyclone-induced phytoplankton blooms, with increasing Si limitation during post-monsoon cyclones and severe iron limitation before the monsoon; PO- was never limiting. Biogeochemical gradients were most pronounced nearshore, reflecting the complex interaction between regional hydrography and cyclone forcing. These findings demonstrate that cyclone-induced nutrient dynamics in the NBoB are seasonally controlled, nutrient-specific, and spatially heterogeneous, emphasizing the need for sustained monitoring to predict ecological outcomes in a regime of accelerating extreme weather events.

Keywords: Tropical Cyclones, Northern Bay of Bengal, Ocean Primary Productivity, Seasonal variation, Phenology, Marine biogeochemistry.

IIOE-2 Endorsed Project No: -

[ABS-05-0063]

Historical simulation and future projection of marine heatwaves over the Northern Tropical Indian Ocean using CMIP6 models.

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Marine Heatwaves (MHWs) are extreme events of unusually high ocean temperatures threatening marine life, ecosystems and coastal communities. This study analyses MHW events and their characteristics, such as duration and intensity, over the North Tropical Indian Ocean for the historical (1982 to 2014) and future projection (2015-2100) period using CMIP6 simulations. NOAA OISST data was utilised for observational comparison. During the historical period, 50 to 90 events were detected with durations of 5 to 15 days. The average SST ranges from 27.5° to 31°C with peak SST values up to 33.5°C. Models tend to overestimate duration and underestimate the number of events, simulating longer but less frequent MHWs. Model performance was evaluated using Taylor diagrams and Taylor skill score. Based on Taylor skill score, IPSL-CM6A-LR, IPSL-CM6A-LR-INCA, and GFDL-CM4 models are considered the best performing models. Multi-model ensemble was prepared based on the three selected CMIP6 models under different SSP scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5). This reveals a near-permanent MHW state due to the occurrence of multi-year MHWs by the end of the century, by using a fixed baseline. Average SSTs range from 27° to 30.5°C (near-future) to 33.5°C (far-future). The central-west Equatorial Indian Ocean is projected to be a hotspot region with frequent, longest, and most intense MHWs. In contrast, the East equatorial Indian Ocean and Northern Arabian Sea (except the Gulf of Oman) show comparatively lower intensification in SST. The extreme scenario of far-future shows a 2.5°C increase in average SST over historical levels, with peak SST reaching an alarming value of 36.5°C, which was 3°C more than the historical maximum. All metrics, except the number of events, show an increasing trend with increasing emissions, highlighting the critical role of controlling emissions in regulating the occurrence of extreme events.

Keywords: MHW, CMIP6, Indian Ocean, Future projection

IIOE-2 Endorsed Project No: -

[ABS-05-0144]

Extreme Weather Events (EWEs) in Coastal India: Long-term Trends and mortality pattern over four decades

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This study investigates long-term trends in the occurrence of Extreme Weather Events (EWEs) and its related mortality in the maritime states of India using 42 years of data (1981-2023) from India Meteorological Department (IMD). The analysis focuses on three major EWEs: Floods and heavy rains dominate all EWEs (83%) across maritime states, with western coastal states such as Karnataka (98.27%), Kerala (95.34%), and Maharashtra (85%) being the most affected. In eastern coastal states, alongside floods and heavy rains, heatwaves (Odisha: 42%, Andhra Pradesh: 27%, West Bengal: 18%) and cyclones (Andhra Pradesh: 15%, Tamil Nadu: 11%, Odisha: 8%) are more prevalent, making them more vulnerable than their western counterparts. Andhra Pradesh, Odisha, Gujarat, and Maharashtra recorded high mortalities across these events. Floods and heavy rains were the major cause of deaths in most states, except in Odisha (cyclones), Andhra Pradesh (heatwaves), and Telangana (heatwaves). The death-to-event ratio shows cyclones are far more lethal than other events in most coastal states, while floods dominate mortalities in Karnataka and heatwaves in Telangana. Over the two 20-year periods, the percentage change in the frequency of EWEs has increased across all coastal states except West Bengal, while most saw declining mortality rates. Kerala and Tamil Nadu are exceptions, with rising mortality highlighting persistent vulnerabilities. Heatwave-related mortality has increased in recent decades across all states. Events once rare in some states have now become frequent, while others continue to experience increasing frequency due to climate change. This highlights the urgent need for state- and event-specific disaster management plans.

Keywords: Extreme weather events, Climate change, flood and heavy rains, Cyclones, Heat waves, Death to event ratio, Mortality rate

IIOE-2 Endorsed Project No: -

[ABS-05-0353]

Modelling Sediment Dynamics in the Brahmaputra River

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The Brahmaputra River is one of the most sediment-rich rivers in the world. It presents a complex challenge for sediment transport and morphodynamic modelling. The highly dynamic behaviour is characterised by rapid channel avulsion, extensive bank erosion, and a complex braided planform. The tectonically active Himalayas supply the immense sediment load exacerbated by the heavy monsoonal precipitation. Riverine communities, infrastructure, and navigational routes are all at serious risk due to the constant large-scale morphological changes caused by this sediment flux. Such extreme dynamics are frequently not adequately represented by conventional modelling techniques. Moreover, model calibration and validation are constrained by the limited availability of field measurements during monsoon-induced flood peaks, characterised by maximal sediment fluxes and morphological activity. The current study proposes implementing resilient mathematical models to model and predict sediment dynamics in the Brahmaputra River. The study aims to improve the ability to predict large-scale morphological evolution by simulating bar development, channel migration, sediment partitioning, and erosion patterns. These findings assist in evidence-based decisions to monitor flood risks, develop sustainable infrastructure and ensure safe navigability in waterways. Ultimately, the research facilitates the development of rigorous, process-oriented modelling instruments to manage one of the planet's most dynamic and sediment-laden rivers.

Keywords: Sedimentation, Brahmaputra, Sediment Transport Modelling, Inland Waterways, Navigation

IIOE-2 Endorsed Project No: -

[ABS-05-0315]

Unravelling the mystery of Tropical Cyclone Rapid Intensification: A Bibliometric and Scientometric Analysis (1982-2025)

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Rapid Intensification (RI) of tropical cyclones (TC) is one of the most challenging processes to predict even with the latest scientific understanding about TCs and technological developments in coupled modelling. The frequency of RI events in the Arabian Sea (AS) has doubled since 2013. Studies highlight that India experiences the highest number of landfalling RI cyclones among the North Indian Ocean (NIO) countries. In this review, we present a bibliometric analysis of RI literature published since 1982, using peer-reviewed studies from Scopus and scientometric visualization through VOSviewer, to understand the ongoing research trends, collaborations, and emerging themes in this field. The analysis reveals a global transition in research focus over the years from diagnosing environmental precursors such as vertical wind shear, ocean heat content, mid-level humidity, and inner-core structure using high-resolution numerical models, to the adaption of AI and ML approaches in recent years. Compared to other ocean basins, research on RI in the NIO is still in its infancy as reflected by the relatively lower number of publications identified in this bibliometric study. Additionally, recent research highlights a shift from classical RI theory toward recognizing long-lived, sustained intensification and explosive, short-lived intensification occurring even under strong shear, with climate change increasingly linked to this shift, although the exact processes remain poorly understood. Studies in the BoB have received relatively more attention, likely due to its higher cyclone frequency and socio-economic vulnerability in that basin, whereas the AS remains less studied, reflecting both fewer cyclone occurrences and limited observational data. Despite the reported progress, key gaps remain, including understanding of inner-core dynamics under multi-scale forcing, basin-specific differences that weaken model transferability and incomplete representation of airâ¿¿sea interactions and mesoscale features. The study aims to guide future research priorities, methodological advancements, and interdisciplinary collaboration in the field of TC RI.

Keywords: Tropical Cyclone, Rapid Intensification, bibliometric analysis, North Indian Ocean

IIOE-2 Endorsed Project No: -

[ABS-05-0352]

Application of Underwater Domain Awareness (UDA) to Predict Sedimentation Patterns in Indian Reservoirs

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India's ever-increasing water and energy security requires the development of dams and reservoirs. However, they face a severe threat from accelerated sedimentation, leading to a significant annual loss of storage capacity. The problem is exacerbated under tropical hydro-climatic conditions. The intense monsoonal precipitation and runoff events generate exceptionally high fine silt and clay inputs from the young, erosion-prone Himalayan catchments. The Central Water Commission predicts the effective storage of some reservoirs will diminish by over 1% annually, undermining operational efficiency and design life. Traditionally, sediment transport modelling using mathematical models has been the cornerstone of this effort. While indispensable, these models often face challenges in accurately capturing the high spatiotemporal variability of Indian river systems and require extensive, often scarce, calibration data. This study suggests an integrated Underwater Domain Awareness (UDA) based data-driven framework. A thorough, near-real-time representation of reservoir hydrodynamics and sedimentation processes is proposed. This integrated information stream can calibrate and validate mathematical sediment transport models, significantly enhancing their predictive ability and providing direct operational insights. The long-term resilience of India's vital water infrastructure could be ensured by converting reservoir sediment management from a reactive to a proactive, anticipatory strategy by combining UDA and process-based modelling.

Keywords: Sedimentation, Sediment transport modelling, UDA, Reservoir, Mathematical modelling

IIOE-2 Endorsed Project No: -

THEME-6

UNIQUE GEOLOGICAL, PHYSICAL, BIOGEOCHEMICAL, AND ECOLOGICAL FEATURES OF THE INDIAN OCEAN

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Theme-6: Unique geological, physical, biogeochemical, and ecological features of the Indian Ocean

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[ABS-06-0109]

Biogeochemistry-atmosphere processes in the Bay of Bengal: First results from the SO305 BIOCAT-IIOE2 cruise in April/May 2024

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The overarching goal of SO305 BIOCAT-IIOE2 was to quantify key (micro)biological processes in the water column and ocean/atmosphere exchange fluxes to assess their impacts on the oxygen minimum zone (OMZ) of the Bay of Bengal. To this end, we conducted a measurement campaign with the research vessel (RV) SONNE from 10 April to 22 May 2024 (SO305) as part of the BIOCAT-IIOE2 project, covering the main carbon and nitrogen cycle processes and physical processes in the water column. The oceanic measurements were complemented by an intensive atmospheric measurement program to investigate the effects of atmospheric inputs on water column processes. During SO305 the GEOMAR Helmholtz Centre for Ocean Research Kiel, the University of Hamburg, the Helmholtz Centre Hereon (Geesthacht), the Leibniz Institute for Tropospheric Research (TROPOS, Leipzig), the University of Oldenburg and the University of Southern Denmark (SDU, Odense, DK) were collaborating. A team of 39 scientists, students and technicians made measurements in the water column and in the atmosphere at 33 regular CTD stations and five 24h-stations along a cruise track from the eastern equatorial Indian Ocean to the central Bay of Bengal. The results of SO305 BIOCAT-IIOE2 will contribute to a significantly improved assessment of the future impacts of global climate change and pollution for the ecosystems and the OMZ of the Bay of Bengal.

Keywords: Bay of Bengal, OMZ, air/sea exchange

IIOE-2 Endorsed Project No: IIO2-EP07

[ABS-06-0095]

Tracing Nitrogen Cycling and Loss with Nitrate Isotopes in the Bay of Bengal and East Equatorial Indian Ocean

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Oxygen minimum zones (OMZ) play a key role in the global marine nitrogen cycle, contributing 20~40% of the total loss of bioavailable nitrogen, despite occupying only ~1% of ocean volume. The Bay of Bengal (BoB) hosts one of the most pronounced OMZ with near anoxic conditions. However, it has not yet been recognized as a site with significant nitrate reduction. Here, we present new data on nitrogen cycling from the East Equatorial Indian Ocean (EEIO) and BoB, collected during the SO305 BIOCAT-IIOE2 cruise (April-May 2024). Water column profiles of temperature, salinity, oxygen, and nutrients, alongside nitrate isotopic compositions, reveal distinct biogeochemical processes in both regions. Hydrographic data indicate limited exchange between BoB and EEIO intermediate waters at ~5°N. Nitrate isotope depth profiles varied with depth and region, influenced by water mass structure below 300 m and biological processes above. In surface waters, phytoplankton uptake led to isotopic enrichment and nitrate deficits. Regenerative nitrification dominated in subsurface layers, primarily recycling nitrogen from previously assimilated organic matter. Within the OMZ of the BoB, we identified a persistent nitrogen deficit and slightly enriched nitrate isotopes, indicating nitrogen loss, which we attributed to anammox as the dominant nitrogen loss pathway in the BoB.

Keywords: Oxygen Minimum Zone, Bay of Bengal, East Equatorial Indian Ocean, Nitrogen, Nitrate Isotopes, Nitrogen Loss, Nitrate Isotopes

IIOE-2 Endorsed Project No: - IIOE2-EP07, IIOE2-EP52

[ABS-06-0120]

Sources of suspended matter in the Bay of Bengal and the equatorial Indian Ocean

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Suspended particulate matter (SPM) was sampled at various depths along transects in the Bay of Bengal and the equatorial Indian Ocean. Large volumes of water were filtered at up to seven different water depths. The SPM on filters was analyzed for organic carbon, nitrogen and amino acids (AA) to improve our understanding of sources and degradation processes of organic matter in the SPM pool as AA are the main nitrogenous compounds in fresh organic matter of plankton and sinking particles of the epipelagic ocean. As food-sources to microbes and zooplankton, AA undergo rapid qualitative and quantitative changes with depth and time. While sinking particles show indications of degradation with water depth, the AA spectra of SPM change with increasing residence time of SPM in the ocean. This is probably due to sorption processes and exchange with the dissolved AA pool. Such changes can be traced by using biogeochemical indicators based on AA content and spectra, providing fine-tuned markers of organic matter cycling processes and SPM sources. In this study we found that significant differences in AA-based biogeochemical indicators may be related to the age of water masses. We further show that SPM from several stations in the deep Bay of Bengal originates from a sediment source, indicating resuspension or downslope transport within the channel system on the Bengal deep-sea fan.

Keywords: Suspended particulate matter, amino acids, Bay of Bengal, Equatorial Indian Ocean

IIOE-2 Endorsed Project No: IIOE2-EP52, IIOE2-EP07

[ABS-06-0123]

Unravelling the spatial variability in sedimentary phytodetrital flux in the central Arabian Sea: evidence from lipid biomarkers

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The Central Arabian Sea, a tropical basin in the northwestern Indian Ocean, experiences seasonality in surface circulation, biogeochemistry and particle flux dynamics due to monsoon winds. High primary productivity, characterised by phytoplankton blooms and associated particle flux, occurs in its northern part (above ~15°N), due to summer monsoon-induced open-ocean upwelling and winter convection. This region also hosts a thick oxygen minimum zone (OMZ), which influences composition, export and preservation of sinking organic matter. This study examines sedimentary phytodetrital variability along a north-south transect (21-11°N, 64°E) in the central Arabian Sea, utilising lipid biomarkers and identifies the key factors governing organic matter export and preservation. Satellite data analysis revealed a clear north-south variability in sea surface temperature (SST) and chlorophyll concentrations. These trends are consistent with C37 alkenone-based SST, showing cooler waters (27.6±0.25°C) in the north and warmer SSTs (28.0±0.26°C) in the south. Lipid biomarkers indicate higher contributions from dinoflagellates throughout the transect, with dinosterol and dinostanol dominating over brassicasterol and alkenones, markers for diatoms and coccolithophores, respectively. Northern stations show the highest organic carbon (0.97±0.06%), nitrogen (0.087±0.018%), and biomarker concentrations (e.g., dinosterol: 12.81±6.30â¿¯Î¼gâ¿¯gâ»Â^{1} TOC), but low cholesterol suggesting lower zooplankton. Siliceous microfossil analyses support these findings, with high diatom frustules (5.46±0.9510 valves g^{1}) and low radiolarian abundance (1.26±0.3510 individuals g^{1}). Contrarily, in the south, low phytoplankton and high zooplankton biomarkers were observed, supported by the occurrence of fewer diatom frustules (3.26±1.08 -104 valves g^{-1}) and high radiolarian abundance (1.98±0.43 individuals g^{-1}), respectively. This study thus utilises lipid biomarkers as a proxy of sedimentary organic matter to unravel the relative contributions of different plankton groups to export and preservation of organic matter in sediments in relation to surface processes.

Keywords: Organic carbon, Phytosterol, C37 alkenone, Sediments, North Indian Ocean

IIOE-2 Endorsed Project No:

[ABS-06-0126]

Present and past carbon accumulation in the northeast Indian Ocean

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The excessive release of carbon dioxide (CO2) into the atmosphere as a result of anthropogenic activities, is a major concern. The oceans help remove a significant amount of atmospheric CO2 through organic (Corg) and inorganic carbon (CaCO3) sequestration. The ocean's ability to bury carbon varies depending on several factors. We studied the factors affecting the basin scale spatio-temporal variation in carbon burial in the climatically sensitive northeast Indian Ocean, by using the data [CaCO3, Corg, Corg/Nitrogen, and isotopic ratio (Î´13C, Î´15N) of organic carbon] from a total of 718 surface sediments and 19 cores. The entire continental shelf and slope contain <10% CaCO3. The highest CaCO3 is in the deepest parts of the central northeast Indian Ocean, away from the mouth of major river systems. Despite of the high productivity, the low Corg on the continental shelf is attributed to the well-oxygenated coarse-grained sediments. The lowest Corg is found in the well-oxygenated deeper central northeast Indian Ocean. Interestingly, the highest total carbon is in the deeper central and equatorial regions, far away from the highly productive marginal marine regions. We also report that different regions of the ocean stored varying amounts of carbon, indicating a strong spatial heterogeneity in carbon burial since the last deglaciation. During the last glacial maximum (LGM), the sediments' CaCO3 content decreased in the deep sea but increased on the shelf. The opposite was true for Corg burial patterns, with values higher than recent throughout the LGM, and the highest Corg content during LGM. Marginal seas' carbon burial changes were mainly influenced by monsoon-induced productivity, sedimentation rate, sediment texture, and dissolved oxygen concentration. On the other hand, water mass changes primarily drove carbon burial in deeper regions. The findings will help in assessing the carbon burial potential of this region in the warming world.

Keywords: Carbon, calcium carbonate, Indian Ocean, sediments

IIOE-2 Endorsed Project No:

[ABS-06-0232]

Spatial Distribution and Isotopic Signatures of Particulate Organic Carbon in the Western Indian Ocean and Their Interannual Variability

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The particulate organic carbon (POC)produced by primary producers in the surface ocean through atmospheric CO2 uptake, plays a central role in the biological carbon pump and is closely linked to vertical carbon fluxes. The Seychelles-Chagos Thermocline Ridge (SCTR) in the tropical western Indian Ocean is an open-ocean upwelling system with relatively high productivity, making it an important area for studying biogeochemical and carbon cycles. However, studies on POC in this region remain scarce. We investigated POC concentrations and stable carbon isotopes (Î´Â¹Â³C) in the western Indian Ocean (65°E, 5°N to 65°E, 20°S) in 2023 and 2025 to examine spatial distribution patterns and source variations. POC concentrations ranged from 12.8 to 57.8 Î¼g Lâ»Â¹, with higher values in the SCTR. Î´Â¹Â³C values ranged from 20.0 to 25.0. In 2023, a strong upwelling in the SCTR core produced higher POC concentrations, enriched Î´Â¹Â³C values, and lower C/N ratios, indicating enhanced productivity and contributions from fresh marine organic matter. In contrast, weaker upwelling year led to reduced POC and PN, lighter ^{13}C signatures, and slightly higher C/N ratios, suggesting lower productivity and degraded organic matter. These results indicate that variations in upwelling intensity control both concentration and source of POC in the tropical Western Indian Ocean.

Keywords: POC, SCTR, Stable carbon isotope

Endorsed Project: - IIOE2-EP51

[ABS-06-0189]

Phytoplankton dynamics in the Eastern Indian Ocean: physiological and genetic diversity and remaining challenges

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One of the key remaining scientific issues on marine food-web and biogeochemical cycles is the mechanisms of phytoplankton dynamics in oligotrophic oceans. The broad area of the planet is characterized by high temperature and low nutrient concentration, also known as ocean desert. Most global ecosystem models reproduce the region as a stable system with small variations in nutrient and phytoplankton concentration. However, recent monitoring studies revealed that the area showed large seasonal and annual variations in phytoplankton composition and productivity, which influence the biological carbon pump, stoichiometry, and production of higher trophic levels. We do not have enough knowledge to explain the variations. The eastern Indian Ocean is one of the oligotrophic regions on the planet. We conducted a meridional research cruise on board R/V Hakuho Maru along 88°E from the Bay of Bengal to the southern Indian Ocean and examined phytoplankton community structure, functional genes of Prochlorococcus, and their physiological response to nutrient supply. As expected, physical oceanographic perturbations, such as the Wyrtki Jet and mesoscale eddies, influence the nutrient supply and phytoplankton biomass. One surprise was the growth of phytoplankton, especially for Prochlorococcus, was not limited by nutrients even depleted nitrogenous nutrients throughout the region. We also found the size, division rate and chlorophyll production rate were highly variable along the transect. Shotgun genome sequencing of Prochlorococcus revealed the significant difference in functional gene composition, such as nitrate/nitrite reduction and iron complex transport along the transect. The present study shows that the Eastern Indian Ocean is not uniform at all in terms of the functional composition of phytoplankton and biogeochemical cycles. In the presentation, we will compare the ecosystems in the Eastern Indian Ocean and the Pacific Ocean and discuss the remaining issues in order to understand the dynamics of oligotrophic ecosystems.

Keywords: nutrient, phytoplankton, Prochlorococcus, biogeochemical cycle

IIOE-2 Endorsed Project No: - IIOE2-EP36

[ABS-06-0125]

Patterns of Dinoflagellate Vertical Descent in the Indian Ocean: Distribution, Diversity, and Ecological Factors

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Dinoflagellates, key primary producers with diverse trophic strategies, remain unexplored beyond the epipelagic zone (0-200m). This study gives an account of the dinoflagellate vertical descent into various pelagic zones- epipelagic (0-200m), mesopelagic (200-1000m), bathypelagic (1000-4000 m) and abyssopelagic (>4000m) in the north eastern Indian Ocean (NEIO) and south tropical Indian Ocean (STIO). Using vertical hauls with multiple plankton nets (MPN), 156 microphytoplankton taxa (>100µm) were recorded, 83 species (53.2%) of which were dinoflagellates, with 20 autotrophic, 39 mixotrophic, 20 heterotrophic dinoflagellates (ATDs, MTDs, HTDs) and one unidentified species. These included 16 cyst-forming species, 69 thecates, 13 athecates and nine symbionts. Genus Tripos exhibited the highest diversity (36 species). Dinoflagellate abundance and diversity were highest in the epipelagic zone (77 species) and declined sharply with depth: mesopelagic (18), bathypelagic (13), and abyssopelagic zones (4). Of the epipelagic dinoflagellates, only a small portion descended deeper: in NEIO, 3.7% and 1.1% descend to the meso- and bathypelagic zones, respectively, whereas in STIO, 13.9%, 3.9% and 1.3% descend to the meso-, bathy- and abyssopelagic zones. Vertical patterns revealed dominance of athecate and thecate dinoflagellates in the epipelagic; athecate sharply declined below the epipelagic, and was completely absent in the abyssopelagic. Only structurally and physiologically adaptable taxa reached the deepest layer. Symbiotic dinoflagellates were limited to the epipelagic, possibly due to a symbiotic depth barrier and reliance on photosynthetic symbionts requiring light. Overall, descent through the water column is filtered by environmental (temperature, salinity, light intensity, density) and biological factors such as grazing. They select dinoflagellate taxa based on their morphological and ecological traits. This 'Pelagic Zone Filtration' limits the descent of delicate and morphologically complex species. This study highlights the dinoflagellate descent pattern and the supporting factors influencing them to descend to deeper depths of the IO.

Keywords: Dinoflagellates, Indian Ocean, pelagic zone, thecate, athecate, symbionts, pelagic filters

IIOE-2 Endorsed Project No:

[ABS-06-0058]

A preliminary study on the distribution and diversity of Rhizarians in the Arabian Sea

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Rhizarians are a diverse group of unicellular eukaryotic protists, including major groups such as Phaeodaria, Foraminifera, Acantharia, Taxopodida, and Polycystinea, in the marine environment. They build complex mineral skeletons with biogenic silica and strontium sulphate. In epipelagic and mesopelagic zones, they regulate carbon, silicon and strontium cycling, contributing notably to organic carbon stocks and biogenic silica pools in the world's oceans. In some oligotrophic environments, mixotrophic rhizarians surpass copepods in abundance, dominate zooplankton communities, and play a major role in carbon and silicon cycling (Davies et al., 2022). In the Arabian Sea, Rhizarians play an important role in the water column. There are a few studies targeting this group. The studies have shown that these can form large colonies, exhibit high diversity, and significantly contribute to plankton biomass and carbon flux, especially in regions with oligotrophic conditions (Gowing et al., 2003; Biard et al., 2016; Das et al., 2019; Xiawen et al 2023). NGS analyses indicate that rhizarian are the major parts in the sub-surface waters of central and eastern Arabian Sea (Das et al., 2019). There are very limited research regarding the diversity, distribution of rhizarians in the water column of different regions of the Arabian Sea. This article gives an overview of the previous studies and some preliminary results on the Rhizarians of the central and eastern Arabian Sea with a focus on their diversity and abundance.

Keywords: Protists, Indian Ocean, Cercozoa, Retaria

IIOE-2 Endorsed Project No:

[ABS-06-0129]

Embarking on a diatom odyssey: Insights from a systematic study across pelagic zones in the equatorial and south tropical Indian Ocean

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Diatoms, prominent microbial eukaryotes, contribute ~40% of marine primary productivity and are central to the Biological Carbon Pump. Yet, their ecological dynamics and mechanistic drivers beyond the euphotic zone (~200 m; ~4.5% of ocean volume) remain poorly understood despite their role in carbon export. This first systematic, depth-resolved survey of >100µm diatom communities across epipelagic, mesopelagic, bathypelagic and abyssopelagic layers in the understudied Equatorial (EIO) and South Tropical Indian Ocean (STIO), incorporating gradients of island proximity and bathymetry. Diatom abundance declined steeply (85-95%) from epipelagic to bathypelagic and by up to 99% in the abyssopelagic; nevertheless, mesopelagic species richness was retained (36-270% of surface values), supporting the existence of deep-sea 'seed banks' and functional diversity reservoirs. Strong morphological filtering favours cylindrical frustules in deeper zones, optimising sinking and export potential. Community structure was regionally distinct: EIO-A1 (shallower, 1,500 m) hosted higher diatom abundance than EIO-A2 (4,000 m) despite similar proximity to land, implicating bathymetric enhancement of nutrient advection and the island mass effect as key assembly drivers. Remarkably, in the STIO-A, weak upper-ocean density stratification facilitated rapid sinking and a mesopelagic biomass trap, producing higher mesopelagic than surface abundance pattern not observed in regions with stronger density gradients. Distinct taxa dominated different zones (e.g., *Climacodium frauenfeldianum* epipelagic, *Chaetoceros coarctatus* bathypelagic, *Asterolampra marylandica* abyssopelagic), indicating niche partitioning along depth and trait axes. These findings reveal a crucial interplay among frustule architecture, hydrography, and loss processes (grazing, degradation) in structuring diatom-mediated carbon export across pelagic strata, advancing mechanistic understanding of vertical microbial ecosystem function.

Keywords: Diatom sinking, Seed bank, Density, Bathymetry, shapes

IIOE-2 Endorsed Project No:

[ABS-06-0283]

Seasonality and spatial distribution of secondary chlorophyll maxima in the Arabian Sea based on BGC-Argo Data

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The Arabian Sea (AS) is a vital component of the Indian Ocean, playing a crucial role in regional climate patterns and ocean dynamics. The AS is one of the highly productive regions in the world's oceans, characterized by an intense OMZ in its subsurface depths. Apart from the primary chlorophyll maxima, a secondary chlorophyll maximum (SCM), mainly contributed by picoplankton, *Prochlorococcus*, was also reported in the AS. Mostly, the SCM was reported in the southern boundary of the AS OMZ, mainly during the northeast monsoon (NEM) season. Here, we use biogeochemical data from the Argo floats deployed from 2013 to 2025 to find the seasonal variability and spatial distribution of SCM in the AS, and also to understand the factors responsible for its occurrence. By investigating 438 profiles having a SCM, our study indicates that it mostly occurs during the NEM and spring inter-monsoon (SIM), but also appears during the Southwest monsoon (SWM). Spatially, these peaks were found not only at the southern boundary of the AS OMZ, but it was also present throughout the OMZ. Based on two case studies on BGC floats in the AS, it was found that the SCM forms just above the upper boundary of the OMZ. It's also noticed that the occurrence or disappearance of SCM in the AS is mostly linked to the shoaling or deepening of the upper boundary of OMZ. The SCM is well developed when the upper boundary of the OMZ is shallow, and under optimum light and secondary nitrite availability, *Prochlorococcus* probably proliferates. This was also validated with insitu water column data on picoplankton and marker pigments. Overall, our results confirm the presence of SCM as a consistent and dynamic feature of the AS and warrant further studies on its role in carbon transfer and feedback to the OMZ.

Keywords: Secondary Chlorophyll Maxima, Arabian Sea, BGC-Argo Data, Marker Pigments, OMZ

IIOE-2 Endorsed Project No:

[ABS-06-0342]

Integrating Phytoplankton Photo-Physiological Metrics into Indian Ocean Monitoring: Insights from Fast Repetition Rate Fluorometry in the Arabian Sea

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Phytoplankton's physiological responses to changes in environmental conditions serve as critical indicators of marine ecosystem health and resilience across the Indian Ocean (IO). This study employs active fluorometry to assess key physiological parameters-variable fluorescence (Fv=Fm-F0), photosynthetic efficiency (Fv/Fm), and functional absorption cross-section, providing insights into phytoplankton stress responses and ecosystem condition. These photophysiological metrics are influenced by multiple environmental factors, including temperature, salinity, irradiance, and nutrient availability, alongside anthropogenic stressors, necessitating integrated temporal analysis to elucidate underlying physiological mechanisms. While extensive research has documented phytoplankton biomass, productivity, and taxonomic composition throughout IO, systematic assessments of their physiological status remain critically limited. Recent investigations utilising Fast Repetition Rate Fluorometry have significantly advanced understanding of phytoplankton physiological dynamics in monsoonal estuaries and various regions of the Eastern Arabian Sea (from north to south and from coast to ocean). The findings reveal that phytoplankton in the open ocean and coastal areas exhibit spatial variations in photosynthetic efficiency. Notably, frontal zones demonstrate higher photosynthetic efficiency compared to non-frontal regions, attributed to enhanced nutrient availability and optimal light conditions. In contrast, monsoonal estuaries display marked seasonal patterns in photosynthetic performance, directly correlated with monsoon-driven discharge and related environmental changes. Consistent with global oceanic observations, Arabian Sea phytoplankton communities operate at approximately half of the theoretical maximum photosynthetic efficiency (Fv/Fm-0.65), reflecting regional oceanographic adaptations. Environmental variability, along with pressures like coastal eutrophication and pollution, significantly affects phytoplankton physiology and ecosystem functioning. The emergence of mixotrophic species such as Noctiluca scintillans further highlights the need for ongoing monitoring. The study emphasises integrating physiological scaling metrics into routine monitoring frameworks to effectively capture responses to variable monsoon systems, climate variability, and intensifying anthropogenic pressures. This approach provides essential early-warning capabilities for detecting ecosystem stress and supports evidence-based management of marine resources in IO under changing environmental conditions.

Keywords: Phytoplankton, Photosynthetic Efficiency, Fast Repetition Rate Fluorometry, Arabian Sea, Monsoon Dynamics, Ecosystem Monitoring

IIOE-2 Endorsed Project No:

[ABS-06-0062]

How do eddies influence zooplankton communities in the Southwest Indian Ocean?

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Zooplankton communities globally are strongly influenced by temperature and food availability. On a local scale, these patterns may be moderated by oceanic features such as upwelling and mesoscale eddies. Here, we review three case studies of how eddies influence zooplankton biomass and diversity in the Southwest Indian Ocean, in the Mozambique Channel, off southern Madagascar, and off the Agulhas Bank. Mesoscale eddies that propagate southwards in the Mozambique Channel play a fundamental role in shaping the pelagic ecosystem through the concentration, enhanced growth and redistribution of zooplankton communities. Zooplankton assemblages in anticyclonic and cyclonic eddies showed a high degree of taxonomic homogeneity, but biovolume was on average 55% greater in cyclonic (cold-core) eddies than in anticyclonic (warm-core) eddies during four cruises from 2007-2010. This was likely due to upwelling in the cyclonic eddies enhancing nutrient concentrations, primary production and food availability, and hence increased zooplankton production. Interaction of large anticyclonic eddies with the shelf can also lead to entrainment and advection of shelf biomass, supplementing offshore feeding conditions for higher trophic-level predators. DNA barcoding of meroplankton within a cyclonic eddy off the southern shelf of Madagascar in 2013 indicated dominance by taxa of coastal origin, supporting the 'suitcase hypothesis' that planktonic organisms are entrained within eddies as they propagate south-westwards of the Madagascan shelf. Higher abundance of dinoflagellates within the eddy compared to the shelf suggests this community was enhanced through upwelling in the eddy core. Lastly, DNA metabarcoding of zooplankton within a cyclonic eddy off the Agulhas Bank in 2022 indicated that species trapped within the eddy were transported southwards from the Western Indian Ocean within the Agulhas Current and were also entrained from the Agulhas Bank.

Keywords: SWIO, mesoscale eddies, zooplankton biomass and diversity, DNA barcoding and metabarcoding, connectivity

IIOE-2 Endorsed Project No: IIOE2-EP04, IIOE2-EP26, IIOE2-EP57

[ABS-06-0040]

ADCP-derived backscatter as a zooplankton proxy

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We demonstrate the potential of acoustic Doppler current profiler (ADCP) backscatter measurements for generating continuous, high-resolution time series of zooplankton biomass. Data were acquired from ADCP moorings deployed at seven continental slope locations in the eastern Arabian Sea (EAS), compiling a robust data set spanning October 2017 to December 2023. The methodology involves the conversion of raw ADCP backscatter signals into zooplankton biomass in two major steps. First, we obtain the backscatter from echo intensity. Second, we convert the backscatter to biomass using a regression relationship between ADCP-derived backscatter and volumetric zooplankton samples collected via net hauls near the mooring sites. This sampling was conducted at all mooring locations over several years during each ADCP servicing cruise. Analysis of data across depths ranging from 24 to 140 m consistently indicated a decline in both backscatter intensity and zooplankton biomass with increasing depth, but the rate of decrease varies along the slope. A key finding from these ADCP data is the pronounced intraseasonal variability (periods of 30-90 days) in zooplankton biomass; the variability in this period band is particularly evident during August- November though only for a few years. The range of this high-frequency variability is comparable to and often exceeds that of the seasonal cycle of the zooplankton biomass and standing stock. Interannual variations (periods > 400 days) are observed with higher intensity in the southern EAS. Neither the rapid shifts, nor the longer year-to-year variations can be effectively determined by traditional, intermittent sampling methods over a large domain. This methodology marks a significant advance for environmental monitoring and assessment, offering insights into the marine ecosystem. Just as satellite chl-a measurements have changed the way we study phytoplankton dynamics, acoustics can change the way we study zooplankton dynamics.

Keywords: ADCP backscatter, moorings, zooplankton sampling, multiple plankton net, intraseasonal variability

IIOE-2 Endorsed Project No:

[ABS-06-0142]

Exploring the Distribution and Community Structure of Microzooplankton in the Indian Ocean during spring inter-monsoon: Insights from Surface and Chlorophyll Maxima Samples

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Microzooplankton (MZP) represent the most diverse group within the marine ecosystem, serving as the vital link between traditional and microbial food webs while playing a pivotal role in the energy flow and nutrient cycling. The present study addresses the distribution and community structure of MZP across 22 stations in different regions of the Indian Ocean (IO) â¿¿ northeastern Indian Ocean (NEIO), equatorial Indian Ocean (EIO), southeast (SETIO), and southwest (SWTIO) Tropical Indian Ocean. Samples were collected from both surface waters and the chlorophyll maxima (Cmax), which demonstrated significant regional depth variations ranging from 45 to 135 meters. Cmax was found to be shallower in the NEIO (43-75 m) compared to the SETIO (115-135 m). In this study, MZP were classified into Copepod nauplii, Heterotrophic dinoflagellates (HTD), Tintinnid (Loricate ciliates), Aloricates, Foraminifera, Pheodaria, and Radiolarians. Altogether, 271 MZP species were recorded, among them 135 were radiolarians, 107 were tintinnids, and 29 were HTD. Radiolaria and tintinnids were highly diverse, evidenced by the Shannon-Wiener diversity indices of 2.57 ± 0.20 and 2.54±0.36, respectively. MZP abundance varied between 7.2 and 107.8 ind/L. The MZP abundance was greater in the Cmax (Avg: 59.78 ±23.32 ind/L) than in surface water (45.1 ± 23.23 ind/L). Surface water across all regions was dominated by HTD (28-69%), followed by copepod nauplii (13-22%), tintinnid (9-23%), and radiolaria (5-28%). In contrast, the community structure in the Cmax showed regional variation. In NEIO and SWTIO copepod nauplii (32% and 27% respectively) form the dominant group, meanwhile, the EIO is dominated by HTD (40%), whereas tintinnid (33.5%) in the SETIO. This study enhances our understanding of MZP community distribution in IO and contributes to ongoing research in the diversity and biogeography of microzooplankton.

Keywords: Microzooplankton, Chlorophyll maxima, Surface water, Diversity, Distribution, Indian Ocean

IIOE-2 Endorsed Project No:

[ABS-06-0231]

Jellyfish diversity and niche partitioning during a scyphozoan swarm in the coastal Bay of Bengal: interactions and environmental drivers of coexistence

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Jellyfish swarms are ecologically dynamic but remain poorly studied in terms of diversity, interactions, and environmental drivers, especially in tropical monsoonal regions like the Bay of Bengal (BoB). This study explores jellyfish assemblages and ecological interactions during a Pelagia noctiluca swarm in the coastal BoB during the southwest monsoon, focusing on how environmental factors and trophic dynamics shape jellyfish and mesozooplankton (MZ) assemblages. Hydrographical data revealed non-significant variations in water temperature and salinity between the shallow coastal zone (SCZ) and deep coastal zone (DCZ). Elevated nutrient concentrations in the DCZ sustained dense P. noctiluca swarms. Dissolved oxygen (DO) levels were lower in the DCZ, likely due to metabolic oxygen consumption by larger jellyfish taxa. MZ abundance was notably higher in the DCZ (1208 ± 150 ind./m^3) than in the SCZ (916 ± 95 ind./m^3), exerting top-down trophic pressure that lowered chlorophyll a (Chl a) concentrations in the DCZ, while the SCZ exhibited higher Chl a levels. A total of 30 jellyfish species were identified, including Hydromedusae (11 species), Siphonophorae (13 species), Scyphozoa (1 species), and Ctenophora (5 species), making this the first comprehensive documentation of jellyfish diversity during a scyphozoan swarm in the BoB. Niche partitioning played a key role in jellyfish coexistence, easing competition and predation. Smaller taxa like hydromedusae and siphonophores dominated the SCZ, while larger ctenophores and scyphozoans were more common in the DCZ. P. noctiluca swarms notably influenced jellyfish assemblage patterns and trophic dynamics, with broader implications for pelagic food webs, nutrient flow, and fisheries.

Keywords: Ctenophora, Hydrozoa, Marine Ecosystems, Pelagia noctiluca, Scyphozoa, Taxonomy.

IIOE-2 Endorsed Project No:

[ABS-06-0377]

Potential of optical and ecological proxies to quantify phytoplankton carbon in oligotrophic waters

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Satellite ocean color observations provide two proxies to estimate the phytoplankton carbon concentration, Cphyto, then used as input to models quantifying growth rates and primary production, namely the phytoplankton chlorophyll-a concentration, Chl-a, and the particulate backscattering coefficient, bbp. Variability in phytoplankton community composition, pigment assemblages and contribution of non-algal material all interplay in the relation between these proxies and Cphyto, so that no ubiquitous relationship exists between them. It is accordingly still unclear which of Chl-a or bbp is best suited to quantify Cphyto, or whether they both are yet each in specific trophic conditions, especially for low-productivity oligotrophic waters. Here we use a data set from the eastern Indian Ocean that includes phytoplankton cell counts, phytoplankton pigments, particulate organic carbon (POC) and inherent optical properties (IOPs) to perform a comparative assessment of Cphyto derived from either Chl-a or bbp or cell counts combined with allometric relationships. We found significant correlations ($r2 > \sim 0.5$-0.6) between the three Cphyto estimates and IOPs, Chl-a or POC when samples from all depths down to 150 m are included. When only the top 25 m are included (amenable to ocean color remote sensing), no significant relationships were found, except between the cytometry-derived Cphyto and both Chl and POC. The bbp-derived Cphyto showed the smallest variability across the entire data set. These results warn about applying to satellite ocean color observations relationships derived from data collected throughout the euphotic layer.

Keywords: Phytoplankton carbon; Particulate organic carbon; Inherent optical properties; Indian Ocean; IIOE2

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[ABS-06-0024]

Occurrence of cetaceans and seabirds along the Indian Ocean 110 ^{0}E meridian from temperate to tropical waters

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The aim of this study, as part of a large number of related studies, was to examine the occurrence of cetaceans and seabirds along the 110E meridian from temperate to tropical waters (39.5-11.5S). Cetaceans and seabirds were actively scanned for across a four-week period spanning austral autumn to winter. Acoustic recordings of vocalising cetaceans were made using directional and omnidirectional sonobuoys (n = 87 deployments). In total, seven cetacean sightings, 186 seabird sightings and 225 cetacean acoustic detections were recorded. Pygmy blue whales were detected across Subantarctic to Tropical Surface Waters, and were the most commonly detected cetacean. There was some delineation in other cetaceans: the spot call was detected in Subantarctic and Subtropical Surface Water (south of 23â¿¦S); fin whales in Subtropical Surface Water (between 23 and 30.5S); and Antarctic minke whales in Tropical Surface Water (between 14â¿¦ and 23S). Data were not collected on cetaceans during IIOE-1, so data here represent baseline occurrence along 110E for future studies. A total of 22 seabird species were sighted, including, petrels, albatrosses, tropicbirds, terns, shearwaters, boobies, frigatebirds, gannets, gulls, skuas and prions. Soft-plumaged petrels (*Pterodroma mollis*) were observed across all water masses and were the most commonly sighted seabird. There was some delineation of seabird species; albatrosses were sighted south of the Subtropical Front (south of 32S); flesh-footed shearwaters (A*rdenna carneipes*) in Subantarctic and Subtropical Surface Waters (south of 27S); and tropicbirds in Tropical Surface Water (north of 20S). The occurrence of highly mobile species is particularly important to investigate as the waters in the eastern Indian Ocean have been warming faster than in the Pacific and Atlantic Oceans.

Keywords: Whales, seabirds, Indian Ocean, acoustic detection

IIOE-2 Endorsed Project No: IIOE2-IN2019_V03

[ABS-06-0089]

Hydrothermal Activity along the Southwest Indian Ridge: Capturing a Massive Volcanic-Hydrothermal Episode at an Ultraslow-Spreading Ridge (67.7Â°E)

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Ultraslow-spreading ridges (full spreading rate <20¯mm/year) have traditionally been regarded as magma-starved systems, characterized by limited, discontinuous, and spatially localized volcanic activity. However, recent evidence from the Indian Ocean reveals that large-scale magmatic and hydrothermal events can also occur along these slowest-spreading ridge systems. Water column surveys were conducted along a ~600 km segment of the eastern Southwest Indian Ridge (SWIR) between 63°E and 69°E from 2014 to 2020. Using conductivity-temperature-depth (CTD) profilers equipped with turbidity and oxidation reduction potential (ORP) sensors, multiple hydrothermal plumes were identified, including an unusual large and anomalous event near 67.7°E, located directly above an axial volcanic ridge. This site showed evidence of a major magmatic - hydrothermal episode between 2017 and 2020, temporally linked to a seismic swarm event during September-October 2018. Post surveys revealed a thick, vertically stratified hydrothermal plume spanning 2300-4600¯m water depth. The plume exhibited strong turbidity anomalies (up to 0.35 NTU), temperature-salinity deviations, and coherent ORP anomalies indicative of intense hydrothermal discharge likely driven by lava eruption and subsequent cooling. The vertical thickness of the plume (~2 km), with distinct layering centered near 3300m, and an along-axis dispersion exceeding 160 km, highlights the exceptional scale of this event - comparable to rare, large hydrothermal plumes observed over mid-ocean ridges since 1987. The spatial and temporal correlation between the seismic activity and the plume supports a magmatic origin, involving lava effusion rather than diking alone. These findings demonstrate that significant volcanic and hydrothermal processes can occur even at ultraslow-spreading ridges, with broad implications for seafloor accretion, chemical fluxes, and hydrothermal ecosystems.

Keywords: Ultraslow spreading ridge, water column anomalies, hydrothermal event plume, earthquakes

IIOE-2 Endorsed Project No:

[ABS-06-0204]

Geochemistry of basement lavas in the Laxmi Basin, NW Indian Ocean: Implications for regional tectonics in South Asia during Late Cretaceous

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The Laxmi Basin is a prominent geomorphic feature and a marginal depression in the Northwest Indian Ocean. This ~300 km wide basin separates the western Indian continental margin from the Laxmi Ridge (LR), which is believed to be continental. The exact nature of the basin's basement remains debated, with different views suggesting it to be either a stretched continental crust with continental rift-related magmatic intrusions or a pre-Paleogene oceanic crust. Additionally, a geochemical study of the basin's igneous rocks, collected during IODP 355, proposes that these rocks formed in a subduction zone setting. Here, we present new geochemical and Nd-Sr-Pb isotopic data for the basaltic lava samples from this basement, recovered during IODP 355, to settle the controversy. The Primitive Mantle (PM)-normalized multi-element and chondrite-normalized rare-earth-element (REE) patterns of the lavas resemble those of typical mid-ocean ridge basalts (MORB). Their Nd and Sr isotopic compositions (ÎµNd(t) = +5.6 to +6.2 and 87Sr/86Sr(t) = 0.7037 to 0.7039 at t = 72 My) fall within the depleted quadrant and overlap with those of present-day Central Indian Ridge (CIR) field on the ÎµNd vs. 87Sr/86Sr diagram. Pb isotopic compositions (206Pb/204Pb = 17.571 to 17.944, 207Pb/204Pb = 15.469 to 15.674, and 208Pb/204Pb = 37.391 to 38.141) are also similar to CIR and preclude significant involvement of crustal materials. They are distinctly different in chemistry from the Deccan flood basalts and Reunion hotspot lavas. All our findings point to the presence of an MORB basement (oceanic crust) beneath the Laxmi Basin, making it a paleo- or extinct MOR. Considering earlier geophysical results, we infer that the formation of oceanic crust in the Laxmi Basin was driven by pre-Deccan rift-to-drift tectonics. The spreading in the basin likely ceased, possibly due to the separation of Seychelles and LR that led to the formation of the Carlsberg Ridge.

Keywords: Laxmi Basin, IODP, geochemistry, Nd-Sr-Pb isotopes, mid-oceanic ridge

IIOE-2 Endorsed Project No:

[06-0022]

Analysis of Gravity Data Over the Central Indian Ridge Between 3oS and 11oS, Indian Ocean

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Detailed gravity investigations using the shipboard gravity data over the Indian Ocean ridges are sparse especially over the slow spreading Central Indian Ridge and Carlsberg Ridge systems. Shipboard gravity and multibeam bathymetry data over a 750 km long section of the Central Indian Ridge has been analysed to understand the crustal structure and the ridge segmentation pattern. Computed mantle Bouguer anomaly (MBA) and residual mantle Bouguer anomaly (RMBA) have shown significant variations along the ridge segments that are separated by transform and non-transform discontinuities. MBA lows have been observed over the linear ridge segments bounded by well-defined transform faults and these are attributed to the thickening of the crust at the middle portions of the ridge segments. The two non-transform discontinuities have shown MBA highs suggesting crustal thinning. MBA and relative RMBA highs have also been observed over the transform faults. The identified megamullion structures have relative MBA highs suggesting thinner crust. The most significant MBA and RMBA highs were observed over the Vema transform fault suggesting anomalously thin crust over the Vema transform fault where the depth reached to 6350 m. Besides the MBA lows along the ridge axis, significant off-axis MBA lows have been noticed suggesting off-axis mantle upwelling zones indicative of thickening of the crust. The rift valley morphologies vary from the typical V shaped valley to the shallow valley floor with undulations on the inner valley floor. Segments with shallow rift valley floor have depicted well defined circular MBA lows with persistent RMBA low, suggesting modulation of the valley floor morphology due to the variation in crustal thickness and the mantle temperature. These are supported by thicker crust and weak mantle lithosphere.

Keywords: Gravity, Central Indian Ridge, mantle Bouguer anomaly, Crustal structure, Segmentation

IIOE-2 Endorsed Project No:

[ABS-06-0069]

The imprint of tectonics on observed sea-level rise in the Indian Ocean

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The islands of the Maritime Continent are highly vulnerable to sea-level rise driven by a range of barystatic and sterodynamic processes. The region also sits astride a complex network of active tectonic boundaries, and deformation along these boundaries produces vertical displacements of the seafloor and gravitational field perturbations, altering sea surface height (SSH). However, the long-term impact of tectonics on SSH has not been identified in SSH observations due to the difficulty of disentangling this signal from other processes. We decompose satellite observations of SSH change during 1993-2021 into ocean sterodynamic changes, sea-level fingerprints originating from contemporary mass redistribution between ocean and land (GRD effects), and glacial isostatic adjustment (GIA), using model predictions for each component. Our results reveal a persistent SSH anomaly along the Sumatra-Andaman subduction zone that cannot be attributed to sterodynamic or GRD/GIA processes. This anomaly is coincident with long-term GRACE-derived geoid height changes near the rupture zone of the 2004 M9.1 Indian Ocean Earthquake. These findings present the first observational evidence of tectonic activity modulating regional SSH trends and highlight the necessity of integrating tectonic effects into future sea-level projections for seismically active regions.

Keywords: Sea-level rise, sterodynamic changes, GRD fingerprints, Subduction tectonics, Sea-level projections

IIOE-2 Endorsed Project No:

[ABS-06-0018]

Influence of Oceanic Fronts and Mid-Oceanic Islands on Coccolithophore Biogeography and Carbonate Production in the Southwest Indian Ocean

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Coccolithophores, a group of calcifying phytoplankton, play a vital role in oceanic carbon cycling through both organic carbon fixation and calcium carbonate production. Although well-studied in many oceanic regions, their distribution and ecological functioning in the Southern Ocean remain relatively underexplored. This study investigates the spatial variability of coccolithophore abundance and diversity in the Southwest Indian Ocean, using surface water and sediment samples collected during the CROTALE expedition (February-March 2019). Sampling across the Subtropical Gyre, Agulhas Return Frontal Zone (ARFZ), Subtropical Zone (STZ), and Subantarctic Zone (SAZ), we observed strong regional contrasts influenced by oceanic fronts, mesoscale eddies, and physical properties such as temperature, salinity, and nutrient availability. Notably, coccolithophore abundance and diversity were significantly lower in waters surrounding mid-oceanic islands (e.g., Crozet Islands), suggesting that island-driven topographic and hydrographic features modulate phytoplankton communities, potentially creating localized zones of suppressed carbonate production within the broader Great Calcite Belt (GCB). These findings underscore the importance of mid-oceanic islands in shaping the distribution of siliceous and calcareous phytoplankton and highlight their potential role in regulating regional biogeochemical cycles, especially under projected climate-driven shifts in ocean circulation and frontal dynamics.

Keywords: Coccolithophores, Oceanic fronts, Mid-oceanic islands, Great Calcite Belt, Marine biogeochemical cycling

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[ABS-06-0117]

Subseasonal to seasonal CO_2 emissions in the eastern Arabian Sea: physical and biogeochemical drivers

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Rising atmospheric carbon dioxide (CO2) concentrations, driven by human activities, are altering the ocean's natural ability to sequester carbon. The Arabian Sea, recognised as a major source of CO2 to the atmosphere, remains poorly constrained in terms of coastal flux estimates, necessitating detailed investigation. To better understand the underlying mechanisms and key drivers, basin-scale observations were conducted nine times across the eastern Arabian Sea (EAS) between January 2018 and January 2019. Surface pCO2 ranged from 289 to 1310 µatm, with the lowest mean in early spring (428±30 µatm) and the highest in the late summer monsoon (606±97 µatm). Strong upwelling and cyclonic eddies in the south and central EAS elevated surface pCO2 during the summer monsoon, while moderate upwelling and strong winds drove similar enrichment in the north. Coastal stratification and benthic production suppressed surface pCO2 during non-monsoon periods. Changes in dissolved inorganic carbon and total alkalinity together accounted for 24-85% of pCO2 variability, while temperature explained 12-52%, underscoring the dominant biogeochemical controls on air-sea exchange. Persistently higher surface pCO2 relative to the atmosphere confirms the EAS as a perennial CO2 source, with a mean flux of 4.7±8.4 mmolCm-2d-1 and peak efflux during the summer monsoon (15.9±19.5 mmolCm-2d-1). The monsoon season alone contributed 66% of annual emissions (9.9 TgCy-1), due to upwelling-driven CO2 supply exceeding biological drawdown. The northern EAS accounted for the highest annual emissions (6.5 TgCy-1), driven by shallow thermoclines, weak stratification, and persistent winds. Conversely, deeper thermoclines and strong thermohaline stratification limited fluxes in the central (2.4 TgCy-1) and southern (1.0 TgCy-1) regions. While no clear long-term trend in pCO2 was observed over the past two decades, substantial inter-annual variability was evident. Variations in upwelling and monsoon intensity, linked to ENSO and the Indian Ocean Dipole, significantly modulated CO2 fluxes, highlighting the region's sensitivity to climate variability.

Keywords: CO2 flux, Eastern Arabian Sea, pCO2 drivers

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ABS-06-0141]

Unrepresented Subsurface Temperature Inversion in the Northern Bay of Bengal and Associated Forcing Mechanisms

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Temperature inversions (TI) in the northern Bay of Bengal (BoB) have considerable influence on the upper ocean thermal structure and air-sea interaction. In this study, we systematically investigate the seasonal and interannual variability of TI and associated forcing mechanisms using the long-term (1958-2023) ORAS5 reanalysis dataset. The wintertime TIs display significantly large interannual variability compared to other seasons and are closely associated with the inversion layer thickness (InvLT). Composite analysis reveals that the strong TI amplitude (TIA) years are characterized by strong stratification, shallow mixed layer, and thick barrier layer, whereas weak TIA years exhibit weaker stratification and a deeper mixed layer. In the strong TIA years, northward offshore surface currents along the east coast of India help to retain fresh water in the northern BoB, enhancing stratification. In contrast, during weak years, southward currents transport freshwater away, weakening the barrier layer and enhancing the mixing. The inversion layer heat budget analysis shows that surface cooling via net surface heat loss and subsurface warming through penetrative shortwave radiation are the main drivers of TI. Although entrainment cools the base of the inversion layer, the thicker inversion layer, stronger barrier layer potential energy (BLPE), and weaker kinetic energy (KE) in the strong TIA years help retain subsurface warming and sustain strong TI. In contrast, weaker BLPE and thinner inversion layer during weak years allow mixing to disrupt subsurface warming, leading to weak TI. The results underscore the role of ocean state via surface heat flux, penetrative heat flux, and entrainment in shaping TI variability.

Keywords: Temperature Inversion, Inversion Layer Heat Budget, Stratification, Barrier Layer, Coastal Current, Bay of Bengal

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[ABS-06-0252]

The Role of Advective Ventilation in Intensifying the Arabian Sea Oxygen Minimum Zone.

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The Arabian Sea hosts one of the most intense and persistent oxygen minimum zones (OMZs) in the global ocean, with profound implications for regional biogeochemistry and ecosystem functioning. Using multi-decadal (1993-2021) biogeochemical model outputs (NEMO v3.6) from the Copernicus Marine Environment Monitoring Service, we examine the evolution of dissolved oxygen variability in the upper 1500 m of the water column. The analysis reveals a sustained decline in oxygen concentrations on annual to decadal scales, with the strongest signal observed in the mesopelagic zone, where the OMZ core exhibits both vertical thickening and lateral expansion towards the south. Latitude-depth sections highlight a pronounced reduction in oxygen supply from the south, coinciding with the weakening of large-scale advective ventilation. By investigating the underlying mechanisms, our results suggest that a weakening in lateral ventilation pathways mediated through reduced inflow of oxygen-rich intermediate waters from the south, coupled with intensified stratification, limits the replenishment of subsurface oxygen. This weakened advective supply enhances the residence time of low-oxygen waters, allowing microbial respiration and organic matter remineralization to dominate, thereby accelerating oxygen depletion. Together, these findings emphasize the central role of advective ventilation in modulating oxygen balance in the Arabian Sea and provide new insights into the mechanisms driving OMZ intensification. They also underscore the vulnerability of regional ecosystems to future climate-driven shifts in circulation and ventilation that may further amplify oxygen loss.

Keywords: Arabian Sea, Dissolved Oxygen, Oxygen Minimum Zone, NEMO

IIOE-2 Endorsed Project No:

[ABS-06-0278]

Validation of Sensor-based Dissolved Oxygen measurements from the BIOARGO Floats in the Arabian Sea

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The Arabian Sea contains one of the most significant oxygen minimum zones (OMZ) in the world, attributed to monsoonal productivity and restricted ventilation. Although numerous important programs have been implemented in this basin to comprehend its hydrographic features and biogeochemical processes, there has consistently been a lack of biogeochemical data on both spatial and temporal scales necessary to assess long-term changes and the impacts of climate change. The BIOARGO program was launched to address this gap. In addition to recording depth, temperature, and salinity, BIOARGO floats measure dissolved oxygen, fluorescence, and backscatter. Since 2012, a total of 44 floats have been deployed in the Arabian Sea, of which 15 remain active. While the data from these floats undergo standard quality control checks and corrections as established by the Biogeochemical Argo team, there has been no systematic validation against water-column measurements. This study is aimed to fill that gap by comparing the dissolved oxygen (DO) data from the recent time-series programmes of CSIR-NIO with the BIOARGO DO data. The depth-wise patterns were broadly consistent between BIOARGO and sampled DO, though differences were noted in the absolute values. Differences were noted in the surface (mixed layer) and deep-water DO, whereas the oxycline (thermocline) and OMZ DO values showed good agreement. Importantly, individual floats displayed consistent variations over their operational times, suggesting that corrections could be applied to improve data accuracy.

Keywords: Arabian Sea, BIOARGO, dissolved oxygen, float, oxygen minimum zone, productivity

IIOE-2 Endorsed Project No:

[ABS-06-0293]

Nutrient dynamics in the Bay of Bengal during the spring 2024: Physical drivers and biological responses

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The investigation of nutrient dynamics during the oligotrophic period is crucial to understanding how productivity and ecosystem functioning are sustained under nutrient scarcity. This study examines the nutrient variability and its controlling mechanisms within the upper 200 m water column of the Bay of Bengal (BoB) (2°N to 19°N) during the spring intermonsoon (SIM) of 2024, based on in situ observation from RV Thomas G. Thompson (Cruise No. TN432). The hydrography and nutrient distributions display distinct south-north variabilities along the transect. The thermocline shift and salinity changes coincide with the subsurface variability of nitrate, phosphate and silicate. The phosphate and silicate ranged from 0.3 to 2.7Î¼M and 0.5 to 37Î¼M, respectively, with their variability largely regulated by physical forcing. A pronounced upshift of the nutricline between 4°N to 8°N was linked to the westward propagating upwelling favourable Rossby wave, accompanied by a primary nitrite maximum associated with the dissolved oxygen change. High subsurface chlorophyll a (up to 1.3 Î¼g/L) is observed in the southern stations compared to the northern stations, linked to this nutricline displacement. In the central and northern stations, mesoscale eddy-driven vertical mixing further influences nutrient variabilities and enhances nutrient supplies to the upper layers. These physically mediated processes jointly govern nutrient availability, sustain primary productivity and shape phytoplankton distribution during the oligotrophic SIM in the BoB.

Keywords: Nutrients, Bay of Bengal, Spring inter monsoon, Mesoscale eddy

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[ABS-06-0288]

Signatures of Diffusive Convection Associated with Thermal Inversion in the Barrier Layer of the North Indian Ocean

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Diffusive convection (DC), a form of double-diffusive mixing, plays an important role in regulating vertical fluxes of heat, salt, and dissolved properties in the ocean. The barrier layer (BL), situated between the base of the mixed layer and the top of the isothermal layer, is generally characterized by weak shear-driven mixing. To investigate signatures of DC associated with thermal inversions within the BL, we developed a global climatology using Argo and eXpendable Conductivity-Temperature-Depth (XCTD) observations. The analysis identifies the northern Bay of Bengal (BoB) and the southeastern Arabian Sea (SEAS) as prominent hotspots during winter, where strong salinity stratification supports thermal inversions and establishes conditions favourable for DC. Microstructure measurements from two research cruises, collected in this region using the Vertical Microstructure Profiler (VMP-250), further confirm the presence of DC-favourable stratification, with low shear-driven mixing reflected in eddy diffusivity values on the order of 10µ mÂ² sâ»Â¹. We also quantified the relative importance of DC on the mixed-layer heat budget during the peak phase of DC activity in the BL. These results demonstrate that DC contributes significantly to sea surface temperature (SST) variability in the BoB and SEAS during winter.

Keywords: Diapycnal mixing, Ocean turbulence, Mixed layer

IIOE-2 Endorsed Project No:

[ABS-06-0195]

Feeding habits and trophic ecomorphology of Acanthurus triostegus (Linnaeus, 1758) from South Andaman Islands: A preliminary study

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Acanthurus triostegus specimens were collected from the reef areas of South Andaman Islands and their ecomorphology was elucidated through gut content analysis, morphometrics and anatomical features. Various ecomorphological indices related to food and feeding were calculated. Gut content analysis revealed that the species mainly fed on filamentous algae, with preference for Chlorophytes, which contributed to 93% of the gut content. *Enteromorpha clathrata and E.paradoxa* were found to be the most abundant food items in the gut. The trophic level indicated the species to be a herbivore. The niche/diet breadth was 0.075, indicating that this species is a specialist with regard to diet. The morphological features of the teeth and gill rakers were found to influence food item preference and processing. The morphological features observed in the study were found to have a significant influence on the food and feeding habits, hence confirming the correlation of trophic ecology with morphology. This work is the first of its kind from this region.

Keywords: Algae, Ecomorphology, Niche, India, Indices, Reef

IIOE-2 Endorsed Project No:

[ABS-06-0019]

Temporal variation of Micro Phytoplankton in Arabian Sea

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This study investigates the temporal variation of micro phytoplankton in the Arabian Sea, a globally significant and highly productive marine region characterised by pronounced seasonal oscillations in biological activity. Phytoplankton is the base of the marine food web categorised by size into picoplankton (<2um), nanoplankton (>2um and <20um) and microplankton (>20 um). The microplankton dominates the high productivity in nutrient rich coastal waters. The Arabian Sea has unique hydrographic conditions which driven by the summer southwest monsoon (causing upwelling) and winter surface cooling (leading to vertical mixing) making it an ideal location for studying these temporal dynamics. The research utilised satellite derived data from AQUA-MODIS level 3 with 4Km resolution. Key parameters analysed include Chlorophyll-a concentration (Cm), Sea Surface Temperature (SST), Diffused Attenuation Coefficient (Kd490) and Absorption (ADG) at 443nm. A three-component abundance model, as described by Brewin et al., was applied to discriminate and quantify phytoplankton size classes from these ocean color data. The results present comprehensive monthly maps illustrating the temporal variability of Cm, SST, Kd490 and ADG across the Arabian Sea. These visual analyses reveal distinct seasonal patterns in micro phytoplankton distribution and abundance. The further correlation study was undertaken with the observed fluctuations in SST (23 - 26 Deg C), Kd490 (0.02-1.6) and ADG (>0.069). This study provides valuable insights into dynamic nature of micro phytoplankton populations in the Arabian Sea especially dinoflagellates which have the remarkable ability to produce Bioluminescence which is both a challenge and an opportunity for Indian Navy. Bioluminescence is of significant strategic importance for naval operations, particularly in Anti-Submarine Warfare (ASW) and the stealth of underwater vehicles. This research aims at optimally leveraging the in-situ information of biomass production, studying the temporal variability and enhancing our understanding the relation of marine ecosystem and bioluminescence, which is critical from the military perspective.

Keywords: Temporal Variation, micro phytoplankton, Arabian Sea, OCM data, Bioluminescence

IIOE-2 Endorsed Project No:

[ABS-06-0149]

Understanding Decadal Trend of Algal Blooms in Northern Arabian Sea: An Ocean Colour Remote Sensing Approach

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The Northern Arabian Sea (NAS) experiences substantial algal blooms during the tropical winter. Significant convective mixing of the water column makes the conducive condition by transporting nutrient-rich subsurface waters to the euphotic zone, favouring high-biomass algal enrichment. Since the early 2000s, traditional diatom-dominated assemblages have been increasingly replaced by the mixotrophic dinoflagellate Green Noctiluca scintillans (GNS), which maintains predator-prey relationships with diatoms. This study employs ocean colour remote sensing to examine spatial and temporal patterns of diatom and GNS distributions across the NAS from 2002 to 2019. Ocean colour algorithms utilizing MODIS-Aqua (MODISA) retrieved Remote Sensing Reflectance (Rrs) to identify and differentiate GNS from diatom assemblages within a heterogeneous phytoplankton community. Algal bloom variability is evaluated through MODISA-retrieved chlorophyll-a concentrations and Sea Surface Temperature (SST). The inverse chlorophyll-a and SST relationship indicated convection-driven nutrient supply mechanisms supporting phytoplankton evolution and growth. Spatial analysis revealed elevated chlorophyll-a magnitude for both algal classes/species during December, representing pre-bloom conditioning phases facilitating subsequent GNS evolution-development. The maximum GNS spread area occurred during February-March. Temporal evolution patterns demonstrate clear indications of mixotrophic predation on diatoms by GNS. Multi-year analysis confirmed February-March as the primary bloom period, with cooler temperatures favouring open-ocean high-biomass bloom episodes. Results indicate marginal increasing trends in overall bloom intensity, characterized by stable diatom distributions but slight increases in GNS spatial coverage. MODISA retrieved information provided a robust analytical framework for monitoring long-term phytoplankton community dynamics and succession patterns in NAS.

Keywords: Noctiluca; Diatom; Chlorophyll-a; Arabian Sea; MODISA

IIOE-2 Endorsed Project No:

[ABS-06-0218]

Phytoplankton size class dynamics during bloom and non-bloom conditions in the Northeastern Arabian Sea using in situ and satellite observations

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Phytoplankton size classes (PSCs) play a central role in surface carbon export to the deep ocean by influencing photosynthetic efficiency, particle sinking rates, and food web structure. However, knowledge of PSC dynamics during bloom and non-bloom periods in the northeastern Arabian Sea is limited. To address this, phytoplankton absorption (aph) characteristics were investigated using concurrent in situ bio-optical measurements and satellite-derived products during three research cruises (SS348, SS356, and SS383). The PSCs were classified using phytoplankton absorption (aph(443)) and Slope (S443-510). Out of 18 stations, three micro-phytoplankton dominated stations with chlorophyll-a ranged between 3 and 5 mg m^{-3}, five nano-phytoplankton dominated stations with chlorophyll-a, 0.5 and 3 mg m^{-3}, and ten pico-phytoplankton stations under oligotrophic conditions (<0.5 mg m^{-3} Chl-a). The slope-based approach accurately estimates micro-plankton bloom and slightly underestimates nano as pico phytoplankton, in this region. The validation results in situ aph(443) versus satellite VIIRS retrieved aph(443) showed a moderately strong correlation (R^2=0.733, slope = 0.60, n = 18, RMSE of 0.0153 m^{-1}, Bias = 0.0056 m^{-1}, and MAPE of 52.9%), with underestimation most evident in bloom conditions. Comparison of Hirata-derived PSCs with a region-specific model developed here showed well agreement (R^2=0.996), highlighting the reliability of absorption-based approaches in this region. Overall, results demonstrate that aph(443) and S443-510 are robust indicators for PSC retrievals, highlighting the compatibility of in situ and satellite observations for bloom monitoring and phytoplankton community assessments in the Arabian Sea.

Keywords: Keywords: Phytoplankton absorption spectra; Phytoplankton size classes; VIIRS-Satellite data validation; North Eastern Arabian Sea

IIOE-2 Endorsed Project No:

[ABS-06-0127]

Environmental regulation of picophytoplankton assemblages in the eastern Arabian Sea during early winter monsoon

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Picophytoplankton play a crucial role in marine ecosystems by contributing significantly to global primary production and driving carbon cycling processes. To understand their distribution and ecological dynamics during the early winter monsoon, a research cruise (SSK-161) was conducted in the Eastern Arabian Sea from 25 October to 10 November 2023, covering latitudes 10.49°N to 21.49°N and longitudes 67.99°E to 75.48°E. Environmental parameters revealed strong spatial gradients. The coastal station in the Southeastern Arabian Sea (SEAS-C) was characterized by the highest sea surface temperature, dissolved oxygen, and chlorophyll fluorescence, as well as the lowest sea surface salinity and the shallowest mixed layer depth (MLD). The nitrate, nitrite, and phosphate concentrations were below 1 Î¼M in the MLD, while silicate remained below 10 Î¼M, except at SEAS-C. Picophytoplankton community structure varied distinctly across regions. *Synechococcus* and picoeukaryotes were most abundant at SEAS-C, while *Prochlorococcus* dominated in the open ocean stations. Vertical distribution patterns indicated that Synechococcus thrived above the sub-chlorophyll maxima layer (SCML) under high temperature and low nutrient conditions, whereas Prochlorococcus and picoeukaryotes were more abundant at or below the SCML, correlating with moderate temperatures and nutrient-rich waters. A diverse suite of photosynthetic and accessory pigments, including zeaxanthin, divinyl chlorophyll-a, fucoxanthin, chlorophyll b, 19â¿²-hexanoyloxyfucoxanthin, alloxanthin, and lutein, reflects a taxonomically rich picophytoplankton community with distinct spatial niches. These observations underscore the ecological importance of picophytoplankton in maintaining productivity and biogeochemical cycling in the Arabian Sea during early winter monsoon period.

Keywords: Eastern Arabian Sea, Pigments, Synechococcus, Prochlorococcus, picoeukaryotes

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[ABS-06-0259]

Genomic insights of Shewanella algae RTL_RDS_006 and its metabolic diversity of Dimethylsulfoniopropionate (DMSP) in oceanic environment

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Dimethylsulfoniopropionate (DMSP) is a significant organosulphur compound, which plays a crucial role in osmoprotection, cryoprotection, a grazing deterrent, a signalling molecule, stress tolerance, chemotaxis, global carbon and sulphur cycling, and climate regulation. DMSP is produced by many communities of microalgae, corals, and heterotrophic bacteria. Moreover, DMSP can serve as an important carbon and sulphur source for phytoplankton and bacteria in the ocean and plays a vital role in maintaining the normal life activities of plankton. The genus Shewanella is one of the most abundant Î³-proteobacteria in the marine and fresh water environment. Its metabolic versatility and ability to utilize a variety of extracellular electron acceptors is a key feature in its role in the turnover of organic matter, denitrification and bioremediation. In this study, we investigate the whole genome sequencing of Shewanella algae isolated from shrimp gut was performed and annotated using the Prokka and NCBI prokaryotic genome annotation pipelines. The Shewanella algae RTL_RDS_006 genome assembly was analysed to identify functional genes associated with DMSP. Preliminary screening revealed several loci identified as TorD/DmsD molecular chaperones, which are involved in the maturation of DMSO reductase, the DMSP-transporting gene acrylyl-CoA reductase (AcuI), the DMSP demethylase gene dmdC and dddY gene which is involves in cleavage pathway, converts DMSP into DMS and acrylate. This genomic evidence indicates the potential role of Shewanella algae in DMS/DMSO cycling, which leads to the further experimental validation of its role in the sulphur cycle and biogeochemical dynamics.

Keywords: DMSP, DMS, Sulphur cycling, Shewanella algae, WGS

[ABS-06-0291]

Is the Bay of Bengal Primary and Secondary Productivity within the Euphotic Zone Co-Limited by Silicate and dissolved Nitrogen ?

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A single-column coupled physical and biological model based on the North Pacific Ecosystem Model for Understanding Regional Oceanography (NEMURO) with nitrogen and silicon cycles is adapted for the Bay of Bengal (BoB) environment. The model simulated plankton biomass and nutrients along the track of Bio-Argos over East and West BoB (from 2016 to 2017) are validated with the observations. The model fairly simulates the perennial structure of subsurface chlorophyll maximum (SCM). Further, three experiments are carried out to know the limitations in primary and secondary production in terms of nitrogen (NO3 + NH4) and silicate (Si(OH)4) in the open ocean BoB. In a no-NO3 experiment, the nitrate limiting term [i.e., NO3/(NO3 + KNO3)] is set to zero so that the difference from the control case gives the role of 'regenerated production' in the total primary and secondary production. Similarly, a no-NH4 experiment was conducted to infer the role of 'new production'. The new (regenerated) production fuels 85±1% (28±6%) of the living biomass in the East part of open ocean BoB (East BoB). The corresponding values for the west part (West BoB) are 86±1% (42±2%). Among the primary producers, the new (regenerated) production contributed 72±1% (24±6%) in the East BoB and 74±1% (37±2%) in the West BoB. The silicate limits the diatom production by 46±22% (45±27%) of the actual amount of diatom in the East BoB (West BoB) diatom.

Keywords: Ecosystem modelling, primary production, secondary production, nitrate, silicate, nutrient limitation

[ABS-06-0307]

Mixing Layer Depth in the North Indian Ocean

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Turbulent mixing is the primary mechanism regulating the vertical exchange of heat, momentum, and dissolved substances within the ocean surface boundary layer (OSBL). The mixing layer depth (XLD), defined as the depth of active turbulent mixing, therefore provides a direct measure of OSBL dynamics. This study investigates XLD in the Arabian Sea using microstructure observations from three research cruises spanning multiple seasons. Measurements were collected with the Vertical Microstructure Profiler (VMP-250), and XLD was determined as the depth at which turbulent dissipation rates decreased to a background threshold of 10¸ W kg^{1}. In spring, XLD shows strong correspondence with the mixed layer depth (MLD), with a correlation of 0.76 and values consistently slightly deeper than MLD. During summer, XLD follows MLD with a moderate correlation of 0.60 but exhibits a pronounced diurnal cycle, being shallower than MLD during daytime and deeper at night. In winter, the correspondence weakens further, with a correlation of 0.57, and XLD remaining almost always shallower than MLD. These results highlight the strong seasonal variability in the relationship between MLD and XLD, with wind forcing, stratification, and surface waves likely contributing to the observed XLD variability. Clarifying these relationships advances understanding of upper-ocean mixing processes and their feedback on air-sea interactions in the Arabian Sea.

Keywords: Diapycnal mixing, Ocean Turbulence, Mixed Layer, Mixing layer

IIOE-2 Endorsed Project No:

[ABS-06-0335]

Phaeocystis bloom: An Emerging Threat to Coastal Waters of India

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The *Phaeocystis* is a cosmopolitan *prymnesiophyte*; it belongs to the harmful algal bloom category because of its adverse effects on the ecosystem. We have witnessed an outbreak of *Phaeocystis* globosa for three consecutive years. Detailed time series observations indicate the bloom formation begins during the onset of the Northeast Monsoon (NEM) and peaks in the middle of the NEM. Cool temperature, polyhaline salinity and moderate nitrate likely triggered the *Phaeocystis* bloom formation. A maximum of 652 colonies/L was reported during the peak bloom period. *Phaeocystis* blooms are recurrently documented worldwide, with continuous reports from the North Sea since 1948, the China Sea since 1997 and the coastal waters of Vietnam since 2002. During our investigation, bloom recurrence was reported in three consecutive years in the Bay of Bengal (BoB). Considering the negative impacts of *Phaeocystis* bloom on surrounding organisms, thick foam accumulation along the coast, substantial economic losses, and even human mortalities imply the importance of their regular monitoring. East India Coastal Current (EICC) transports water masses from the northwestern BoB towards the south during the Northeast Monsoon period. This could spread bloom-favorable conditions further south and facilitate the expansion of *Phaeocystis* bloom in Bay of Bengal. Continuous monitoring and in-depth studies are essential to monitor bloom and their impacts on sustainability and ecological balance in the Bay of Bengal.

Keywords: *Phaeocystis* bloom, Harmful algal bloom, Northwestern Bay of Bengal, Northeast monsoon, Winter cooling.

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[ABS-06-0370]

Comparative Assessment of Field and Satellite-Derived Chlorophyll-a Concentrations along the East Coast of Tamil Nadu

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Chlorophyll-a concentration serves as a fundamental indicator of phytoplankton biomass and marine ecosystem health. While traditional field-based spectrophotometric methods provide accurate measurements, satellite remote sensing offers the potential for large-scale, temporally dense monitoring of chlorophyll distributions. This study presents a comparative analysis of chlorophyll-a concentrations obtained through in-situ field measurements using ESS method 1991 and those derived from satellite remote sensing data (MODIS, VIIRS, SENTINEL-3, etc) around the sampling locations at Ennore, Cooum and Kovalam along East coast of Tamilnadu. Statistical methods were employed to quantify the agreement between datasets. The validation results reveal low, moderate and high agreement between field and satellite measurements.

Keywords: Chlorophyll-a, In-situ Measurements, Satellite Data, Statistical Comparison, Validation

IIOE-2 Endorsed Project No:

[ABS-06-0228]

Particulate organic carbon distribution in the Western Indian Ocean based on Biogeochemical-Argo floats

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Primary producers in the surface ocean play a key role in the marine carbon cycle by fixing atmospheric carbon dioxide into particulate organic carbon (POC). While ship-based in situ measurements have improved our understanding of POC dynamics, their spatial and temporal coverage remains limited. To complement these observations, remote platforms such as satellites and Biogeochemical-Argo (BGC-Argo) floats enable continuous ocean monitoring. In this study, we analyzed a biogeochemical dataset from a BGC-Argo float deployed in the Seychelles-Chagos Thermocline Ridge (SCTR). Over the two-year period (March 2023-April 2025), the float collected 152 vertical profiles of pressure, temperature, salinity, chlorophyll-a, and backscattering. Quality assurance and quality control (QA/QC) procedures, including filtering, calibration, and outlier removal, were applied to the backscattering data, and the processed dataset was cross-validated against ship-based CTD measurements. QA/QC-processed backscattering was compared with beam transmission from CTD casts conducted within ±5 days and ±1° of the float measurements, revealing strong negative correlations ($r = -0.83$ to -0.93, $n = 6$). In addition, POC concentrations derived from discrete water samples collected during the CTD casts were analyzed to examine their relationship with both beam transmission and backscattering. This stepwise evaluation aimed to investigate the applicability of backscattering as a proxy for continuous vertical POC profiling, complementing discrete sampling and mitigating the spatiotemporal limitations of ship-based observations. Using the validated dataset, we further evaluated the potential of applying established backscattering-POC relationships to characterize vertical POC structure and seasonal variability in the SCTR.

Keywords: BGC-Argo, POC, SCTR, Backscattering

IIOE-2 Endorsed Project No:

[ABS-06-0032]

Vertical Profiles of Phytoplankton Biomass Variability in the Central Part of the Eastern Arabian Sea: Evidence from Bio-Argo Observations

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The variability of phytoplankton biomass in the central part of the Eastern Arabian Sea is not fully understood. Using satellite and biogeochemical Argo data, we found a distinct climatological variation of Chlorophyll-a (Chl-a) characterised by a distinct drop in surface Chl-a during September, followed by a sharp increase in October, which is unique to the region. Results show that shoaling or deepening of the mixed layer (ML) and stratification play a significant role in adjusting the phytoplankton biomass in different layers. During March-May and October-November, the ML shoals (~20m) due to surface warming and stratification, thus resulting in low phytoplankton biomass within the ML, but a significant subsurface Chl-a maxima below the ML. However, increasing wind stress and upwelling from June-August induce mixing in the upper water column (MLD > 35m), which increases phytoplankton growth due to higher nutrient levels. A distinct fall in the biomass during September is observed and attributed to reduced atmospheric and physical forcing parameters. The influence of strong upwelling in the south and convective mixing in the north does not have a significant influence on phytoplankton proliferation due to its distinct location between two significant areas. Furthermore, Hovmöller plots indicate distinct latitudinal variations, indicating the uniqueness of the region and highlighting the influence of potential stressors on its productivity. The findings elucidate the response of vertical phytoplankton to changes induced by various atmospheric and physical forcing factors in prospective climate change scenarios.

Keywords: Bio-Argo, phytoplankton biomass, Chlorophyll-a, Eastern Arabian Sea

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[ABS-06-0105]

Surface sediment studies from Kalpeni Atoll, Lakshadweep

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The Lakshadweep Archipelago, comprising coral atolls atop the Laccadive-Chagos Ridge situated in the Arabian Sea represents a distinctive carbonate platform influenced by dynamic Indian Ocean currents. The Kalpeni Atoll is a part of this archipelago, which lies within the Indian Ocean Warm Pool (IOWP), making it highly sensitive to climatic changes. Preliminary studies have shown a significant shift in the Northern Indian Ocean dynamics, viz. increased cyclone intensity and frequency due to ocean warming, with predictions of a sea level rise of ~0.76m and a sea surface temperature increase of ~3.4°C by the end of the 21st century. These changes are expected to intensify mechanical wave energy and current velocities, affecting the low-lying coral islands of Lakshadweep, leading to sediment erosion, reworking and redistribution. Despite several preliminary studies on reef health and general sedimentation around various coral atolls of Lakshadweep, a micropaleontological assessment focusing on benthic foraminifera and their relationship with sediment dynamics remain sparse. Therefore, twenty-five surface sediments collected from Kalpeni Atoll were used to investigate the benthic foraminiferal distribution integrating grain size analysis, foraminiferal taxonomy and statistical correlation with regional hydrodynamics. Grain size analysis reveals a grainstone-dominated, sand rich texture with bimodal to polymodal distributions, suggestive of strong hydrodynamic forcing. Within this reef-lagoonal setting, calcareous forms of foraminifera are dominant, while arenaceous forms are relatively scarce, reflecting a lack of finer sediments. This supports the inference of a coarse-dominated depositional setting. Three families of foraminifera viz. *Calcarinidae, Miliolidae, and Amphisteginidae* are most abundant, with Miliolids suggestive of high energy conditions. Overall, this study provides a comprehensive information regarding the distribution of reef associated benthic foraminifera in Kalpeni and associated local hydrodynamic processes and regional oceanographic influences, offering a framework for comparative studies across tropical reef systems.

Keywords: Kalpeni Atoll, Lakshadweep Archipelago, Benthic foraminifera, Indian Ocean, Tropical reef system

IIOE-2 Endorsed Project No:

[ABS-06-0139]

Biogeography and Dispersal dynamics of dinoflagellate cysts in the Indian Ocean deep-sea sediments: implications for deep-sea ecology and resource exploration

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This study assesses dinoflagellate cyst assemblages (DCA) from deep-sea sediments (200 m - 5400 m depth) of the Indian Ocean (IO), focusing on their biogeographic distribution and ecological-environmental indicators. The DCA exhibits distinct geographic patterns influenced by both large- and small-scale lateral transport processes. Notably, the highest richness and concentration of DC species, many of which are potential harmful algal bloom (HAB) species, were recorded in the ecologically significant northern Indian Ocean (NIO), characterized by high productivity, the presence of oxygen minimum zones, and upwelling phenomena. In contrast, the economically substantial (e.g., mineral deposits and shipping routes regions) Equatorial and South Tropical IO regions demonstrated lower species diversity. Among the identified cyst types, 21 are cosmopolitan, including one HAB species, while 27 are exclusive to the NIO. Notable NIO-specific five potential HAB species include *Polysphaeridium zoharyi, Lingulodinium machaerophorum, Polykrikos hartmannii*, cysts of *Alexandrium*, and *Gonyaulax*. Conversely, *Operculodinium centrocarpum* is widespread in IO. Among cosmopolitan taxa, *N. labyrinthus, Nematosphaeropsis, O. centrocarpum (a* yessotoxin producer*), S. mirabilis, S. hyperacanthus,* and cysts of *Protoperidinium* could be crucial indicators for environmental, oceanic, and climatic changes. Furthermore, the morphometric variations of some cosmopolitan cysts between low- and high-salinity bioregions suggest the existence of different strains or influencing factors, highlighting the potential of morphometry as ecological-environmental indicators in IO and beyond. In summary, these findings significantly enrich our understanding of dinoflagellate biogeography and offer new perspective for biodiversity assessments and climate change monitoring in ecologically and economically vital regions.

Keywords: Dinoflagellate cysts, Pelagic Indian Ocean, Arabian Sea, Equatorial Indian Ocean, Bay of Bengal, South tropical Indian Ocean

IIOE-2 Endorsed Project No:

[ABS-06-0029]

Ecological Role of the Sundarbans Mangroves in Enhancing Fish Diversity and Aquatic Productivity

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Mangroves play a vital role in supporting fisheries production within aquatic ecosystems. This study aimed to understand the interaction between mangroves and fisheries in the coastal ecosystems of Bangladesh. Data on water quality and fisheries were collected from 60 stations located near the Sundarbans mangrove forest and 30 stations situated farther from the mangrove ecosystem. The results revealed significant differences in water quality variables between mangrove and non-mangrove aquatic ecosystems, with major variations observed in nutrient levels and primary production. In the mangrove-associated aquatic ecosystem, nitrate and phosphate concentrations were measured at 7.42 µmol/L and 2.15 µmol/L, respectively, while lower concentrations were recorded in non-mangrove areas. Phytoplankton and zooplankton abundance were also higher in aquatic ecosystems near mangroves compared to those farther away. The study found a strong relationship between mangroves and fisheries. Species diversity of fish was highest in the mangrove ecosystem (65 species) and lowest in non-mangrove aquatic areas (22 species). The high fish species diversity near mangroves was attributed to increased productivity driven by elevated nutrient levels, which were significantly correlated with mangrove litterfall. Furthermore, several commercially important fish species showed a positive association with mangrove fruits. Gut content analysis of these species indicated that they feed on mangrove fruits, with their seasonal occurrence corresponding to the availability of these fruits. This study provides the first evidence of mangrove-fisheries interactions in the coastal ecosystem of Bangladesh, highlighting the critical role of mangroves in sustaining aquatic biodiversity and productivity.

Keywords: Sundarbans Mangrove Ecosystem Services, Fish Species Abundance and Diversity, Nutrient Dynamics, Plankton Productivity, Environmental Parameters

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[ABS-06-0096]

Atmospheric dust deposition and its influence on phytoplankton composition and primary productivity in the eastern Arabian Sea coastal waters: An Experimental Study.

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Microcosm experiments have been conducted along the west coast of India at six locations, namely Veraval (Gujrat), Mumbai (Maharashtra), Goa (Goa), Mangalore (Karnataka), Kochi (Kerala), and Kanyakumari (Tamil Nadu). This experimental study investigates the impact of atmospheric aerosol deposition on coastal phytoplankton dynamics, nutrient enrichment, pigment variability, and primary production along the west coast of India. Airmass back trajectory (AMBT) analysis revealed mixed marine-terrestrial origins of aerosols, with high concentrations of total suspended particulates (TSP), nitrate, phosphate, and sulfate varying across locations. Microcosm experiments demonstrated that aerosol additions significantly enhanced nitrate and phosphate concentrations by up to 99% and 94%, respectively, with a concurrent pH decrease of 0.088-0.205 units. These nutrient enrichments resulted in decreasing in phytoplankton composition and diversity, but an increasing in cell abundance, which stimulated phytoplankton blooms, particularly diatoms such as *Thalassiosira sp. and Chaetoceros sp*., leading to elevated Chl-a biomass and other carotenoid pigment concentrations. Microscopic and pigment analyses confirmed a two-phase bloom succession, with microphytoplankton dominating early and picophytoplankton increasing in later stages. Ecological indicators showed diversity and dominance pattern shifts, with region-specific bloom and decay responses. Primary production increased by up to 160% post-aerosol enrichment, significantly correlating to nutrient uptake. Despite a pH decrease of up to 0.205 units, phytoplankton biomass, pigment content, and primary production were positively influenced, indicating a fertilization effect of atmospheric aerosols on coastal productivity.

Keywords: Phytoplankton, Aerosol, Pigment, pH, Arabian Sea, Primary production

IIOE-2 Endorsed Project No:

[ABS-06-0199]

Mechanisms governing the recent trends and variability of air-sea CO_2 flux over the dynamically different sectors of the Indian Ocean

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The increase in anthropogenic carbon emissions in the atmosphere is partially counterbalanced by the oceans' increased carbon uptake. The tropical region exhibits a nearly balanced net carbon flux compared to other areas. The Indian Ocean (IO), located in the tropics, experiences a seasonal climate and significant river influx, resulting in annual variability in CO2 flux across different ocean regions. The landlocked northern boundary and seasonal reversal of surface winds and upper oceanic current patterns constitute the fundamental factors driving the spatiotemporal variability of biogeochemical processes over this region. Of particular significance is the seasonal variability of phytoplankton bloom and carbon flux exchange occurring at the air-sea interface over this highly dynamic region. Further, the two intracontinental basins of the northern tropical IO i.e., the Arabian Sea and the Bay of Bengal exhibit strikingly different biogeochemical properties irrespective of the fact that are situated within the same latitudinal extent and experience the seasonal reversal of atmospheric and oceanic general circulation patterns. This study examines the spatiotemporal variability of air-sea CO2 flux by utilising a resolution dataset from the Surface Ocean CO2 Atlas version 2024 (SOCATv2024). Seasonal variations in CO2 flux are particularly evident over the Bay of Bengal and the Arabian Sea. Several driving factors influence these changes in CO2 levels, such as the upper oceanic temperature, salinity, upwelling processes and presence dissolved inorganic carbon, etc. which exhibit varying strength and dominance over the dynamically different sectors of the IO. Because the IO is experiencing basin-wide warming at an alarming rate in the last few years, the impact of such high SST distribution on the climatological CO2 source and sink regions over the IO are also examined. The variations with the driving factors of air-sea flux and their trends over the recent decades provide important implications for Indian Ocean warming.

Keywords: Carbon dioxide flux, Jena CarboScope, Indian ocean biogeochemical cycle

IIOE-2 Endorsed Project No:

[ABS-06-0321]

Seasonal Cycle in the upper ocean and its regulation by ENSO and IOD - A Comparison Between Arabian Sea and Bay of Bengal

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Seasonal cycle is a dominant mode of variability of the northern Indian Ocean (NIO) driven by the summer and winter monsoons. Though the temporal evolution of the seasonal cycle and spatial variability of its magnitude are well-researched and well understood, the vertical extension of this signal is poorly known. This is the motivation of the present study in which high resolution spatial data from the recently released World Ocean Atlas 2023 (WOA23) were used. The monthly mean climatology of temperature and salinity profiles were used to compute the amplitude and phase of the annual and semi-annual variability in the Arabian Sea (AS) and the Bay of Bengal (BoB). The spatial structure of the amplitude and phase of both annual and semi-annual cycle showed distinct difference between the AS and the BoB. Similarly, the vertical penetration of this signal also showed a large difference between the two basins. The reasons for this were examined in the light of basin-specific regional oceanography. Analysis underscored the role of stratification and Rossby waves in regulating the vertical extension of the semi-annual and annual cycles. On the inter-annual time scale El Niño -Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) played a major role in regulating the vertical extension.

Keywords: Seasonal cycle, Amplitude, Phase, Stratification, Rossby wave, North Indian Ocean

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[ABS-06-0388]

Nitrification in the Indian Ocean and the OMZ of the central Bay of Bengal

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Oxygen minimum zones (OMZs) account for 20-40% of global oceanic nitrogen loss. Despite the presence of a pronounced OMZ in the Bay of Bengal, no significant nitrogen loss has been reported in this area. One proposed explanation is a nitrite limitation, as trace levels of oxygen enables nitrite oxidation to outcompete nitrogen loss for available nitrite. Nitrification, which can occur at very low oxygen levels, adds further complexity to nitrogen cycling in low oxygen environments. However, the oxygen thresholds regulating key nitrogen processes remain highly uncertain. This study provides the first reported nitrification rate measurements from the central Bay of Bengal OMZ, collected during the SO305 BIOCAT-IIOE2 cruise (April - May 2024), alongside comparative data from the equatorial Indican Ocean-an understudied region without a pronounced OMZ-collected during the SO303 BIOGIN-IIOE2 cruise. Using 15N-ammonium tracer incubations, we quantified nitrification rates and examined their spatial and vertical variability in relation to environmental drivers. Preliminary results reveal pronounced spatial and vertical variations in nitrification with significantly higher rates above 100 m. In the BoB, nitrification rates sharply declined within the OMZ and oxygen availability emerged as a key regulator of nitrification, with additional influences from substrate availability, temperature, and salinity. Ultimately, our goal is to provide new insights into the dynamics of nitrification and its role in the nitrogen cycle in the equatorial Indian Ocean and OMZ of the Bay of Bengal, contributing to a better understanding of biogeochemical processes under changing ocean conditions.

Keywords: Oxygen minimum zones,SO305, BIOCAT-IIOE2 cruise

IIOE-2 Endorsed Project No:

[ABS-06-0324]

Distinct fisheries of the Indian Continental shelf: Implications in PFZ advisory

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By analyzing the gut content of small pelagic forage species, it reveals that they generally consume phytoplankton, zooplankton, fish larvae, eggs, particulate matter including bones and scale. By definition mackerels and sardines- major representatives of the Indian shelf are 'RAM' feeders filtering what- so-ever passes through their buccal gape. Such non-selective omnivory (Giske and Salvanes 1995) governs their dominance in the pelagic realm decimating available primary and/ secondary production and organic matter. While the dominant carnivores caught from the Northern Indian shelf (both in AB and BoB) are Bombay duck, pomfret, ribbonfish, pink perch, croakers, threadfins/ breams and hilsa, which are predominantly demersal species feeding on smaller teleosts, benthic crustaceans, annelids, molluscs, with notable cannibalism. In the backdrop of fish feeding mechanism, their guilds and accordingly acquired habitat defines the fisheries and the gears used for targeting such grounds. Omnivorous planktivory by the mid trophic tier (small pelagic fishes) and ontogeny determines the relay of biomass to the next tier thus pelagic oceans are governed from the middle rather than top-down or bottom-up (Rice, 1995; Cury et al., 2000). From zooplankton upwards when the biomass enters the protein regime, its metabolism results in great amounts of ammonia released by all ammonotellic fishes during predation at each trophic level. Feedback to the biogeochemical process is the large amount of defecated nutrient (macro & micro) within hours post- grazing remains unknown. Grazing by small pelagic forage fish mobilizes the biomass within patches as they are not long-distance migrants. Energy escalation above forage fish into the upper trophic strata is governed by size- dependent predation. These large highly mobile predators can move between mesoscale oceanic structures. A precursor for understanding their distributional pattern can be productivity using PFZ machinery along with ground truthing analysis.

Keywords: Indian continental Shelf, small pelagics, forage fishes, omnivory, carnivorous, PFZ.

IIOE-2 Endorsed Project No:

[ABS-06-0049]

Seasonal and Spatial Variability of Plankton Communities Across Mangrove and Non-Mangrove Zones in the Sundarbans

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Mangrove ecosystems influence aquatic biodiversity by affecting nutrient dynamics and primary production. This study investigates the interaction between mangroves and the plankton community in the world's largest mangrove forest, Sundarbans, in Bangladesh. The data were collected from 35 stations, including 20 within mangrove areas and 15 from non-mangrove areas. Physiochemical parameters were measured from the Sundarbans area, and nutrient analysis focused on nitrite and phosphate concentrations. For the nutrient analysis water samples were filtered, while phytoplankton and zooplankton were collected using plankton nets. Also, mangrove data were collected using a 20-meter by 20-meter quadrat method to assess litterfall contributions. The results shows that nitrite and phosphate levels were higher in mangrove areas compared to non-mangrove regions. The higher concentration of nutrient availability in mangrove zones was due to organic matter input from litterfall. The abundance of phytoplankton and zooplankton were significantly higher in mangrove-influenced waters, suggesting that nutrient increase from decomposed litterfall fosters plankton productivity. The study also found dominant plankton species, showing the ecological role of mangrove in supporting primary and secondary productivity. Compared to, lower nutrient concentrations in the non-mangrove areas, which reduced plankton abundance, showing the valuable role of mangrove ecosystems in aquatic food webs. The findings indicate that the essential function of mangroves in maintaining coastal ecosystem stability. Conserving mangrove ecosystems is crucial for sustaining marine biodiversity, supporting fisheries, and mitigating the impacts of environmental change.

Keywords: Phytoplankton, Zooplankton, Abundance, Distribution, Nutrients, Mangrove, Sundarbans

IIOE-2 Endorsed Project No:

THEME-7

IIOE-2 CONTRIBUTION TO SUSTAINABLE DEVELOPMENT: TOWARD THE UN DECADE OF OCEAN SCIENCE

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[ABS-07-0249]

Building capacity for coastal oceanography across the Indian Ocean

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A central objective of the next phase of the 2nd International Indian Ocean Expedition (IIOE-2, 2025-2030) will be to address the serious lack of reliable and comparable oceanographic observations that exists for most coastal areas across the Indian Ocean. The Coastal Observation Lab in a Box (COLaB) initiative is a UN Decade-endorsed project (under the CoastPredict programme). Its aim is to deliver instruments, protocols and training for water sampling and a wide range of 'old-school' methods for physical, biological and biogeochemical observations. The package will include both commercial instruments and affordable counterparts that, wherever possible, are open-source and can be built by the end user. A key feature is that the methods can be applied in settings ranging from coastal wetlands to the open continental shelf, without need of a formal research vessel or laboratory. Training will be both hands-on, through regional training camps, and online, and the package will include data management and modelling tools. Trainees will come not only from academic institutions but also from bodies such as NGOs, port authorities, MPA management teams and the mariculture industry. In particular, a key COLaB objective is to engage with early career scientists from around the Indian Ocean, to become multi-skilled coastal oceanographers and to be trainers in their own right. An overview of the COLaB initiative will be presented, with descriptions of planned contributions to IIOE-2 and the CoastPredict Global Coast project, to begin with a regional training camp in Mozambique in 2026.

Keywords: Coastal observations, oceanography, capacity building, instruments, affordable, open source

IIOE-2 Endorsed Project No: -

[ABS-07-0281]

Data-driven Techniques to Achieve Accurate, Timely and Precise Tsunami Warnings

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The Ocean Decade Tsunami Programme (UNODTP) aims to achieve a generational improvement in the timeliness and accuracy of tsunami warnings globally, similar to the scale of advances following the 2004 Indian Ocean Tsunami. This ambitious goal requires increased emphasis on direct ocean wavefield measurements that can transform the current tsunami warning and forecasting paradigm with strong reliance on proxy relationships. A significant increase in observational data, and an updated forecasting strategy is required. We argue that by re-imagining the global sensor grid to focus on the required observational density that is achievable with new and existing observational technologies, source-agnostic forecasting can transform the current strategies strongly relying on the earthquake source as a proxy for the tsunami source. We build upon the concept of the tsunami threat lifecycle phases identified by the UNODTP to define actionable advances in the warning system continuously over the course of an event: (1) Initial Indicators; (2) Confirmation, (3) Forecasting; (4) Verification, and (5) Cancellation. An overarching goal is to provide as much certainty of the likely impacts at all phases of the tsunami threat lifecycle as possible, including information on the duration of impacts. This new framework is patterned after similar frameworks that have proven successful for weather forecasting. This approach allows tsunami forecasts to be continually updated throughout the entire tsunami threat lifecycle. Forecasts can be continually updated and provide high-confidence information to emergency managers as tsunami threats unfold, even for tsunamis not caused by earthquakes. While in the time scale of the Ocean Decade, improved earthquake characterisation techniques and deep ocean tsunameters will continue to be the primary tools, we will look to other technologies and techniques, where and when available, to augment, expand or in some cases substitute for these traditional sensing platforms and strategies.

Keywords: Tsunami Observations, Source Agnostic Tsunami Detection, Ocean Decade Tsunami Programme, Tsunami Threat Lifecycle

IIOE-2 Endorsed Project No: -

[ABS-07-0097]

Chasing ocean observations in Africa - The benefits and challenges of multilateral training research cruises - IIOE-2 - as an example

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After the IOC of UNESCO and SCOR announced and launched the IIOE-2, South Africa undertook several national initiatives towards supporting the IIOE-2 programme within its identified themes. It was envisaged that South Africa's participation will have a regional impact and leave a legacy for the region. South Africa's Cabinet approved a proposal from the then Ministry of Environmental Affairs (DEA) (currently Ministry of Forestry, Fisheries and the Environment (DFFE)) to use the research vessels, SA Agulhas II and RV Algoa, as research platforms in the region during the IIOE-2 period. Two regional training and research cruises undertaken in 2017 and 2018 onboard the SA Agulhas II with a regional coverage along South Africa, Mozambique, Tanzania and Comoros. The two regional training and scientific cruises were undertaken onboard the SA Agulhas II with more than 100 (hundred) expert and early-career participants sourced from almost twelve (12) countries, namely, South Africa, Comoros, Madagascar, Zimbabwe, Mozambique, Kenya, Tanzania, Nigeria, India, Egypt, France and Italy. Several disciplines were covered ranging from physical oceanography, bio-geochemical science, top predators. Several scientific reports, presentations, training workshops, peer-reviewed papers were produced. At least one high-learning degree was completed from the data collected during these cruises. The presentation will further address the challenges experienced during the planning and execution of the regional cruises including, but not limited to, diplomatic clearances, immigration, and shortage of funds to support participants. Several solutions were also proposed for the challenges experienced, and how these solutions can be beneficial to the regional activities related to the UN Decade of Ocean Science for Sustainable Development (2021-2030) and/or extended IIOE-2 programme to fill the identified gaps.

Keywords: South Africa, regional cruises, SA Agulhas II, IIOE-2

IIOE-2 Endorsed Project No:

[ABS-07-0013]

Remote Sensing and GIS-Based Site Suitability Mapping for Seaweed Farming in the Indian EEZ.

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Blue economy envisages the potential and sustainable use of marine resources for the improvement of the livelihood as well as the conservation and restoration of the marine ecosystem. Seaweeds, marine macro algae, are crucial for Sustainable development and are considered as the Nutritional Powerhouse from the ocean. They are vital sources of food and ecosystem services, fostering economic stability through various means (e.g., employment) and a connection between humans and the environment. They support other marine habitats (which include marine flora and fauna) and act as a carbon sink also. In India several seaweed natural hotspots were identified. Along the coast of India, seaweed culture practices are also promoted due to its economic, cultural as well as commercial value. So, there is a significant obligation for conserving the natural seaweed bed due to its increasing demand and it should equally balance the cultivation strategies also. One such initiative is the mapping of the site suitability of seaweed using a Geographic Information System (GIS) enabled Satellite Remote Sensing. This study identified potential seaweed cultivation zones along the Indian coast by remotely sensing environmental parameters like Sea Surface Temperature (SST), Sea Surface Salinity (SSS), Dissolved Oxygen, Water clarity, pH, Chlorophyll (CHL), Nutrients (Phosphate & Nitrate), Wind, Wave, Depth, etc. A weighted overlay analysis was done to classify regions as Highly, Moderately, or Not Suitable based on the optimal range of these environmental parameters required for the seaweed growth. The present study resulted the mapping of Suitable Seaweed growing areas along the coasts of India on March 2022, March and May 2023. GIS study versus validation with literature survey found High and Moderate zones from Gujarat (2), Maharashtra (4), Karnataka (3), Kerala (2), Tamil Nadu South (6), Tamil Nadu North (3), Andhra Pradesh South (4) and Andhra Pradesh North (2) respectively.

Keywords: Blue Economy, Marine Ecosystem, Seaweed, Sustainable development, Site suitability, GIS, Satellite Remote Sensing, Environmental parameters.

IIOE-2 Endorsed Project No: -

[ABS-07-0154]

Strategic Perspectives on Indian Ocean Seabed and Habitat Mapping: A Maritime Policy Imperative

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As nations increasingly turn their attention to the oceans for resources, sustainability, and strategic advantage, seabed and habitat mapping in the Indian Ocean has emerged as both a scientific priority and a geopolitical necessity. This article offers a strategic perspective on the evolving landscape of seabed mapping in the Indian Ocean, underscoring the convergence of scientific capability, data infrastructure, and maritime policy. Drawing upon operational maritime experience and India's growing role in the Blue Economy and deep-sea governance frameworks, the paper explores how integrated seabed mapping can support not only ecological protection but also informed decision-making in resource exploration, infrastructure development, and marine spatial planning. It reflects on India’s progress in multibeam bathymetry, habitat classification, and ocean observation systems, while calling for greater regional cooperation, data-sharing standards, and alignment with global frameworks. The article advocates for the institutionalization of seabed mapping as a national and regional priority supported by a multi-ministerial approach and technological partnerships to ensure that India’s ocean development remains sustainable, secure, and science-led.

Keywords: sustainability, and strategic advantage, seabed and habitat mapping, evolving landscape of seabed mapping in the Indian Ocean

IIOE-2 Endorsed Project No:

[ABS-07-0182]

Satellite-Based Detection and Persistence Mapping of Hazardous Rip Current Zones Along Major Beaches of the Visakhapatnam Coast, India

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Rip currents pose a persistent hazard to coastal recreation worldwide and are a leading cause of nearshore drownings, with negative impacts on tourism and public safety. The Visakhapatnam coast, particularly RK (Rama Krishna) Beach, records highest rip current related drownings, highlighting the need for systematic detection and mapping. Generally, lifeguards rely on globally recognized visual clues, such as gaps in breaking waves, seaward plumes of turbulent water, churning surfaces, scalloped embayments, and rips near coastal structures, to detect rip currents. Building on these established indicators, this study presents a satellite-based methodology for the systematic identification and mapping of hazardous rip current zones along major visakhapatnam beaches, including RK, Rushikonda, Yarada, Bheemili, Sagar Nagar, and Jodugullapalem. Leveraging high-resolution optical satellite imagery from Sentinel-2, ResourceSat-2 LISS-IV, and Google Earth collected between 2016 and 2024, this approach integrates manual interpretation with AI/ML detection techniques to enhance detection accuracy, persistence analysis, and the spatial-temporal understanding of rip current dynamics. The identified rip locations are validated through correlation with historical drowning records, while the surf similarity parameter calculated from beach morphology and offshore wave data serves to confirm the type of beach stages conducive to rip current formation. Based on the recurrent occurrences of rip currents, seasonal and annual frequency analyses reveal persistent hotspots, including the Aqua Sports complex and Kursura submarine area at RK Beach, North Rushikonda, South Yarada, and North Bheemili, with peak frequencies during pre-monsoon, southwest monsoon, and post-monsoon seasons. The integration of additional archival and high-resolution imagery, alongside ongoing AI/ML model development, may improve detection accuracy and reduce false positives, enabling near real-time satellite-driven advisories and automated alerts that provide lifeguards and coastal managers with timely information to safeguard beachgoers and promote safe tourism.

Keywords: Rip current hotspots, Persistence, satellite, surf similarity, AI/ML

IIOE-2 Endorsed Project No: -

[ABS-07-0076]

Collaborative partnerships addressing complex challenges off the coast of Western Australia

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Cutting-edge science and effective partnerships are needed to deliver practical solutions for marine and coastal management. The Western Australian Marine Science Institution (WAMSI) leads large scale collaborative marine science programs to deliver independent evidence-based advice through better science, data integration and stakeholder engagement. Three WAMSI programs are used to demonstrate the success of multi-institution partnerships including 1) a UN Ocean Decade and IIOE-2 endorsed marine heatwaves project in the eastern Indian Ocean that aims to develop practical tools to forecast extreme ocean temperatures and their impacts, 2) a rigorous science program with over 150 scientists that informs an environmental impact assessment for the largest proposed port off the coast of Western Australia, and 3) an innovative â¿¿Shared Environmental Analytics Facility that integrates diverse data and modelling frameworks to deliver timely, user-oriented decision tools to support blue economy goals. The key outcomes of these programs is to generate data and/or tools that will inform government and industry decision making, and progress to date on these outcomes aim will be discussed. WAMSI programs also provide open access to data and reports, allowing knowledge to be applied or adapted in other locations that require better management of marine and coastal environments. Collaborative partnerships are key for addressing complex pressures from climate change, coastal development, and societal expectations.

Keywords: Partnerships, heatwaves, data integration, stakeholder engagement

IIOE-2 Endorsed Project No: IIOE2-EP58

[ABS-07-0183]

Metabarcoding of zooplankton to derive indicators of pelagic ecosystem status in South Africa

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The marine pelagic ecosystem is the largest and most diverse environment on Earth, yet it is increasingly impacted by climate-driven changes such as ocean warming, acidification, and deoxygenation. These physical changes affect species distributions and, in turn, disrupt the structure and functioning of marine food webs. As a crucial link between primary producers (phytoplankton) and higher order trophic levels, zooplankton biodiversity and abundance are recognised as Essential Ocean Variables (EOVs) for measuring biological change. Advances in molecular techniques now enable the identification of all zooplankton species in mixed samples, transforming biodiversity research by allowing for rapid and accurate processing of complex biological material. Within this context, DNA metabarcoding of zooplankton has emerged as a powerful, well-tested tool for deriving indicators of pelagic ecosystem status. However, challenges remain to its uptake by environmental management agencies, including the need for effective engagement of stakeholders to demonstrate its value and cost-efficiency, and the development of a roadmap towards its routine application in ocean monitoring. To address these challenges, a multi-institutional Zooplankton Inter-Calibration Experiment (Zoo-ICE) was launched in South Africa in 2021. This initiative aims to optimize scientific protocols, overcome logistical hurdles and strengthen engagement with key stakeholders and decision-makers. As a national framework, Zoo-ICE facilitates: access to offshore sampling on large research vessels; standardised laboratory processing and data analysis; strengthening of the regional DNA barcode reference database; ecological research on pelagic ecosystems; and the integration of molecular biodiversity data into existing long-term monitoring transects. We present a bespoke, multi-faceted approach towards integrating metabarcoding outputs into mainstream environmental management initiatives.

Keywords: Molecular ecology, DNA metabarcoding, zooplankton, policymaking, biomonitoring.

IIOE-2 Endorsed Project No: -

[ABS-07-0091]

An approach to scale net primary production to fish Biomass in Indian Marine waters using trophic transfer models

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Translating oceanic Net Primary Production (NPP) into fish biomass is essential for understanding marine productivity and guiding ecosystem-based fisheries management. This study proposes a framework for scaling NPP to higher trophic levels across the Indian Exclusive Economic Zone (EEZ), divided into Northeast (NE), Northwest (NW), Southeast (SE), and Southwest (SW) sectors over the period 2013-2024. Unlike conventional models that assume a fixed energy transfer between trophic levels, this approach provide due consideration to standing stock biomass, trophic diversity, and group-specific assimilation rates. The method uses mass-balanced Ecopath models from published studies representing each sector of the Indian EEZ. Key parameters such as production-to-consumption ratios (P/Q), ecotrophic efficiency (EE), and baseline biomass at the first trophic level were integrated with remote sensing-derived NPP estimates from MODIS-Aqua, calculated using the Vertically Generalized Production Model (VGPM). Considering phytoplankton biomass from the mass-balanced model as the baseline, this study estimates the additional biomass supported by the excess NPP at each trophic level (TL) on a monthly scale-from primary consumers (TL2) to apex predators (TL4). Results show strong regional variation in fish biomass potential. Small pelagic fish (TL2) biomass ranged from 3.96 to 14.56 million tonnes (MT), peaking in the SW and SE sectors, reflecting strong phytoplankton-mediated trophic pathways and balanced predation pressure in these sectors. Conversely, higher TL3 and TL4 biomass was recorded in the NW and NE sectors (NW: 19.02-29.17 MT; NE: 4.29-8.37 MT), indicating detritus-driven pathways and greater omnivory. This spatially explicit, ecologically grounded model offers a realistic tool for predicting fish biomass from primary production, supporting sustainable fisheries and ecosystem assessments in the Indian Ocean. The framework holds potential for future refinement by including more finer functional group compartmentalization and differential consideration of neritic and oceanic trophic dynamics.

Keywords: Primary Production, Remote Sensing, Ecopath, Fishery, Fronts

IIOE-2 Endorsed Project No:

[ABS-07-0355]

Marine Spatial Planning with Integrated Shipping Radiated Noise and Habitat Suitability Modelling in the Indian Ocean

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Sustainable Development Goal 14 (Life Below Water) highlights the urgent need to reduce anthropogenic pressures on marine ecosystems while ensuring sustainable use of ocean resources. Underwater Radiated Noise (URN) from shipping, is increasingly recognized as a chronic stressor that disrupts acoustic communication, navigation, and foraging behaviours of marine fauna. To address this challenge, we propose a dynamic, real-time Marine Spatial Planning (MSP) framework that integrates Shipping Radiated Noise Estimation (SRN) with Habitat Suitability Modelling (HSM). The SRN estimation in MSP, ingests AIS vessel data, machinery (engine) parameters, and environmental inputs (bathymetry, salinity, temperature) to produce instantaneous and cumulative noise maps across the Indian Ocean. These visualizations capture spatio-temporal variability in shipping noise and allow evaluation of cumulative stressors. Complementing this, species-specific HSMs have been developed using MaxEnt and environmental predictors such as sea surface temperature, chlorophyll-a, Net Primary Productivity (NPP), and bathymetry. This work demonstrates HSM for sea turtles, whales, and dolphins, however the framework can be generalised to a broad range of marine species and habitats. By overlaying noise propagation with predicted biodiversity hotspots and migratory corridors, the integrated system enables identification of high-risk conflict zones and supports interventions such as re-routing, speed regulation, and precision design of Marine Protected Areas (MPAs), thereby contributing towards the sustainability goals.

Keywords: SDG-14, Marine Spatial Planning, Shipping Radiated Noise, Habitat Suitability Models, Indian Ocean, UN Decade of Ocean Science

IIOE-2 Endorsed Project No: -

[ABS-07-0329]

Chromium Detoxification by Marine Bacterium *Alkalihalobacillus clausii* ABF28: Insights from Microscopy, Genomic Analysis, and Bioreactor Studies

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A Gram-positive strain of *Alkalihalobacillus clausii* ABF28, found in environments contaminated with Cr(VI), was identified through molecular imaging and de novo genomic profiling. To evaluate the remediation efficiency of this bacterial strain, it was cultivated in a Novel Column Bioreactor designed to achieve a higher retention time. The minimum inhibitory concentration (MIC) for the indigenous strain was determined to be 2500 mg/l. X-ray photoelectron spectroscopy (XPS) confirmed that the bacterial strain successfully reduced Cr(VI) to a +3 oxidation state. The strain was cultivated in both free and immobilized forms and subsequently analysed using scanning electron microscopy (SEM), XPS, and Fourier-transform infrared spectroscopy (FTIR). A similar finding was observed in the elemental mapping conducted via energy-dispersive X-ray spectroscopy (EDX). Molecular characterization through whole genome sequencing identified the genes responsible for the reduction of chromium (VI) to chromium (III) via the chromate reductase enzyme in this study. Given its notable chromium removal capability and strong resilience, this bacterial isolate offers a promising solution for the biotechnological remediation of chromium and other heavy metals from environments contaminated with trace metals.

Keywords: *Alkalihalobacillus clausii* ABF28, Novel column bioreactor, Circular genome map, Bioremediation, Immobilised and free bacterial cells

IIOE-2 Endorsed Project No: -

[ABS-07-0093]

Seascape connectivity has low influence on seagrass blue carbon in tropical oligotrophic islands

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Seagrass meadows are important blue carbon sinks, yet significant knowledge gaps exist in understanding the role of seascape connectivity in influencing carbon (C) and nitrogen (N) stocks. This study addressed this existing knowledge gap, by quantifying the sediment and seagrass (*Thalassia hemprichii)* biomass C and N stocks, and utilized stable isotope mixed modelling to assess the contribution of various sources to the sediment C pool in mixed (with other seagrass) and connected (with mangroves) meadows in the Andaman and Nicobar Islands, India. We found that mixed meadows sediment contained 3.7-fold higher total N, and enriched 13C and 15N values compared to connected meadows. Contrastingly, the sediment in connected meadows exhibited higher organic matter, total C, and more depleted 13C and 15N. Surficial sediment C stocks (3.50 ±1.78 Mg C ha^{-1}) were higher in connected meadows, while N stocks (1.21 ± 0.71 Mg N ha^{-1}) were higher in mixed meadows. Higher N availability led to higher density and biomass N stocks in mixed meadows. Stable isotope modelling indicated that the average contribution of *T. hemprichii* biomass was highest (0.68-0.69%) to the sediment C pool, followed by other seagrass biomass (0.4-0.7%) or mangrove biomass (0.10-0.14%) in mixed and connected meadows respectively. This study highlights that the influence of seascape connectivity for cross habitat subsidies of C and organic matter is lower in intertidal oligotrophic island ecosystems of the Indian Ocean region.

Keywords: Blue Carbon, Blue Nitrogen, Stable Isotopes, mangroves, *Thalassia hemprichii*, *Halophila beccarii*

IIOE-2 Endorsed Project No: -

[ABS-07-0328]

Optimizing Tsunami Buoy Deployment: Strategies and Best Practices for Enhanced DART-II Tsunami Buoys

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Tsunami buoy systems are a critical component of the global tsunami warning chain, providing essential confirmation of tsunami generation and reducing the likelihood of false alerts. Among these, the DART-II tsunami buoys are widely recognized as robust observational platforms; however, their deployment is inherently complex, requiring carefully timed, interconnected, and sequential procedures to ensure successful operation and long-term endurance. This study outlines deployment techniques and best practices for tsunami monitoring buoys, with a focus on enhancing their operational reliability and lifespan. The first aspect of improvement involves refining deployment strategies through optimal site selection, guided by historical tsunami records, oceanographic dynamics, geological factors, and data-sharing considerations. By strategically positioning buoys in regions of high seismic and oceanic activity, the monitoring network can maximize coverage and minimize response times. Equally important are the pre- and post-deployment phases, which encompass configuration, maintenance, and rigorous testing. The study establishes protocols for pre-deployment checks, routine inspections, sensor calibration, and predictive maintenance to ensure sustained functionality. Additionally, standardized training programs for personnel involved in buoy deployment and data interpretation are recommended to improve operational efficiency. By combining refined deployment strategies with structured maintenance protocols, this study contributes to optimising deployment procedures and reducing data dropout rates. These improvements enhance the overall effectiveness of tsunami monitoring systems, thereby strengthening early warning capabilities and offering coastal communities a more reliable defence against the devastating impacts of tsunamis.

Keywords: DART-II deployment strategies, operational reliability, pre- and post-deployment protocols, data continuity, coastal safety, monitoring network optimization

IIOE-2 Endorsed Project No: -

[ABS-07-0137]

Forecasting Global Seaweed Production Trends Using Autoregressive Time Series Models: Machine Learning Approach

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With the global population rising and traditional resources under strain, seaweed aquaculture is emerging as a vital solution for future food security and sustainable development. Data available in literature reflects a significant global shift in seaweed aquaculture, rising from 6.58 million tons in 1992 to over 35.14 million tons in 2022, with market value increasing from USD 3.12 billion to USD 16.8 billion in the same period. Most of this growth (97%) stems from aquaculture rather than wild capture. A strategic production shift from brown to red seaweeds, especially *Eucheuma, Gracilaria, and Kappaphycus spp*., underlines market-driven demand for hydrocolloids like carrageenan and agar. The present study aims to forecast global seaweed production using classical statistical time series models ARIMA, SARIMA, SARIMAX, and PROPHET based on data sourced from the FAO FishStatJ database (1950-2022). The models were developed to predict future trends based on historical data. Model validation has been done by splitting the dataset into two groups, of which 70% was used for model training and 30% for testing. Performance was assessed using Root Mean Square Error (RMSE) and regression coefficient (R^2), and the R^2 values were more than 0.7 for the tests, indicating a strong model fit. Based on these findings, we have predicted the country-wise global production and the choice of seaweed species by year 2030. Results confirmed SARIMAX outperformed ARIMA and SARIMA across most forecasting scenarios, particularly in regions like East and Southeast Asia with strong exogenous drivers. The models outlined a continued upward production trend globally, though regional dynamics like species shifts and socio-environmental constraints introduce nonlinearity. The work highlights the critical role of various forecasting models in marine Agri-economics and lays a foundation for future hybrid approaches incorporating deep learning for robust, long-term predictions.

Keywords: ARIMA, Sustainable Aquaculture, Food Security, SARIMAX, Marine Economics

IIOE-2 Endorsed Project No: -

[ABS-07-0260]

The Indian Ocean's Gentle Giants: Whaleshark Conservation in Indian waters- Population status, threats and community led efforts with preference to their pupping grounds

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The whale shark (Rhincodon typus) is the largest extant fish species and a migratory filter feeder of global conservation concern, classified as Endangered by IUCN. These blunt-headed giants are found along both the east & west coasts of India. Genetic results indicate that two major subpopulations exist, in the Atlantic and Indo-Pacific, with approximately 25% & 75% of the population respectively, in the Indo-Pacific. In Indian waters, some of the most significant seasonal aggregations are known with sightings along the coasts of Gujarat, Karnataka, Kerala, Lakshadweep, and the Andaman & Nicobar Islands which indicates the region's ecological importance. Of particular interest is the occurrence of juveniles along the Gujarat & Lakshadweep coasts, suggesting the potential presence of pupping or developmental grounds- an aspect still poorly known in Bay of Bengal waters. The east coast of India has documented occasional strandings or releases, but no neonatal captures are reported till date so pupping there remains unconfirmed. In this study, an incidental catch of a small neonatal specimen is found along the Kakinada coast, Andhra Pradesh. The neonate was caught by gill net operated at Kakinada coast & landed at Kasimedu, Chennai. The waters off Kakinada and its nearby coastal areas are now considered to be one of the prominent nursery grounds as these species can be seen all around the year. Since the species inclusion under Schedule I of the Indian WPA (2001), direct exploitation has been significantly reduced & conservation measures includes community-led initiatives which foster fisher engagement in live-release operations & reporting. Recognising and safeguarding potential pupping grounds is essential for sustaining whale shark populations in the Indian waters. In this study, we delve into the significance of stranding reports and occurrences, the potential causes behind them, and the crucial conservation measures needed to protect these gentle giants.

Keywords: whale sharks, endangered, pupping areas, conservation-efforts, East-coast, India

IIOE-2 Endorsed Project No: -

[ABS-07-0071]

Phragmites karka habitats provide similar ecosystem services compared to other keystone macrophytes in Asia's largest lagoon ecosystem.

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Macrophytes in wetlands provide various ecosystem services and play an important role in functioning of the ecosystem. However, limited information is available for plant-specific ecosystem services within these wetlands. Within this framework, this study aimed at assessing the regulating ecosystem services (i.e., trace metal bioindicator potential, nutrient retention, carbon and nitrogen stocks) and population demography of *Phragmites karka* for the first time from Asia's largest lagoon ecosystem. Significant differences were observed in surface water abiotic parameters and nutrients (except nitrate) and sediment variables across *P. karka* habitats. The concentration of Sr and Zn were higher in the sediment of *P. karka* habitats than plant tissues. The Enrichment Factor (EF) indicated, EF>1.5 only for Co, Mn and Zn in sediment indicating moderate anthropogenic enrichment. *P. karka* floating roots and roots are efficient bioindicators of Mn and Ni and Co and Na respectively. The Bio-sediment accumulation factor (BSAF) highlighted the increased accumulation (BSAF>1) of Co, Mn, Na and Ni by *P. karka* roots from sediment. Sediment C stocks across the 10510 ha of *P. karka* was 526462.22 ± 190434 Mg C with CO2 mitigation potential 1932116.36-ton CO2 and economic value of US$ 1.93 million. The sediment N stocks across 10510 ha of *P. karka* was 50583.60 ±16858 Mg N. Population demography showcased, the present recruitment (R0: 0.56 yr^{-1}) of *P. karka* population being higher than long-term average recruitment (R: 0.50 ± 0.17 yr^{-1}) indicating positive population growth. This growth resulted in the presence of a higher younger population (42%) compared to the older population (6%:> 4 years old) in the current sampling period. *P. karka* habitats of the Chilika lagoon contribute towards five sustainable development goals (SDGs) such as SDG 1,2,6, 13 and 14 highlighting the importance of *P. karka* regulating ecosystem services compared with similar ecosystems (e.g., seagrass) of the lagoon.

Keywords: Aquatic macrophytes, Conservation, Management, Blue carbon, Blue nitrogen, Bioindicators, SDGs

IIOE-2 Endorsed Project No: -

[ABS-07-0360]

Adaptive Maritime Routing on Dynamic Spatio-Temporal Fields with Hybrid Search Algorithms

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Maritime route planning is a critical challenge in modern shipping, where efficiency, safety, and sustainability must be simultaneously addressed. We model the ocean not as a fixed map but as a changing spatio-temporal grid. This study presents a hybrid routing algorithm that relies on a spatio-temporal cost function to generate safe and fuel-efficient vessel trajectories. As a vessel progresses through oceanic grids, the algorithm dynamically evaluates routing costs on the fly, incorporating forecast conditions at the estimated time of arrival and historical patterns specific to the location and season. This adaptive framework ensures that the most relevant environmental information is applied to each segment of the voyage. An evolutionary algorithm is first used to produce multiple locally optimal routes, followed by a parallelized A* search that synthesizes these into a globally optimized path. By minimizing fuel consumption, enhancing safety, and reducing environmental risks, the approach contributes directly to the reduction of shipping-related emissions and supports climate-resilient operations. The outcomes demonstrate the potential of spatio-temporal optimization to improve maritime logistics while aligning with the objectives of the UN Decade of Ocean Science for Sustainable Development, promoting safer, smarter, and more sustainable ocean use.

Keywords: Spatio-temporal routing, Dynamic ocean grid, Hybrid routing algorithm, Evolutionary algorithm, Parallelized A* search, Fuel-efficient navigation, Risk-aware maritime planning

IIOE-2 Endorsed Project No:

[ABS-07-0028]

Harnessing Environmental DNA (eDNA) for Marine Food Web Reconstruction and Potential Fishing Zone (PFZ) Validation: Opportunities and Challenges

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Environmental DNA (eDNA) transforms the marine ecological research, by offering innovative non-invasive opportunities to understand the trophic links. This study explores the potential of eDNA in food web reconstruction and potential fishing zone (PFZ) validation, aiming to bridge intricate ecological insights with fisheries management. eDNA has already established itself as a powerful tool in fisheries and biodiversity monitoring, resource assessment, and conservation efforts, utilizing metabarcoding, next-generation sequencing technologies, and advanced bioinformatics tools. Integrating eDNA metabarcoding into food web reconstruction will enhance the understanding of trophic structure with higher taxonomic resolution to aid ecosystem-based management. This review elucidates the concepts of eDNA and explores its applications in food web studies and potential fishing zone (PFZ) dynamics. Additionally, the review presents a bibliometric analysis of the global publications related to eDNA, food web and marine fishes, scrutinizing the co-occurrence of these keywords in publications, underscoring the need to integrate the eDNA studies with these aspects to accurately derive insights into food web structure and fisheries potential. The review highlights the existing gaps in the effective use of this technique and underscores its immense potential to enhance efforts toward the sustainable utilization of marine resources and the advancement of the blue economy.

Keywords: Potential fishing zone, fisheries management, environmental DNA, food web, ecological insights, metabarcoding, blue economy

IIOE-2 Endorsed Project No:

[ABS-07-0348]

Towards the development of an aerosol sampling network for the Indian Ocean

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Over the last few decades there has been a significant increase in atmospheric pollutants in Asia, Africa, and Oceania due to the rapid growth in industrial and agricultural activity. Much of this new atmospheric load has been transported to, and deposited in, the Indian Ocean, where it can influence primary productivity and modulate biogeochemical cycling in the ocean. While satellite remote sensing data have greatly enhanced our ability to track the transport pathways of pollution plumes as they move over the ocean, they do not yet provide information on trace elemental composition, which is necessary for determining fluxes as inputs to Earth System Models. Currently the majority of the data acquired in the Indian Ocean on the elemental concentration of aerosols has been gained during shipboard surveys (often as part of activities connected to IIOE and IIOE-2) and from sporadic coastal time series stations. However, shipboard surveys are expensive and provide limited spatial and temporal coverage. This situation has led to poor spatiotemporal data coverage for the Indian Ocean region and significant knowledge gaps around the deposition fluxes of elements to the Indian Ocean. In this context, SCOR (https://scor-int.org/) working group 167 Reducing Uncertainty in Soluble aerosol Trace Element Deposition (RUSTED) (https://scor-int.org/group/reducing-uncertainty-in-soluble-aerosol-trace-element-deposition-rusted/) identifies an opportunity now within the UN Decade of Ocean Science to build on recent research carried out in the Indian Ocean within the SCOR projects, IIOE-2 (https://iioe-2.incois.gov.in/IIOE-2/index.jsp) SOLAS (https://www.solas-int.org/) and GEOTRACES (https://www.geotraces.org/), to initiate a program towards establishing an international baseline aerosol sampling network across the Indian Ocean using shore based stations, most likely linked to existing meteorology facilities and standardized protocols. This presentation will outline the current situation in the Indian Ocean for aerosol sampling and invite researchers from around the Indian Ocean basin to co-develop this initiative further with us.

Keywords: Aerosols, time-series, trace elements, RUSTED, Indian Ocean

IIOE-2 Endorsed Project No:

THEME-8

MARGINAL SEAS OF THE INDIAN OCEAN

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[ABS-08-0099]

Treasures from the Extremes: Unlocking the Bioactive Potential of Marine Life along the Kuwait Coast of the Arabian Gulf

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The Kuwaiti coast of the Arabian Gulf, a marginal sea of the Indian Ocean, is characterized by unique environmental conditions, including elevated water temperatures, salinity, and ultraviolet (UV) index. Despite these challenging conditions, the region boasts a rich biodiversity. We hypothesize that to adapt to these harsh environments, marine organisms in this area produce a distinct array of secondary metabolites that differ from those found in other oceanic regions. Phyco-prospecting research revealed that, unlike temperate waters, seaweeds from this region contain higher levels of flavonoids than phlorotannins. Red seaweeds contain higher concentrations of mycosporine-like amino acids (MAAs). Seven novel, four known, and several unidentified MAAs were isolated from the seaweeds. Interestingly, microalgae exposed to UV radiation respond by altering their pigment profiles, shifting from chlorophylls to photosynthetic and photoprotective carotenoids, and producing unique stress-responsive proteins. Pigment profiling of seaweeds revealed that fucoxanthin is the dominant pigment in species that thrive under Kuwait's extreme summer conditions. The UV-protective efficacy of fucoxanthin varies depending on its molecular structure and the seaweed species from which it is isolated. In microbial bioprospecting studies, *Pseudoalteromonas citrea* has been identified as a potent antimicrobial producer. Among the 11 pigment-producing bacteria with high antioxidant activity, violacein from *Pseudoalteromonas amylolytica* and prodigiosin from *Zooshikella ganghwensis* exhibited strong antihypertensive effects, with the latter also carrying antitumor genes. The culturable and metagenomic bacterial diversity of Kuwait's hypersaline habitats was documented, and functional screening of a metagenomic library prepared from these samples was conducted to identify novel enzymes. A novel halotolerant Î±-amylase with exceptionally high specific activity was isolated from *Priestia flexa* from the Mina Abdullah sabkha. A novel thermophilic alkaline protease isoenzyme was purified from *Marinobacter sediminum* isolated from Bubiyan Sabkha. The findings from these studies offer exciting prospects for marine bioprospecting in extreme environments

Keywords: Marginal sea, Arabian Gulf, Marine Life, Bioactive Potential

IIOE-2 Endorsed Project No: -

[ABS-08-0171]

Acceleration of Warming, Deoxygenation, and Acidification in the Arabian Gulf Driven by Weakening of Summer Winds

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The Arabian Gulf (AG) exports hypersaline, dense waters into the Sea of Oman (SOO), replaced by fresher inflowing surface waters from the Indian Ocean. We investigate the impact of recent AG warming on its exchange with the SOO and the implications this has on the AG biogeochemistry. Using an eddy-resolving hindcast model simulation, we analyze the hydrography and biogeochemistry of the AG and the SOO from 1980 to 2018. Our study reveals that changes in summer surface winds have accelerated AG warming and weakened it in the SOO, reducing the density gradient and water exchange between the two seas during late summer. This has led to nutrient buildup, increased productivity, and heightened deoxygenation and acidification in the AG. These findings underscore how subtle wind changes can exacerbate the vulnerability of marginal seas to climate change and stress the need to properly represent regional winds in global climate models.

Keywords: Ocean Warming, Ocean Deoxygenation, Ocean Acidification

IIOE-2 Endorsed Project No: -

[ABS-08-0214]

Nutrient Dynamics Under Climate and Anthropogenic Stress: Lessons from the Persian Gulf for Marginal Seas

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Marginal seas are hotspots of biogeochemical exchange, supporting productive ecosystems yet highly vulnerable to climate change and human pressures. The Persian Gulf (PG), a semi-enclosed and shallow basin in the northwest Indian Ocean, is experiencing rapid environmental change, making it an important natural laboratory for studying nutrient dynamics under multiple stressors. Recent high-resolution oceanographic surveys reveal marked shifts in nutrient concentrations, stoichiometric ratios, and limitation patterns, alongside hydrographic changes such as sustained warming, reduced dissolved oxygen, and increasing salinity. Observations indicate a transition from predominantly nitrogen limitation to a more complex mosaic of nutrient stress, including phosphorus and silicon co-limitation, with strong seasonal variability linked to circulation, atmospheric deposition, and diminishing riverine inflows. Elevated N:P ratios in surface waters suggest intensified nitrogen fixation, echoing patterns seen in other oligotrophic marginal seas such as the Red Sea and Eastern Mediterranean. These changes have significant implications for phytoplankton community structure, productivity, and food web dynamics, potentially affecting fisheries and biodiversity. This presentation will discuss the mechanisms driving these shifts, highlight parallels with other marginal seas, and consider the Persian Gulf as a sentinel system for anticipating the trajectory of nutrient regimes under combined climatic and anthropogenic pressures.

Keywords: Persian Gulf; Nutrient dynamics; Climate change; Marginal sea; Anthropogenic Stress

IIOE-2 Endorsed Project No: IIOE2-EP61

[ABS-08-0230]

Application of decadal of time-series satellite data for assessment of trend of change and marine climate dimension in ROPME Sea Area

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Many coastal sectors in the ROPME Sea Area (non-UNEP administered Regional Sea) and other marginal Seas of the Indian Ocean are now threatened by sea level rise and impacts of the climate change. Among other hazards, hurricanes and storm surges, sand and dust storms, and extreme heat waves are remarkably increased in both frequency and severity in this Sea Area. The coastal ecosystems particularly, in the inner part of the ROPME Sea Area (Arabian / Persian Gulf), are started to experience variable ecological troubles e.g. increase of low-oxygen (dead) marine zones, frequent harmful algal blooms, and sea surface temperature anomalies and extreme heat waves. Unfortunately, knowledge of marine climate change dimension and its impact on coastal and marine areas in this part and other subdivisions of the ROPME Sea Area, which is very critical for marine resource and risk-management issues of the Region, is relatively poor compared with other Regional Seas. In order to effectively manage these risks and to select proper mitigation and / or adaptation strategies, it is essential and vital to assess the degree of vulnerability of coastal areas and associated coastal ecosystems to climate change. In compliance with this pre-requisite, time series analysis of decadal multi-sensor satellite records of sea surface temperature and chlorophyll-a have been applied for evaluating the dimension of marine climate change and assessment trend of change in this Inner and middle parts of the ROPME Sea Area. Results of time series analysis reveal that the Inner ROPME Sea Area experienced a long-term surface warming of about 1.1 °C in about 20 years (2002-2022). In contrast, variability of surface chlorophyll and marine productivity showed a general downward trend suggesting a significant shift in the structure and assemblage of the common phytoplankton groups. The Middle part of the ROPME Sea Area manifested similar change.

Keywords: ROPME Sea Area, satellite sst and chl-a, change trend, coastal and marine ecosystems

IIOE-2 Endorsed Project No: -

[ABS-08-0287]

Biological-Physical Interactions Regulating Nutrient Dynamics in the Lakshadweep Sea during the Winter Monsoon

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Hydrographic profiles (up to 500m) from the open-ocean region of the Arabian Sea near the Lakshadweep Islands (8°N - 12°N) were examined during the winter monsoon (November) of 2019, to understand biogeochemical dynamics in this region. The temperature profile from 25 locations, exhibited strong stratification, with surface waters exceeding 30°C and gradually decreasing to ~17°C at 300 m depth. Salinity ranged from 38.6 to 40.4, with the highest values occurring in the upper 100 m between 10 and 10.5°N along the transect, indicating high evaporation and limited freshwater input during the northeast monsoon. Below 100 m, salinity gradually decreased to less than 39 at 300m. Chlorophyll concentrations ranged from 0.06 to 0.36 µg l^{1}, with higher values mainly in the upper 50-100 m, coinciding with the chlorophyll maximum zone. Three distinct high-chlorophyll patches (>0.33 µg l^{-1}) were observed (around 50 m depth), suggesting localized biological enhancement. Below 150 m, concentrations declined sharply (<0.15 µg l^{-1}), reflecting reduced light availability and weaker primary productivity. Dissolved oxygen ranged from 1.75 to 5.85 mg l^{-1}, exhibiting strong vertical and spatial gradients. Surface waters (0-50 m) were well-oxygenated (>5.5 mg l^{-1}), while concentrations decreased to as low as 1.75 mg l^{-1} between 150 and 300 m, indicating intense subsurface respiration and limited ventilation. During the study, the surface water was mostly limited in dissolved inorganic nitrogen and oxygen depleted waters, coinciding with the nitrite maximum in the mid-section, at ~100-150 m depth. Lateral variability revealed localized low-oxygen intrusions in the mid-water column (9 - 10.5°N), possibly associated with mesoscale eddies and advective processes transporting low-oxygen waters from the central Arabian Sea. The observed oxygen structure highlights the interplay between physical circulation and biological productivity, providing important baseline information on biogeochemical dynamics in the Lakshadweep open waters during the winter monsoon.

Keywords: Thermocline; stratification; biogeochemistry; Nutrients; Lakshadweep Sea; Winter Monsoon

IIOE-2 Endorsed Project No: -

[ABS-08-0325]

The New ROPME Strategic Directions (2026-2030) and its vital role in Marine Data Management and Knowledge Sharing to Achieve the Conservation and Sustainable Development in the ROPME Sea Area.

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The Regional Organization for the Protection of the Marine Environment (ROPME) was established in early 1978 by the 8 Member States (Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and UAE). ROPME is one of the 18 Organizations of the International Regional Seas Program. The ROPME Sea Area (RSA) was declared as a Special Area by the International Maritime Organization (IMO)/the Marine Environment Protection Committee (MEPC) (Resolution # 168(56) adopted on 13 July 2007). The ROPME Strategic Directions 2026-2030 provides a comprehensive framework for addressing the critical environmental challenges facing the ROPME Sea Area (RSA) and aligns with global, regional, and national priorities, including the United Nations Sustainable Development Goals (SDGs) and the UNEP Regional Seas Strategic Directions. The ROPME Strategic Directions are built around three main goals: securing resilient ecosystems, advancing knowledge and innovation, and enhancing advocacy and public engagement. ROPME aims to secure the future of RSA's marine ecosystems through these strategic directions, build resilience against environmental threats, and promote sustainable development. This plan reflects ROPME's commitment to fostering regional cooperation, protecting biodiversity, and ensuring a healthy and productive marine environment for current and future generations. In the ROPME Sea Area (RSA), there is a critical need for relevant, timely, reliable, and accessible marine data, information, and knowledge. High-quality data and information are essential for marine research, observation, assessment, decision-making, and management of marine ecosystems and resources in RSA. The 'System for Marine Environmental Knowledge (SMEK)' aims at the establishment of a modern integrated observation and information management system for the ROPME Sea Area (RSA) that will deliver and share vital information and marine data to the ROPME 8 Member States, the scientific community, and the public. SMEK will also connect to national, regional, and global marine observation systems, databases, and networks

Keywords: ROPME, RSD, RSA, IMO, UNEP, Marine Data Management, GIS, Marine Information System

IIOE-2 Endorsed Project No: -

[ABS-08-0038]

Assessment of the mesopelagic resources of the eastern Arabian Sea- Implications for Sustainable Exploitation

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The present study helps provide information on the biomass of mesopelagic Nektons and myctophids from mid-water trawl surveys carried out in the Eastern Arabian Sea. In this paper, the swept area method has been attempted in conjunction with a spatial grid analysis in order to estimate the bimodal distribution of nektons and Myctophids in the Eastern Arabian Sea. The effort has been essential in assessing the feasibility of Nekton and myctophids for future exploitation and their role in the carbon sequestration mechanism. The work represents part of the quantification of Mesopelagic resources and its potential in fisheries management. The myctophid biomass is also converted into carbon and the efficiency of the trophic is evaluated. This research findings would, facilitate the management of the developing mesopelagic nekton and myctophid fishery as this is the first detailed study from Eastern Arabian Seas with its implication on the sustainability of global fisheries.

Keywords: Biomass, Mesopelagic, Myctophids, Swept area, Arabian Sea

IIOE-2 Endorsed Project No: -

[ABS-08-0092]

Uncovering the Spatial and Temporal Distribution of Vertical Freshwater Intrusion Using an Unsupervised Machine Learning Approach

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Decoding freshwater fingerprints of the Bay of Bengal (BoB) is paramount for understanding regional climate patterns and ocean dynamics. Five major rivers flowing into the BoB north of 15°N create Sea Surface Salinity (SSS) values as low as ~28 psu, establishing the BoB as one of the world's most freshwater-influenced basins. Present-day ocean forecast models show considerable bias in reproducing currents, especially in the northern BoB, due to inaccurate representation of freshwater inputs and associated mixing processes. Past studies have primarily focused on surface freshwater transport, utilizing observation and model simulations. However, understanding vertical thermohaline structure during freshening events using observations remains limited. A Gaussian Mixture Model (GMM), an unsupervised clustering algorithm, was applied to over 5,000 in-situ low salinity profiles (SSS < 32 psu) and their corresponding temperature profiles to characterize the spatio-temporal variability of vertical thermohaline structures in the BoB. Our analysis identifies five distinct hyposaline classes (HSCs) and five associated temperature classes (ATCs) during freshening events. Seasonal freshwater advection begins with riverine inputs during the second half of the summer monsoon season, when mesoscale eddies and anticyclonic gyres in the north-central BoB control freshwater evolution and drive salinity to its lowest annual values. When the East India Coastal Current intensifies, most of the freshwater is advected along the western periphery of the BoB towards the equator. The rest stays in the north-central bay, creating favourable conditions for inversion layer formation. During winter, strong convective mixing causes freshwater to mix and evolve in the north-central bay. Our findings reveal three dynamic freshwater zones in the North BoB, which evolve seasonally, highlighting an interplay between freshwater input, stratification, and mixing. These results offer a new direction to validate and improve the freshwater forcing in the ocean model.

Keywords: Machine learning, Ocean Observation, Bay of Bengal

IIOE-2 Endorsed Project No: -

[ABS-08-0121]

Characterizing the meso-pelagic resources using underwater acoustic technique and in-situ sampling

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Acoustic studies were conducted to characterize mesopelagic resources in the North Arabian Sea. A split-beam acoustic survey (EK-80) was carried out on board the FORV Sagar Sampada from May 8-23, 2024. This was accompanied by in-situ midwater trawling of mesopelagic organisms, plankton, and other environmental parameters. The echosounder was operated at two frequencies (38 kHz and 120 kHz) to profile the water column from 10m to >1000m, with special thrust on the Deep Scattering Layer (DSL), which is a dominant feature of the Arabian Sea. The calibrated echosounder and the sampled volume backscatter profiles were used for the determination of the organisms' Target Strength (TS), as well as the spatial and temporal distribution of fish and plankton. During our study we employed a post-calibration technique to standardize the volume backscattering data. For unwanted voice removals we used background and impulse noise, based on the signal to noise ratio, using Echoview 14 software. Echo integration techniques were applied to characterize the mesopelagic organisms and their vertical migration patterns of the DSL. This clearly indicates the diel vertical migration of these organisms especially at depths of 250-450m. The TS was also estimated from selected myctophid fish based on the length-weight relationship. Additionally, the interlinkage between the DSL pattern and environmental variables such as dissolved oxygen and chlorophyll was estimated based on the observations. The study suggests that the acoustic method can serve as an effective monitoring tool to characterize mesopelagic resources and their vertical migration patterns. This research highlights the critical role of acoustic monitoring in advancing our understanding of the mesopelagic ecosystem and responsibly estimating its hidden resources.

Keywords: Echo-integration, Mean volume backscattering, Myctophid Biomass

IIOE-2 Endorsed Project No: -

[ABS-08-0194]

Projected Decadal Sea Level Changes and Vertical Land Motion Effects under SSP2-4.5: Implications for the Puri Coast, East Coast of India

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The present study portrays the impact of coastal inundation by sea level rise due to climate change based on the AR6 scenario database. The coastal land subsidence and upliftment also play a crucial role in the rising sea levels by worsening as the land subsidence increases the inundation levels. There are various reasons for urban land subsidence, such as heavy infrastructure load, excess groundwater extraction, soil consolidation, and land use changes. The findings of long-term global sea level rise (absolute sea level) only account for the overall sea level rise without considering the local processes. A coastal city undergoing even a minor subsidence over time will drastically change the trend and speed up the inundation. The prediction and preparedness, considering the rise in global sea level, may not be enough if the coastal city experiences subsidence. Small Baseline Subset (SBAS) method of Interferometric Synthetic Aperture Radar (InSAR) gives land deformation details using microwave images. Using long-term time series analysis, we can detect slow-moving land parts. Tide gauge measurements give relative sea-level rise, including land movement. Satellite altimetry provides absolute sea-level rise. By applying the sea-level equation, we separate vertical land motion from tide gauge records. GNSS data further quantifies land movement. These results assess coastal subsidence contributing to regional sea-level change, enabling precise absolute sea-level change rates. Integrating sea-level rise and vertical land motion is vital for projecting future coastal hazards, aiding policymakers in developing innovative adaptation strategies for vulnerable coastal cities.

Keywords: Vertical Land Motion, Relative Sea Level Change, Coastal Subsidence, coastal vulnerability

IIOE-2 Endorsed Project No: -

[ABS-08-0197]

Three Decades of Ecosystem Change and Plankton Community Dynamics in Kuwaiti Waters: Time-Series Insights from the Northwestern Arabian/Persian Gulf, a Marginal Sea of the Indian Ocean

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Kuwaiti waters in the north-western Arabian/Persian Gulf (NWAG) are among the most environmentally stressed marine systems, shaped by extreme hydrographic variability and chronic human pressures. For more than three decades, the Kuwait Institute for Scientific Research (KISR) has conducted extensive time-series oceanographic monitoring across Kuwait Bay and adjacent coastal and offshore waters, creating the first long-term dataset from the Gulf for evaluating decadal changes in water quality and ecosystem productivity. This study examines salinity, silicate, and total chlorophyll a (Chl a) from 1995 to 2022, alongside the size structure of phytoplankton (2007-2017) and microzooplankton (tintinnid ciliates; 2003-2015), to assess how hydrographic and nutrient dynamics affect productivity and plankton community structure. Over this period, progressive salinity increase, driven by reduced freshwater inflow and upstream damming, coincided with marked declines in silicate and other nutrient inputs from the Shatt Al-Arab River (SAR), disrupting the Si:N:P balance and reducing large microphytoplankton production. Total Chl a trends varied spatially: consistent decline near the SAR mouth (St. A), modest increases within Kuwait Bay (St. 4) and outside the Bay (St. 6), and stability offshore (St. 18). Size-fractionated Chl a indicated a shift toward smaller phytoplankton (0.4-5 µm) and reduced microphytoplankton (>50 µm). Tintinnid data similarly showed smaller ciliates, consistent with salinity rise and nutrient limitation. Episodic rainfall in 2019-2021 temporarily lowered salinity, increased nutrient availability, and partially reversed phytoplankton size shifts at coastal and mid-shelf sites. Findings demonstrate that reduced SAR inflow has fundamentally altered NWAG hydrography and nutrient regimes, with elevated salinity and nutrient decline driving long-term shifts toward smaller plankton cells, weakening diatom-based production, altering trophic pathways, and increasing ecosystem vulnerability. These changes have implications for food-web efficiency, fisheries productivity, and marine food security. Sustained time-series monitoring and adaptive management are vital to protect ecosystem resilience under intensifying pressures.

Keywords: Hypersaline system, Salinity rise, Nutrient limitation, Plankton size-structure, Damming effect, Marine food security

IIOE-2 Endorsed Project No: -

[ABS-08-0331]

Decision and Information System for the Coastal waters of Oman (DISCO) - An Integrative Tool for Managing Coastal Resources under Changing Climate

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The Sea of Oman is among the fastest-changing tropical marine ecosystems, experiencing a marked loss of plankton biodiversity driven by the rise and range expansion of green Noctiluca blooms. These blooms are linked to Eurasian warming, spreading hypoxia, and ocean acidification. Green Noctiluca, a mixoplankton, is not a preferred food for zooplankton; instead, it competes with them for resources. Its dominance is reshaping the food web and threatening a fisheries-rich ecosystem of substantial socio-economic and cultural importance for the region. This presentation synthesizes insights from laboratory experiments, field observations, and satellite-based remote sensing to reveal the drivers of these seasonal blooms, their expansion, and the risks they pose to regional food security, water quality, and broader national security. We also highlight how this knowledge is being translated into decision-support tools designed to mitigate socio-economic losses and support sustainable blue economy initiatives.

Keywords: Marginal Seas, Sea of Oman, Indian Ocean, Harmful Algal Blooms, Blue Economy

IIOE-2 Endorsed Project No: -

[ABS-08-0236]

Seasonal Variability in Direction and Eccentricity of Mesoscale Eddies in the Eastern Arabian Sea

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Mesoscale eddies are critical features of the upper-ocean circulation, modulating energy transfer, heat transport, and biological productivity in the Arabian Sea. This study investigates the seasonal variability in the direction and eccentricity of mesoscale eddies in the Eastern Arabian Sea, with particular attention to how the reversal of the mean monsoonal currents influences eddy propagation pathways. Using eddy-tracking algorithms applied to satellite altimetry products (AVISO), data assimilated products (RAIN) and reanalysis datasets (GLORYS), we assess whether the observed seasonality is consistently represented across data sources. Results reveal a clear seasonal shift in eddy direction, which is northwestward propagation during winter (December) and southwestward propagation during summer (August). This shift in direction reflects the semi-annual reversal of the West India Coastal Current and associated monsoon-driven circulation changes. Eccentricity analysis further highlights systematic seasonal differences in eddy geometry, suggesting that current reversals not only steer eddy trajectories but also modulate their structure and stability. Figures supporting this analysis include eddy trajectory maps for different seasons, as well as monthly heat maps showing the density of southwestward and northwestward propagating eddies. Together, these findings advance our understanding of the regional role of mesoscale eddies in monsoon-driven circulation and provide a foundation for evaluating eddy impacts on transport processes, upwelling, and ecosystem dynamics in the Eastern Arabian Sea.

Keywords: Mesoscale eddies, Seasonal variability, Eddy directionality, Eddy eccentricity, WICC, Eastern Arabian Sea

IIOE-2 Endorsed Project No: -

[ABS-08-0354]

Krishna Estuary Mangroves as Climate Buffers in the Bay of Bengal

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Marginal seas of the Indian Ocean, such as the Bay of Bengal, are ecological and socio-economic hotspots where terrestrial, freshwater, and marine processes converge. Estuarine mangroves within these seas act as blue carbon reservoirs, biodiversity hotspots, and natural coastal buffers. Yet, they face increasing pressures from climate change, cyclones, salinity intrusion, and unsustainable land-use. This study examines the Krishna estuarine mangroves of Andhra Pradesh as a representative case to link local ecosystem dynamics with broader marginal sea processes. The Krishna Wildlife Sanctuary (KWS) represents one of the largest estuarine mangrove ecosystems on India's east coast, directly influencing Bay of Bengal carbon cycling. Land-use and land-cover (LULC) changes from 2014-2024 were analyzed using remote sensing and Geographic Information System (GIS). Soil and water samples were collected to measure salinity, pH, and dissolved oxygen, while laboratory analyses (Total Organic Carbon, FTIR, UV spectrophotometer)

Keywords: Keywords: Bay of Bengal, Blue carbon, Climate resilience, Krishna estuary, Mangroves

IIOE-2 Endorsed Project No: -

[ABS-08-0152]

Physical Drivers of Winter Surface Chlorophyll Blooms in the Southeastern Bay of Bengal

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The southeastern Bay of Bengal (BoB) exhibits marked seasonal and interannual variability in surface chlorophyll-a (SChl) concentrations, with a pronounced peak during the winter monsoon season (December-February). This study investigates the drivers of interannual variability in winter SChl blooms, emphasizing their modulation by large-scale climate modes, particularly the Indian Ocean Dipole (IOD). Twenty-eight years (1997-2024) of satellite derived SChl, sea level anomaly (SLA), mixed layer depth (MLD), and surface current data are analyzed to explore the coupling between biological productivity and upper-ocean physical processes. Climatological analysis reveals a consistent winter maximum in SChl, while interannual anomalies highlight episodic bloom enhancements linked to ocean-atmosphere interactions. Among the climate indices, the SLA based Dipole Index (SDI) shows the strongest correlation with SChl anomalies, outperforming both the Dipole Mode Index (DMI) and Ni±o 3.4. Positive SDI phases are associated with negative SLA, intensified westward surface currents, and elevated SChl concentrations, indicating enhanced offshore nutrient transport and lateral spread of the bloom. During strong IOD years, westward-propagating SChl anomalies match the phase speed of second-mode baroclinic Rossby waves, suggesting a dynamic coupling between upper-ocean circulation and productivity. In contrast, weaker IOD or El Ni±o events fail to produce similar responses. These findings underscore the dominant influence of the IOD over ENSO in shaping winter biological variability in the southeastern BoB and highlight the critical role of upper-ocean dynamics in regulating surface productivity in response to climate forcing.

Keywords: Surface chlorophyll, Interannual variability, Bay of Bengal, IOD, ENSO

IIOE-2 Endorsed Project No: -

[ABS-08-0162]

Interannual Variability of Sea Surface Salinity in the Andaman Sea: Patterns and Drivers

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The Andaman Sea, a semi-enclosed basin in the eastern Indian Ocean, is strongly influenced by freshwater input from the Irrawaddy River and a persistently positive precipitation-minus-evaporation, resulting in low sea surface salinity (SSS) and strong stratification. However, its interannual variability remains poorly understood due to limited in-situ observations. The present study analyzes 14 years (2010-2023) of satellite-derived SSS to investigate the temporal variability in this region. Results show pronounced seasonal and interannual fluctuations, with monsoonal winds driving the seasonal cycle. The strongest interannual variability is evident during the post-monsoon season. Interannual freshening events are closely associated with the positive phase of the Indian Ocean Dipole (IOD), as evidenced by a significant negative correlation between post-monsoon SSS anomalies and the Dipole Mode Index. These SSS anomalies are linked to eastward propagating equatorial Kelvin waves generated by IOD related wind anomalies, which upon reaching the eastern Indian Ocean bifurcate at the Sumatra coast. The resulting northward propagating signal travels along the eastern boundary of the Andaman Sea, enhancing freshwater transport from north to south. The magnitude of this freshening is modulated by the strength of the IOD event. Our findings highlight the crucial role of remote equatorial dynamics in modulating SSS variability in the Andaman Sea and underscore the need for sustained observations in this climatically sensitive region.

Keywords: Andaman Sea, Surface Salinity, IOD, Coastal Kelvin Wave, Interannual Variability

IIOE-2 Endorsed Project No: -

[ABS-08-0167]

First Field Evidence of Microplastic Ingestion by Wild Zoanthids and a Global Meta-Analysis of Cnidaria

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Microplastics (MPs) are pervasive marine pollutants and recognized as a major ecological threat. This study provides the first quantitative assessment of MP ingestion in three zoanthid species (*Palythoa mutuki, Palythoa tuberculosa*, *Zoanthus sansibaricus)* from four rocky shores in Gujarat, India, alongside associated sediment and surface water. MPs were extracted following standard protocols and characterized for abundance, morphology, size, colour, and polymer composition. Zoanthids, sediment, and water contained 886, 389, and 128 particles, with mean abundances of 9.99 ± 6.29 MPs/g, 11.36 ± 4.03 MPs/kg, and 0.93 ± 0.52 MPs/L, respectively. *Zoanthus sansibaricus* showed the highest MP load, and contamination varied significantly among sites, peaking in Dwarka for zoanthids and Sutrapada for sediment and water. Fibres dominated particle morphology, most were < 1 mm, and blue, black, and red were the most frequent colours. ATR-FTIR identified polyethylene terephthalate (PET), polypropylene (PP), polyamide (PA), and polyurethane (PU) as dominant polymers. Principal component analysis indicated pH, sediment characteristics, and water quality as primary drivers of MP occurrence, while temperature and salinity had weaker or negative effects. Pollution indices classified Dhamlej as moderately contaminated and Veraval, Dwarka, and Sutrapada as highly contaminated. A global meta-analysis of cnidarian MP ingestion showed the jellyfish Pelagia noctiluca had the highest contamination, while the sea anemone Edwardsia meridionalis had the lowest. Across taxa, fibres, particles 0.5-3 mm, and red, black, and blue colours predominated, with polyethylene (PE) as the most abundant polymer. These findings identify zoanthids as overlooked bioindicators and sinks for MPs, with potential consequences for reef health and resilience.

Keywords: Marine environment, Plastic pollution, filter-feeding, ATP-FTIR , Raman, Gujarat coast

IIOE-2 Endorsed Project No: -

[ABS-08-0169]

Hidden Plastics in the Catch: Microplastic Contamination in Commercially important Marine Pelagic Fishes of Gujarat state and Its Risk to Seafood Consumers

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Over recent decades, microplastics (MPs) have emerged as a growing global concern, not only as an environmental pollutant but also as a contaminant in seafood. This study evaluated MP occurrence in the gastrointestinal tract, gill, and muscle tissues of 360 fish specimens representing 15 commercially important marine pelagic species, collected from five major fishing harbors in Gujarat, India. The analysis involved sample digestion, density separation, filtration, microscopic examination, and polymer identification. Across all samples, 4,033 MP particles were detected from studied specimens. Among the examined species, *Thryssa setirostris* exhibited the highest abundance of MP (6.85 ± 4.42 MPs/individual), whereas *Trichirus lepturus* showed the lowest (1.83 ± 1.02 MPs/individual). Spatial variation was evident, with Sartanpar harbor presenting the greatest abundance (13.73 ± 4.13 MPs/individual) and Jakhau harbor the least (3.11 ± 0.51 MPs/individual). Muscle tissue was having highest abundance of MPs compared to tissue of gut and gill samples. Most MPs were fibers in shape, predominantly black and blue, and measured under 500 µm. Polymer analysis identified polyethylene, polyethylene terephthalate, polyurethane, polystyrene, polypropylene, polycarbonate, poly (ethylene-co-vinyl acetate), and rubber. Risk assessment using contamination factor, pollutant load index, and polymer hazard index classified all locations as subject to very high MP contamination. Analysis of the estimated daily intake of microplastics among adults and children reveals notable potential risks to human health. These results highlight a significant threat to marine resources and human health via the consumption of MP laden fish.

Keywords: Plastic pollution, sea-food safety, Gujarat fisheries, Polymeric risk, pelagic fishes.

IIOE-2 Endorsed Project No: -

[ABS-08-0184]

Barnacles as bio indicator of microplastic contamination in the rocky intertidal zone of Gujarat state, India

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In marine habitats microplastics (MPs) act as vectors for harmful pollutants by absorbing and accumulating contaminants. Barnacles are well-known filter feeders; they get their food from water by eradicating organic particles from water column in which makes them susceptible to contamination of MPs. This study assessed MP contamination in barnacles from 13 sites in Gujarat state, India. Eight barnacle species were collected and dissected; soft tissues were digested in 10% KOH. After digestion, a NaCl solution was used for density-gradient separation, and the supernatant was filtered. Filter papers were examined under a stereomicroscope, and MPs were quantified for total count, shape, size, and colour. A total of 484 MP particles were recorded from barnacle tissues. The highest contamination was observed in *Chthamalus barnesi* (10 ± 3.74 MPs/g) and the lowest in *Megabalanus tintinnabulum* (1.22 ± 0.31 MPs/g). The highest abundance of MPs was observed at Shivrajpur and lowest abundance was observed at Kuchhadi. Significant variations in contamination levels were observed between species and study sites. Fibres were predominant, mostly blue and 1-2 mm in size. ATR-FTIR analysis identified polyethylene, polyamide, polypropylene, polyvinyl chloride, rubber, acrylonitrile butadiene styrene, and polyurethane. Contamination factor, pollution load, and risk indices indicated varying risk categories. This study highlights the accumulation of MPs in filter-feeding barnacles and their potential trophic transfer to higher taxa

Keywords: filter feeding, contaminant, indices, plastic pollution.

IIOE-2 Endorsed Project No: -

[ABS-08-0170]

Microplastic ingestion and bioaccumulation in the endemic ginger prawn Metapenaeus kutchensis: An environmental assessment

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Plastic pollution has increased globally and poses imminent risks to human health and marine life. This study assessed microplastic (MP) contamination in the gastrointestinal tract (GIT) of the commercial marine prawn *Metapenaeus kutchensis* from three major fishing centres in Gujarat. Samples were laboratory-dissected, and GIT was digested with 10% KOH. MPs were isolated using ZnCl density gradient separation, filtered, and observed under stereo microscopy. Physical and chemical characterisation determined total count, shape, size, and colour. From 135 individuals, 173 MPs were identified, showing 100% contamination. Average MP abundance was 3.94 ± 2.40 MPs per gram (range: 1.68 ± 0.87 to 5.40 ± 1.90 MPs/g). Post-monsoon periods showed highest contamination, followed by monsoon and pre-monsoon periods. MP contamination varied significantly between sites. Environmental MP abundance was 11.25 ± 12.23 MPs/kg in sediment and 1.38 ± 0.78 MPs/L in water. Regression analysis revealed no significant correlation between body length and MP abundance. Principal component analysis demonstrated varied environmental factors influencing prawn MP contamination. Blue and black fibers were most prevalent, with 1-2 mm size class predominating across all sites. Chemical analysis identified polyethylene, polyethylene terephthalate, and polypropylene compositions. This study of MP contamination in endemic species reveals pollution impacts on sensitive, unique organisms, supporting biodiversity conservation and ecosystem health awareness. The findings provide crucial baseline data for future research and inform management strategies for conserving Gujarat's marine ecosystems and safeguarding their health.

Keywords: Decapoda; Hazards; Marine organisms; Plastic pollution; Sea food; Gujarat

IIOE-2 Endorsed Project No: -

[ABS-08-0245]

Picoplankton in a Hypersaline Marginal Sea: First Comprehensive Assessment from Kuwaiti Waters of the Northwestern Arabian/Persian Gulf

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Picoplankton (0.2-2 µm) are major contributors to primary production and carbon cycling in marine ecosystems, often dominating microbial food webs in oligotrophic and stressed environments. Despite their ecological importance, knowledge of their composition and dynamics in shallow, hypersaline systems such as the northwestern Arabian/Persian Gulf (NWAG) remains limited. This study investigated the seasonal and spatial variability of autotrophic and heterotrophic picoplankton in the NWAG from December 2020 to December 2021. Flow cytometry, based on fluorescence and particle size, combined with pigment profiling (HPLC; zeaxanthin as a marker), revealed distinct spatio-temporal gradients. Phototrophic picoplankton were dominated by *Synechococcus* spp., with picoeukaryotes forming the second most abundant group. *Synechococcus* biomass reached up to 88 µg C l^1, particularly at northern coastal stations characterized by elevated salinity and nutrient fluxes, underscoring their ability to thrive under extreme environmental conditions. In contrast, picoeukaryotes exhibited pronounced seasonal peaks during winter and spring. Heterotrophic picoplankton biomass was elevated in coastal waters enriched in dissolved organic matter, highlighting their role in organic carbon processing. The autotrophic-heterotrophic assemblage exhibited clear seasonal and spatial gradients from coastal to offshore waters and across summer-winter seasons. These patterns are consistent with findings from other marginal and oligotrophic seas, where *Synechococcus* dominates under nutrient limitation and thermal stress, while picoeukaryotes contribute significantly to seasonal productivity pulses. The persistence of high *Synechococcus* biomass in the NWAG further emphasizes the resilience of these forms to salinity and temperature extremes. These findings establish a baseline for understanding microbial dynamics in hypersaline marginal seas and stress the need for long-term observations to anticipate shifts in ecosystem functioning under future climatic and anthropogenic change.

Keywords: Microbial food web, *Synechococcus*, Picoeukaryotes, Flow cytometry, Carbon cycling, Environmental gradients, Seasonal variability, Anthropogenic pressures, Marginal seas

IIOE-2 Endorsed Project No: -

[ABS-08-0238]

Assessment of Climate Change Risks to the Coastal and Marine Ecosystems in the ROPME Sea Area Using Marine Ecological Indicators

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ROPME Sea Area (RSA) like many other Regional Seas is susceptible to multiple effects of climate change e.g. sea level rise, salinity increase and shift of phytoplankton assemblages and some other biological systems, extreme environmental conditions with multiple consequences for society and blue economy. In order to assist adaptation planning and better-informed decision-making and identifying marine transboundary issues associated with climate change in the Region, it is essential and quite important to score and prioritize potential marine climate change risks for the marine and coastal environment of this Area. Following this concept, ROPME in cooperation with CEFAS performed a risk assessment focused mainly on marine drivers in the whole RSA. The approach for this risk assessment was informed by the Climate Change Risk Assessment methodology used for the United Kingdom. Overall, a total of 45 different risks were identified, falling under two overarching categories: "Biodiversity Risks" and "Risks to the Economy and Society." Among these, 13 were classified as severe, including the deterioration of coral reef systems and their associated marine life, geographical shifts in wild-capture fisheries, alterations in primary productivity of phytoplankton, adverse effects on coastal populations, threats to critical infrastructure and economic sectors, and disruptions to maritime transport operations and safety. Results concluded are very important for adaptation planning, better management of coastal and marine ecosystems in the RSA and for enhancing their resilience and reduce vulnerability to climate change effects.

Keywords: Climate change risks, ROPME Sea Area, coastal and marine ecosystems, adaption planning

IIOE-2 Endorsed Project No: -

THEME-9

INDIAN OCEAN SEABED AND HABITAT MAPPING

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[ABS-09-0177]

Advancing Seafloor Mapping in the Indian Ocean: Progress, Partnerships, and the Path to 100% Coverage

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The Nippon Foundation GEBCO Seabed 2030 Project is a collaborative international effort to map the entirety of the world's ocean floor by 2030 and make the resulting bathymetric data freely available. The Indian Ocean home to diverse coastal states and vast areas beyond national jurisdiction is rich in scientific and economic potential yet remains significantly under-mapped. Since the projects launch, substantial progress has been made in identifying data gaps, aggregating publicly available bathymetry, and catalyzing contributions from research, industry, and government partners. This presentation will highlight key achievements in the region, including integration of new datasets into the global GEBCO grid and targeted initiatives to address data gaps in data-poor areas. It will also underscore the broader value of comprehensive seabed mapping for navigation safety, disaster risk reduction, sustainable resource management, climate and oceanographic modelling, and biodiversity conservation. While progress has been notable, much of the Indian Ocean remains unmapped to modern standards. Achieving complete coverage will require increased regional engagement, improved data sharing frameworks, and coordinated technical capacity building. This talk will outline specific opportunities for countries, institutions, and vessel operators to contribute, and will call on the Indian Ocean community to play a leading role in closing the mapping gap transforming the regions seafloor from unknown to known and delivering benefits for science, policy, and society.

Keywords: Seabed mapping, data sharing, capacity development, partnership

IIOE-2 Endorsed Project No: -

[ABS-09-0136]

A Machine Learning Framework for long-term monitoring of mangroves along the Ernakulam Coast, Kerala, India

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Mangroves are ecologically significant coastal habitats that play a critical role in shoreline stability, carbon sequestration, and the maintenance of biodiversity. Accurate, continuous mapping and monitoring of mangrove cover and health are essential for understanding the ecosystem changes under anthropogenic and climatic pressures. This study presents a standardized machine learning based framework for mangrove mapping using medium resolution satellite imagery along the Ernakulam district of Kerala coast, and to monitor the relative change in mangrove cover over a 25-year period (2000-2025). Multispectral datasets from Landsat, LISS-3/4, and Sentinel-2 were collected as post-monsoon median composites and classified using multiple ML algorithms, including Random Forest, Gradient Boosting, and Artificial Neural Network, to identify the best model and an efficient ensemble that can be used to understand the change in mangrove cover using satellite data. Extensive field-validated mangrove datasets were used for supervised training and independent validation. Classification performance was assessed using multiple accuracy metrics such as confusion matrix, overall accuracy, Kappa coefficient, precision, specificity, sensitivity, and estimated mangrove area in Ernakulam (sq.km) to ensure mapping accuracy. Among the evaluated ML models, XGBoost and CatBoost emerged as the best-performing classifiers, achieving high Kappa coefficients of 0.925 and 0.908 respectively. This study presents a ML based framework to standardize mangrove cover mapping across diverse multi-spectral sensors and temporal scales, enabling consistent and comparable monitoring efforts of coastal mangrove ecosystems. This framework also enabled us to determine the relative change in mangrove cover, which in turn helped in identifying hotspots of mangrove degradation that need specific mitigation measures, as well as areas of mangrove replenishment. Applied to the Ernakulam coast, the approach demonstrates its potential for integration in regions with fragmented datasets, contributing to scalable frameworks for environmental assessment, conservation planning, and marine spatial management.

Keywords: Mangrove Mapping, Machine Learning, Remote Sensing, Coastal Ecosystem, Change Detection

IIOE-2 Endorsed Project No: -

[ABS-09-0305]

Assessing the progress in understanding the spawning habitat of fishes in the Indian waters

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Marine fish spawning plays a critical role in population replenishment, and thus information on this aspect helps to underpin sustainable fishery management. Despite substantial progress in fisheries science in Indian waters, detailed knowledge of species-specific spawning grounds and periods remains limited. To address this gap, the Centre for Marine Living Resources and Ecology (CMLRE), Kochi, undertook a comprehensive spatiotemporal study of spawning habitats in the eastern Arabian Sea and western Bay of Bengal under the Fisheries Resource and Habitat Assessment Programme. Along with the net sampling, the use of continuous underway fish egg sampler aboard FORV Sagar Sampada, helped in high-resolution quantification of ichthyoplankton abundance and distribution. The resulting data produced seasonal maps of spawning zones and identified peak spawning periods of individual species. Spawning was observed year-round, with intensity peaks associated with the summer or winter monsoon seasons. The integrated oceanographic and biological data encompassing studies linking spawning biology with oceanographic parameters across seasons and regions have helped to identify the preferred spawning habitat of different species of fishes. This study delineates preferred spawning habitats across seasons and regions, thereby advancing our ecological understanding and providing a spatial framework to guide fishery management. Future research should expand on this foundation by incorporating climate-driven phenological shifts, pollution impacts on spawning success, and gene environment interactions influencing reproductive dynamics.

Keywords: Spawning habitat; Marine fish;

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[ABS-09-0309]

Understanding spatio-temporal variability in the ichthyoplankton abundance and distribution in the eastern Arabian Sea

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Seasonal dynamics of ichthyoplankton fish eggs (FE) and larvae (FL) offer key insights into spawning behaviour and marine productivity, yet remain underexplored in the eastern Arabian Sea (EAS). This study presents a detailed assessment of ichthyoplankton abundance during two pivotal seasons: the Early Summer Monsoon (ESM) of 2023 and the Winter Monsoon (WM) of 2024. Sampling along west coast of India encompassed northern (Gujarat, Maharashtra), central (Goa, Karnataka), and southern (Kerala and southern tip of Tamil Nadu) coastal transects. Simultaneously, physicochemical parameters (temperature, dissolved oxygen, salinity, and nutrients) and biotic indicators (phytoplankton, zooplankton) were recorded to evaluate their impact on ichthyoplankton distribution. Ichthyoplankton occurred in all regions across both seasons, displaying pronounced spatial and temporal variation. Overall abundance was markedly higher during ESM (1145±5584 ind/100m^3) than in WM (85±176ind/100m^3). During ESM, high abundance weas observed in southern zone from the southern tip of India through Kerala extending to central coastal Karnataka region. In contrast, WM saw elevated abundance in northern EAS, particularly Maharashtra, while Karnataka also showed high abundance, though lower than during ESM. Interestingly, Gujarat experienced a 3.5-fold increase in abundance in winter compared to summer, indicating WM as dominant spawning period for this region. Enhanced phytoplankton biomass, driven by nutrient-rich upwelling in southern EAS during ESM, likely created favourable spawning conditions there. Conversely, winter cooling and convective mixing enriched northern waters, boosting phytoplankton biomass that encouraged spawning in Gujarat and Maharashtra. Central Karnataka maintained moderate phytoplankton across both seasons, potentially supporting consistent ichthyoplankton abundance. Generalized Additive Models revealed strong influences of physical factors, nutrient levels, and phytoplankton biomass on ichthyoplankton distribution. These findings highlight the need for detailed, region-specific management strategies to safeguard fisheries by protecting habitat of critical early life stages within eastern Arabian Sea.

Keywords: Ichthyoplankton, eastern Arabian Sea, Early Summer Monsoon, Winter Monsoon; spawning habitat mapping

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[ABS-09-0359]

Submarine Slope Failures and Canyons along the Northwestern continental margin of India using High-Resolution Bathymetry data

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The evolution of continental margins is influenced by a complex interaction of diverse factors, including tectonics, sedimentary deposition, subsidence, neotectonic activities, and oceanographic processes. Among these mechanisms, mass wasting is considered pivotal in shaping morphological features and sediment distribution patterns from continental slopes to deep-sea basins. Canyon inception and development are generally related to processes acting in submarine environments, which include downslope eroding sediment gravity flows and/or upslope erosion produced by retrogressive slope failures. The northwestern continental margin of India is recognized as a dynamic region where processes such as slumping, mass movements, and canyon incision contributed to the development of complex seafloor morphology. In this study, we utilized high-resolution multi-beam bathymetry data to characterize the morphological features of the northwestern continental margin of India, acquired by NCPOR, covering the region from the shelf edge to the lower slope. The data reveals the presence of submarine slope failures and canyon system in the continental slope including landslide scars, gullies, knickpoints, sediment waves, and scour features etc. The canyon system was grouped into distinct morphological types, including (i) canyons with relatively straight courses, (ii) tributary-type canyons that converge and join into a single main canyon, and (iii) canyons exhibiting prominent branching patterns at their heads. Morphometric analysis of the identified canyons was carried out to determine the parameters such as thalweg length, width, canyon length, depth range, sinuosity, and slope. The results from this study highlight the complex interplay between sedimentary processes, slope failures, and tectonic factors in shaping the geomorphology of the northwestern continental margin of India. This work underscores the broader significance of detailed seafloor mapping for advancing understanding of the submarine morphology, geohazard assessment, benthic habitat studies and resource exploration in the Arabian Sea.

Keywords: Submarine canyons, Geomorphology, Bathymetry, Geohazards

IIOE-2 Endorsed Project No: -

[ABS-09-0350]

Evolution of a seamount chain through a leaky fracture zone: Insights from the Arabian sea

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Seamounts play a vital role in shaping ocean ecosystems and influencing oceanographic conditions, and they have been extensively studied over the past decades. They also provide important insights into lithospheric and mantle processes, recording the complex interplay among tectonics, magmatism, and plume dynamics. In the eastern Arabian Sea, twelve seamounts are identified using newly acquired multibeam bathymetry (MBES) resembling a linear seamount chain, which runs parallell to the Rudra Fracture Zone (RFZ). The high-resolution bathymetric data reveals various morphologies, including steep, conical seamounts with centralized summits and also elongated, ridge-like structures aligned with the fracture zone. These forms suggest both localized volcanic centres and fissure like eruptions channelled by tectonic lineaments. Gravity anomalies show a strong correlation with mapped seamounts and reveals the extension of long linear trace of the RFZ northward up to ~12Â°N. Band-pass filtered gravity data further highlight volcanic features masked by sediment cover and reveal the fracture zone at multiple scales: short wavelengths (250 km) emphasize individual small volcanic edifices; intermediate wavelength (2100 km, 2150 km) delineate the continuous fracture zone and crustal offsets; and long wavelengths (2250 km) shows broader lithospheric segmentation. The seamounts become larger and more voluminous toward the south, indicating enhanced magmatism in the younger part of the crust. Seismic profiles across the RFZ shows basement offsets, crustal thinning, and chaotic reflections, indicating deformation and weakened lithosphere. The proximity of the RFZ to the Laccadive Plateau further links with the RÃ©union hotspot, and the weakened lithosphere. Thus, the RFZ is described as a leaky transform fault rather than a passive lithospheric boundary. Its structural fabric has provided pathways for magma ascent, guiding the growth of a volcanic chain while accommodating changes in spreading patterns.

Keywords: Rudra fracture zone, Seamount chain, Leaky fracture zone, Arabian sea, Multibeam bathymetry

IIOE-2 Endorsed Project No: -

[ABS-09-0193]

AI-Enhanced Coral Reef Habitat Mapping around Kavaratti Island: Integrating Diver-Based Imagery with GIS and Spatial Analysis

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Comprehensive mapping of the Indian Ocean seabed and associated habitats is critical for assessing ecosystem health and understanding the impact of environmental changes on marine biodiversity. This study focuses on detailed habitat mapping of coral reefs surrounding Kavaratti Island, Lakshadweep, which are undergoing significant stress from ocean warming and climate variability. High-resolution underwater video footage, acquired by divers on 12 May 2025, was analyzed using traditional frame extraction, georeferencing, and GIS-based spatial mapping to document patterns of coral bleaching and related habitat transformation. Key indicators, such as coral paling, discoloration, and algal overgrowth, were visually identified and mapped across distinct reef zones to characterize bleaching severity and distribution. To enhance scalability and accuracy, an AI-driven image processing framework was developed for efficient extraction and classification of habitat features from the video database, enabling rapid mapping and spatial analysis. This integrative methodology demonstrates the potential of combining diver-generated datasets with advanced analytical tools for high-resolution seabed and benthic habitat mapping. The results provide valuable insights for ongoing monitoring of reef ecosystem health and support conservation planning and sustainable resource management initiatives in the Indian Ocean region.

Keywords: Indian Ocean, coral habitat mapping, Kavaratti Island, GIS, underwater imagery, AI-based analysis, seabed features, benthic habitats, conservation, climate change

IIOE-2 Endorsed Project No: -

[ABS-09-0361]

Fine-Scale Geomorphology of Near-Axis Seafloor at the Central Indian Ridge: Tectono-Magmatic Controls and Geodynamic Implications

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Understanding the morphological framework of near-axis seafloor is key to unravelling tectono-magmatic interactions that shape the ocean floor in both local and regional contexts. The southern segments of the Central Indian Ridge, with their intermediate spreading rates, exhibit complementary tectonic and magmatic components that together drive seafloor spreading. We utilise ultra-high-resolution bathymetry and backscatter data acquired by an Autonomous Underwater Vehicle (AUV) survey over an area of ~ 50 sq. km area over a southern segment of the Central Indian Ridge, to characterise the morphological features of this region. A semi-automated workflow for fracture identification was applied to bathymetry derivatives, revealing a well-developed fracture system comprising 1,564 faults and 169 fissures. Statistical analysis indicates that the fracture regime is currently in the growth stage, with indications of early coalescence processes. Fault dip analyses show both east- and west-dipping fault populations, with implications for strain partitioning within the fracture regime. Kernel density estimation highlights fracture density variations across the block, providing quantitative constraints on spatial clustering of tectonic strain. Terrain classification based on bathymetry, fracture density, and backscatter intensity maps reveals that 73.4% of the surveyed area is hummocky, of which nearly half is highly fractured, reflecting strong tectono-magmatic associations. Several eruptive centres are also recognised and characterised, suggesting interplay between deformation and volcanic resurfacing. Integration with regional shipborne bathymetry provides interpretations of strain partition between fault populations of opposite dips, their association with magmatic episodes, and the possibility of this region representing a non-transform discontinuity.

Keywords: Central Indian Ridge, Seafloor morphology, Tectono-magmatic interactions, Fracture system, AUV Bathymetry

IIOE-2 Endorsed Project No: -

[ABS-09-0027]

Morpho-anatomical, and molecular characterization of red algae (Rhodophyta) from the intertidal rocky shore of Visakhapatnam coast of Bay of Bengal, India.

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The Indian Ocean, particularly the Bay of Bengal coast, remains underexplored in terms of its marine biodiversity, especially macroalgal communities, which are crucial indicators of coastal ecosystem health. In the present study, we conducted a detailed survey of red algal diversity along the intertidal rocky shores of the Visakhapatnam coast, eastern India, using an integrated taxonomic approach that combined morphological, anatomical, and molecular tools. Phylogenetic analyses were based on multiple genetic markers, including SSU rDNA, rbcL, and COI, to ensure accurate species delineation. We successfully identified nine red algal species from the study area. Notably, seven of these species represent new records for the region, highlighting the hidden diversity of macroalgae in this stretch of the Bay of Bengal. These include *Centroceras gasparrinii, Gelidium nayaritense, Pterocladiella bartlettii, Hypnea charoides, Hypnea cf. edeniana, Gracilaria multifurcata, and Gracilaria rangiferina. Among these, P. bartlettii, G. multifurcata, and G. rangiferina were newly reported from the Bay of Bengal coast, while H. cf. edeniana and G. nayaritense* were recorded for the first time in the Indian Ocean region. These findings offer key biogeographical insights and help fill knowledge gaps in Indian Ocean seabed mapping. Discovering new regional and oceanic records within a limited survey suggests high, undocumented red algae diversity in intertidal ecosystems.

Keywords: Indian ocean, Bay of Bengal, Algal diversity, Taxonomy, Rhodophyta

IIOE-2 Endorsed Project No: -

[ABS-06-0164]

Mapping PROfitable deep-sea Fishing zone Track (PROFIT) in the North Indian Ocean

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This concept and review study introduces a baseline research work on PROfitable deep-sea Fishing zone Track (PROFIT) for the north Indian Ocean. The primary objective of PROFIT is to identify and track profitable deep-sea fishing zones (DFZs) using a suite of oceanographic parameters such as sea surface temperature, chlorophyll-a concentration, sea level anomaly, currents, upwelling, mixed layer depth, ocean net primary productivity (NPP), euphotic zone, and thermal front etc. These environmental proxies are important to understand the link between marine productivity with fishery resources and the oceanic environment. By employing data-driven, multi-criteria threshold-based analyses, the approach classifies the fishing zones into high, medium, and low probability areas of fish availability, thereby improving spatial targeting of fishing efforts. The PROFIT framework also emphasizes the identification of on-front and back-front zones associated with thermal and productivity gradients, enabling enhanced tracking of DFZs. This has the potential to significantly reduce search time and fuel consumption, thereby increasing profitability for fishers. Additionally, optimizing fishing routes based on environmental conditions can lower operational costs and carbon emissions, while supporting higher catch efficiency, food security, and the economic resilience of coastal communities. Scientific advisories based on such data-driven methods can minimize overfishing in low-productivity areas and promote sustainable harvesting practices. These insights also support policy development, long-term ecosystem monitoring, and the formulation of predictive models for fish resource availability. Ultimately, the PROFIT concept provides a foundational step toward sustainable fishery management and marine conservation in the North Indian Ocean region.

Keywords: Deep-Sea fishing zone (DFZ), SST, Ocean Productivity, Ekman Pumping, Cyclonic Eddies

IIOE-2 Endorsed Project No: -

[ABS-01-0241]

INCOIS operational services to the exploratory Deep Sea Mining activities of NIOT

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NIOT (MoES) plans exploratory mining operations in 6000m water depth for poly-metallic nodules in the Central Indian Ocean Basin. The entire system consisting of the ship, riser, and mining machine would experience environmental loads caused by wind and wave conditions. The mining machine weighs around 10 tons and takes around 4 hours for descent to seabed. A detailed analyses of the three hourly wind and wave data (2009-2023) based on numerical models, is presented for the present deep sea test mining location (13.5 deg. S and 75.5 deg. E). The location is far away from the coast, the nearest port being Port Mathurin (Mauritius), located about 1460 kms away. It is therefore very essential to understand the seasonal variability of these parameters, for safe and efficient operations. India is allotted 75,000 sq. km. area with an estimated 380 MMT of nodules. Detailed studies on the wind and wave data for this location is essential for a better understanding of their seasonal variabilities, for operational planning of the mining operations. INCOIS (MoES) has been providing short term forecasts (three days ahead) and hindcast data (inter-annual) for these parameters, from numerical models. Further, INCOIS is also providing along the route sea state forecasts for the ships sailing from the mainland ports to this location for ensuring a safe voyage.

Keywords: INCOIS, Operational Services, Safe Weather Window, Deep Sea Mining

IIOE-2 Endorsed Project No: -

[ABS-09-0052]

Advancing deep-sea observations in the Western Indian Ocean with BRUVs and lander platforms: Ecosystem and process mapping to support sustainable management

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Despite growing global attention to the deep sea, much of the Western Indian Ocean (WIO) remains unmapped, unexplored, and poorly understood. The South African National Research Foundation (NRF) and the Department of Science, Technology and Innovation (DSTI) are leading efforts to address these gaps through the deployment of innovative remote imagery technologies, including Baited Remote Underwater Stereo-Video Systems (Stereo-BRUVs) and benthic lander platforms. These tools provide cost-effective, non-destructive means of exploring benthic habitats and species, and collecting in situ environmental data, across continental margins and deep-sea environments. Through ongoing national and regional collaborations, including research within South African Marine Protected Areas (MPAs), and other expeditions in the Maldives, Seychelles and Comoros, these research platforms have enabled the discovery of new species, extended range records, and detailed insights into habitat types across broad depth gradients (up to 1000m). Recent innovation includes a 3500m stereo-BRUVs lander with associated environmental instruments (e.g., CTD, current meters and nutrient analysers), and other full ocean technologies. These contribute to marine spatial planning, biodiversity assessments, and the design of monitoring frameworks for deep-sea MPAs. Looking forward, new opportunities are emerging to extend these platforms across the broader WIO region through shared infrastructure, training, and joint expeditions. Future deep-sea exploration must incorporate more process-oriented research, including the integration of microprofilers, sediment traps, long-term lander deployments (multi-year), and respirometers. This will advance ecosystem and biogeochemical process understanding. Proposed deep-sea observation efforts aim to align with IIOE-2 priorities and UN Ocean Decade goals, strengthening collaborations and building regional capacity. This presentation highlights project outputs, methodological advances, and proposed strategies for scaling up seabed and habitat mapping using visual and environmental datasets. It makes the case for enhanced regional cooperation and investment in deep-sea science to better inform conservation, resource management, and marine spatial planning across the Indian Ocean.

Keywords: Stereo-BRUVs, Landers, Benthic Habitats, Ecosystem Processes, Biogeochemistry, Visual observations

IIOE-2 Endorsed Project No: -

[ABS-09-0160]

Ecological and Geological Complexity of the Southern Andaman Deep-Sea: Insights from ROV Surveys

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Deep-sea ecosystems are among the least explored and most vulnerable marine habitats, particularly under increasing anthropogenic pressures and emerging deep-sea mining interests. The seabed of the Andaman Sea near Great Nicobar Island is morphologically and geologically diverse, shaped by the Andaman Accretionary Prism (AAP) and the West Sewell Rise. These features host significant mineral resources, including polymetallic crust and nodules and hydrothermal mineral occurrences, making the region strategically important for both biodiversity conservation and resource management. This study presents a comprehensive inventory of faunal assemblages from the southern part of the AAP, providing valuable baseline data for future environmental impact assessments. Surveys were conducted aboard RV Samudra Ratnakar (GSI) from 23 September to 22 October 2018 under project SR-046, with samples collected using ROVs and dredgers. Key dives included ROV-11/1 (1586 m), ROV-10B/1 (1259 m), and ROV-10B/4 (1304 m). The documented assemblages included diverse sessile and motile organisms such as corals, echinoderms, sponges, crustaceans, and brachiopods, with notable taxa including *Acanthogorgia, Chrysogorgia, Calyptrophora, Enallopsammia rostrata, Stylaster, Corallium, Leiopathes, and Stylopathes*, alongside glass sponges (*Euplectella, Farrea, Aphrocallistes*), echinoderms (*Ceramaster, Pillsburiaster*), squat lobsters, and *Heterocarpus* shrimps. These findings underscore the ecological richness and geological uniqueness of the Andaman deep-sea habitats, providing a critical reference for biodiversity monitoring, conservation planning, and sustainable management of deep-sea resources in the Indian Ocean region.

Keywords: Andaman Accretionary Prism, Deep-sea biodiversity, Benthic fauna, Seafloor morphology, ROV surveys

IIOE-2 Endorsed Project No: -

[ABS-09-0362]

Morphology of the Canyon-Channel Systems in the Cauvery Basin using High Resolution Bathymetric Data

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Submarine canyons and channels are distinctive geomorphic features that act as sedimentary conduits for transporting vast amounts of terrigenous material into the deep ocean. Their development is influenced by geological, tectonic, oceanographic, and climatic processes, leaving behind a range of characteristic morphological signatures. This study examines the canyon channel system in the Cauvery Basin, along the southeastern continental margin of India. This half crescent-shaped basin evolved due to the rifting between India and East Antarctica. High resolution bathymetric data acquired along this region offer a unique opportunity to study the geomorphological and morphometric characteristics of the canyon-channels in detail. In this study, we analyzed the bathymetry data to infer the morphology of canyon channel complexes and to understand the possible controlling factors on their origin and evolution. Bathymetric data reveal the presence of five major canyon-channel systems with distinct morphological characteristics. The identified canyon-channel systems extend more than 100 km into the Bay of Bengal with sinuosity ranging from 1-1.35, and are associated with depositional and erosional features, indicating a dynamic interplay between turbidity currents and seafloor topography. The systems exhibit tributaries, some of which converge to form major channel-levee complexes. Morphological features also include abandoned channels with well-defined levee crests, terraces, meandering bends, and mass transport deposits. Further, the morphometric analysis of the identified canyon-channel systems has been carried out to understand the canyon-channel modifying features. The conformity of Precambrian lineaments and the location of the canyon channel system provide evidence for tectonic and lineament control on canyon-channel genesis. The analysis indicates the impact of migration of the river systems on the evolution of the canyon channel system, indicating tectonic and climatic controls. This work has implications for the assessment of geohazards and the deep marine ecosystem.

Keywords: Canyon, Channel, Morphology, Geohazards, Cauvery basin

IIOE-2 Endorsed Project No: -

[ABS-09-0045]

Citizen Science-Driven Habitat Analysis and Biodiversity Hotspot Mapping for Conservation along the South-Central Coast of Bangladesh

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The ongoing decline in coastal and marine biodiversity has become a global issue, underscoring the urgent need for effective conservation strategies. Similarly, considering the current environmental challenges and anthropogenic pressures, Bangladesh must also prioritize the development and implementation of such strategies. Considering this into account, present study aimed to identify biodiversity hotspot to support conservation initiative around the South-Central Coast of Bangladesh, particularly in the Kuakata region. Citizen science-based approach was used to collect the data on fishing zone, ecological habitats of species and overall biodiversity hotspots from June 2023 to July 2024. In addition, stakeholder consultations were performed to identify the stressors and develop the preliminary biodiversity conservation plan. We identified three clusters in fishing activities, mostly concentrated around the central region of the aquatic ecosystem of the Kuakata coast. Analyzing the habitats of 12 key species, we identified three biodiversity hotspots. The hotspot with maximum density was found near the coast while two other hotspots are located in the central and offshore regions. Overexploitation, unsustainable fishing, pollution, a decline in stock, warming trend and reduced primary productivity were identified as the major stressors for the ecosystem. Stakeholder consultations suggested that implementing locally adapted conservation measures can be a potential conservation strategy through developing and implementing a proper management plan. The findings of this research provide valuable insights for biodiversity conservation in data-deficient marine regions, particularly in developing nations.

Keywords: Biodiversity, habitat, citizen-science, conservation, Bangladesh

IIOE-2 Endorsed Project No: -

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IOGOOS GLOBAL OCEAN OBSERVING SYSTEM FOR INDIAN OCEAN

International Council for Science SCOR Scientific Committee on Oceanic Research

UNESCO United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission