ANNUAL REPORT 2022-23

Front Cover

1. Celebrating its 25th Foundation Day on 03 February 2023, INCOIS marked the start of the silver jubilee year (2023-24) by launching a new logo and is pursuing an ambitious work plan to continually enhance the scope and accuracy of its existing services while continuing to expand the bouquet of services for all Blue Economy stakeholders.

2. Multi-hazard Vulnerability Atlas comprising 1,054 maps covering the Indian mainland and Andaman & Nicobar Islands, representing the coastal multi-hazard zones that are exposed to coastal inundation due to oceanic disasters in a 100-year recurrence interval. These maps are vital input for disaster management authorities to implement coastal disaster management plans and to improve coastal resilience.

3. A modern E-Classroom Training facility established for the International Training Centre for Operational Oceanography (ITCOocean) blending top-tier technology with a spacious design for 72 participants. It's the new global hotspot for oceanography experts to learn, share, and innovate together.

4. Oceansat-3 Data Acquisition and Processing Facility - Oceansat-3 has a sensor called OCM (Ocean Color Monitor), that provides information on water quality parameters such as chlorophyll, suspended sediment, and dissolved organic matter concentrations. INCOIS started acquiring this OCM data through an upgraded ground station and will be using it for operational services such as potential fishing zone (PFZ) advisories.

5. Unified Modeling Mission - Towards implementing the recently conceived Unified Modelling Mission, INCOIS configured a coastal FVCOM for the coastal waters off Kochi. INCOIS is quickly progressing towards a "unified modelling and operational forecasting system" to forecast anything from local beach conditions to regional currents and waves to global oceanic circulation, across a range of time scales.

6. National Glider Operations Facility - Gliders are the new-age autonomous instruments known to be the future of ocean observations. In order to cater the glider piloting and regular maintenance, INCOIS established this facility capable of simultaneous piloting of the glider fleet along with its testing, ballasting, and routine maintenance.

7. Marine heatwave advisory service for the Indian Ocean uses satellite-derived sea surface temperature to provide maps of heat wave intensity and different severity categories daily for the benefit of ecologists and tourism through an interactive web GIS platform.

Back Cover

Atal Atithi Griha (ITCOO Guest House) - Atal Atithi Griha promises a comfortable and memorable stay for all in the ITCOO Complex. Equipped with spacious suite rooms, single/double occupancy hostel rooms, a well-equipped kitchen, a lavish dining area, a VIP dining and lounge area, wellness centre, ample stilt parking, and an open play area.

Annual Report
2022-23

Indian National Centre for Ocean Information Services (INCOIS)
(An Autonomous body under Ministry of Earth Sciences, Government of India)
Hyderabad

Contents

From Director's Desk 2022-23

INCOIS has come a long way since 1999 and this journey is filled with numerous accomplishments and exciting challenges. True to its mission, INCOIS continued to provide the best possible ocean information and advisory services to all maritime stakeholders through sustained observations and constant improvements through systematic and focussed research. After years of hard work, grit and determination, INCOIS is today considered as one of the global pioneers in operational oceanography. Yet there are miles to go and multitudes of peaks to summit, which INCOIS looks forward to. Celebrating its 25th Foundation Day on 03 February 2023, INCOIS marked the start of the silver jubilee year (2023-24) with a renewed vision "to become integral part of the value chain of coastal and ocean communities", through deployment of new-age observational platforms, building digital twin of the ocean, development of unified modelling and forecasting capabilities, enhancing scientific understanding of the oceans, implementation of coastal multi-hazard early warning system, delivery of impact-based services for blue economy stakeholders and capacity building.

During 2022–2023, INCOIS continued to serve round the clock and provided essential ocean information and advisory services, such as tsunami and storm surge alerts, ocean state forecasts, potential fishing zone advisories, coral bleaching alerts, algal bloom information, etc. The Tsunami Early Warning Centre (TEWC) at INCOIS carried out its surveillance on all earthquakes across the globe and detected one tsunamigenic earthquake of magnitude greater than 6.5 Mw in the Indian Ocean and aptly issued 'No Threat' messages for India after a careful analysis. TEWC also monitored tsunamis that occurred in the South Atlantic and Pacific Ocean and issued relevant advisories to Indian Ocean rim countries. As a regular practice, mock drills and tsunami-ready implementation activities have been carried out and supported by INCOIS in coastal states. With a view to promote disaster risk reduction, INCOIS has published an Atlas on Multi-Hazard Vulnerability Maps (MHVM) on a 1:25000 scale for coastal areas of the Indian mainland and Andaman & Nicobar Islands. Timely storm surge advisories were provided for cyclones such as Asani, Sitrang and Mandous. A total of 708 High Wave/Swell Alerts/Warnings and rough sea alerts have been issued during 2022-23. The oil spill monitoring system of INCOIS has monitored and issued advisories for MV Princess vessel wreckage and CPCL pipeline rupture in Nagore Beach, Nagapattinam.

Based on the continuous efforts towards the upgradation of existing and development of new ocean information services, during 2022-23, INCOIS has developed and operationalized a new Marine Heat Wave Advisory Services (MAHAS) for providing information on marine heatwaves and a Search and Rescue Aid Tool-Integrated (SARAT-I) service to extend the search and rescue application to aircraft missing mid-air while flying over the oceans.

Persistent improvement in numerical ocean prediction using ocean modeling and data assimilation has been an integral mandate of INCOIS. To realize this under the recently conceived Unified Modelling Mission, INCOIS has configured a regional MOM6 for the Indian Ocean and a coastal FVCOM for the coastal waters off Kochi. Significant strides are taken in wave modeling, modeling of ecosystem and data assimilation. INCOIS's regional coupled ocean-ecosystem model simulated data submitted to the REgional Carbon Cycle Assessment and Processes (RECCAP) Phase 2 synthesis came out to be at par (if not better) with other community standards. The modeling work related to the development of Ocean Climate Change Advisory Services under Ministry's Deep Ocean Mission has progressed significantly.

INCOIS ensured uninterrupted access to in-situ ocean observation networks and ocean data, that continued to be the backbone of INCOIS services. To augment the existing satellite data, INCOIS has started acquiring Oceansat-3 OCM data through an upgraded ground station. To enhance the capability of simultaneous piloting of the glider fleet along with its testing, ballasting, and routine maintenance, INCOIS has established a new National Glider Operations Facility.

During the reporting period, the IOC-UNESCO has recognized INCOIS as the Indian Ocean Region Decade Collaborative Centre (IOR-DCC) under the framework of the UN Decade of Ocean Science for Sustainable Development. The WMO's 76th Executive Council session (EC-76) has designated INCOIS as the Regional Specialized Meteorological Centre (RSMC) for numerical ocean wave prediction and global numerical ocean prediction. These are clear testaments to the reliability and robustness of INCOIS operational services, and the fact that INCOIS has indeed ascended into the league of best oceanographic institutions. Further, India continued its role as an Executive Member of the IOC-UNESCO, and I served as a Vice Chair of the IOC-UNESCO representing Electoral Group IV, Chair of the UN Ocean Decade Tsunami Programme Scientific Committee, Chair of the Indian Ocean Global Ocean Observing System and Co-Chair of the IOC-WMO Joint Collaborative Board.

INCOIS continued its active involvement in other important international programs, viz. Indian Ocean Global Ocean Observing System (IOGOOS), United Nations Ocean Decade for Sustainable Development (Ocean Decade), IOC Regional Committee for the Central Indian Ocean (IOCINDIO), Partnership for Observation of the Global Oceans (POGO), Regional Integrated Multi-Hazard Early Warning System for Asia and Africa (RIMES), Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER), Second International Indian Ocean Expedition (IIOE-2), Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS), Indian Ocean Rim Association (IORA), etc.

In parallel to oceanographic services and research, INCOIS aims to educate and sensitize the next generation of oceanographers and stakeholders. During the past year, the International Training Center for Operational Oceanography (ITCOOcean) of INCOIS that is recognized as a UNESCO Category-2 Centre continued to impart training offline and online, totaling 12 international/national training courses. INCOIS curated and conducted a four-month long advanced oceanography course for Indian Navy Officials. In order to ascertain the utility of the services and to explore the future needs of the users, INCOIS has organized user interaction workshops/meetings in online/offline/hybrid modes. After the Covid-19 restrictions were eased out, INCOIS resumed facilitating campus visits of students and hosted over 5000 students from various schools, colleges, and universities to raise awareness about INCOIS services and encourage young minds to enter the world of oceanography. To aid telepresence learning and distance teaching, INCOIS established a 72-seater state-of-the-art E-Class Room Training facility at the International Training Centre for Operational Oceanography (ITCOO). ITCOOcean will be used as a strategic platform for academic research in support of INCOIS services, competency development of our own staff, and for capacity development in the whole Indian Ocean region. As a part of Azadi Ka Amrit Mahotsav initiative of the Government of India, INCOIS continued to organize various activities throughout 2022-23. These activities focused on improving the outreach of INCOIS services and scientific research and India's achievements in the past 75 years in Earth sciences with special emphasis on ocean science. To name a few, INCOIS conducted events like fostering a strong AtmaNirbhar Bharat through I-Connect, science-to-society connection through the adoption of schools to impart knowledge, Swachh Sagar, Surakshit Sagar/Clean Coast Safe Sea campaign, etc.

Publications in reputed scientific journals are touted to be the hallmark of a research organization. During 2022-23, INCOIS scientists have published 71 research papers in several peer-reviewed journals, which is the highest among all preceding years. Awards and honors are the encouragement to upscale the ongoing activities and boost enthusiasm for further development. During the reporting period, INCOIS scientists/researchers/services have been conferred with several awards/honors such as ICTP's Associateship, PORSEC Distinguished Service Award, WCDM-DRR Excellence Award, and Anni Talwani Memorial Grant for Young Women Researcher-2022.

The persistent grit and determination of our scientists, finance, purchase and administrative staff, under the able guidance of Dr. M. Ravichandran, Chairman and Members of INCOIS Governing Council (GC) have helped us stride towards pursuit of excellence. I also thank the Chair and Members of the Research Advisory Committee for steering our scientific research in the right direction and the Chair and Members of the Finance Committee in guiding our finance matters. I am also grateful to our colleagues in the Ministry of Earth Sciences and our sister organizations: NIOT, NCPOR, IITM, NCMRWF, NCESS, IMD NCS, CMLRE and NCCR for fruitful collaborations.

The Annual Report is prepared by the Editorial Committee chaired by Kunal and ably supported by Venkat Seshu, Girish, Arya, Padmanabham, Ajay, Dipankar, Sanjiba and Sidhartha. I thank them for doing a wonderful job.

Thank you.

Jai Hind

Dr. T. Srinivasa Kumar

2

INCOIS ORGANIZATIONAL STRUCTURE

2 INCOIS ORGANIZATIONAL STRUCTURE

Indian National Centre for Ocean Information Services (INCOIS) is an autonomous institute under the administrative control of the Ministry of Earth Sciences (MoES), Government of India.

INCOIS was registered as a society under the Andhra Pradesh (Telangana) Public Societies Registration Act (1350, Falsi), at Hyderabad on 03 February 1999. The affairs of the society are managed, administered, directed and controlled by the Governing Council, subject to the Bye Laws of the Society.

2.1 INCOIS Society

1.	Hon'ble Minister, MoES	President (Ex-Officio)
2.	Minister In-charge in the concerned Scientific Ministry, Govt. of Telangana	Member (Ex-officio)
3.	Secretary, MoES	Member (Ex-officio)
4.	Secretary, Department of Space	Member (Ex-officio)
5.	Secretary, Department of Scientific & Industrial Research	Member (Ex-officio)
6.	Principal Secretary In-charge of the Department handling MoES or concerned Scientific Ministry, Govt. of Telangana	Member (Ex-officio)
7.	Joint Secretary, MoES	Member (Ex-officio)
8.	Financial Advisor, MoES	Member (Ex-officio)
9.	Dr. Harsh K Gupta, Former Secretary, DoD/ MoES	Member (Expert)
10.	Dr. P. S. Goel, Former Secretary, MoES	Member (Expert)
11.	Dr. Shailesh Nayak, Former Secretary, MoES & Director, NIAS	Member (Expert)
12.	Dr. K. Radhakrishnan, Former Chairman, ISRO	Member (Expert)
13.	Dr. G. Satheesh Reddy, Secretary, Department of Defence, R&D	Member (Expert)
14.	Dr. K. J. Ramesh, Former Director General, IMD	Member (Expert)
15.	Director, INCOIS	Member Secretary (Ex-Officio)

2.2 INCOIS Governing Body

1.	Secretary, Ministry of Earth Sciences, Govt. of India	Chairperson (Ex-Officio)
2.	Joint Secretary, Ministry of Earth Sciences	Member (Ex-Officio)
3.	Financial Advisor, Ministry of Earth Sciences	Member (Ex-Officio)
4.	Chairperson, RAC-INCOIS	Member (Ex-Officio)
5.	Scientist G/H, Ministry of Earth Sciences & Program Head, INCOIS	Member (Ex-Officio)
6.	Director, INCOIS	Member (Ex-Officio)

7.	Senior most Scientist, INCOIS	Member (Ex-Officio)
8.	Adviser (Earth Sciences), NITI Aayog	Member (Ex-Officio)
9.	Dr. R. R. Navalgund, Former ISRO Distinguished Professor	Member (Expert)
10.	Prof. Sunil Kumar Singh, Director, CSIR-NIO	Member (Expert)
11.	Dr. Prakash Kumar, Director, CSIR-NGRI	Member (Expert)
12.	Dr. Y. V. N. Krishna Murthy, Senior Professor, Indian Institute of Space Science & Technology, DOS-ISRO	Member (Expert)
13.	Head/In-charge of Administration, INCOIS	Member Secretary (Ex-Officio)

2.3 INCOIS Finance Committee

1.	Financial Adviser, Ministry of Earth Sciences	Chairperson (Ex-Officio)
2.	Scientist 'G' /'H', MoES & Program Head, INCOIS	Member (Ex-Officio)
3.	Director, INCOIS, Hyderabad	Member (Ex-Officio)
4.	Head/In-charge of Administration, INCOIS	Member (Ex-Officio)
5.	Director, NIOT	Member (Ex-Officio)
6.	Ms. Mahua Pal, Ex. Dy CAG	Member (Expert)
7.	Mr. Parveen Kumar Bansal, Ex. Vice-President, Income Tax Appellate Tribunal	Member (Expert)
8.	Senior Finance Officer, INCOIS	Member Secretary (Ex-Officio)

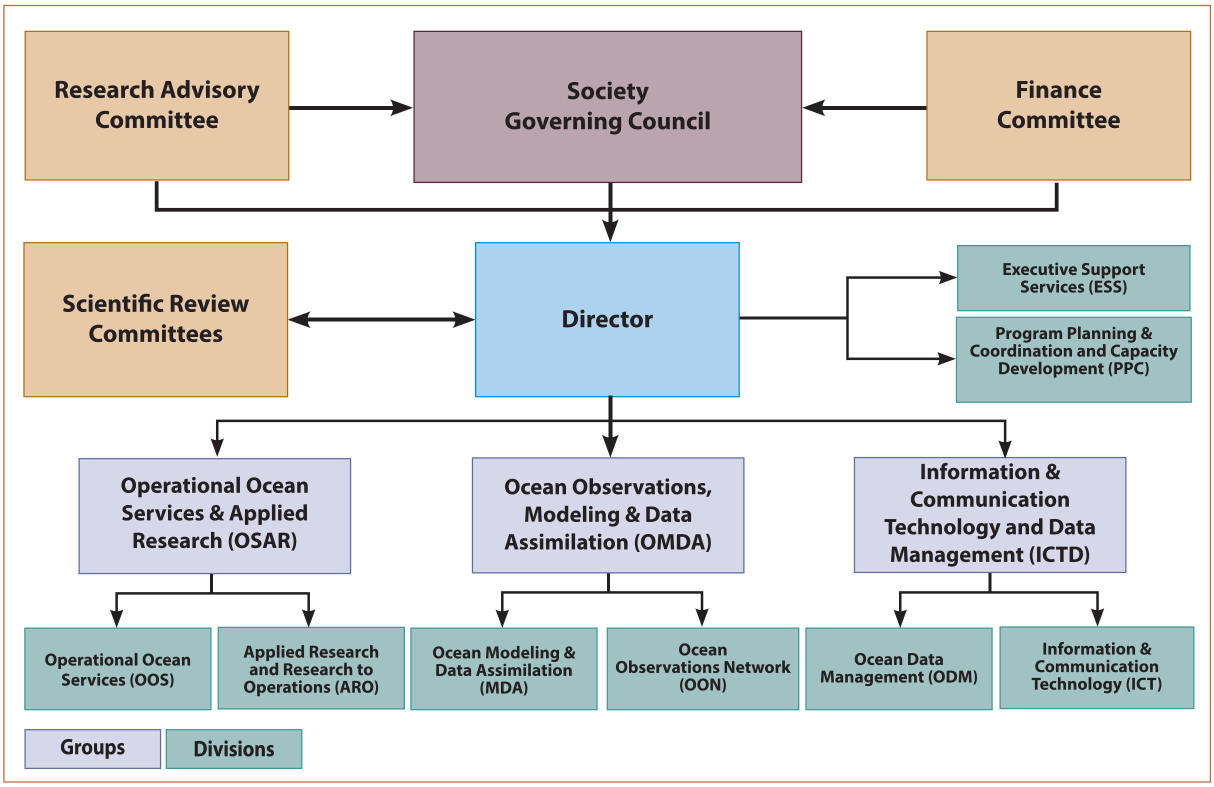
2.4 INCOIS Research Advisory Committee

1.	Dr. Satish R Shetye, Former Vice Chancellor, Goa University	Chairperson (Expert)
2.	Dr. Vijay Kumar, Scientist 'G', MoES & Program Head, INCOIS	Member (Ex-Officio)
3.	Dr. T. Srinivasa Kumar, Director, INCOIS, Hyderabad	Member (Ex-Officio)
4.	Dr. R. R. Navalgund, Former ISRO Distinguished Professor	Member (Expert)
5.	Prof. Sunil Kumar Singh, Director, NIO, Goa	Member (Expert)
6.	Dr. Prakash Kumar, Director, CSIR-NGRI	Member (Expert)
7.	Dr. Y. V. N. Krishna Murthy, Senior Professor, Indian Institute of Space Science & Technology, DOS-ISRO	Member (Expert)
8.	Prof. Raghu Murtugudde, Professor, University of Maryland, USA	Member (Expert)
9.	Prof. Karumuri Ashok, Professor, Hyderabad Central University	Member (Expert)

10.	Prof. P. N. Vinayachandran, Professor, CAOS, IISc, Bengaluru	Member (Expert)
11.	Dr. R. Jeyabaskaran, Director General, FSI	Member (Expert)
12.	Prof. Prasad Kumar Bhaskaran, Professor, IIT- Kharagpur	Member (Expert)
13.	Dr. Sudheer Joseph, Scientist - G & Division Head, ARO, INCOIS, Hyderabad	Member Secretary (Ex-Officio)

2.5. Scientific and Administrative Structure of INCOIS

INCOIS has three major Scientific Groups headed by respective Group Directors and each group has two divisions headed by respective Division Heads. In addition to the scientific groups, there are two divisions, one division to support the program planning & coordination and capacity building and another division to tender the administrative support for the functioning of the organization.



Organization Structure of INCOIS

2.6 The Mission

To provide ocean data, information and advisory services to society, industry, the government and the scientific community through sustained ocean observations and constant improvements through systematic and focused research in information management and ocean modelling.

The major objectives of INCOIS are:

1. To establish, maintain and manage systems for data acquisition, analysis, interpretation and archival for ocean information and related services.
2. To undertake, aid, promote, guide and co-ordinate research in the field of ocean information and related services including satellite oceanography.
3. To carry out surveys and acquire information using satellite technology, ships, buoys, boats or any other platforms to generate information on fisheries, minerals, oil, biology, hydrology, bathymetry, geology, meteorology, coastal zone management and associated resources.
4. To generate and provide data along with value added data products to user communities.
5. To cooperate and collaborate with other national and international institutions in the field of ocean remote sensing, oceanography, atmospheric sciences/meteorology and coastal zone management.
6. To establish an Early Warning System for Tsunami and Storm Surges.
7. To support research centres in conducting investigations in specified areas related to oceanic processes, ocean atmospheric interaction, coastal zone information, data synthesis, data analysis and data collection.
8. To organise training programmes, seminars and symposia to advance study and research related to oceanography and technology.
9. To publish and disseminate information, results of research, data products, maps and digital information through all technologically possible methods to users for promoting research and to meet societal needs for improvement of living standards.
10. To provide consultancy services in the fields of ocean information and advisory services.
11. To coordinate with space agencies to ensure continuity, consistency and to obtain state-of-the-art ocean data from satellite observations.
12. To encourage and support governmental and non-governmental agencies/organizations for furthering programmes in the generation and dissemination of ocean information.
13. To undertake other lawful activities as may be necessary, incidental or conducive to the attainment and furtherance of all or any of the above objectives of INCOIS.

2.7 Quality Policy

INCOIS is committed to provide the best possible ocean information and advisory services to society, industry, the government and the scientific community through sustained ocean observations and constant improvement through systematic and focused research. To achieve this, we will continue to align our actions with organizational values & shall ensure our commitment to continually improve our performance with our Quality Management System, by setting and reviewing quality objectives.

3

HIGHLIGHTS

Highlights during April 2022 to March 2023

New Products & Services:

- **Multi-Hazard Vulnerability Mapping (MHVM):** INCOIS carried out Multi-Hazard Vulnerability Mapping (MHVM) on a 1:25000 scale and published an Atlas for the entire Indian mainland and Andaman & Nicobar Islands.
- **Marine Heatwave Advisory Service:** INCOIS developed a new Marine Heat Wave Advisory Services (MAHAS). Since its inauguration, the interactive Web GIS platform regularly provides the intensity information of Marine Heat Wave, a prolonged extreme oceanic warm water event.
- **Search and Rescue Aid Tool-Integrated (SARAT-I):** INCOIS developed and operationalized the Search and Rescue Aid Tool-Integrated (SARAT-I) in collaboration with the Airports Authority of India (AAI) and the Indian Coast Guard (ICG) to extend the Search and Rescue application to aircraft missing mid-air while flying over the oceans.
- **Small Vessel Advisory Services (SVAS):** INCOIS started an improved version of the Small Vessel Advisory Services (SVAS) advisories to help fishermen and seafarers identify areas prone to boat capsizing due to rough sea conditions based on the vessel beam width.
- **Water Quality Nowcasting System:** INCOIS developed a Water Quality Nowcasting System (WQNS) that was launched by Honorable Minister for Earth Sciences.

New Infrastructure:

- **National Glider Operations Facility:** INCOIS established a National Glider Operations Facility. The facility is capable of simultaneous piloting of the glider fleet along with its testing, ballasting, and routine maintenance.
- **Oceansat-3 Data Acquisition and Processing Facility:** INCOIS started acquiring OCM data through an upgraded ground station and will be using it for operational services such as potential fishing zone (PFZ) advisories.
- **State-of-the-art E-Class Room Training Facility at ITCOO:** INCOIS established a State-of-the-art E-Class Room Training facility at the International Training Centre for Operational Oceanography (ITCOO) with a 72-seater capacity to aid Telepresence learning, Distance teaching, Point to Point or Point to Multipoint Video conferencing.

Key International Recognition:

- **Indian Ocean Region Decade Collaborative Centre:** INCOIS contributed to the implementation and governance of the programmes of the Intergovernmental Oceanographic Commission of the UNESCO (UNESCO-IOC). Most notably, INCOIS has been recognized as the Indian Ocean Region Decade Collaborative Centre (IOR-DCC) under the framework of the UN Decade of Ocean Science for Sustainable Development.
- **Regional Specialized Meteorological Centre:** INCOIS has been designated as a Regional Specialized Meteorological Centre (RSMC) of the World Meteorological Organisation (WMO) for numerical ocean wave prediction and global numerical ocean prediction.
- **G 20 Environment and Climate Sustainability Working Group:** INCOIS contributed to the deliberations of the ECSWG, more specifically to the development of High-Level Principles for a sustainable and climate resilient blue economy.

3 HIGHLIGHTS

Ocean Observations, Data, Modelling, Research and Operational Services:

- **Operational Ocean Services:** INCOIS Sustained 24x7 operations and provided key operational ocean information and advisory services for all blue economy stakeholders.
- **Harmonization of Thresholds for Multi-hazards Services:** Harmonized the thresholds and action messages for all multi-hazard early warning services.
- **Tsunami Advisories:** INCOIS monitored one tsunamigenic earthquake of magnitude more than 6.5 Mw in the Indian Ocean and 'No Threat' messages were issued to India and Indian Ocean Countries, in addition to monitoring of all tsunami events that occurred in the South Atlantic and Pacific Oceans.
- **Storm Surge Early Warnings:** INCOIS provided Storm surge and inundation advisories for three cyclones (Asani, Sitrang and Mandous) through IMD.
- **High Wave/Swell and Rough Sea Warning/Alert:** INCOIS issued a total of 708 High Wave/Swell Alerts/Warnings and rough sea alerts, in addition to the daily Ocean State Forecasts for India and 6 Indian Ocean Countries.
- **Oil Spill Advisory:** INCOIS issued Oil spill advisory to MV Princess vessel wreckage and CPCL pipeline rupture at Nagore Beach, Nagapattinam.
- **PFZ Advisories:** INCOIS provided 343 Potential Fishing Zones advisories and 102 Yellowfin Tuna advisories and disseminated widely through multiple platforms, including 9 new Telegram channels.
- **Coral Bleaching Alerts:** INCOIS provided 121 advisories on Coral Bleaching Alerts for Andaman, Nicobar, Lakshadweep, Gulf of Kutch and Gulf of Mannar.
- **Algal Bloom Information:** INCOIS monitored algal blooms on daily basis and issued 27 alerts in select ecological hotspots of the Indian coastal waters.
- **Ocean General Circulation Modelling:** As part of the Ocean Climate Change Advisory Services (OCCAS) of the Deep Ocean Mission (DOM) and the Unified Modelling Framework, INCOIS configured a regional MOM6 for the for the Indian Ocean and a coastal FVCOM for the coastal waters off Cochin. Both these models show promising results.
- **Wave Modelling:** INCOIS configured a high-resolution wave model for the Global Ocean using WAVEWATCH III 6.07 at a spatial resolution of (1/8) degree. The configuration for climate projections will be based on ST4 parameterization scheme, which is identified after numerous sensitivity studies.
- **Participation in RECCAP-2:** INCOIS's regional coupled ocean-ecosystem model simulated data submitted to the 'REgional Carbon Cycle Assessment and Processes (RECCAP) Phase 2' came out to be at par (if not better) with other community standards.
- **Autonomous Coastal Water Quality Observatory:** INCOIS deployed a state-of-the-art autonomous coastal water quality observatory at Kochi, in addition to effectively sustaining all other ocean observing platforms.
- **Research Publications:** A total of 71 research papers were published with a cumulative impact factor of 238.23.

Capacity Building, Education & Training:

- **Trainings / Workshops:** ITCOocean, a Category2Centre under UNESCO located at INCOIS conducted a total of 12 training courses. In these courses, a total of 669 persons were trained of which 550 (Male: 348, Female: 202) are from India and 119 (Male: 72, Female: 47) are from 96 other countries.
- **Advanced Oceanography Course for Indian Navy Officials:** INCOIS conducted a four-month course on Operational Oceanography exclusively for the officers of the Indian Navy from 10 Oct 2022 to 28 Jan 2023.
- **Tsunami Mock drill:** INCOIS conducted a tsunami mock drill to (i) Odisha stakeholders on 05 November 2022 and (ii) Andaman & Nicobar Islands on 09 February 2023. Public evacuations were carried out at several locations during both mock drills.
- **Tsunami Communications Tests:** INCOIS conducted 24th and 25th Communications (COMMs) tests of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) on 08 June 2022 and 07 December 2022 to validate the dissemination processes for tsunami messages to national and international users.
- **Tsunami Ready:** INCOIS supported the State of Odisha, Kerala and Andaman & Nicobar in their efforts towards implementation of the UNESCO-IOC Tsunami Ready community recognition programme across several villages.
- **Tsunami Evacuation Planning Workshop:** INCOIS hosted an international workshop on “Tsunami Evacuation Planning” on 13 September 2022, as a part of IOC-UNESCO and UNESCAP project on ‘Strengthening Tsunami Early Warning in the Northwest Indian Ocean Region through Regional Cooperation’.
- **Azadi Ka Amrit Mahotsav:** As a part of Azadi Ka Amrit Mahotsav initiative of the Government of India, INCOIS continued to organize several activities focused on better outreach of its services and scientific research and India’s achievements in the past 75 years in the field of Earth sciences with special emphasis on Ocean Science. Further, INCOIS conducted an event to foster a ‘Strong AtmaNirbhar Bharat through I-Connect’ in the spirit of Aatmanirbhar Bharat.
- **Swachh Sagar, Surakshit Sagar/Clean Coast Safe Sea campaign:** INCOIS scientists actively participated in a 75-day citizen-led campaign for improving ocean health through collective action. The campaign started on 05 July 2022 and culminated with the largest beach cleaning event on 17 September 2022, covering 75 beaches of India. As a part of this program, INCOIS conducted beach cleanup and awareness campaigns at 9 beaches in Andhra Pradesh (Bhimili, Yarada, RK, Kakinada, NTR, Suryalanka, Dindi, Manginapudi, and Krishnapatnam).
- **Campus Visit of Students:** INCOIS hosted over 5000 students from various schools, colleges, and universities at its facilities to raise awareness about INCOIS services and encourage young minds to enter the world of oceanography.
- **Academic Projects/Internships:** A total of 32 students from different universities and institutions have undertaken academic project/internship work under the guidance of INCOIS scientists as part of their degree.

Awards /Honors/Celebrations:

- **WCDM-DRR Excellence Award:** ITEWC of INCOIS received the 'World Congress on Disaster Management - Disaster Risk Reduction (WCDM-DRR) Excellence Award-2021' for the tsunami early warning services.
- **ICTP's Associateship Scheme:** Dr. Kunal Chakraborty has been selected as a 'Regular Associate' of the Abdus Salam International Centre for Theoretical Physics (ICTP) for a period of six years from 2023 until 2028.
- **PORSEC Service Award-2022:** Dr. Nimit Kumar was awarded the PORSEC Distinguished Service Award for his achievements including an award-winning MOOC (IUCEL-2021 silver award) during the 15th PORSEC.
- **Anni Talwani Memorial Grant for Young Women Researcher-2022:** Ms. Trishneeta Bhattacharya, Senior Research Fellow has received the Anni Talwani Memorial Grant for Young Women Researcher of Indian Geophysical Union (IGU) for the year 2022.
- **25th Foundation Day & New Logo:** INCOIS celebrated its 25th Foundation Day on 03 February 2023 and a new Logo was released to mark the start of the silver jubilee year to commemorate the celebration of 25-year journey of INCOIS.

4

SERVICES

4.1 Multi-Hazard Early Warning Services

4.1.1 Tsunami Early Warning Services (TEWS)

The Indian Tsunami Early Warning Centre (ITEWC) monitored 24 earthquakes of magnitude ≥ 6.5 during the period from April 2022 to March 2023. Out of 24 earthquakes, only one earthquake has occurred in the Indian Ocean region. The ITEWC assessed the situation carefully during the earthquakes and declared that there would not be any tsunami threat for India. Being the Tsunami Service Provider (TSP) for the Indian Ocean, the necessary bulletins were also sent to 25 Indian Ocean rim countries and IOC through emails, GTS, FAX, and SMS. The locations of these earthquakes are shown in Figure 4.1.1.

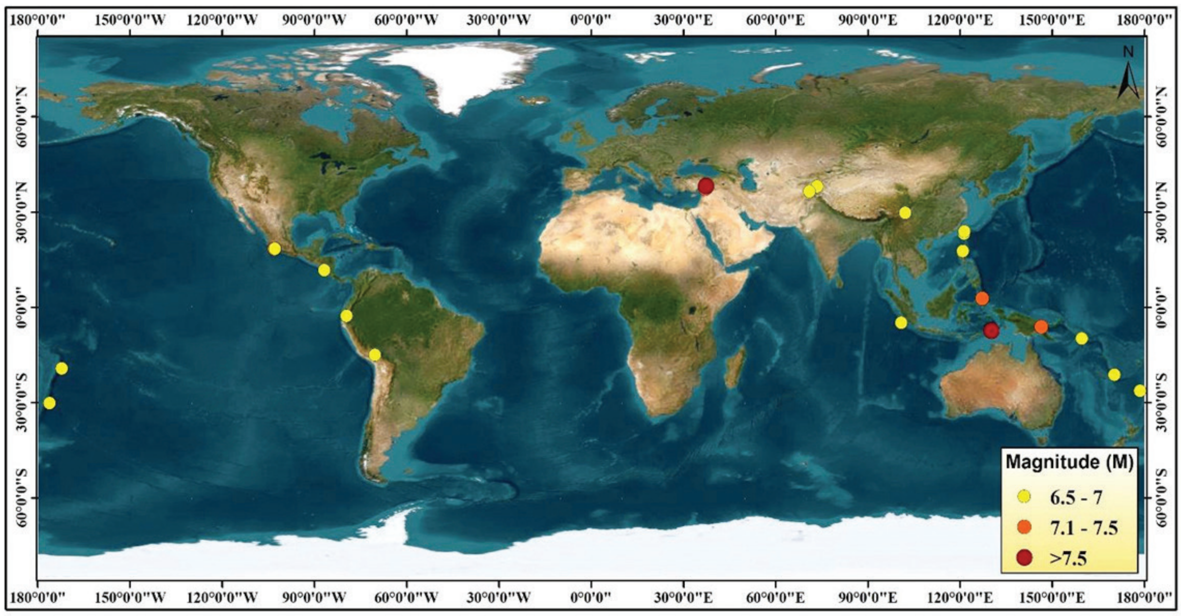


Figure 4.1.1. Location map of earthquakes of magnitude ≥6.5 monitored at ITEWC during 2022-23

4.1.1.1 Key Performance Indicators (KPI) of ITEWC

The below table shows Key Performance Indicators (KPIs) of the ITEWC.

Table 4.1.1. KPIs of ITEWC

S. No.	Key Performance Indicator	Target	ITEWC Performance
KPI 1	Elapsed time from the earthquake to the issuance of the first Earthquake Bulletin	10 min	9.2
KPI 2	Probability of Detection of IO EQ with Mw >= 6.8	100%	100%
KPI 3	Accuracy of earthquake magnitude in comparison with Final USGS parameters	0.3	0.2
KPI 4	Accuracy of earthquake hypocenter depth in comparison with Final USGS parameters	30 Km	28.5
KPI 5	Accuracy of earthquake hypocenter location in comparison with Final USGS parameters	30 Km	28.3
KPI 6	Elapsed time from the earthquake to the issuance of the first Threat Assessment Bulletin	20 Min	25.5

4.1.1.2 Monitoring of Tsunamigenic Earthquakes

In the Indian Ocean, an earthquake of magnitude 6.6 occurred Southwest of Sumatra, Indonesia, on 18 November 2022 at 13:37 UTC (19:07 IST). The epicentre of the event was at 4.81° S, 100.81° E, with a focal depth of 10 km. The ITEWC issued the first bulletin at 13:46 UTC (9 minutes from earthquake occurrence) with a tsunami evaluation statement. For this earthquake, ITEWC issued a second bulletin stating, "Based on pre-run model scenarios, there is NO THREAT to India and to countries in the Indian Ocean". The Tsunami threat map and travel time maps are shown in Figure 4.1.2.

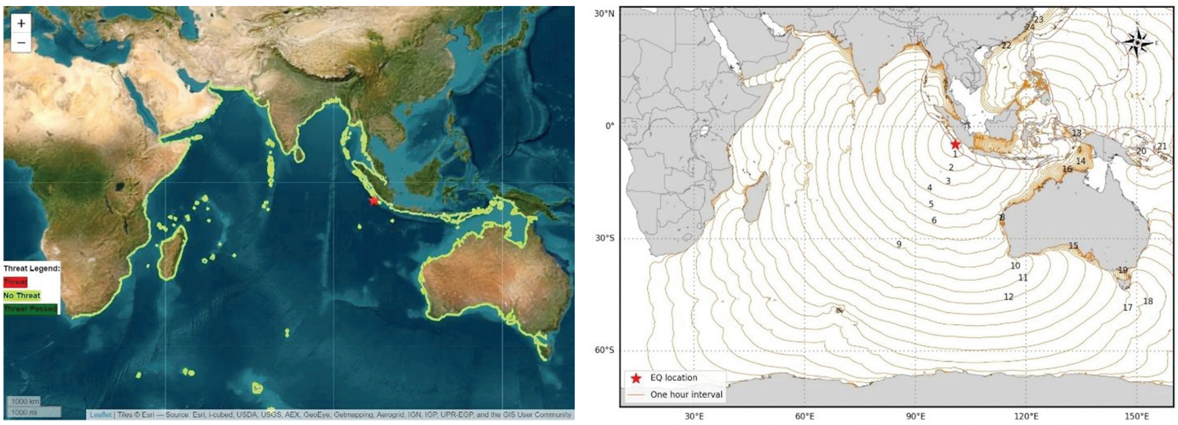


Figure 4.1.2. Tsunami Threat details and Travel time Map for Southwest Sumatra, Indonesia earthquake on 18 November 2022

4.1.1.3 Communication Test

24th and 25th Communications (COMMs) tests of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) were conducted on 08 June 2022 and 07 December 2022 to validate the TSPs (Tsunami Service Providers) dissemination process

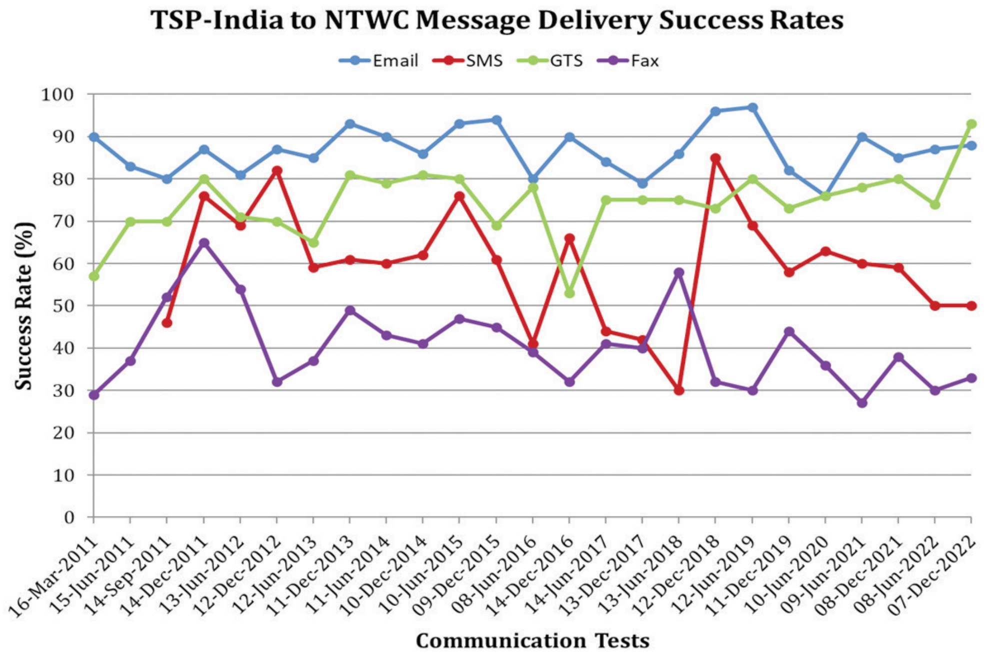


Figure 4.1.3. Success rates of TSP-India message delivery during COMMs Tests

to NTWCs (National Tsunami Warning Centres), validate the dissemination chains for tsunami notification messages with national disaster management contacts, reception of the notification messages by NTWCs and the access by NTWCs to TSP password-protected web sites. During the COMMs test, the scenarios of magnitude 9.2 at Northern Sumatra, Indonesia, and M9.0 at the Andaman Islands, India, were evaluated, and ITEWC disseminated notification messages through email, fax, GTS, SMS as well as the website to 25 NTWCs and including two TSPs (Australia & Indonesia) in the Indian Ocean Region. TSP-India success rate is shown in Figure 4.1.3.

4.1.1.4 Tsunami Mock Exercises

For Odisha: On 05 November 2022, a tsunami mock exercise was conducted in coordination with Odisha State Disaster Management Authority (OSDMA) and Odisha State Emergency Operation Centre wherein INCOIS issued bulletins to Odisha stakeholders for evaluating their SOPs and Communication media. As part of the mock drill, ITEWC simulated a tsunami for an earthquake of magnitude 9.2 at Andaman & Nicobar Islands. Six coastal communities (Jayadevkasaba, Pahi, Podhuan, Tantiapal Sasan, Keutajanga, Noliasahi, and Venkatraipur), including two UNESCO-IOC Tsunami Ready communities, actively participated and evacuated to test the Tsunami Ready indicators. Community participation photos shown in Figure 4.1.4.

Figure 4.1.4. Odisha community participation during tsunami mock drill on 05 November 2022

For Andaman & Nicobar Islands: On 09 February 2023, a tsunami mock exercise was conducted in coordination with National Disaster Management Authority (NDMA) wherein INCOIS issued bulletins to Andaman & Nicobar Islands stakeholders for evaluating their SOPs and Communication channels. As part of the mock drill, ITEWC simulated a tsunami for an earthquake of magnitude 9.0 at Northern Sumatra, Indonesia, and issued seven bulletins. The public evacuation was carried out at several locations. Scenario details and Community participation photo shown in Table 4.1.2 and Figure 4.1.5 respectively.

Table 4.1.2. Scenarios details for Mock drill

Magnitude	9.0 Mw
Latitude	3.316° N
Longitude	95.850° E
Depth	10 km
Origin Time	09:07 IST
Date	09 February 2023
Region	Northern Sumatra, Indonesia

Figure 4.1.5. Andaman & Nicobar Islands community participation during tsunami mock exercise on 09 February 2023

4.1.1.5 Tsunami Ready Programme Implementation

The Tsunami Ready programme is essential for enhancing preparedness, and INCOIS continued its support of the programme. Post the recognition of Venkatraipur and Noliasahi villages of Odisha as Tsunami Ready communities by UNESCO-IOC, Odisha State Disaster Management Authority took up implementation of the tsunami ready programme in its other coastal villages/wards, and work is in progress.

- Andaman & Nicobar Islands initiated the Tsunami Ready process in Car Nicobar area, which was worst affected during the 2004 tsunami.
- Kerala initiated the Tsunami ready programme in 6 villages in 6 coastal districts. Kerala State Disaster Management Authority (KSDMA) conducted training and awareness programs in these 6 villages during December 2022.
- Tsunami Ready start-up program was conducted for the Alappad community at Amritapuri, Kollam District, Kerala, on 09 June 2022 in coordination with Amrita Vishwa Vidyapeetham. Tsunami Ready is being implemented at Alappad with support from KSDMA and Amrita Vishwa Vidyapeetham.

Figure 4.1.6. Tsunami ready meeting participants of Alappad, Kerala, on 09 June 2022

4.1.2 Storm Surge Early Warning Service

During 2022-23, INCOIS successfully monitored 03 cyclones and issued timely storm surge and inundation advisories through Indian Meteorological Department (IMD). Storm surge and inundation forecasts for cyclones are shown in Table 4.1.3 and Figure 4.1.8.

Table 4.1.3. Cyclones and deep depressions during 2022-23

Sl. No.	Cyclone Name	Dates Active	No Advisories / Graphic products issued
1	Severe Cyclonic Storm Asani	08 – 12 May 2022	11
2	Cyclonic Storm Sitrang	23-25 October 2022	10
3	Severe Cyclonic Storm Mandous	07-10 December 2022	16

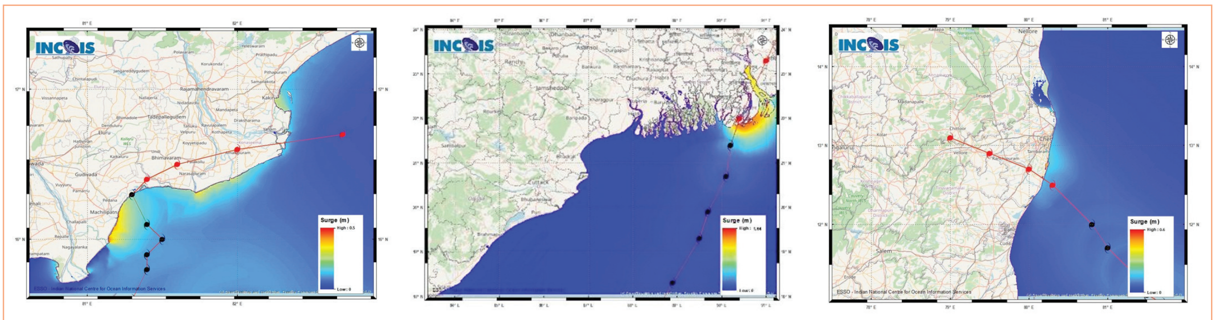


Figure 4.1.8. Real-time storm surge and inundation forecast for Asani, Sitrang, and Mandous cyclones, respectively.

4.1.3 Ocean State Forecast (OSF)

INCOIS successfully issued daily operational forecasts seamlessly during the entire period (365 days), covering the parameters of waves, winds, currents, tides, SST, MLD, and D20 for various regional and coastal domains. In addition, INCOIS monitored cyclone/depression conditions, issued joint INCOIS-IMD bulletins, and disseminated the warnings through multiple modes to the user communities. Advisory services were provided to specific users like disaster management authorities, fishermen, ports and harbours, ships plying in the seas, offshore industries, and defence authorities. INCOIS also provided daily OSF data to Sri Lanka, Maldives, Seychelles, Comoros, Mozambique, and Madagascar.

Based on the request from Puducherry and Lakshadweep, OSF information is displayed in new web portals for better visualization.

During the reporting period, INCOIS issued OSF services seamlessly, supporting the operational requirements as well as the safety of a diverse and large user community through multiple dissemination modes. A total of 708 High Wave/Swell Alerts/Warnings and rough sea alerts were issued. Month-wise and state-wise alerts are shown in Figure 4.1.9 and 4.1.10, respectively. The highest number was issued for Gujarat and the lowest for Andhra Pradesh.

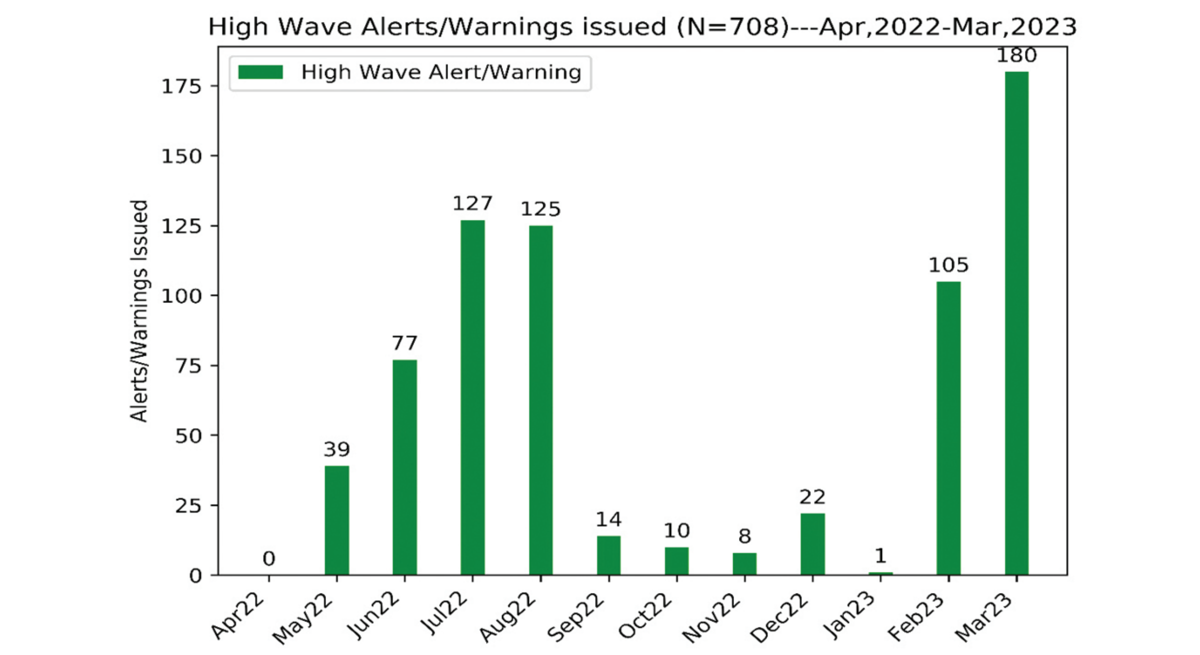


Figure 4.1.9. Number of high wave/swell/ rough sea alerts issued during Apr 2022 – Mar 2023

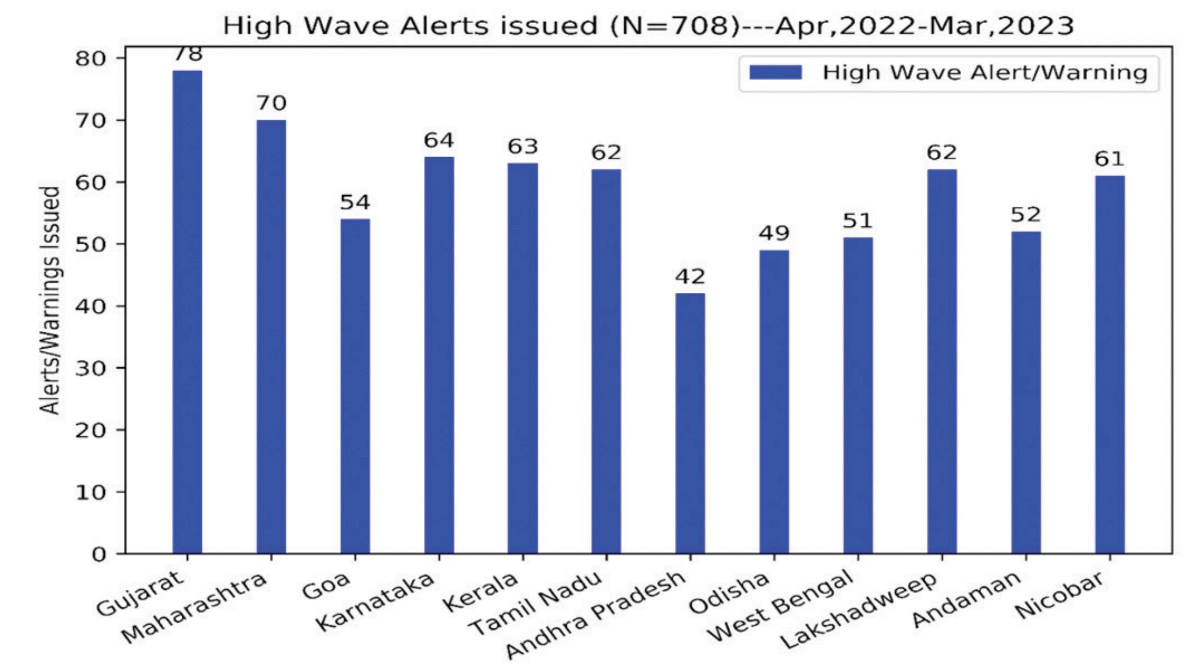


Figure 4.1.10. State-wise distribution of the high wave/swell/rough sea alerts during the period

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INCOIS continued to extend the necessary support required to the users through customization and providing location-specific services (including a large number of fish landing centers). INCOIS provided ocean state forecast services to ONGC, AFCONS, NIOT, etc. INCOIS provided 1207 forecasts to ONGC (KG-DWN-98/2, Kakinada Centre) on surface and bottom currents during the reporting period. INCOIS also provided regular forecasts for NIOT deep sea mining locations in the central Indian Ocean basin. INCOIS also provided forecasts along the planned ship routes to the MoES vessels; this is in addition to the access provided to multiple users through registration.

4.1.3.1 Ocean state forecast during the passage of cyclonic storms in the Bay of Bengal and Arabian Sea

INCOIS continuously monitored the wave, wind, sea level, and current regime in the nearshore region as well as far offshore for the cyclones Asani, Sitarang, and Mandous using models, in-situ instruments as well as satellite observations. Extreme events during the period are displayed in the below table, all the phases of the events, e.g., depression – cyclone – deep depression, and its dissemination statistics mentioned. The list of extreme events is shown in Table 4.1.4. A total of 135 bulletins were issued for the 13 extreme events, as listed in the table below. The most affected states in terms of duration/intensity due to these events are West Bengal, Odisha, Andhra Pradesh, and Tamil Nadu (Fig. 4.1.13.).

The maximum significant wave height was in the range of 5.5 - 6.0 m in the three cases, the maximum being to the right of the cyclone path.

Table 4.1.4. OSF forecast for cyclones and depressions during the reporting period

Extreme weather event	Period	Number of bulletins issued	States/UTs affected
Severe Cyclonic Storm Asani	7 - 12 May 2022	29	Tamil Nadu, Andhra Pradesh, Odisha, West Bengal
Depression ARB 01	16 – 18 Jul 2022	7	Gujarat
Depression BoB 01	9 – 10 Aug 2022	4	Odisha, Andhra Pradesh, West Bengal
Depression ARB 02	12 –13 Aug 2022	4	Gujarat, Maharashtra, Goa, Karnataka
Depression BoB 05	14 – 17 Aug 2022	2	Odisha, West Bengal
Deep Depression BOB 06	19 Aug 2022	4	Odisha, West Bengal
Depression BoB 02	11 Sep 2022	2	Odisha, West Bengal, Andhra Pradesh
Cyclonic Storm Sitrang	22 – 25 Oct 2022	20	Odisha, West Bengal, Andaman, Nicobar
Depression BoB 08	20 – 22 Nov 2022	11	Tamil Nadu, Andhra Pradesh
Severe Cyclonic Storm Mandous	6 – 10 Dec 2022	22	Tamil Nadu, Andhra Pradesh, Andaman, Nicobar

Deep Depression ARB 03	14 – 15 Dec 2022	5	Goa, Karnataka, Lakshadweep
Depression BoB 10	22 – 25 Dec 2022	12	Andhra Pradesh, Tamil Nadu, Kerala, Andaman & Nicobar
Depression BoB 01	30 Jan – 2 Feb 2023	13	Tamil Nadu (and Puducherry)

Spatial plots of the forecast waves and wind during the cyclones are presented in Figure 4.1.11. Validation of forecast waves with WRB observations during cyclones is shown in Figure 4.1.12.

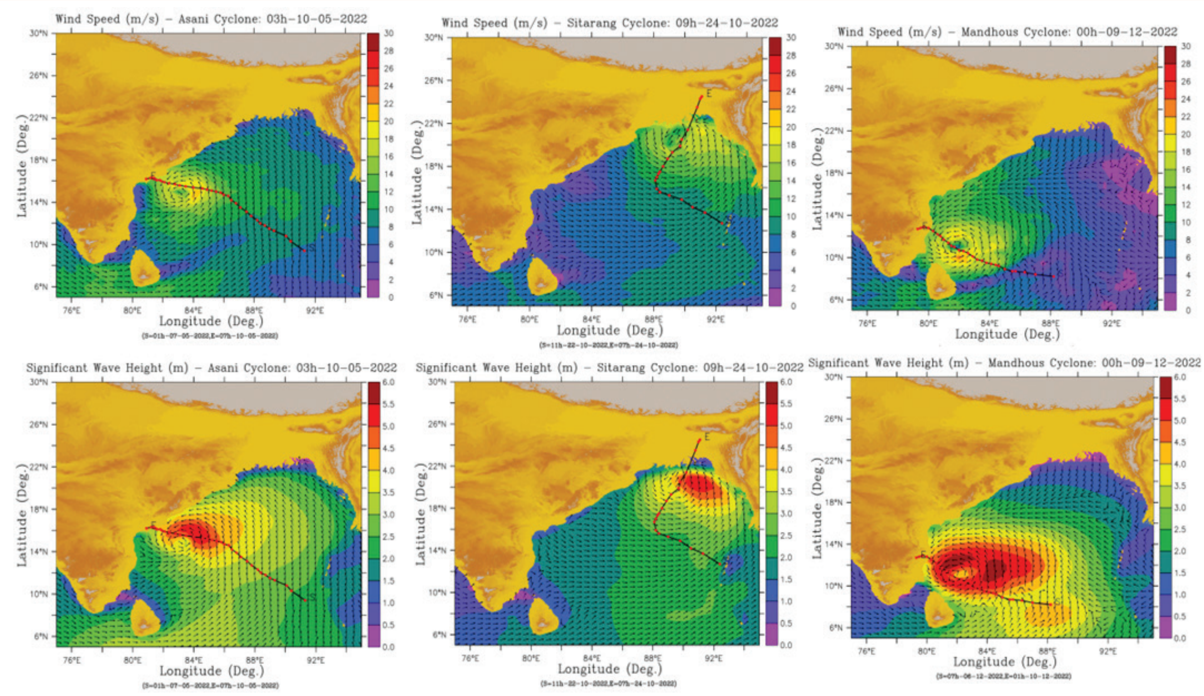
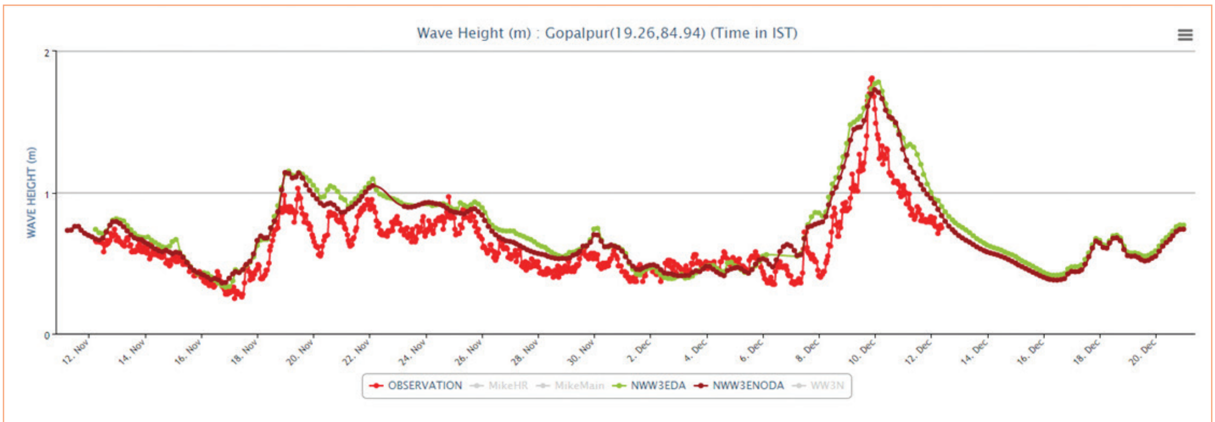


Figure 4.1.11. Spatial plots of the forecast wind speed (top figures) and significant waves height (bottom figures) Asani, Sitrang, and Mandous cyclones

INCOIS monitors the real-time situation of the conditions over the sea using a suite of instruments. The validation of Significant Wave Height at Wave Rider Buoys (WRB) during cyclone Mandous presented for the Gopalpur, Visakhapatnam, and Krishnapatnam locations are shown in Figure 4.1.12.



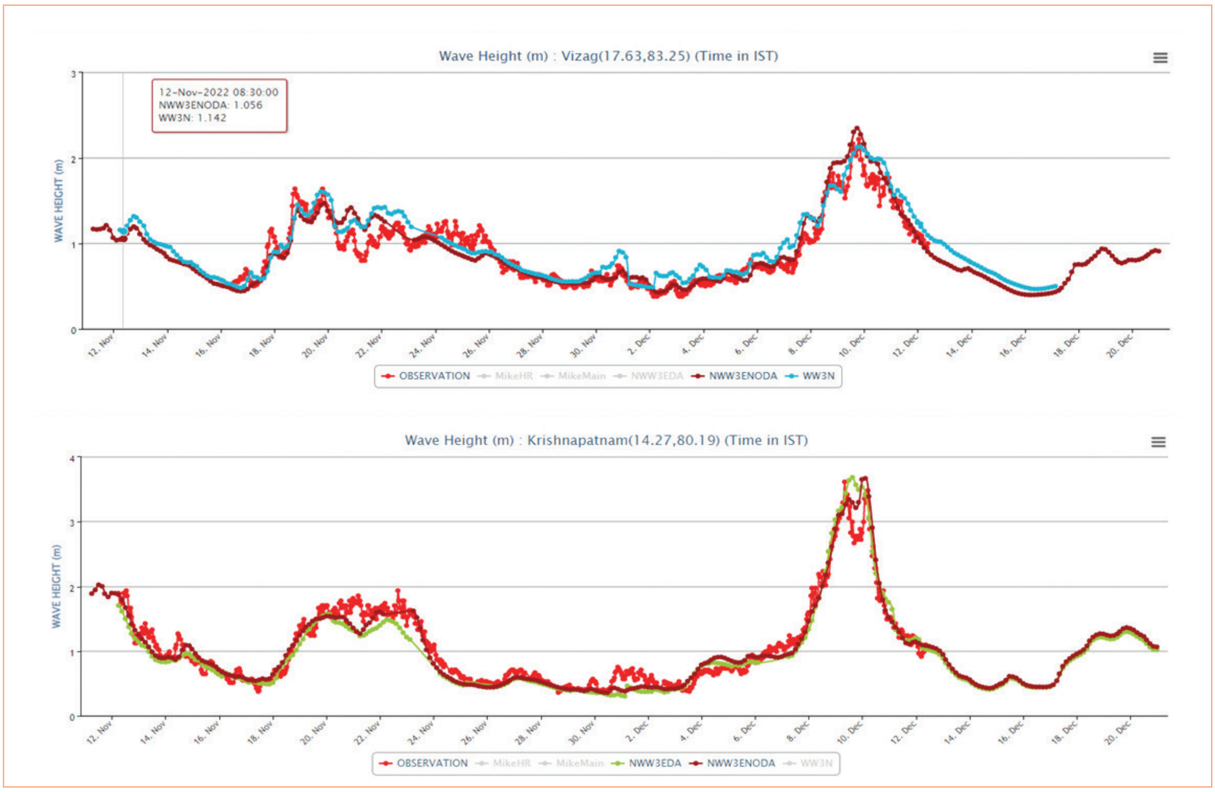


Figure 4.1.12. Validation of forecast wave with WRB observations during cyclone Mandous.

The number of INCOIS-IMD joint bulletins issued and States/UTs affected during cyclones shown in Figure 4.1.13.

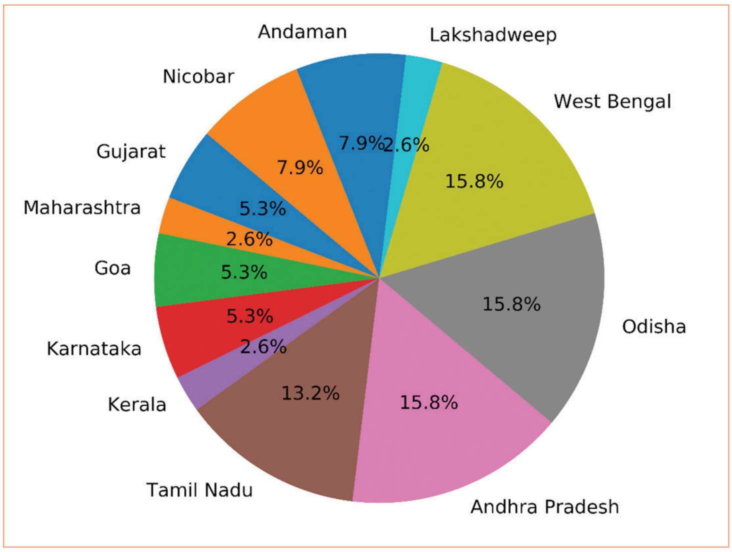


Figure 4.1.13. The number of INCOIS-IMD joint bulletins issued during 2022-23 cyclones.

4.1.3.2 Oil-spill trajectory advisories

During the reporting period, two oil-spill trajectory advisories were provided. The first oil spill advisory was issued to the MV Princess vessel wreckage off Mangalore, and the second advisory was issued to the CPCL pipeline rupture at Nagore Beach, Nagapattinam.

Oil spill due to MV Princess vessel wreckage in June 2022

Based on the request from Karnataka State Disaster Management Authority (KSDMA), INCOIS simulated oil drift patterns on regular intervals from the spill location 12^0 45.5'N, 74^0 51.1'E of the wrecked vessel MV Princess which had 220 Tons of Fuel oil on board, from 21 June 2022 to 04 July 2022. These advisories were sent to Indian Coast Guard, KSDMA, Pollution Control Boards, Coastal Police, Fishing department, Mangalore Refineries, New Mangalore Port Authority, etc.; as per the simulation, the pollutant was found to move southward predominantly.

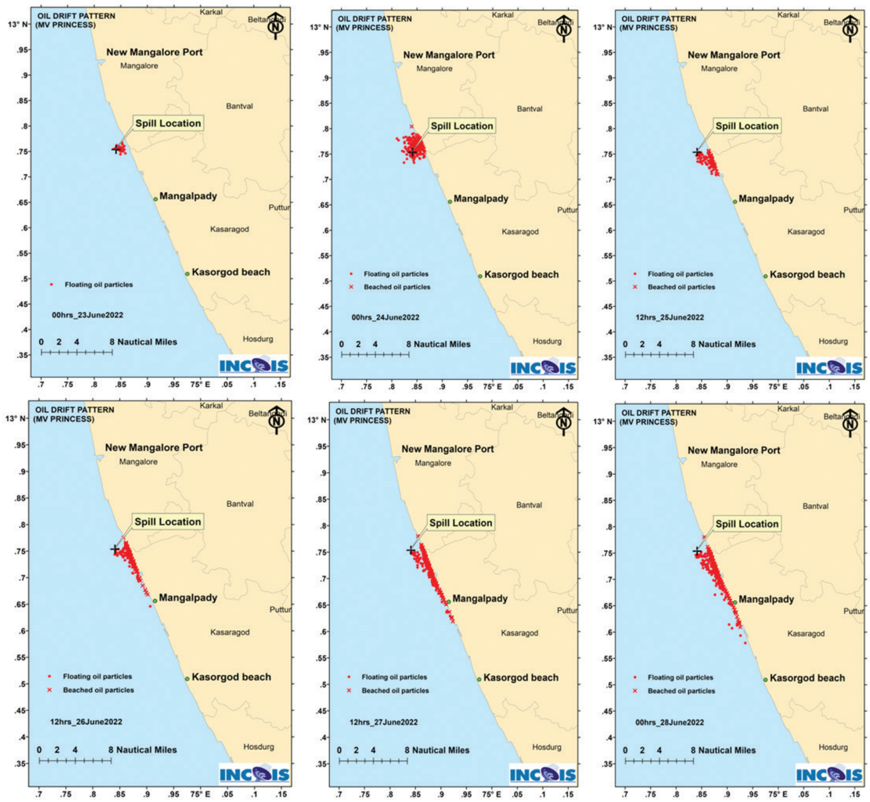


Figure 4.1.14. Snapshot of the oil spill advisory issued during June 2022

Oil spill due to CPCL pipeline rupture, Nagore Beach, Nagapattinam in March 2023

INCOIS generated oil spill trajectory patterns on a forecast basis for the spill reported due to pipeline rupture at (10.82°N, 79.85°E,) Nagore Beach, Nagapattinam. On the night of 02 March 2023, an oil leak was noticed by the local community. The spilled crude oil reached the shore on the same day. Later it was noticed to spread along the coast. INCOIS generated oil drift patterns to advise the coastal community on the further spread of the pollutant. Oil spill advisories Off Mangalore and Nagore beach shown in Figure 4.1.14 and 4.1.5.

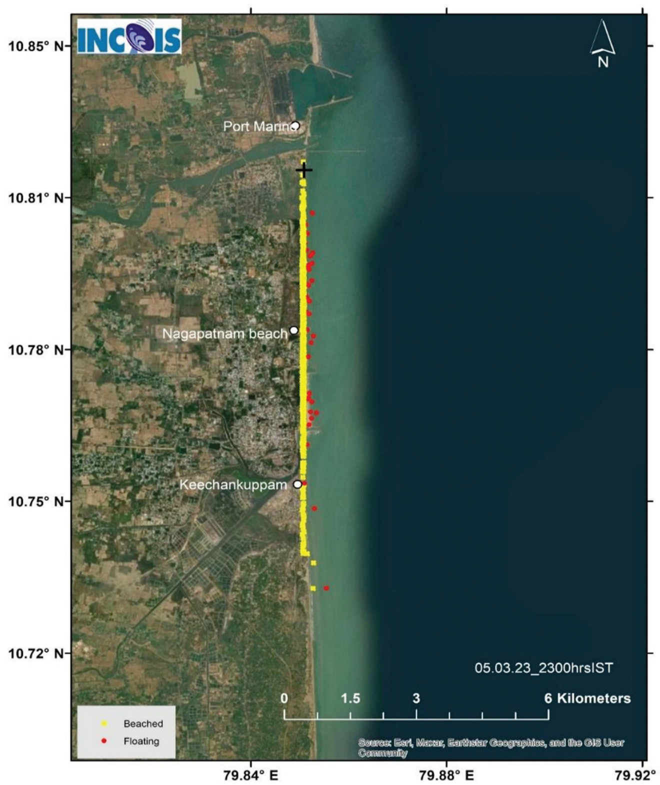


Figure 4.1.15. Snapshot of the oil spill advisory issued during March 2023

4.1.3.3 Search and Rescue Aid Tool

During the reporting period, Search And Rescue Aid Tool (SARAT) advisories

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were provided for Indian Coast Guards for Merchant vessel Kymea on 12 September 2022, BMS Platform on 24 February 2023, and various others based on the request.

4.1.3.4 Small Vessel Advisory Services (New Service)

INCOIS has initiated a service, namely "Small Vessel Advisory Services (SVAS)" to provide boat-specific safety information for fisherfolk, aiming at enhancing the safety of the fisherfolk and any seafarer at sea. The SVAS warns fisherfolks and seafarers against potential zones where vessel overturning can take place ten days in advance, which helps them to avoid such unfortunate incidences. This warning system is based on the Boat Safety Index (BSI) derived from wave model forecast outputs such as significant wave height, wave steepness, directional spread, and wind sea.

To make the advisories boat-specific, the warning was issued with the region of danger in conjunction with the category/size of the boat in an inclusive manner by using the significant wave height information from the model. Thus, SVAS was categorized according to the beam width of the vessel. Advisories are valid for small vessels of beam width up to 7 m. This limit covers the entire range of beam widths of the fishing vessels used in all 9 coastal states and 3 union territories of India.

4.1.3.5 Marine Heatwave Advisory Services (New Service)

Climate change is a global phenomenon, and the impacts vary locally. Hence it is necessary to estimate the intensity and variability of the heat content in the sea. A Marine Heatwave is a parameter to understand the persistence of heat content in the marine environment. The Marine Heatwave is a discrete prolonged, anomalously warm water event. INCOIS has set up a Marine Heatwave Advisory Service (MAHAS) on a daily basis comprising the parameters Intensity of Marine Heatwave, categories, and percentage of the area of Marine Heatwave spread over the different basins and sectors over the Indian Ocean through the web interface for users. These advisory services can be helpful for understanding the impact of Marine habitat and the frequency and intensity of disaster events for Indian rim country and research communities. The service was inaugurated on the INCOIS foundation on 03 February 2023.

4.1.3.6 Harmonization of thresholds for multi-hazards services of INCOIS

INCOIS harmonized the thresholds and action messages of Warning, Alert, Watch, and No Threat information for multi-hazard early warning services such as tsunami, high waves, swell surges, strong ocean currents, and storm surges. The same information was shared with the National Disaster Management Authority dissemination platform Common Alert Protocol (CAP) for implementation at the CAP-Sachet application for mass dissemination of advisories. Thresholds and action messages shown in Table 4.1.5.

Table 4.1.5. Thresholds and action messages for multi-hazard services of INCOIS

SERVICE	WARNING	ALERT	WATCH	NO THREAT / THREAT PASSED
Tsunami	EWA >2.0 m	0.5 m ≤ EWA ≤ 2.0 m	0.2 m ≤ EWA < 0.5 m	No Significant / No further Tsunami Waves
	(Take Action) Public advised to move in-land towards higher grounds. Vessels should move into deep ocean.	(Take Action) Public advised to avoid beaches and low-lying coastal areas. Vessels should move into deep ocean.	(Be Updated) No immediate action is required.	(No Action) No immediate action is required
High Wave	SWH > 3.5 m	3.0 m ≤ SWH ≤ 3.5 m	2.0 m ≤ SWH ≤ 3.0 m	SWH < 2.0 m
	(Take Action) Small vessels not to ply. Nearshore recreation activities to be totally suspended, erosion/wave surges possible.	(Be Prepared) Exercise caution for all marine operations and nearshore recreation.	(Be Updated) No immediate action is required. Check for updates.	(No Action) No action is required.
Swell Surge	Swell Period > 18 sec + Surge Height > 2.5 m / High Tide	15.0 sec ≤ Swell Period ≤ 18.0 sec + Surge Height > 1.5 m	12.0 sec ≤ Swell Period ≤ 15.0 sec / 1.0 m ≤ Surge Height ≤ 1.5 m	No significant Swell
	(Take Action) Surging of waves nearshore possible, small vessels not to ply, no recreation at beach/ nearshore waters, nearshore erosion possible.	(Be Prepared) There is a possibility of surging of waves, boats to ply with utmost vigilance, recreation with due caution.	(Be Updated) No immediate action is required. Check for updates.	(No Action) No action is required.
Strong Ocean Currents	Currents > 2.0 m/s	1.0 ≤ Currents ≤ 2.0 m/s	0.5 ≤ Currents ≤ 1.0 m/s	Currents < 0.5 m/s
	(Take Action) Exit/entry at harbours with sufficient caution. Ships/boats flowing against current in open sea to be very cautious.	(Be Prepared) Harbour/marine operations to be cautious.	(Be Updated) No immediate action is required. Check for updates.	(No Action)
Storm Surge	SSH >2.0 m OR Inundation extent more than 500m	0.5 m ≤ SSH ≤ 2.0 m OR Inundation extent between 100 to 500m	0.2 m ≤ SSH < 0.5 m OR Inundation extent less than 100m	SSH < 0.2 m OR No inundation
	(Take Action) The public is advised to avoid low-lying areas. Follow local disaster management guidelines.	(Take Action) The pubis is advised to avoid beaches. Follow local disaster management guidelines.	(Be Updated) No immediate action is required.	(No Action) No action is required

4.2 Ecosystem-based Service

4.2.1 Marine Fisheries Advisory Services (MFAS)

4.2.1.1 Potential Fishing Zones (PFZ) and Tuna PFZ Advisories

PFZ advisory has become part of the value chain of the fishing community of India. INCOIS continued

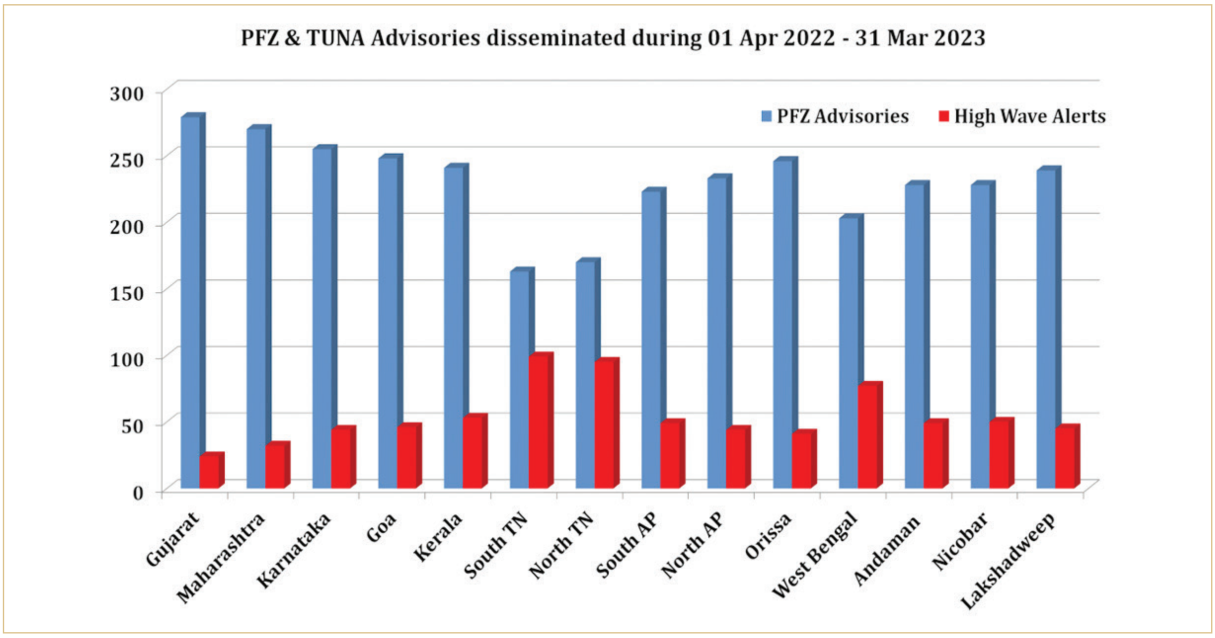


Figure 4.2.1. Number of PFZ advisories issued during 2022-23.

to provide the advisories on Potential Fishing Zones (PFZ) generated using the satellite-derived Sea Surface Temperature (SST), chlorophyll, water clarity, and sea level data. The advisories were disseminated in the form of smart maps and text on a daily basis, except during the fishing-ban period and during adverse sea-state conditions. During the period April 2022 to March 2023, multilingual PFZ advisories and Yellowfin Tuna advisories were provided for 343 and 102 days, respectively. PFZ and TUNA advisories issued figures are shown 4.2.1 and 4.2.2, respectively.

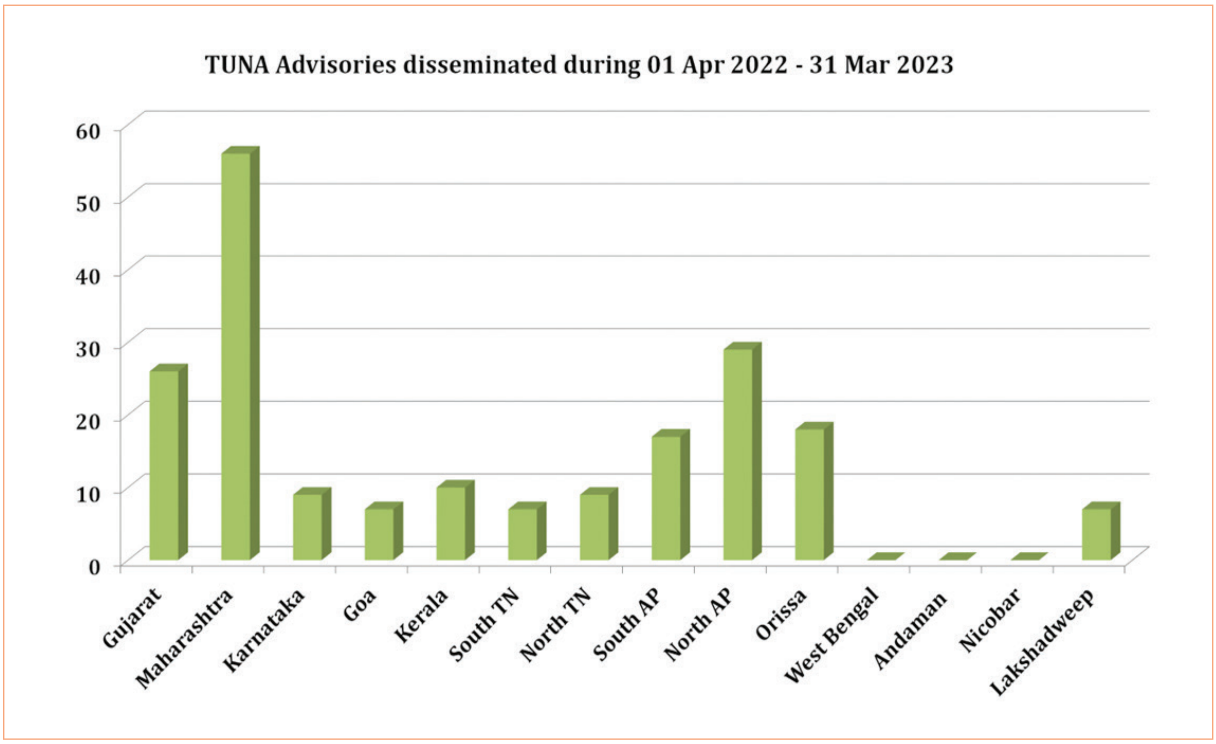


Figure 4.2.2. Number of Tuna PFZ advisories issued during 2022-23.

4.2.1.2 PFZ Dissemination

INCOIS initiated 09 broadcast channels for different coastal states (i.e., Gujarat, Maharashtra, Karnataka, Goa, Kerala, Tamil Nadu, Andhra Pradesh, Odisha and West Bengal, Andaman & Nicobar, Lakshadweep) on the TELEGRAM platform for dissemination of PFZ Advisories in additions to regular modes. These 09 PFZ Telegram Channels get updates on daily advisory maps along with textual information. Presently popularizing this service as a complementary service to the SMS platform. INCOIS has received about 550 feedback forms during the user interaction workshops held at the field level, and the same numbers were added to the PFZ dissemination list and enhanced the user database. INCOIS continued broadcasting advisories/ information like PFZ and ocean state forecast high wave alerts through GEMINI devices on a daily basis.

4.2.1.3 Android App for Fishermen Feedback

INCOIS designed a mobile app for collecting feedback from fishermen's society which can help in improving & fine-tuning advisories. The same is also integrated with the Fisher Friend Mobile Application (FFMA) of MS Swaminathan Research Foundation (MSSRF). Received several feedback from fishermen along with fish catch photos shown in Figure 4.2.3.

Figure 4.2.3. Fish catch photos at Azhikkal, Kerala (left) and Mappila Bay, Kannur, Kerala (right).

4.2.2 Coral Bleaching Alert System

Coral Bleaching Alert System (CBAS) provided 121 advisories on Coral Bleaching Alerts for Andaman, Nicobar, Lakshadweep, Gulf of Kutch, and Gulf of Mannar from April 2022 to March 2023. These advisories comprise HotSpots (HS) and Degree of Heating Weeks (DHWs) estimated using SST anomalies derived from satellite data on a bi-weekly basis. No warning was recorded during this reporting period. Coral bleaching advisories issued and Hotspot values are shown in figures 4.2.4 and 4.2.5, respectively.

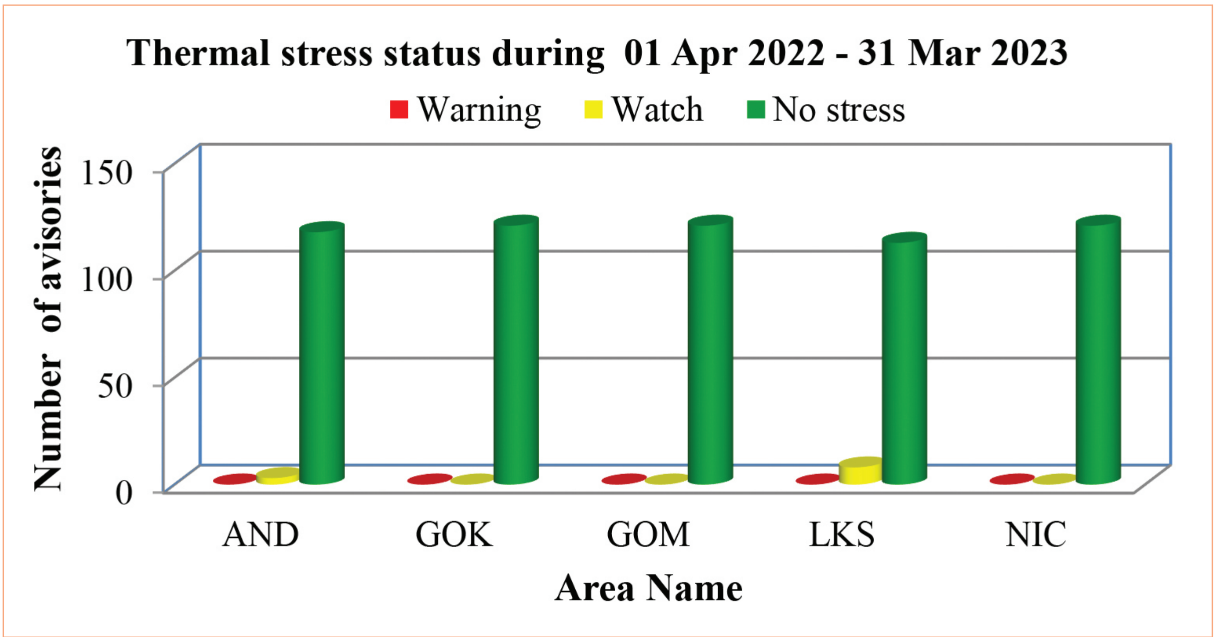


Figure 4.2.4. Total number of coral bleaching advisories generated and their alert status during 2022-23.

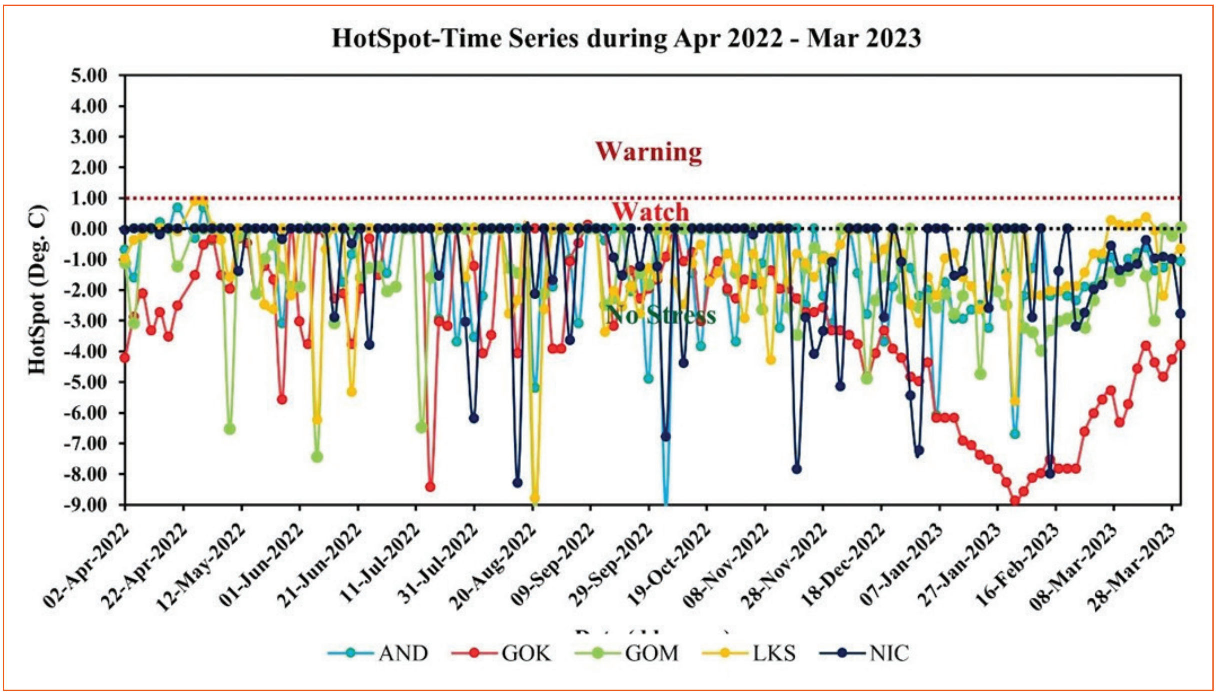


Figure 4.2.5. Line chart depicting variations of HotSpot (HS) values during 2022-23 pertaining to Indian coral environs.

4.2.3 Automatic Data Processing Chain (ADPC) and Algal Bloom Information Services (ABIS)

Ocean colour satellite products in a near-real-time are being generated and disseminated through Automatic Data Processing Chain (ADPC) for the Indian region and other Indian Ocean countries. The ADPC provides both MODIS-Aqua (for ABIS, PFZ & TUNA) and VIIRS-SNPP (for PFZ & TUNA) on a daily basis to provide near real-time data. MODIS-Aqua based Algal Bloom Information Services (ABIS) is sustained, and information has been disseminated daily.

ABIS Product Generated	361 days
Alert issued	27 days

4.3 Data Service

The basis of all scientific endeavours is data. The International Oceanographic Data Exchange (IODE) Programme of the IOC designated INCOIS as the National Oceanographic Data Centre (NODC), and it continues to provide data services and distribute diverse oceanographic data to various national stakeholders. The data centre sustained and strengthened the real-time data reception, processing, and quality control of in-situ and remote sensing data from a wide variety of ocean observing platforms such as Argo floats, moored buoys, drifting buoys, wave rider buoys, tide gauges, wave height meter, ship-mounted autonomous weather stations, HF radars, XBT/XCTD, Met observations from NODPAC, dedicated scientific cruises, ADCP moorings, and remote-sensing satellites. Most of the data received is being regularly disseminated to various operational agencies in the country using various means such as email/website/FTP in near-real time. The data centre continued to provide value-added data products to various users.

4.3.1 Real-time Satellite Data Acquisition and Operational Data Services at INCOIS

Ground stations serve as vital components of satellite data acquisition and processing systems (SDAPS), facilitating satellite data's real-time acquisition and processing. As per this objective, INCOIS has established three ground stations: X/L (Year 2006), Oceansat-2 (February 2011), and Soumi-NPP (April 2016). These stations are primarily responsible for providing data for real-time operational advisory services. They acquire data from a variety of satellite sensors, including AVHRR (Metop-A, Metop-B, NOAA-18, and NOAA-19), VIIRS (Soumi-NPP), MODIS (AQUA and TERRA), and OCM (Oceansat-2). These satellites provide extensive coverage and frequent observations, allowing INCOIS ground stations to acquire real-time data over the Northern Indian Ocean domain (0°N - 30°N; 40°E - 110°E).

The acquired remote sensing data is processed to generate various products and made available to users in near real-time and in offline modes. These data products find application in several operational scientific domains, including:

- Supplying Sea Surface Temperature (SST), Chlorophyll-a, and K_d490 data as input for operational marine fishery advisories, assisting in managing marine fisheries.
- SST data as input to the RAIN (Regional Analysis of Indian OceaN) data assimilation system, enabling the incorporation of real-time SST information into oceanographic models to improve regional analysis and forecasting.
- Utilising SST as a crucial input for Coral Reef Mapping and Reef Health Monitoring, aiding in assessing coral reef health and mapping of reef areas based on temperature patterns.
- Employing SST as an essential input for Marine Heatwave Advisory Services (MAHAS), supporting the identification and prediction of marine heatwaves, which can have significant ecological impacts.
- Collaborating with NCMRWF, INCOIS has achieved a significant milestone by automating the near real-time data transmission processing chain from INCOIS Ground stations to NCMRWF. This automated system seamlessly uploads the data to the Global DBNet, a global network for sharing meteorological data. This accomplishment has garnered widespread recognition and appreciation from esteemed organisations such as EUMETSAT, the University of Wisconsin, and the UK Met Office.
- Leveraging real-time satellite data during cruise planning and facilitating data transfer to the ship via email during the cruise period, enabling research activities at sea and supporting scientific investigations.
- Sharing archived data with research scholars for their research studies, allowing them to access valuable historical data for various scientific analyses and investigations.
- INCOIS has upgraded the existing ground station to be compatible with acquiring Oceansat-3 OCM data, enhancing the station's capabilities and expanding the range of satellite data that can be acquired.

These advancements and activities have played a pivotal role in the successful execution of INCOIS's operations and have contributed significantly to scientific research and applications.

4.3.2 In-situ Data

INCOIS, designated as the National Oceanographic Data Centre (NODC) by the International Oceanographic Data Exchange (IODE) Programme of the Intergovernmental Oceanographic Commission, continued serving as the country's central repository for oceanographic data. The INCOIS data centre sustained and strengthened the real-time data reception, processing, and quality control of surface meteorological and oceanographic data from a wide variety of ocean observing systems such as Argo floats, moored buoys, drifting buoys, wave rider buoys, tide gauges, wave height meter, ship-mounted autonomous weather stations, and HF radars. Further, surface met-ocean data has been regularly disseminated to various operational agencies, e.g., IMD, Navy, Universities, and Coast Guard in the country through email/website/FTP in near-real time. The data centre also served the ocean science community in its various R&D endeavours by providing tailor-made data and products via request-based offline data dissemination mode. The data centre obtained and archived the real-time in situ data from the various ocean observing systems. The data centre also received and archived delayed mode data from various observing systems such as XBT/XCTD observations, Met observations (NODPAC), OMM cruise data, ADCP data, OMNI hard-disk data etc. Details of data received in the present reporting period are provided (Table 4.3.1).

Table 4.3.1. Details of data received from April 2021 to March 2023

Institute / Programme	Parameters	Period of Observation	No. of Platforms / Stations Reported	Status
INCOIS (Argo CTD)	Temperature and Salinity	Apr 2022 – Mar 2023	26489 profiles	Added to the database
NIOT - NDBP (Moored buoys)	Met-ocean parameters	Apr 2022 – Mar 2023	16 buoys	Added to the database
INCOIS (Drifting buoys)	Met-ocean parameters	Apr 2022 – Mar 2023	22 buoys	Added to the database
INCOIS (Ship-mounted AWS)	Met parameters	Apr 2022 – Mar 2023	29 stations	Added to the database
INCOIS (Wave rider buoys)	Wave parameters	Apr 2022 – Mar 2023	16 stations	Added to the database
INCOIS (Tide gauges)	Sea level	Apr 2022 – Mar 2023	35 stations	Added to the database
INCOIS-NIOT (Tsunami Buoy)	Sea level	Apr 2022 – Mar 2023	06 stations	Added to the database
NIOT (HF RADAR)	Currents	Apr 2022 – Mar 2023	03 pairs of stations	Added to the database
NODPAC (Met Observations along Ship track)	Surface met parameters	Jan 2022 - Sep 2022	3229 observations	Archived
NODPAC (XBT data)	Temperature profiles	Jan 2020 – Dec 2020	1013 profiles	Archived
NIO (XBT data)	Temperature profiles	Feb 2023	25 profiles	Archived

Other than the freely available data for download, In-situ data was served to different user groups based on their specific request. A total of 145 data requests from various government organizations, research institutes, academic institutes, and commercial agencies were received. INCOIS provided

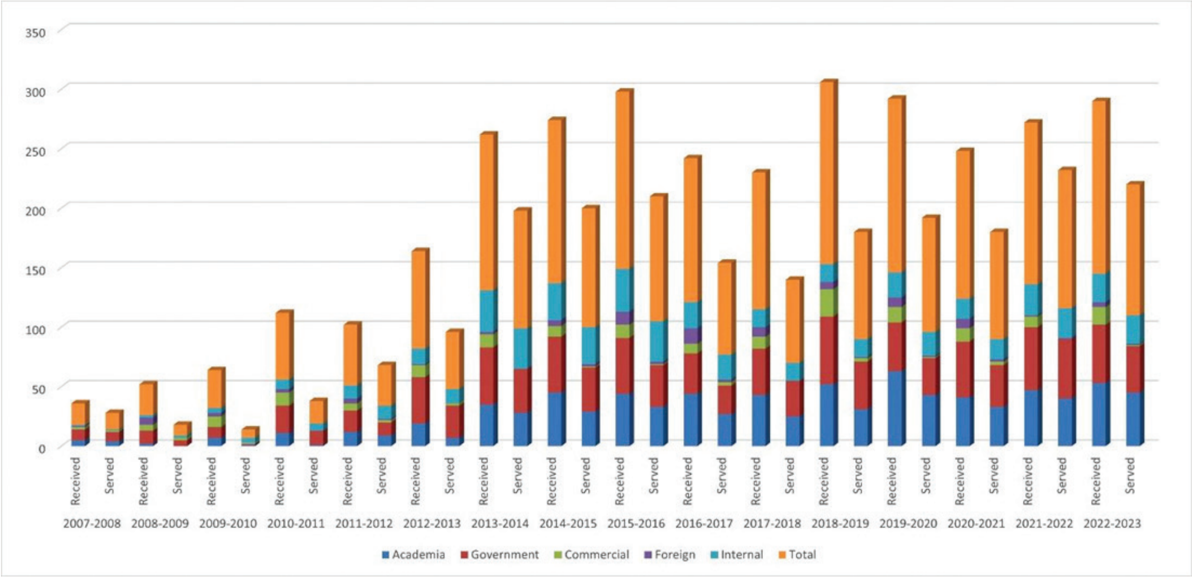


Figure 4.3.1. Summary of data requests

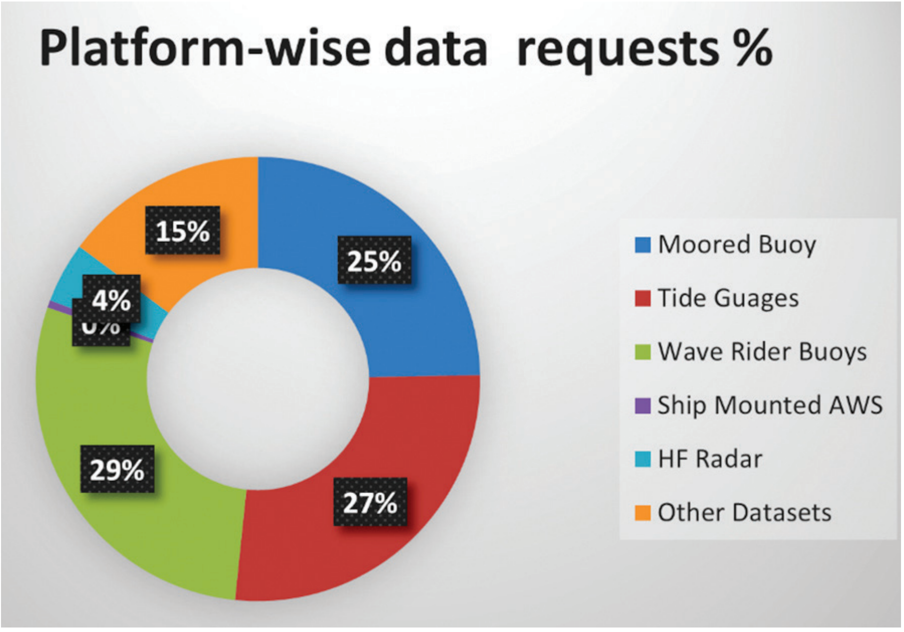


Figure 4.3.2. Platform-wise requests

data for 110 requests based on the availability of data. A detailed analysis of data requests processed in terms of number is given in Figure 4.3.1 and Figure 4.3.2 for platform-wise requests.

4.3.3 Digital Ocean

Digital Ocean (www.do.incois.gov.in) is gaining popularity among the oceanographic community as an interactive data analysis, visualization and analysis of oceanographic data, and downloading available data (in-situ and spatial). Digital Ocean's statistics for 2022-23 are as follows. In total, 774 members registered on the Digital Ocean website, including 173 new registrations. A total of 387 workspaces were created, of which 112 are new workspaces. The Digital Ocean application recorded 260 downloads, of which 31 correspond to new downloads.

4.4 Information & Communication Technology (ICT) Services

The Information and Communication Technology (ICT) Division's mission is to deliver information and communication technology services that enable the operations, R&D, and functions of INCOIS. It provides reliable, high-quality solutions and products to support INCOIS missions. Broader services are computing facilities, application software development and services, communication facilities, engineering services, and estate management.

4.4.1 Computing Facilities

ICT supports INCOIS' research and forecasting goals through mission-critical enterprise-wide computing services, including web hosting, administrative computing, networking, security monitoring, HPC systems, and supercomputing technologies. More than 150 high-end servers can be accommodated in INCOIS data centres, which also support a wide range of technologies. It includes 2 Peta Bytes of storage, ERP servers, FTP server, web and application servers, Live Access Server, workstations, desktops, laptops, link load balancers, application load balancers, DNS, firewalls, core switches, edge switches, and a 45 km long campus-wide networking. The network and the compute infrastructure are redundant to avoid any single point of failure. ICT division initiated various tenders for the upgradation of enterprise storage, Computing Infrastructure of Operational Ocean Services, and technology refreshment of the existing INCOIS Web Environment.

4.4.2 Application Software Development

INCOIS Website

The INCOIS website (https://www.incois.gov.in/) is the main channel for disseminating information about products and services related to the ocean. The web-based online delivery system accommodates consumers across many languages thanks to this flexible website. It disseminates ocean information and advisory services at various geographical and temporal resolutions attributed to the features. Website Statistics shown in Figure 4.4.1.

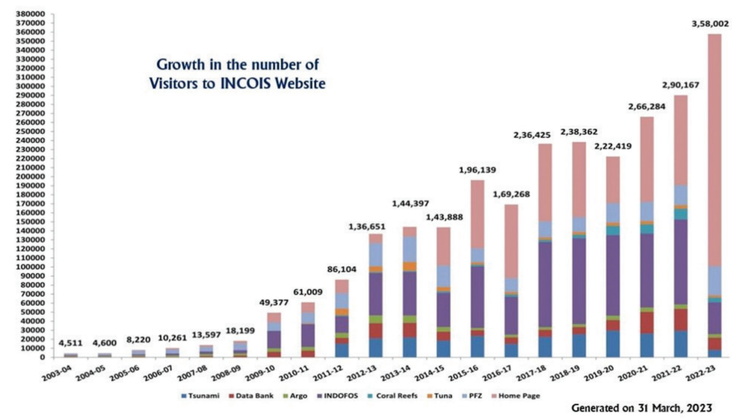


Figure 4.4.1. INCOIS website Statistics

Tsunami Application Software and Website

The in-house team at INCOIS plays a crucial role in supporting the mission-critical application software of the Tsunami Early Warning Centre. This software is responsible for delivering timely and accurate information related to tsunamigenic events to India and 25 Indian Ocean rim countries. The primary platform for disseminating this information is the Tsunami website (https://tsunami.incois.gov.in).

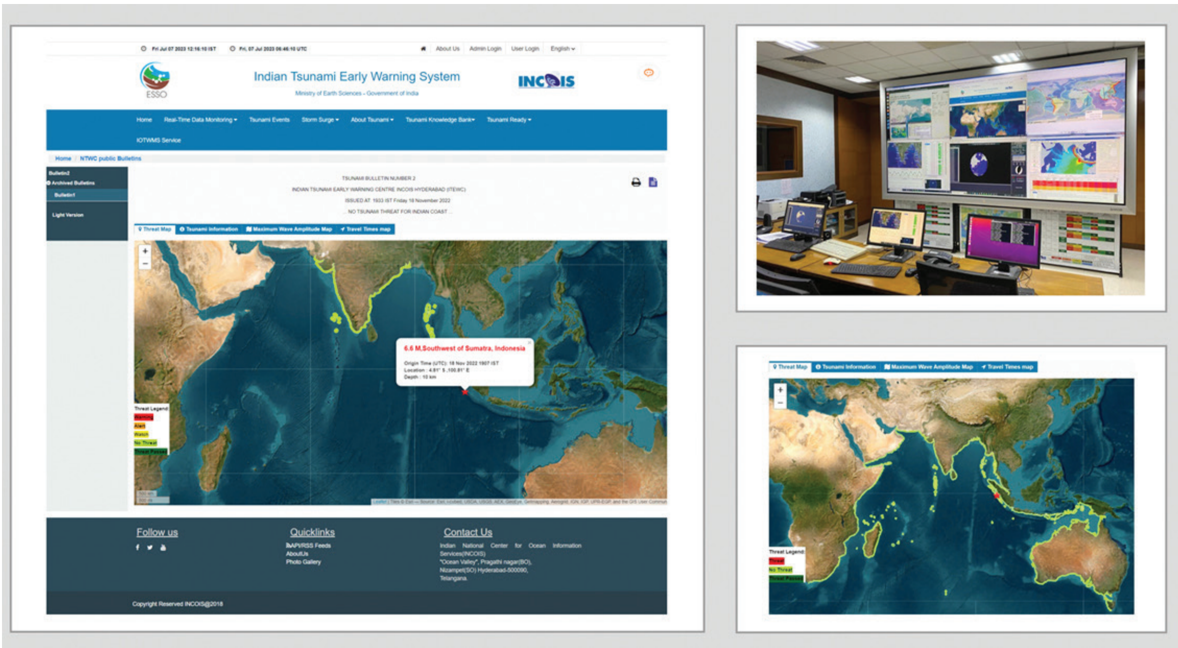


Figure 4.4.2. Tsunami Website shows no threat information for the event of M6.6 in the Southwest of Sumatra, Indonesia.

During the reporting period, the tsunami application software successfully fulfilled its responsibilities by delivering information about all tsunamigenic events. Following the Standard Operating Procedure (SOP), the software efficiently disseminated the necessary alerts and warnings to stakeholders using a multi-channel mechanism. This ensured that the relevant authorities and individuals were promptly informed about potential tsunami threats, allowing them to take appropriate actions.

In line with the International Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) communique on enhanced data sharing, INCOIS continued to contribute to the regional tsunami warning and analysis capabilities. Real-time data from tsunami buoys and tide gauges, which are essential for monitoring and detecting tsunamis, were consistently shared with the National Data Buoy Centre (NDBC) and the Intergovernmental Oceanographic Commission's Sea Level facility (IOC-Sea Level). This collaborative effort ensured that comprehensive and up-to-date data were available for accurate analysis and timely warnings in the Indian Ocean region.

4.4.3 Operationalization of Small Vessel Advisory Services (SVAS) - Enhanced

Small Vessel Advisory Services (SVAS) aims to identify the areas where potential boat capsizing can take place and issue advisories to respective regions. SVAS takes into consideration significant wave height, wave steepness, directional spread, and wind-sea wave height from unstructured SWAN operational setups that are available at 3-hour intervals and up to 10 days in advance. Advisories are issued for the respective regions up to 3 days in advance in textual format with a single advisory for each day. Further, animated images of the advisories will be made available on the INCOIS website for the next nine days. The extent of these advisories is up to a 1-degree offshore distance that is parallel to the coast. Sample Advisory are shown in Figure 4.4.3.

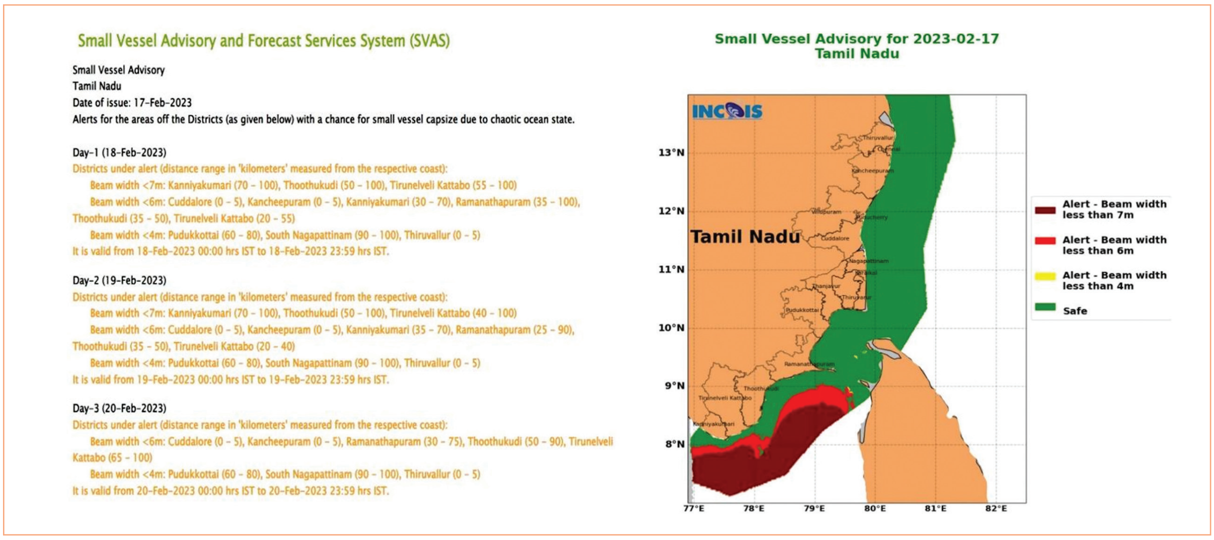


Figure 4.4.3. Small Vessel Advisory Services sample message and map

4.4.4 WebGIS Application for Marine Heatwave Advisory Services (MAHAS)

Marine Heatwave is an event of warmer-than-usual waters, often lasting for days. Marine Heatwave is said to occur when the sea surface is extremely warmer compared to the long-term average for the time of year. The occurrence of Marine Heatwaves leads to the large-scale bleaching of corals,

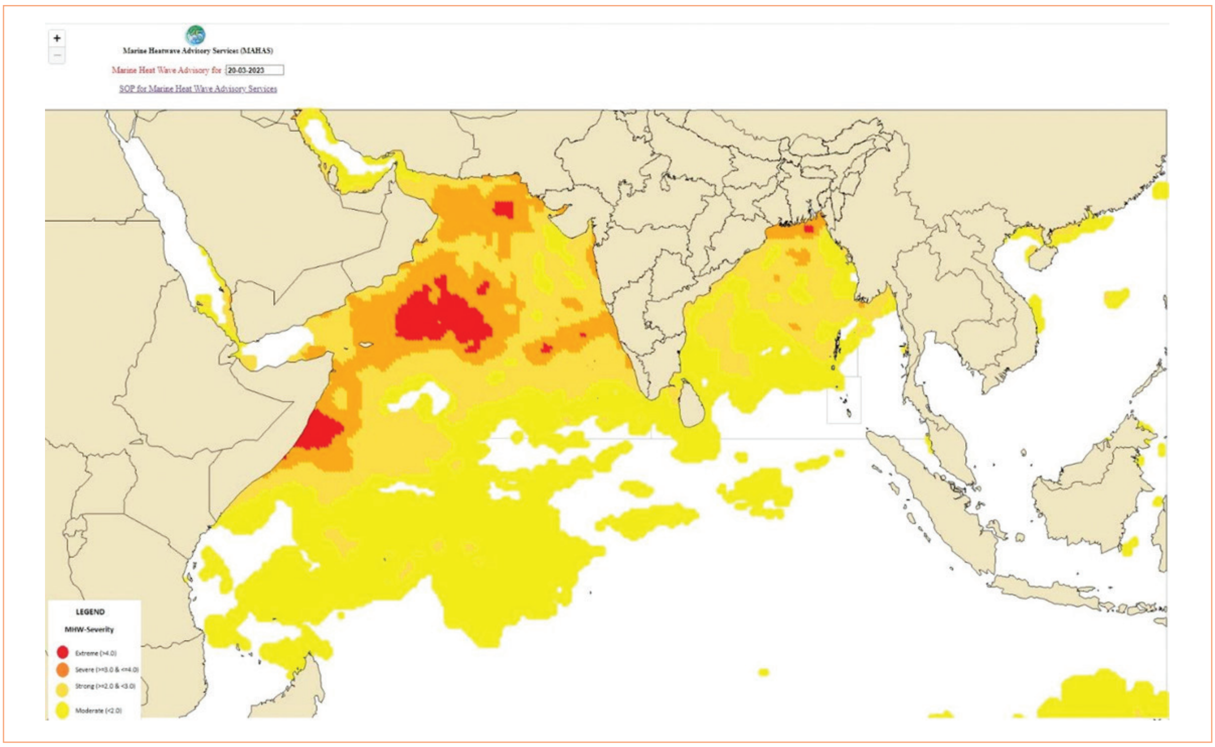


Figure 4.4.4. WebGIS Application for Marine Heatwave Advisory Services (MAHAS)

destruction of seagrass and kelp beds, fish mortality, etc., seriously affecting the availability of seafood and marine biological products on which the coastal communities and economies of the PICs largely depend. A skillful MAHAS of when such an event can occur and for how long it can last has the potential to guide the conservation of marine biodiversity and sustainable fisheries management. The MAHAS is issued using scientifically developed statistical methods. This advisory is probably the first-of-its-kind for the region and is made available on INCOIS Website. Sample Advisory are shown in Figure 4.4.4.

4.4.5 Operationalization of Web Application for Coastal Buoy-based Water Quality Nowcast System (WQNS)

INCOIS has now developed a new capability for real-time monitoring and nowcasting of Coastal Water Quality by deploying a state-of-the-art buoy-based automated coastal observatory off the coast of Kochi. This state-of-the-art observatory makes real-time measurements of about 19 water quality parameters, including dissolved oxygen, nutrients, hydrocarbons, pigments, and Carbon dioxide. This is the first such installation in the Indian Ocean with the capability to make direct measurements through chemical sensors onboard an autonomous observatory. Real-time data from this observatory will be used for generating nowcasts of coastal water quality, assessing the health of coastal ecosystems, assimilation into ecosystem models, and for calibration and validation of Oceansat data. A dedicated website has been developed by INCOIS (Figure 4.4.5) for the dissemination of data and information products where users can choose from the various parameters and visualize time-series plots. Users of this system include coastal residents, Indian Navy & Coast Guard, Disaster Management Authorities, Ports & Harbors, Maritime & Pollution Control Boards, and industries such as Shipping, Oil & Natural Gas, Tourism Departments, Ocean Scientists, and Non-Governmental Organizations.

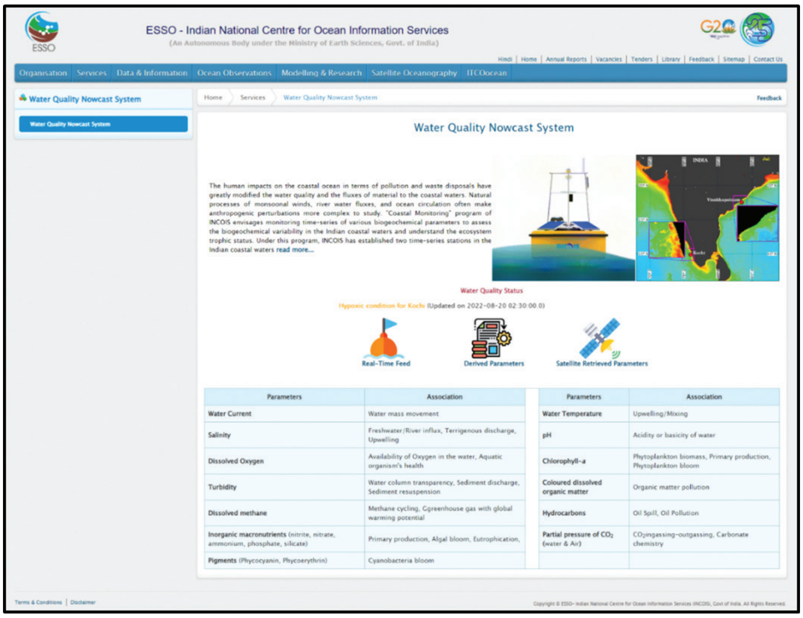


Figure 4.4.5. Web Application for Coastal Buoy Water Quality Nowcast System

4.4.6 Online Recruitment Portal for various posts at INCOIS, MoES, NCPOR, NCMRWF, NCESS, IMD & NIOT

INCOIS continued to host Recruitment portals for various posts/vacancies of INCOIS, MoES, NCPOR, NCMRWF, NCESS, IMD, and NIOT.

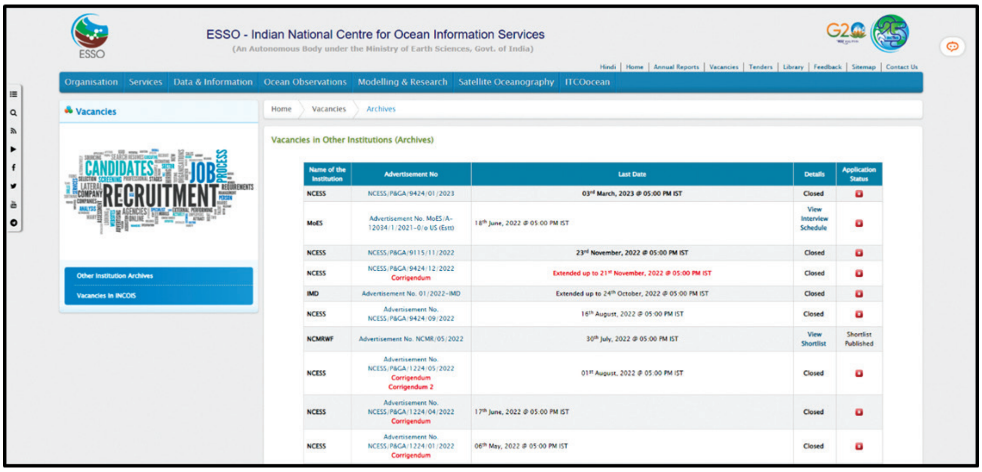


Figure 4.4.6. Recruitment Portal on INCOIS Website

4.4.7 Forecast Assessment Support Tool (FAST) – Enhanced

The Forecast Assessment Support Tool (FAST) is an internally designed tool built to visualize and analyse various ocean parameters such as wave height, wave period, etc. It provides a comparative analysis of model forecasts against actual observations, thereby offering crucial statistical insights regarding the accuracy of the forecasts.

Throughout the past year, numerous improvements have been made to FAST. The tool's efficiency and usability have been significantly enhanced to streamline its operation and improve user experience. These developments have culminated in the operationalization of FAST, demonstrating its readiness for regular use.

Figure 4.4.7. FAST application with wave height display

Currently, the Operational Services team is leveraging FAST for routine monitoring, particularly during significant weather events like cyclones. The ability of FAST to provide a comparative analysis of forecasts versus observations is critical in these situations, as it allows the team to verify the accuracy of the forecasts, and accordingly adjust their actions or advice to ensure maritime safety.

4.4.8 INCOIS Mobile Apps Development

The INCOIS Feedback App and the INCOIS Mobile App are two significant digital initiatives undertaken to facilitate user interaction and gather crucial data for analysis.

The INCOIS Feedback App is an Android application specifically designed to collect feedback from fishermen about their fish catch and other related information. The app allows for both textual feedback and geo-tagged images, all of which are stored on a server for further analysis. Additionally, it has a feature that enables tracking of user location and path. Over the past year, all existing issues with the app have been rectified, and certain enhancements have been introduced, making it a more effective tool for data collection.

Parallel to this, the development of the INCOIS Mobile App is underway. Envisioned as a user-friendly interface for real-time updates and critical alerts, this app also offers dynamic visualization of various INCOIS services and products. It's designed to function across different platforms, including Android, iOS, and Web. The past year saw the introduction of numerous new features along with a revamped user interface.

The first version of the INCOIS Mobile App is nearing its release. This application aims to be a comprehensive platform catering to various needs, combining the functionalities of the various INCOIS Apps and integrating real-time updates and alerts to provide a more holistic and streamlined user experience.

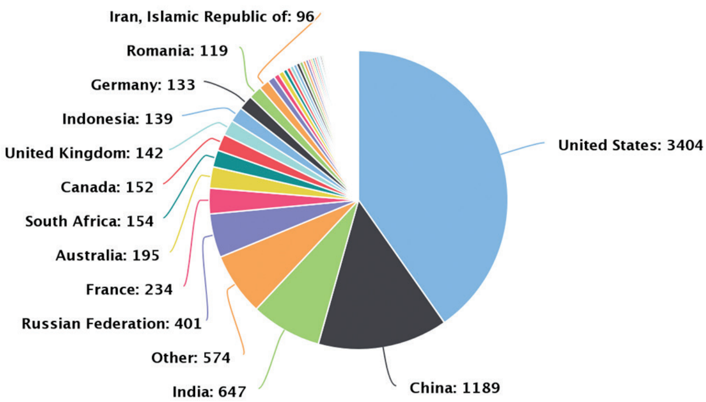
4.4.9 Second International Indian Ocean Expedition (IIOE-2) Website

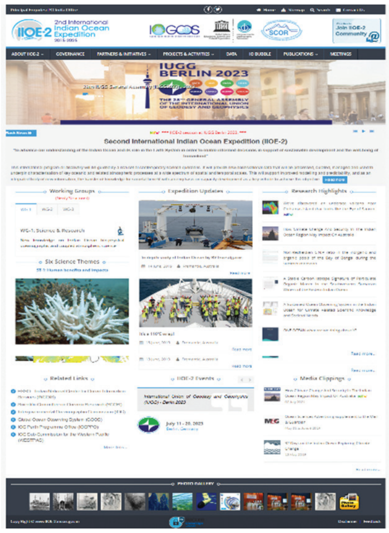
- On behalf of the WG-3, Project Office, India through the ICT Division at INCOIS has been responsible for the development, hosting, and maintaining the IIOE-2 Website
- Provides a user-friendly environment for the presentation of the various activities under IIOE-2 and their progress in a lucid manner.
- The responsive layout of the website makes it accessible through a wide range of web browsers and devices, including mobiles and tablets.
- In addition, developed a WebGIS application that presents the status and progress of all the scientific projects endorsed under IIOE-2.

4.4.10 Other Developments

- Operationalization of WebGIS Application for Ocean Services for Lakshadweep & Puducherry.
- Web application for the participants applying for ITCOOcean Training Courses
- Upgradation & operationalization of INCOIS eOffice-eFile Version to Ver.6.3.1
- Initiated development & hosting of OSICON-23 Conference Website

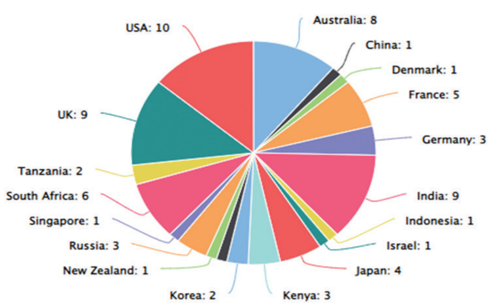
Country wise No. of Visitors to IIOE-2 Website during April 2022– March 2023 are 8,452

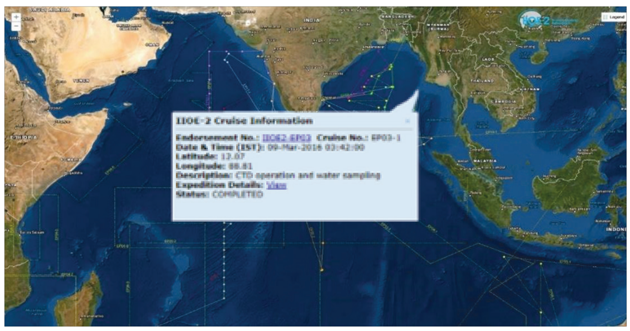




https://iioe-2.incois.gov.in/

Participants from various countries





WebGIS application that presents the status and progress of all the scientific projects endorsed under IIOE-2.

Figure 4.4.8. IIOE-2 Statistics and related displays

4.5 Communication Facilities

4.5.1 Unleashing Oceanic Knowledge: The Cutting-Edge E-Classroom Training Facility at ITCOOcean Campus, INCOIS

The establishment of the state-of-the-art 72-seater E-Classroom Training facility at the ITCOOcean Campus in INCOIS is a significant milestone in the realm of national and international training and conferences. The facility, inaugurated by Dr. K. Radha Krishnan, Former Chairman of the Department of Space (DoS), on 03 February 2023 (Figure 4.5.1), showcases a commitment to fostering knowledge dissemination and skill development in the field of oceanography.

The E-Classroom Training facility is equipped with cutting-edge technology and modern infrastructure, providing a conducive environment for participants to engage in high-quality training programs and conferences. With its spacious seating capacity of 72, the facility accommodates a considerable number of learners, facilitating a wide range of educational events. It serves as a Learning hub for professionals, scientists, and researchers from around the world to gather and exchange insights, best practices, and the latest advancements in oceanographic studies.

Figure 4.5.1. Dr. K Radhakrishnan inaugurating the E-Classroom facility at INCOIS. Images of the E-classroom

4.5.2 Upgraded INCOIS Ground Station & Tracking of Oceansat-3 Satellite Passes

The past year has been momentous for INCOIS as it marked significant advancements in our technical capabilities and contributions to India's ocean observation capabilities. ISRO launched the third-generation Indian Ocean monitoring satellite, Earth Observation Satellite-6 (EOS-6), also known as Oceansat-3, in partnership with the Ministry of Earth Sciences (MoES). This development has augmented our capacity to monitor critical ocean parameters, contributing to the country's blue economy aspirations and marking the first major ocean satellite launch from India since the initiation of the UN Decade of Ocean Science for Sustainable Development (UNDOSSD, 2021-2030).

INCOIS has achieved a milestone with the successful completion of the upgrade of our ground station, enabling us to enhance our capacity to receive passes from the Oceansat-3 (EOS-06) satellite. This upgrade was formally inaugurated on 03 February 2023, by Dr. S. Chandrasekhar, Secretary of the Department of Science & Technology (Figure 4.5.2). The EOS-06 satellite is a critical part of our data collection network, with our upgraded ground station enhancing our capabilities to track and receive this data.

Figure 4.5.2. Dr. S. Chandrasekhar, Secretary of the DST is inaugurating the upgraded Oceansat-3 ground station.

The Oceansat-3 satellite is equipped with three ocean observing sensors: Ocean Colour Monitor (OCM-3), Sea Surface Temperature Monitor (SSTM), and Ku-Band scatterometer (SCAT-3). These sensors are integral to our operations, providing data crucial for fishery resource management, ocean carbon uptake, harmful algal bloom alerts, and climate studies. Furthermore, the SSTM and Ku-Band Pencil beam scatterometer provides vital data for various forecasts and seafarers.

4.5.3 Establishment of INSAT Communication for Radar Tide Gauge Stations

The tide gauge network plays a crucial role in ocean services and operations and provides invaluable information for various applications such as coastal management, navigation, climate research, and hazard assessment.

The successful testing, integration, and installation of the INSAT (Indian National Satellite System), MSS (Mobile Satellite Service), and UHF (Ultra High Frequency) transmitters at 10 radar tide gauge stations is a significant achievement. These stations are located at Adani Hazira, Beypore, Gopalpur, Jaigarh, Jakhau, Kollam, Marmagoa, Porbandar, Puducherry, and Veraval. This development has enhanced the capabilities of the tide gauge network by enabling the real-time transmission of tide gauge data to the INCOIS Hub through INSAT communication (Figure 4.5.3).

The integration of INSAT MSS and UHF transmitters with the radar tide gauge stations expands the coverage and capabilities of the tide gauge network in India. The ongoing progress of installing the INSAT MSS and UHF transmitters at the remaining five stations further strengthens the tide gauge network's effectiveness and coverage.

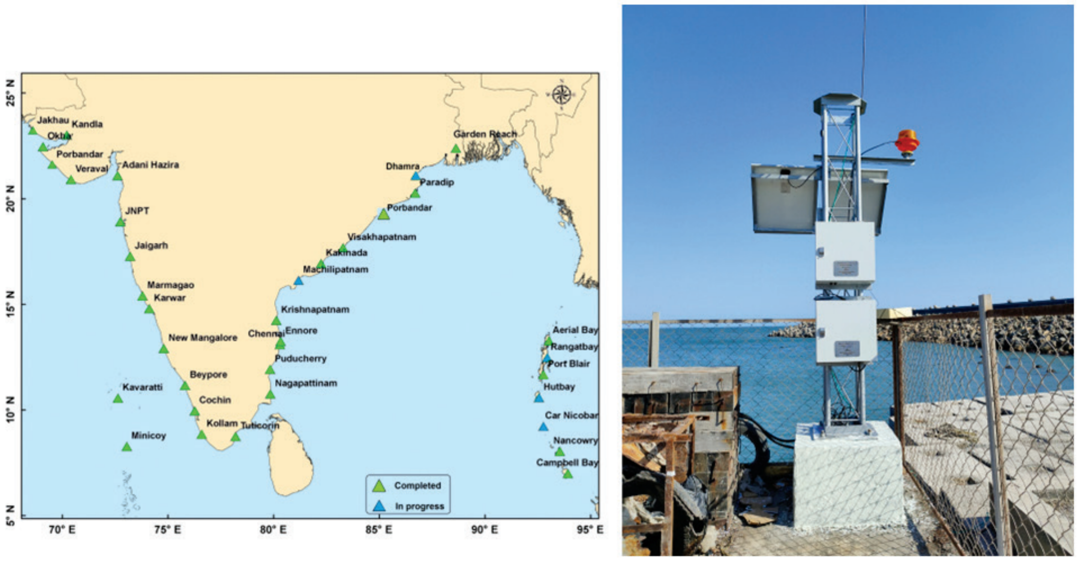


Figure 4.5.3. INSAT communication setup at Radar Tide gauge location

4.5.4 Enhancing Connectivity: Upgraded VSAT Communication Network at 32 SMA & GNSS Observatories at A&N Islands

A remarkable achievement has been made with the establishment of an upgraded VSAT communication network at all 32 Strong Motion and Accelerometer (SMA) & Global Navigation Satellite System (GNSS) data observatories at Andaman and Nicobar Islands. This upgrade includes the installation of new solar charge controllers with power banks, ensuring a reliable power supply and enabling the reception of real-time seismic and GNSS data for INCOIS operational and research activities. The diligent maintenance of these stations further highlights their critical role in Tsunami Early Warning systems, making them indispensable assets for safeguarding coastal areas.

4.5.5 INSAT MSS & DRT Hub Stations

The INSAT (MSS & DRT) Hub Stations hold paramount importance in facilitating the operational and research activities of INCOIS. These hub stations are specifically maintained to receive real-time data from various field stations, including Tide Gauge Observatories, Ship-based Automatic Weather Stations (AWS), Wave Rider Buoy Network, Drifters, and other observational platforms deployed by INCOIS and MoES institutions.

The diligent maintenance of the INSAT MSS & DRT Hub Stations ensures the continuous and reliable reception of real-time data from these field stations. This data is invaluable for supporting critical tasks such as monitoring sea levels, supporting tsunami Operations, and tracking oceanic dynamics. The ongoing maintenance of the INSAT MSS & DRT Hub Stations underscores their significance in facilitating reliable data reception and supporting the success of INCOIS in their operational and research endeavours.

4.5.6 Remote Sensing Satellite Ground Stations

INCOIS has established 2.4 m NPP and 2.4 m X/L remote sensing ground stations to receive NOAA series, METOP, NPP, AQUA & TERRA satellite passes for regular operational activities like PFZ and other research activities. Both the stations were well maintained.

5

APPLIED RESEARCH AND RESEARCH TO OPERATIONS (ARO)

5.1 Coastal Multi-Hazard Vulnerability Atlas

INCOIS has carried out coastal Multi-Hazard Vulnerability Mapping (MHVM) on a 1:25000 scale for the entire Indian mainland coastline and Andaman & Nicobar Islands. The MHVM is a holistic approach to estimate the composite hazard zones based on the synthesis of Extreme Water Levels, Sea-level Change, Shoreline Change Rate, and High-Resolution Topography in a GIS environment. These maps represent the projected coastal inundation due to oceanogenic disasters with 100-year recurrence. The Atlas, comprising 1054 maps on the 1:25000 scale covering the Indian mainland coastline and Andaman & Nicobar Islands, was released during the 24th INCOIS Foundation Day held on 03 February 2023. The snaps of the cover page, MHVM overview map, and release photo are shown in Figure 5.1. The maps presented in this Atlas provide vital inputs for coastal zone management and planning activities.

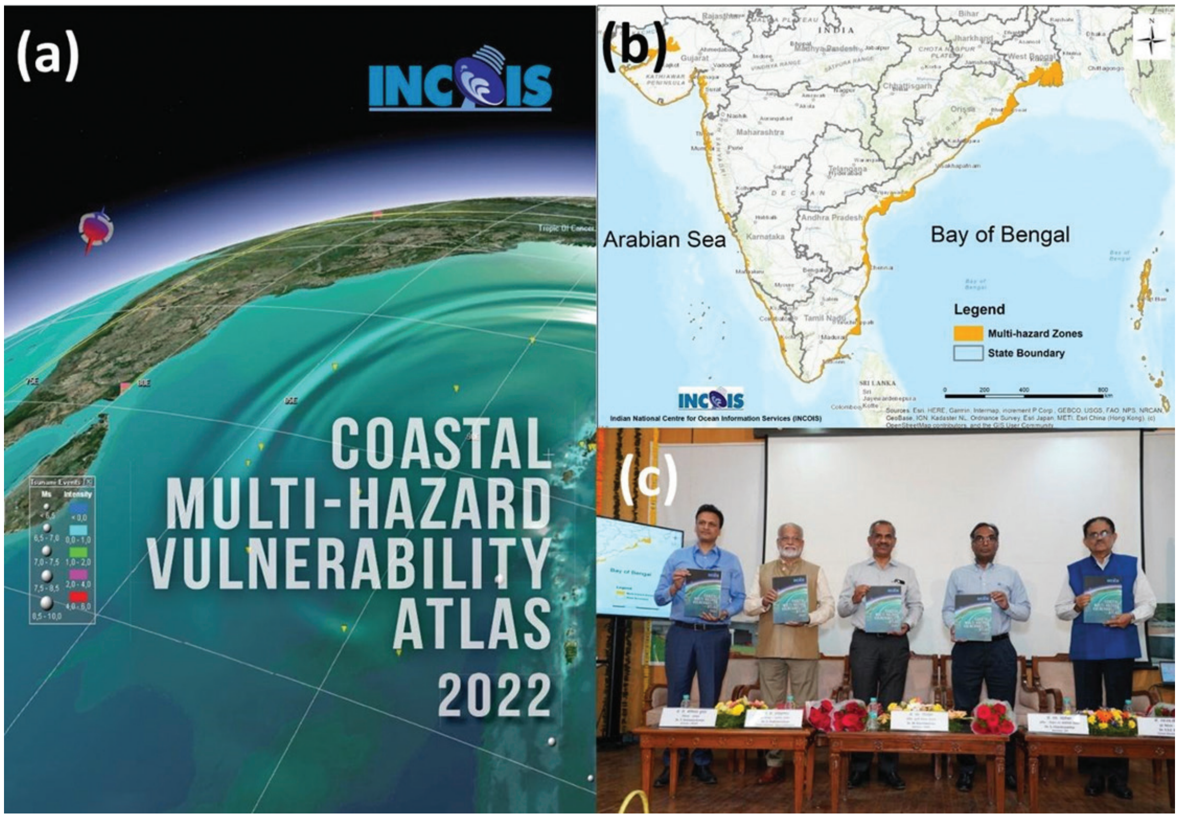


Figure 5.1: (a) The cover page of MHVM Atlas (b) MHVM overview map (c) showing multi-hazard zones and release photo.

5.2 New Service on MArine Heat Wave Advisory Services (MAHAS)

Climate change events have triggered the rise in temperatures of the global oceans leading to frequent extreme heat wave episodes. Though climate change is a global phenomenon, it's impacts vary locally. Hence, it is necessary to understand the impending impacts and variations of climate-driven heat content in the Indian Ocean region. Marine Heat Wave (MHW) is a parameter to measure

APPLIED RESEARCH AND RESEARCH TO OPERATIONS (ARO) heat content in the ocean. MHW is a discrete, and prolonged anomalously warm water event that persists over two days above the 90th percentile of climatology. In this regard, INCOIS has developed a new **MA**rine **H**eat Wave Advisory Services (MAHAS). This new service uses the Optimum Interpolation Sea Surface Temperature (OISST) as input data to generate different marine heat wave products. MAHAS provides information on daily basis that comprises of the parameters such as Intensity of Marine Heat Wave (IMHW), MHW severity categories, and percentage of the area of MHW spread over the different basins and sectors over the Indian Ocean and South China Sea. This advisory is provided through the interactive WebGIS platform. MAHAS can help to understand the implications of extreme heat conditions on marine biodiversity and ecosystems and their negative impacts on the fishery, aquaculture and tourism industries. The adverse impacts of MHW on these systems can result in huge ecological and economic losses. More research, better prediction, and regional measures to build ocean resilience can help protect marine ecosystems from MHWs. The methodology adopted, products displayed in the WebGIS viewer, threshold criteria for different categories, and probable implications of the MHW are shown in Figure 5.2.

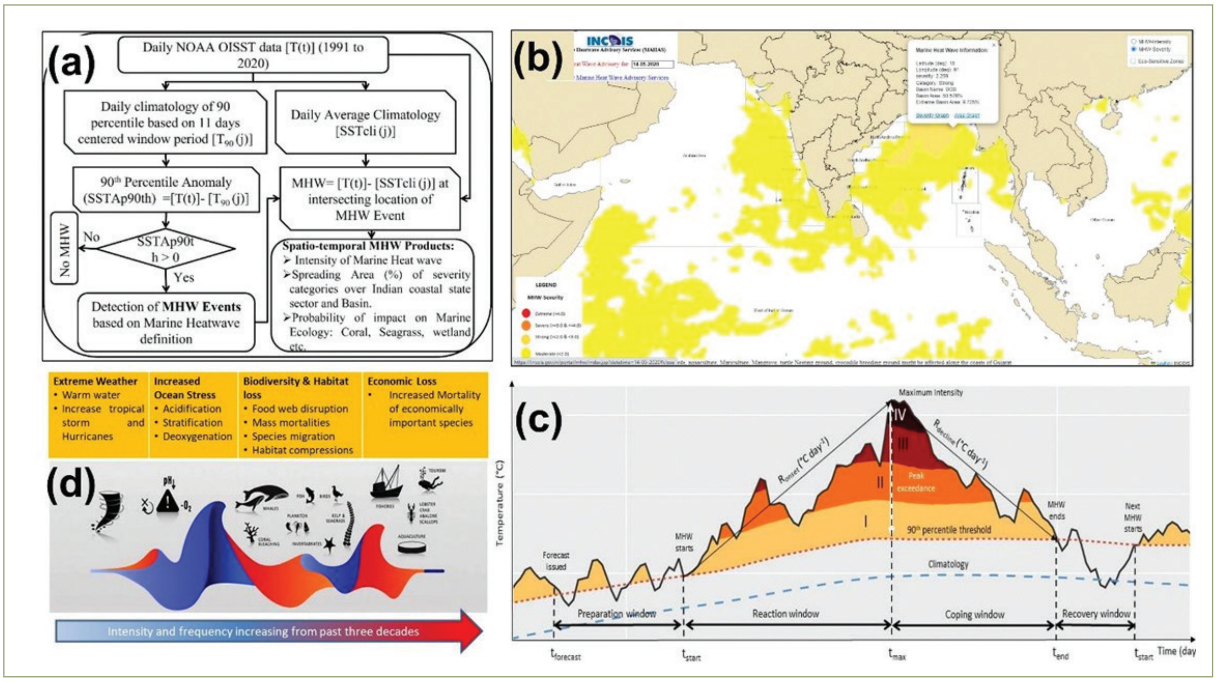


Figure 5.2: (a) The methodology adopted, (b) Products displayed in the WebGIS viewer, (c) Threshold criteria for different categories and (d) probable implications of the MHW.

5.3 Probabilistic Tsunami Hazard Assessment (PTHA) of North-West Indian Ocean (NWIO) region

INCOIS is collaborating with scientists from GFZ, Germany, and INGV, Italy, for the probabilistic tsunami hazard assessment of the North-West Indian Ocean region in a UNESCO-supported project (UNESCAP TTF-31). For PTHA, only earthquake sources are considered, and it is assumed that earthquakes can occur anywhere. The seismicity of the whole region is classified into two groups, predominant seismicity (PS) and background seismicity (BS). The PS type captures the larger earthquakes generated by well-known major faults, such as plate boundaries and subduction interfaces, which is the Makran subduction zone in this case. The BS type captures all the diffuse seismicity in the region. The source parameters for PS are relatively well-constrained by existing data compared to BS. Hence, source parameters for BS exhibit large variability leading to a substantial number of probable sources for tsunami simulation. The scientists of GFZ and INGV are simulating tsunamis of the PS sources using the "HySEA" model, whereas INCOIS is using the "ADCIRC" model to simulate the BS sources. After filtering out highly improbable sources, 3,97,698 simulations for the Persian Gulf region and 1,061,014 simulations for the Red Sea region have been performed so far at INCOIS for BS sources. Results for all these simulations were extracted at predefined points of interest (POIs) (Figure 5.3). Combining results from both PS and BS simulations, hazard curves were calculated at the POIs by scientists of GFZ. The preliminary results were presented during the workshop on Makran Subduction Zone Science Strengthening Tsunami Warning and Preparedness, held in Abu Dhabi, United Arab Emirates, on 14-16 November 2022.

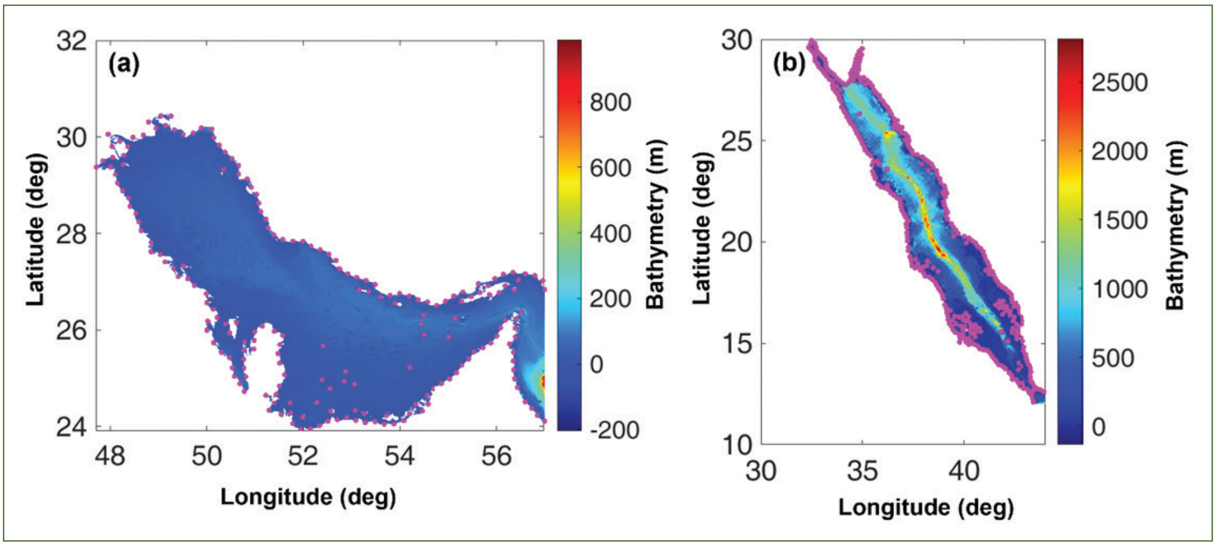


Figure 5.3: (a) Persian Gulf region and (b) Red Sea region for which PTHA simulations were carried out. The magenta dots show the points of interest (POIs)

5.4 Site characteristic using horizontal-to-vertical response spectral ratios (HVSR) of earthquakes at strong motion station locations in the Andaman and Nicobar Islands

Site amplification (expressed as site fundamental frequency f_0) is a key factor in determining the degree of damage caused by earthquakes. The Horizontal-to-Vertical response Spectral Ratios (HVSR) is one of the several methods introduced for estimating site response, which is provided by the ratio of Fourier amplitude spectra of the observed horizontal and the vertical component of ground–motion data. An alternative common site index parameter for describing the stiffness of the deposit in engineering seismology is $V_{s_{30}}$, the time-averaged shear wave velocity to a depth of 30 m. Primarily $V_{s_{30}}$ is used as the simplified classification of a site in terms of its seismic response in building codes. It has also been used as an explanatory variable for site effects in Ground-Motion Prediction Equations (GMPEs). HVSR is, in general, easier to obtain for a specific site and carries information on response from deeper deposits in comparison to $V_{s_{30}}$. Moreover, the relationship between f_0 and $V_{s_{30}}$ is linear for f_0>1 and hence $V_{s_{30}}$ can be derived empirically from f_0, when the site fundamental frequency is greater than 1. HVSR have been calculated for the 30 strong motion station sites in Andaman, derived the $V_{s_{30}}$ for 23 sites (where f_0>1) using the empirical relation of Gofrani & Atkinson (2014), and finally classified the sites based on the $V_{s_{30}}$ values. The results of this analysis and the final classification of the sites are summarized in Table 5.1.

Table 5.1: Site classification of the strong motion stations in the Andaman and Nicobar Islands.

Station Code	Latitude	Longitude	f_0 (Hz)	$V_{s_{30}}$ (m/s)	Site Classification
AFRA	7.19	93.74	3.51	184.78	Stiff Soil
ALUR	8.31	93.11	5.02	221.12	Stiff Soil
ARON	9.16	92.75	3.82	224.86	Stiff Soil
BAKU	12.51	92.86	1.33	160.41	Soft Soil
BARA	12.17	92.76	2.4	150.94	Soft Soil
BETA	12.62	92.95	2.31	192.94	Stiff Soil
CHID	11.5	92.7	2.69	242.25	Stiff Soil
CHUK	8.22	93.17	1.72	250.06	Stiff Soil
CWRA	8.45	93.05	0.9	-	
DARG	8.1	93.49	0.49	-	
FERR	11.72	92.65	1.77	181.74	Stiff Soil
HAVL	11.96	93.01	4.67	251.24	Stiff Soil
HUTB	10.74	92.56	0.6	-	
KAKA	8.19	93.51	0.58	-	
KAMO	8.04	93.54	2.37	306.49	Stiff Soil
KISH	13.18	92.88	2.69	142.3	Soft Soil
LONG	12.38	92.93	2.64	173.47	Soft Soil
MAKA	7.4	93.71	0.8	-	
MILD	8	93.38	1.8	183.77	Stiff Soil
MOHA	12.94	92.84	2.21	179.95	Soft Soil
NAMU	11.67	92.68	1.6	239.76	Stiff Soil
NEIL	11.83	93.03	0.62	-	
NIMB	12.49	92.96	2.4	136.49	Soft Soil
RADA	13.37	92.93	1.38	162.37	Soft Soil
RAMN	13.08	93.01	2.33	195.9	Stiff Soil
RUTI	11.49	92.65	2.07	155.19	Soft Soil
SHOA	11.86	92.74	3.56	167.82	Soft Soil
TRIN	8.05	93.59	4.74	278.44	Stiff Soil
UKAT	7.94	93.45	1.3	251.73	Stiff Soil

5.5 Deep Low-Velocity Layer (LVL) in the sub-lithospheric mantle beneath India

Globally, there is growing evidence for a low-velocity layer in the deeper part of the upper mantle above the 410 km discontinuity (LVL-410). Still, its origin and ubiquitous nature remain contentious. In this study, a large dataset was analyzed for 1,38,410 receiver functions (RF) computed using waveforms registered at 385 broadband seismic stations to probe the possible presence of this layer beneath diverse tectonic regions of the Precambrian Indian shield, the Himalayas, its foredeep, and the Burmese arc regions. 3D depth migration of the receiver function is primarily employed to delineate this layer. The depth-migrated receiver functions are binned and stacked using the bootstrap resampling technique to enhance the P-to-s conversion from weak discontinuities like the LVL-410. In addition, to ascertain the authenticity of detection, differential slowness stacking analysis is performed that effectively isolates direct Ps conversions from multiple reflections. Results reveal the unequivocal presence of a deep low-velocity layer at depths varying from 300 to 400 km beneath the Indian Shield and Himalayas (Figure 5.4). This layer appears more pervasive and shallower beneath the Himalayas, where presence of detached subducted slabs in the transition zone has been previously reported. Interestingly, the layer is deeper in the plume-affected Deccan volcanic province and the Precambrian part of the shield. The transition zone water filter model is the most popular model to explain the presence of LVL at these depths. However, it alone does not explain the observed variation In depth and strength of LVL-410s. Although a common explanation currently does not appear feasible, detecting this deep LVL in diverse tectonic settings affirms its ubiquitous nature.

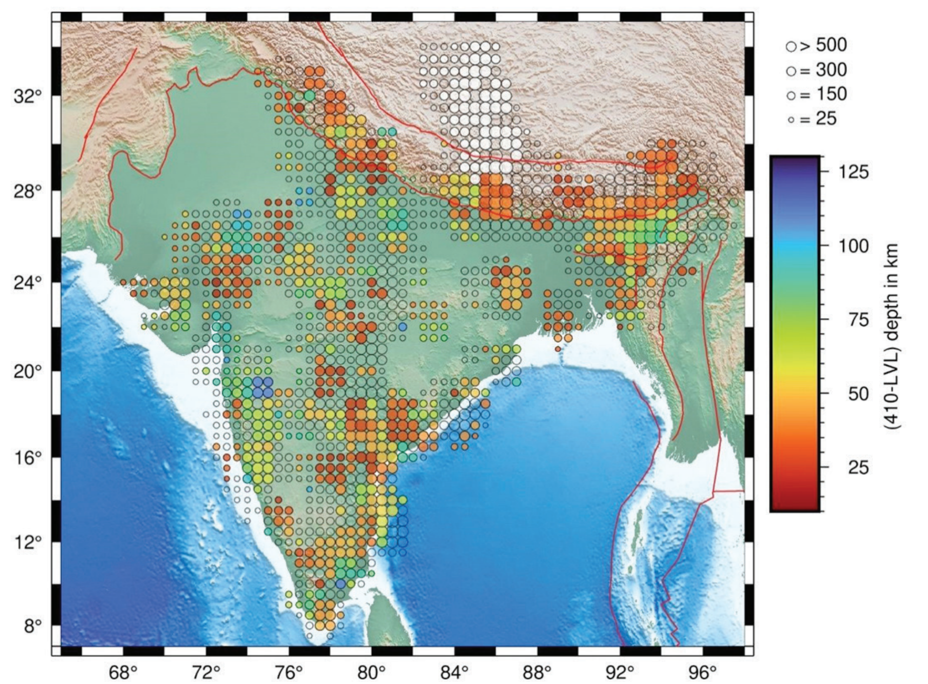


Figure 5.4: The circles represent grids at 0.5^0 intervals of 75 km radius where RFs are stacked. The size of the circles is proportional to the number of RFs in that grid. The color of the circles indicates the distance of the detected LVL from the 410 km discontinuity. The open circles represent the grids where evidence of LVL is not found, and circles filled with white color represent grids where LVLs are not picked due to possible contamination from crustal multiples.

5.6 Variability of the thermal front and its relationship with chlorophyll-a in the north Bay of Bengal

The spatial-temporal variability of the thermal fronts and their relationship with chlorophyll-a in the north Bay of Bengal (BOB) was studied using MODIS daily Sea Surface Temperature (SST) and weekly chlorophyll-a data (Figure 5.5). Further, the intense fish catch activities over the study area were also observed from NOAA-Visible Infrared Imaging Radiometer Suite (VIIRS) night-time boat detection products. An edge-detection algorithm applied on each SST image to identify thermal fronts in which a gradient of 0.3°C/pixel (~ 0.075 °C/km) was chosen following the sensitivity analysis. Distinct locations of thermal front maxima co-occurring between the 10 and 50 m isobaths in the continental shelf and slope region coincided with the areas of the VIIRS-mapped fishing vessels cluster sites. The annual frequency dominates the seasonal cycles of thermal front density with a positive phase during November–March (winter and spring seasons) and peaks in January. These locations with a high probability of thermal fronts and high concentrations of chlorophyll-a can be considered as the perennial potential fishing zone, with the winter season being a more favourable period for fishing.

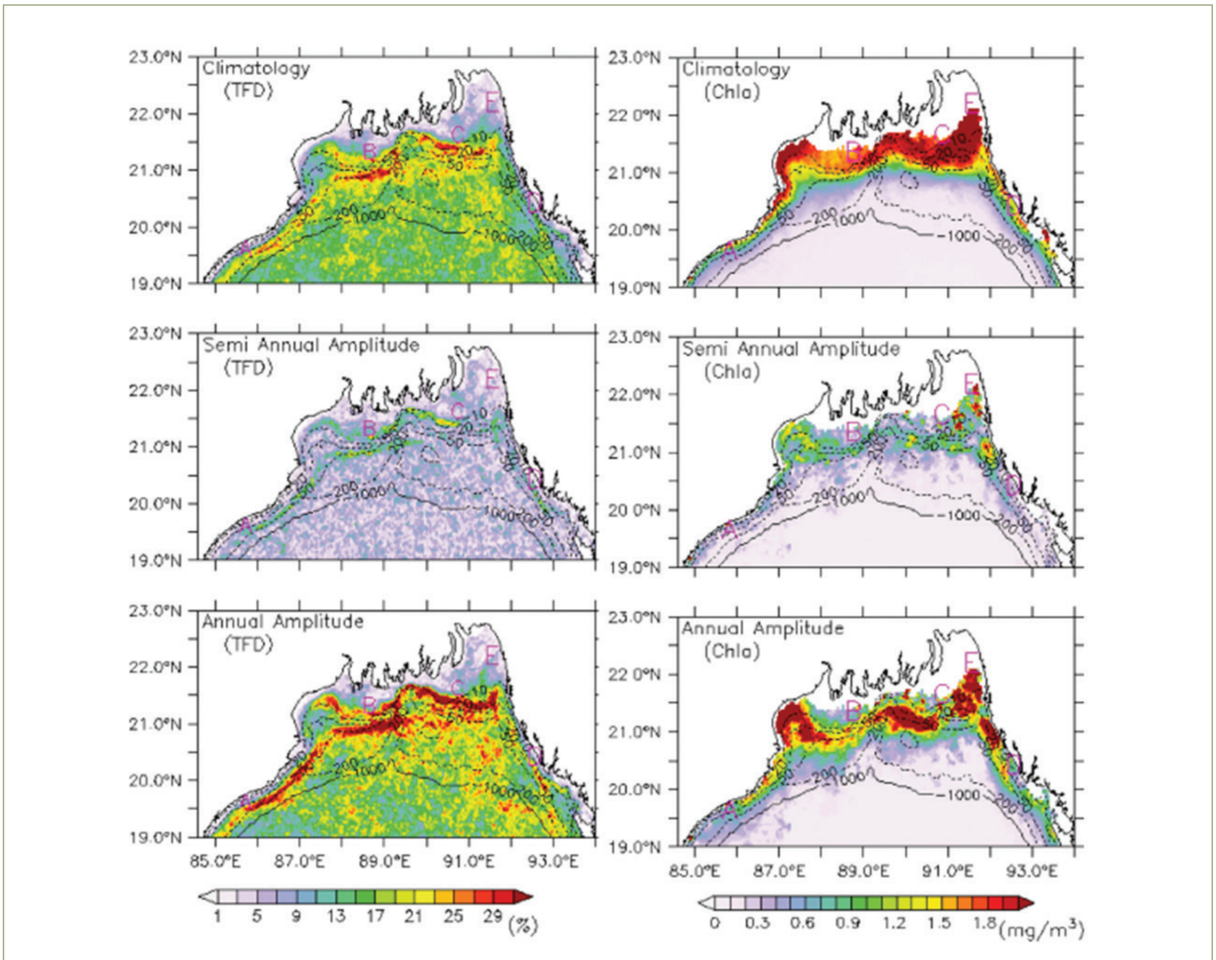


Figure 5.5: The left panel shows the maps of mean climatology and amplitude of the semiannual and annual harmonics of the thermal front density. Bathymetry contours of 10 m, 20 m, 50 m, 200 m, and 1000 m are overlaid. The right panels show the same but for the chlorophyll-a concentration.

5.7 Investigating sea level extremes in relation to astronomical tides and their modulation

Astronomical tides, caused by the gravitational interactions between the Earth, Moon, and Sun, play a crucial role in shaping the world's coastlines and influencing sea levels. These tides are primarily driven by the Moon's gravitational pull, followed by the Sun's influence. An investigation was conducted using the extensive hourly sea-level data spanning from 1972 to 2007 at 18 tide gauge stations (Figure 5.6, 5.7). The primary focus was on examining the characteristics of astronomical tides, as well as identifying sea-level trends and extremes in the vicinity of India's mainland coastline. To achieve this, the de-tided signals were utilised to assess these parameters and explore the interaction between tides and surges. The observed sea-level patterns exhibited noteworthy fluctuations across daily, seasonal, and yearly timeframes. Among the high-frequency tides, those occurring twice daily (semidiurnal tides) were particularly dominant along the northwestern and northeastern continental shelf areas, gradually diminishing towards the southern regions. Conversely, the amplitude of tides occurring once daily (diurnal tides) exhibited relatively modest strength across all monitored stations. Moreover, in terms of the seasonal cycle, the annual harmonics displayed greater prominence along the east coast in comparison to India's west coast.

The magnitude of lunar nodal and perigee tides shows remarkable elevation (reaching up to 25 mm) at multiple stations when compared to the overall long-term global average sea level trend (approximately 3.3 mm per year). The interplay between semidiurnal tides and surges demonstrated notable intensity across most stations, with a considerable likelihood of surge peaks aligning with

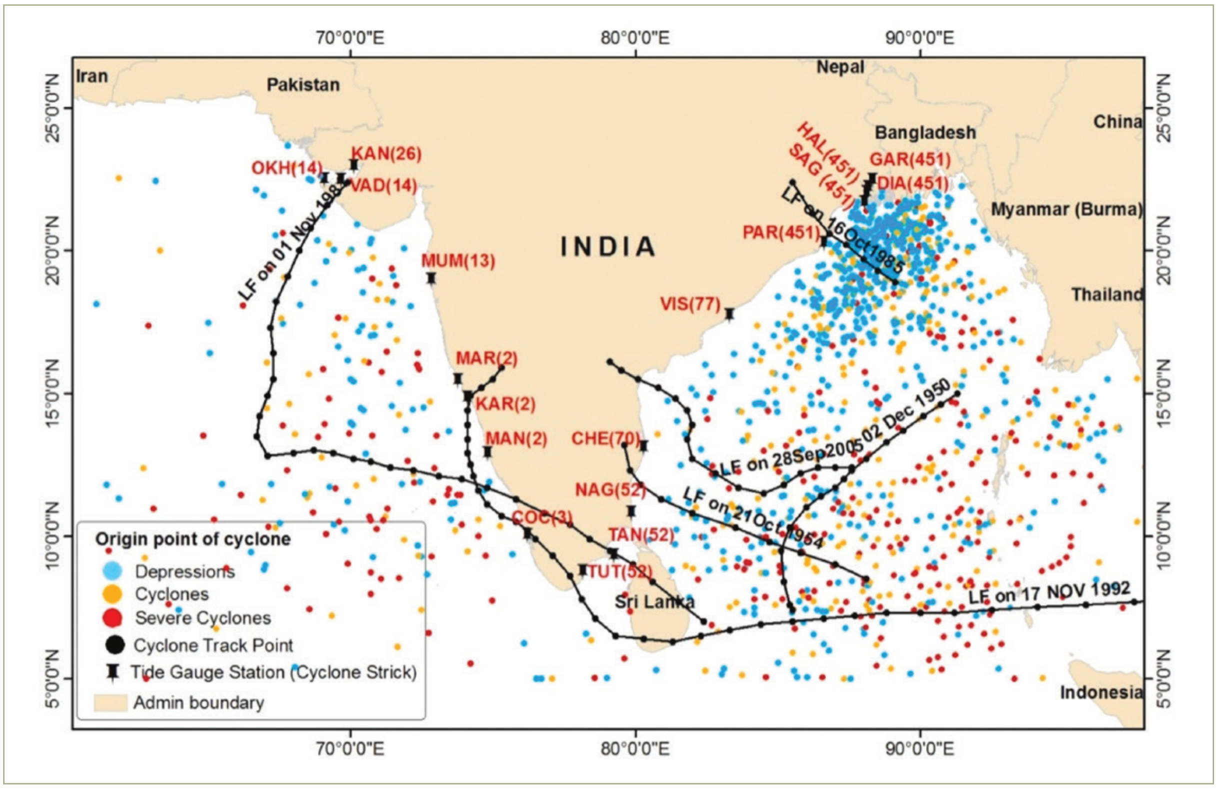


Figure 5.6: The study area of the Indian coast overlaid with tide-gauge stations, the location of the cyclone origin with their category, and a few sample cyclone tracks.

the decline of tides in the northern continental shelf. Conversely, in the southeastern and western peninsula areas, these surge peaks were associated with the increasing tide. The extent of interaction between tides and surges amplifies from the southern to the northern regions due to a rise in tidal range and significant modulation by nodal and perigee tides. The findings have practical implications for coastal planners and responsible management/policy-making agencies, offering insights for the formulation of both immediate and long-term strategies to manage and mitigate the vulnerabilities associated with high wind or cyclone events.

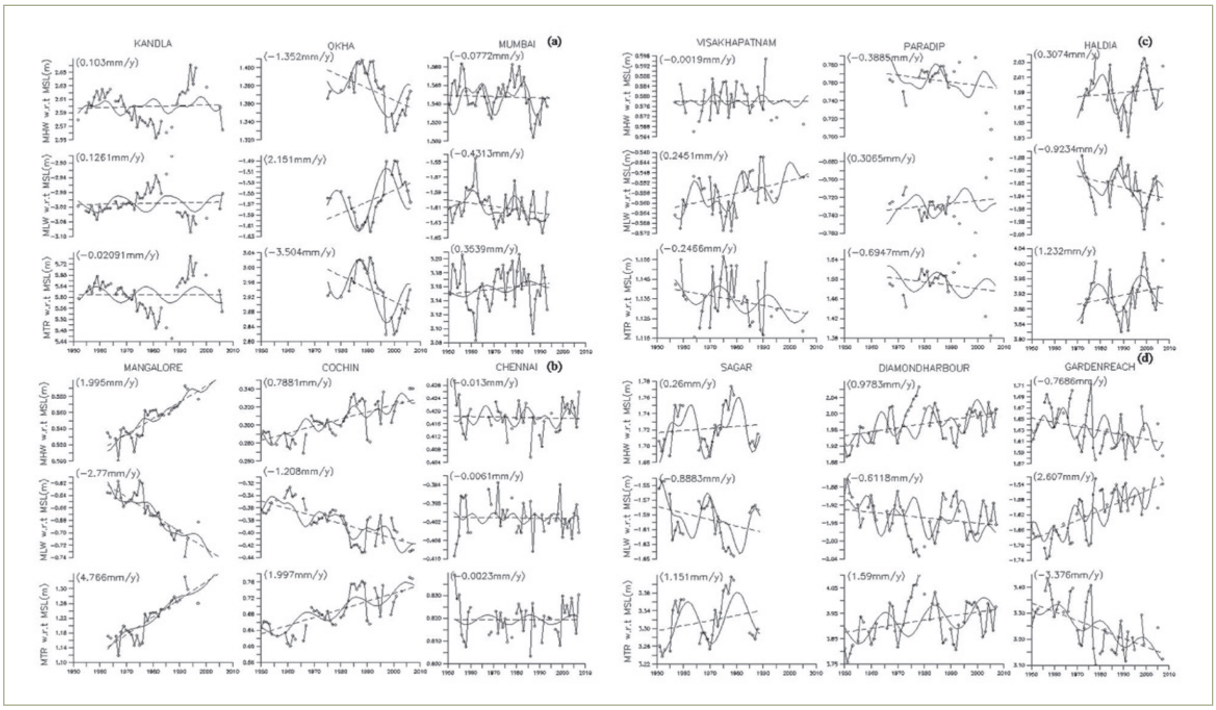


Figure 5.7: Annual Mean High Water (MHW), Mean Low Water (MLW) Level, and Mean Tidal Range (lines connected dots) with respect to mean sea level (MSL) for tide gauge stations (a) northwestern coast (b) south peninsular coast (c) east coast (d) northeast coast for each tidal station around India, and reconstructed low-frequency tidal level corresponding to lunar nodal and lunar perigee cycles (continuous line); and linear trend line (dash).

5.8 Assessment of chlorophyll-a seasonal cycle in the North Indian Ocean using observations from OCM2, MODIS, and SeaWiFS

A study on the seasonal variability of chlorophyll-a concentration (chl-a) in the north Indian Ocean is carried out based on different sensors: MODIS during 2002–2017, SeaWiFS during 1999–2009, and OCM-2 during 2010–2020. The spatial seasonality patterns of the annual and semiannual amplitudes are coherent among the datasets with a high chl-a climatology (0.5 mg m^{-3}) over the north Arabian Sea and north Bay of Bengal and continental shelf around India and Sri Lanka. Moderate magnitudes of chl-a climatology occur in the central Arabian Sea and Somalia offshore and the southwestern Bay of Bengal adjacent to Sri Lanka. On the other hand, major parts of the open oceanic domain of the Bay, the Equatorial Indian Ocean, and the southeastern part of the Arabian Sea show a very smaller climatological mean of chl-a with reduced seasonality. The regions of high climatology and intense seasonality of chl-a are co-occurring with upwelling and nutrient-rich zones. Chl-a also exhibits significant inter-annual variability in the areas of high climatological mean as a response to the background oceanic conditions and availability of nutrients. The strength of seasonal cycles of chl-a from OCM-2 is comparable to that of the MODIS and is stronger than the SeaWiFS. Hence, significant uncertainty for overestimating chl-a extremes can be attributed to the inherent spectral and radiometric characteristics of the OCM-2 sensor and their response to various corrections applied for geophysical parameter retrievals.

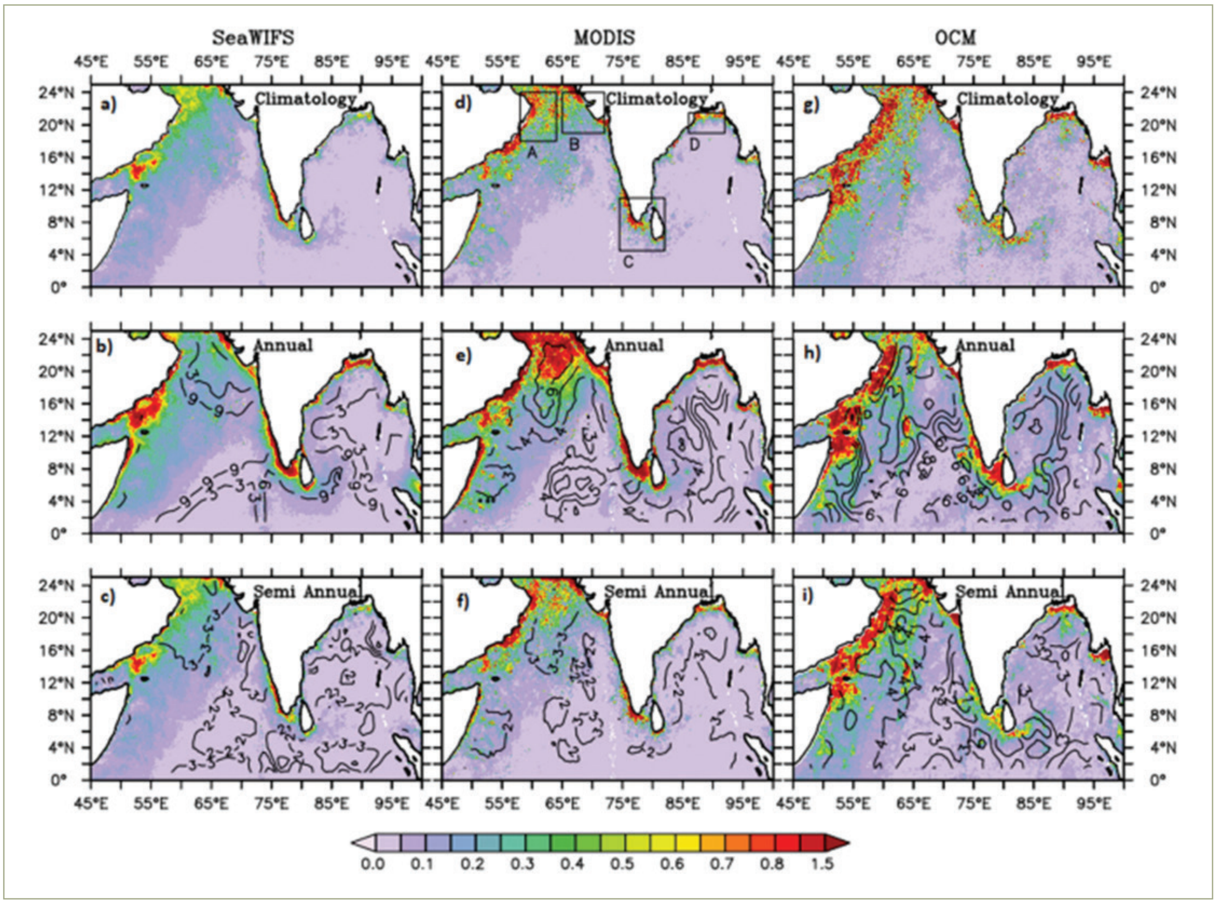


Figure 5.8: Mean climatology and amplitudes of annual and semiannual harmonics of the Chl-a for the North Indian Ocean based on SeaWiFS (in left panels), MODIS (in middle panels), and OCM2 (in the right panels).

5.9 Algal Bloom Information Service (ABIS)

INCOIS has a sustained ABIS to disseminate the daily near-real-time algal bloom information for the north Indian Ocean as well as the bloom hotspots along the Indian coast (Figure 5.9). ABIS has been set up covering the deployment locations of the INCOIS autonomous biogeochemical observatories. ABIS has been incorporated into the Water Quality Nowcast System to provide collocated information on algal bloom and associated parameters. Feasibility studies have been carried out to upgrade ABIS by incorporating higher-resolution OLCI sensor (onboard Sentinel-3) data. The necessary data access method has been finalized, and an automated script has been prepared.

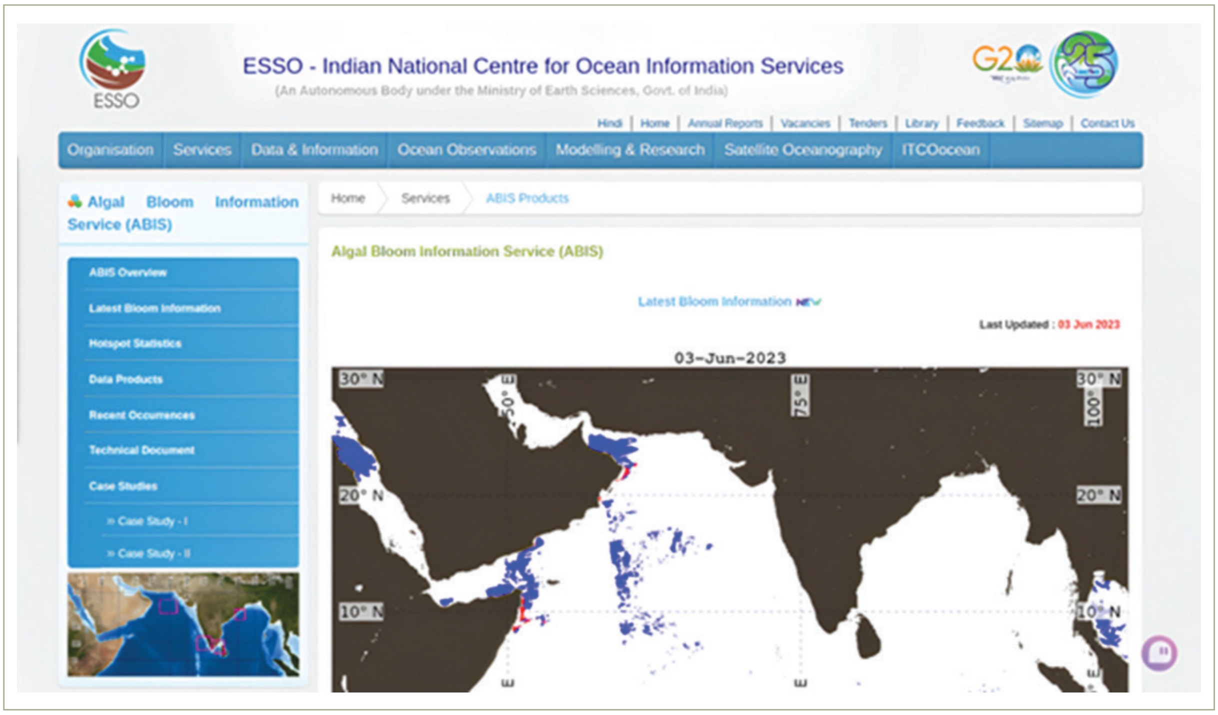


Figure 5.9: INCOIS-ABIS web page disseminating algal bloom information for 03-June-2023.

5.10 Research towards species-specific marine fishery advisory

5.10.1 Hilsa habitat suitability modeling for developing experimental Hilsa fishery advisory

A detailed framework for the adult Hilsa habitat suitability modeling was developed for the coastal waters of West Bengal. From the earlier research on Hilsa carried out by INCOIS, some parameters - oceanographic (SST, salinity), meteorological (rainfall and wind vector) and astronomical (lunar phases) were identified, which were observed to have a significant impact on the Hilsa catch (Figure 5.10). In addition to these existing parameters, the coastal current was also incorporated in the ongoing study to understand its impact on the variability of Hilsa catches in the coastal waters of West Bengal. This understanding of the relationship between Hilsa catch and different parameters will be integrated with the suitable statistical model through a multi-model approach to delineate the probable zones of Hilsa abundance. Validation exercises of the model will be carried out in collaboration with Vidyasagar University, West Bengal, where INCOIS has already funded a sub-project on Hilsa research. In the ongoing study, the feasibility of using data products of the Ocean General Circulation Models and reanalysis of meteorological data is being tested with an aim to ensure the continuous data source for the generation of experimental Hilsa advisory.

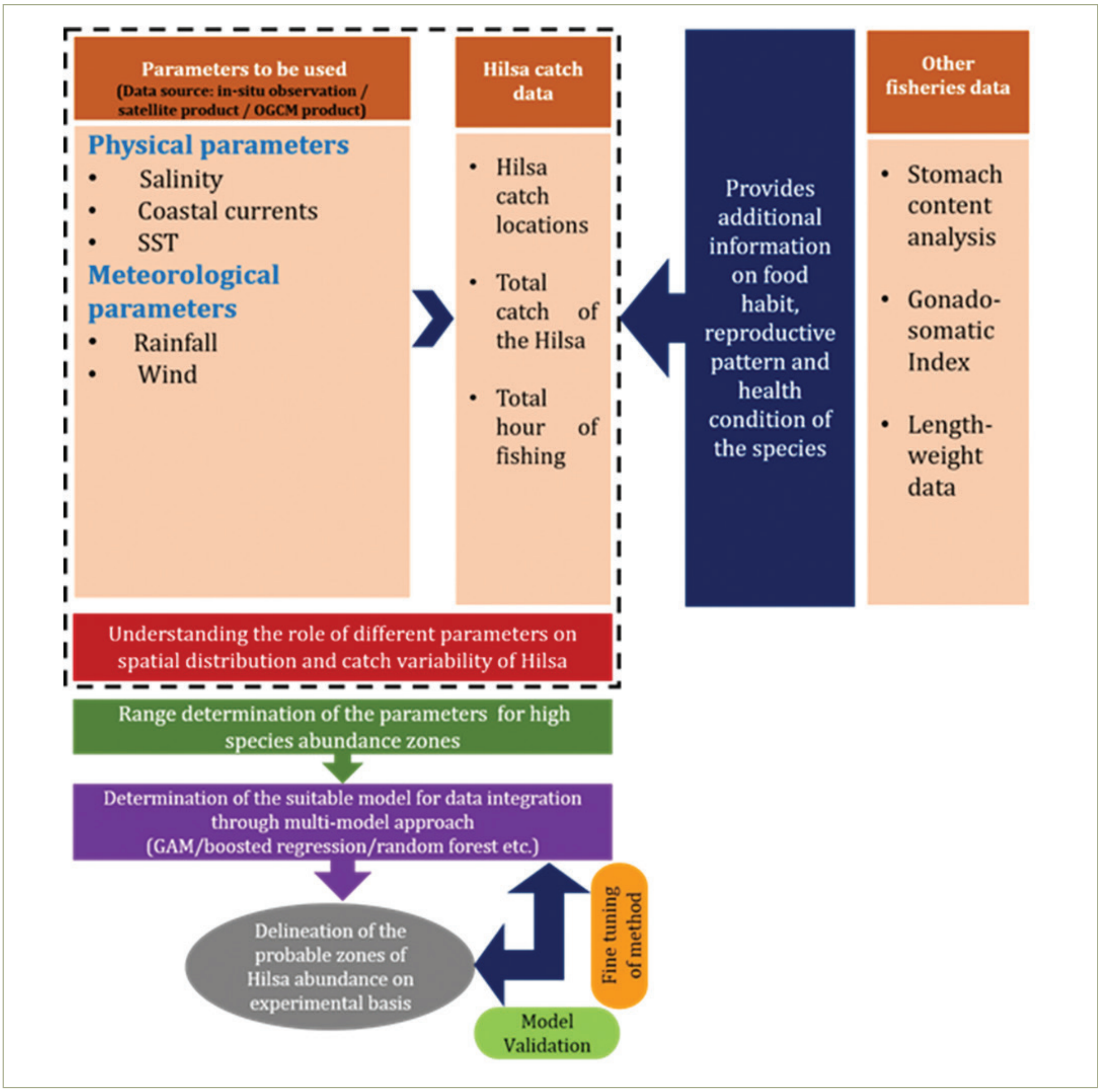


Figure 5.10: Framework for developing experimental Hilsa Fishery Advisory for West Bengal

5.10.2 Oil sardine habitat suitability modeling for the development of experimental Indian Oil Sardine fishery advisory

Indian oil sardine (*Sardinella longiceps*) has a unique position in terms of its economic value, and in the last decade, it has contributed about 17 - 20% to the total marine fish landings in India. Oil sardine sustains a commercial fishery on the southwest coast of India, specifically Kerala, which has been the major producer and consumer of the fish. An explicit literature review was carried out to understand the detailed life cycle of sardines, seasonal migration patterns, fluctuation in landing, and its relation to environmental parameters on the southwest coast of India. From the literature review, it was evident that till now, a successful sardine forecasting system has not been implemented by any of the research institutes/agencies of India. Therefore, INCOIS has taken the initiative to develop and provide species-specific advisory of sardines for Kerala on an experimental basis. In order to achieve this, a comprehensive dataset was collected from previous ventures of INCOIS on Indian oil sardines and organized for habitat suitability studies. A synergistic research approach has been initiated in collaboration with INCOIS outsourced project PIs towards field surveys to collect georeferenced data on sardine spawning, recruitment, catch, gut content, etc., along with collocated environmental parameters (Figure 5.11). Different multi-model approaches are under evaluation based on the available literature, aimed toward the generation of oil sardine advisory. A joint research proposal (in collaboration with the Institute of Marine Research) has been submitted to the Research Council of Norway to investigate the habitat change impact on the distribution of sardines attributed to ocean warming in eastern boundary upwelling systems of the African countries and India.

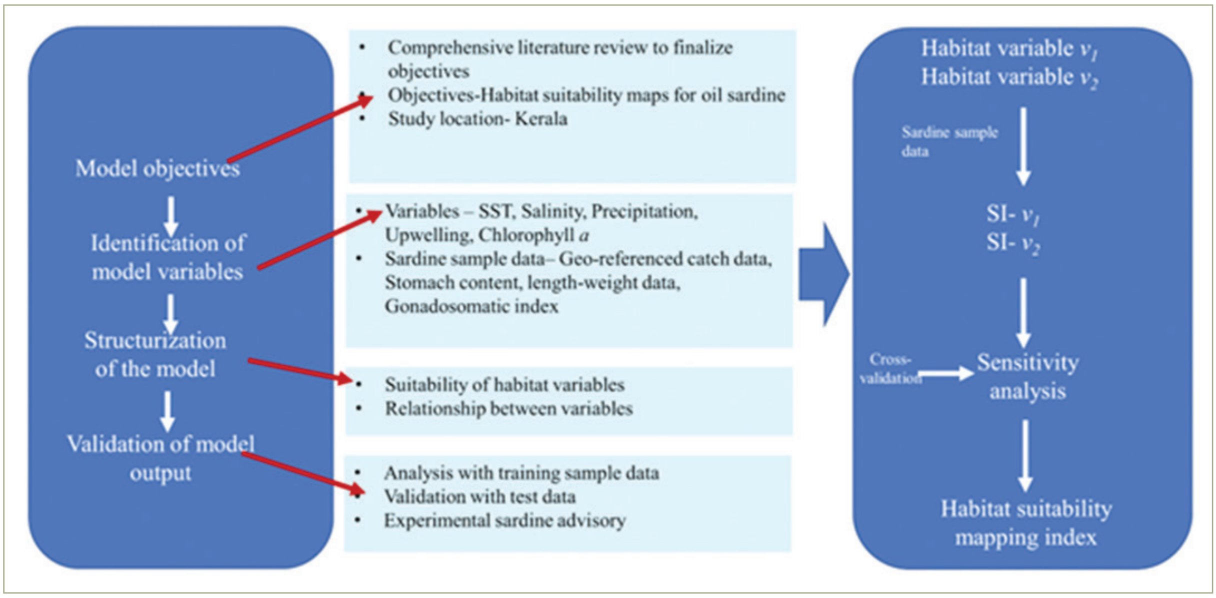


Figure 5.11: Conceptual framework of Indian oil sardine habitat suitability modeling.

5.10.3 Habitat suitability assessment for developing experimental Indian mackerel fishery advisory

Absolute datasets (1985-2012) were collected from previous undertakings of INCOIS on Indian mackerel and structured for habitat suitability studies. Multidecadal trend and correlation between precipitation, total fish catch, and Mackerel catch were evaluated for Karnataka and Kerala coast (Figure 5.12). Initial studies were carried out to understand the spatiotemporal recurrence of mackerel in relation to rainfall and PFZ in the southeastern Arabian Sea corresponding to the Malabar upwelling region. Significant correlations were found among these covariates and the Multiple Linear Regression method, which signified that these covariates could capture the trend of Mackerel landings and elucidates these parameters' influence on Mackerel catch.

5.11 Coastal biogeochemistry research

INCOIS is in the process of deploying and sustaining autonomous physical-biogeochemical observatories at strategic locations of the Indian coastal waters to provide real-time information on water quality/ecosystem health. The observatory recorded data will be displayed in a nowcast mode on the INCOIS website. A Water Quality Nowcasting System (WQNS) has been established for disseminating real-time information on water quality with input from autonomous water quality

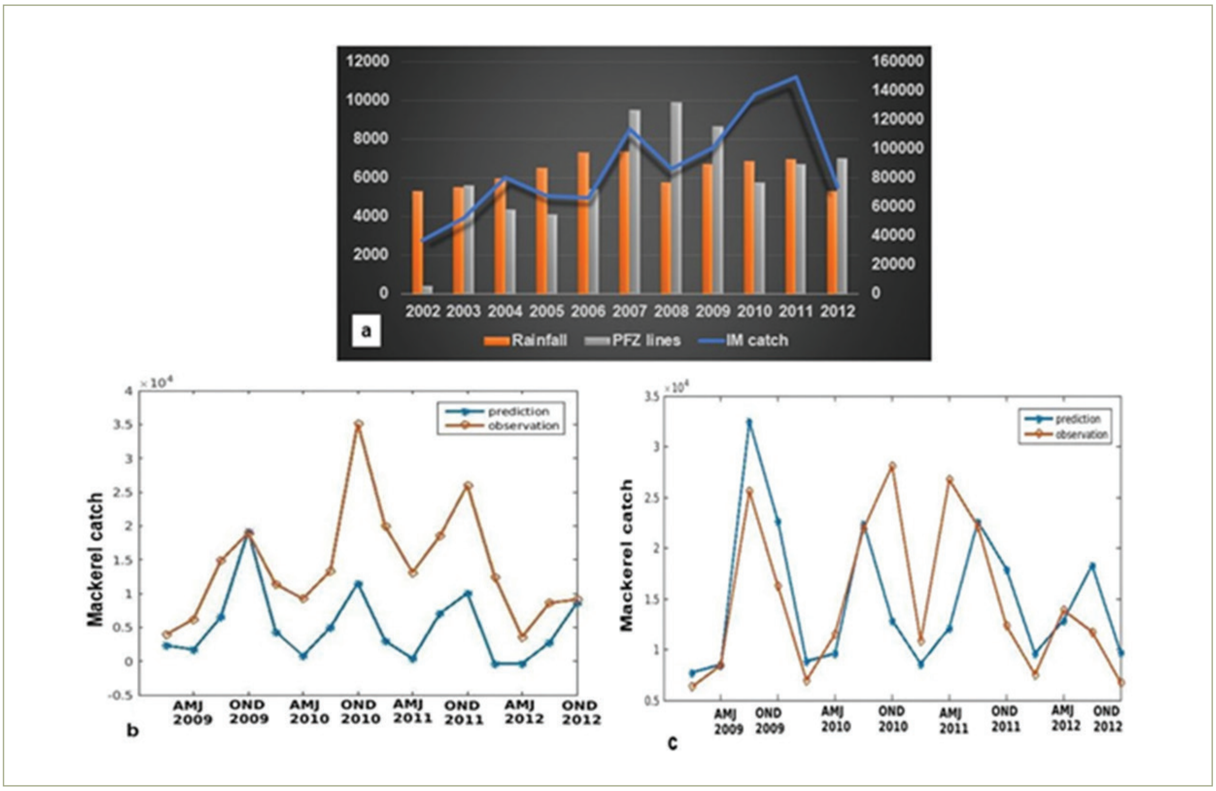


Figure 5.12: (a) Trend of Rainfall (in mm) and PFZ lines with Indian Mackerel landings (in tons) along Karnataka and Kerala coasts (2002-2012). Observed and predicted Mackerel landings by multiple linear regression techniques with rainfall, occurrences of PFZ lines, and mackerel landings as covariates with time lag along b) Karnataka and c) Kerala coast.

observatories (Figure 5.13). For the performance evaluation of the INCOIS' autonomous coastal water quality buoy system, necessary methodologies were formulated for acceptance tests for the individual sensors of the buoys for deployment in the coastal waters of Kochi. In addition to the

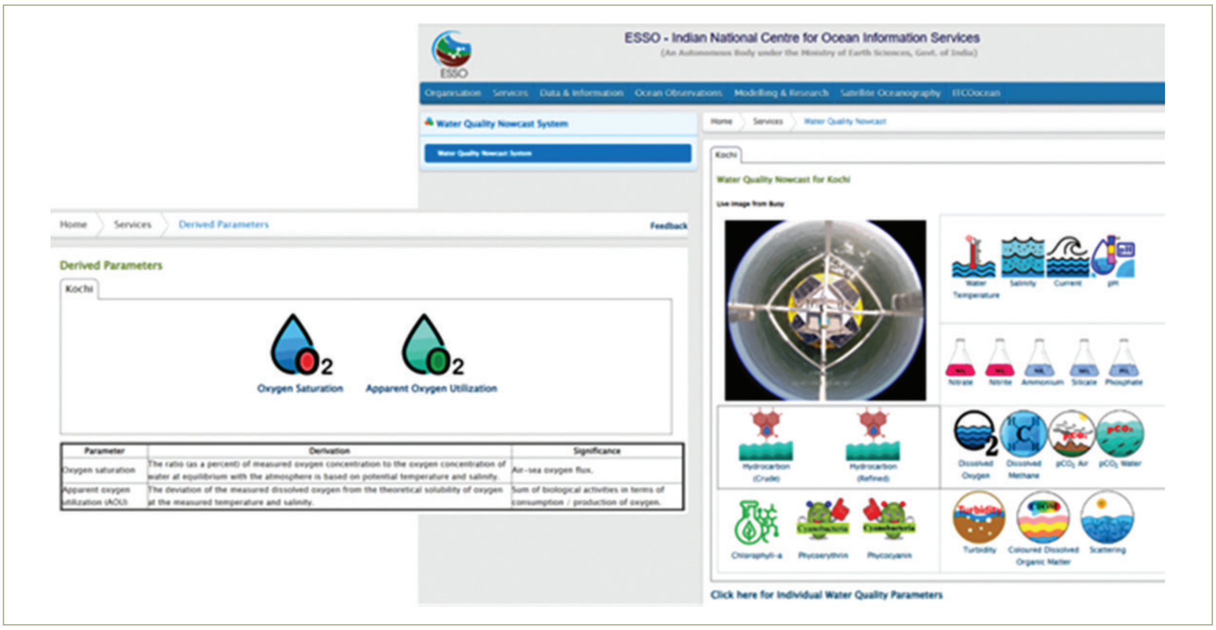


Figure 5.13: A screenshot from the INCOIS water quality nowcasting system web portal.

real-time data, INCOIS is also set to disseminate a set of derived parameters (using the real-time in-situ data), which will be helpful to the stakeholders. A set of derivable parameters was finalized, and necessary computational criteria were incorporated in the data archival-processing set-up for disseminating derived variables along with observed data. In order to provide comprehensive information on water quality, ABIS was augmented into WQNS.

5.12 Oil spill trajectory prediction

INCOIS has been actively involved in issuing oil spill advisories in operational mode since 2015, for events happening in the waters surrounding India as well as other locations. Oil drift patterns were simulated from the INCOIS oil spill trajectory prediction system, an integrated setup of oil spill trajectory model, general ocean circulation models, atmospheric models, and Geographical Information System (GIS). During the financial year 2022-23, oil spill advisories were issued for the following events.

5.12.1 MV Princess Oil Spill – Simulation of oil drift and validation through Synthetic Aperture Radar (SAR) dataset

Simulated oil drift patterns were issued to the Indian Coast Guard (ICG) on regular intervals from the spill location (12° 45.5'N, 74° 51.1'E) of the wrecked vessel MV Princess that had 220 Tons of fuel oil onboard during 21.06.2022 to 04.07.2022. They were validated using SAR data acquired on 30.06.2022 from the European Space Agency (Figure 5.14).

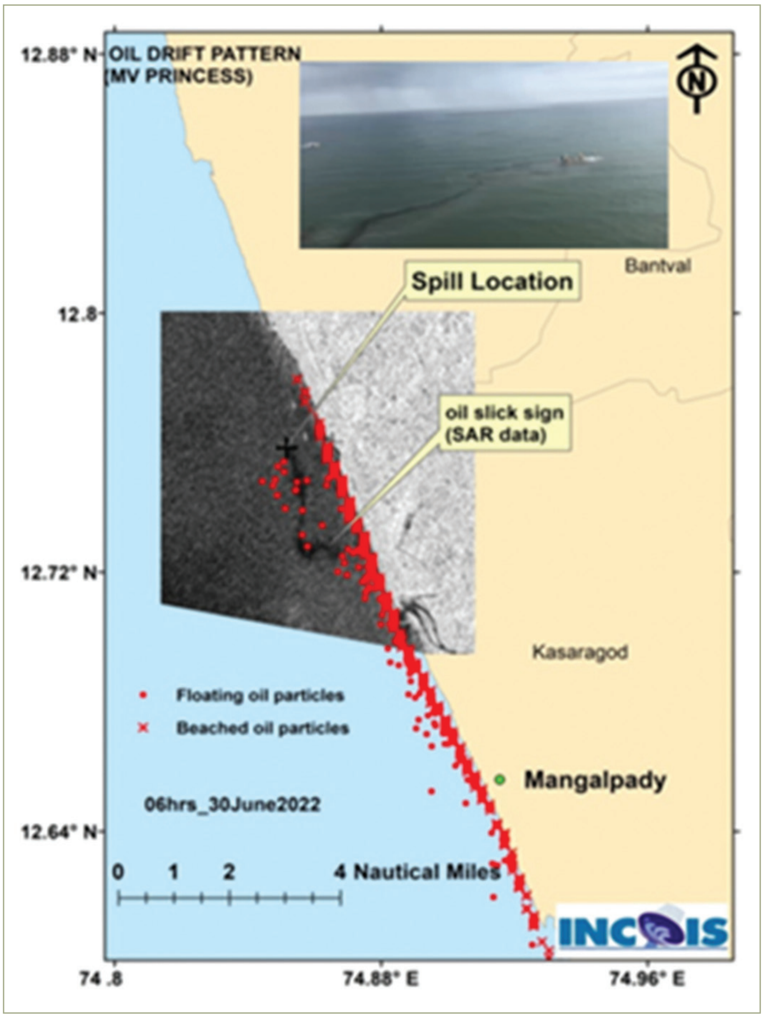


Figure 5.14: Simulation/validation of oil drift pattern.

5.12.2 Nagore Beach - pipeline oil spill – simulation of oil drift and validation through field survey/sampling

Simulated oil drift patterns were issued during 02-03-2023 to 08-03-2023 to the coastal villages of Nagapattinam districts through MS Swaminathan Research Foundation (MSSRF) after the leak of crude oil from a Carbon steel pipeline at Nagore beach (79.85 °E, 10.82 °N) (Figure 5.15). Field Survey/soil sampling was conducted by INCOIS and MSSRF officials during 10-03-2023 to 11-03-2023 along the coastal stretch extending from the spill location to Keechankuppam (Figure 5.15). From laboratory analysis, it was validated that a higher oil concentration (1.445g/Kg) was found at Nambiar Nagar, which is ~ 4.5 Km from the source (spill) location, even after eight days of the spill. The simulation was in tune with the reality, particle density being higher at Nambiar Nagar.

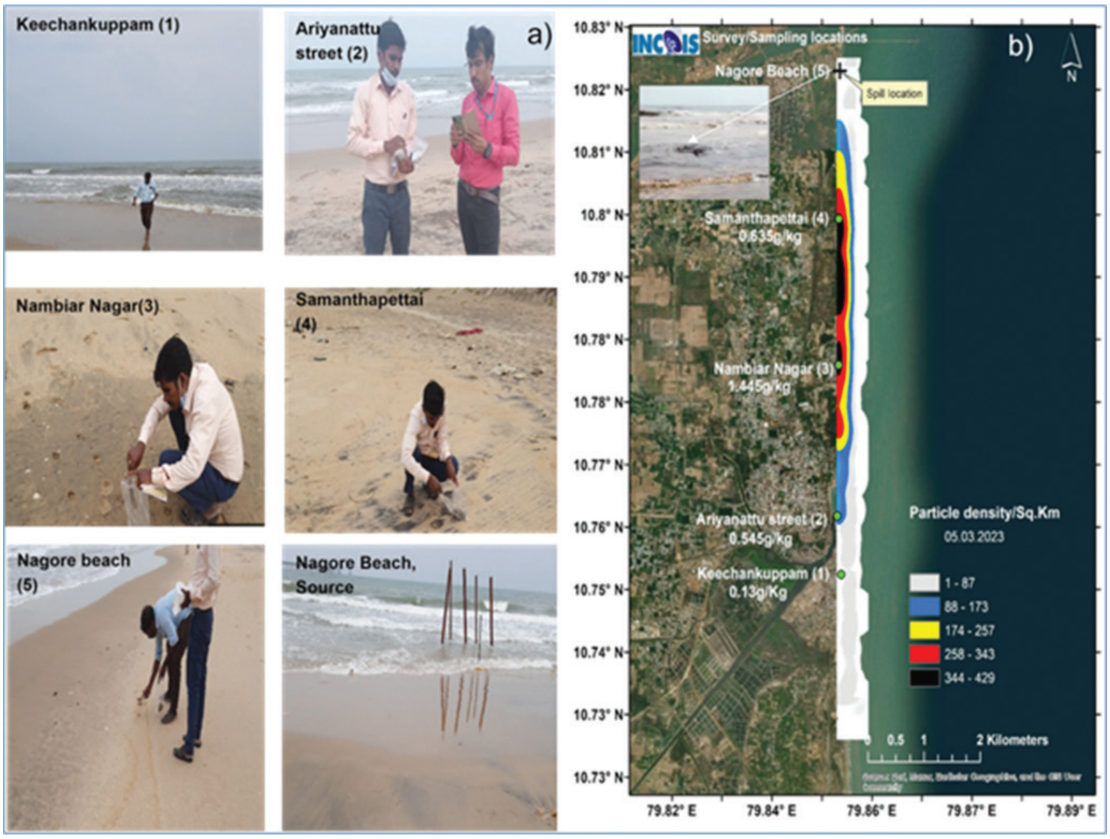


Figure 5.15: (a) Field survey/sampling by INCOIS & MSSRF, (b) Simulated particle density & analyzed oil concentration.

5.13 The summer monsoon rainfall variability over homogeneous regions of India linked to antecedent Southwestern Indian Ocean (SWIO) capacitance

All India Summer Monsoon Rainfall (AISMR) variability on the inter-annual and intra-seasonal time scale has puzzled the scientific community due to its complex and regional heterogeneity. With innovative technological advancement and many years of sustained research, most dynamical and statistical models still fail to predict the seasonal and intra-seasonal AISMR variability and associated extremes, with reasonable accuracy. This could be due to the unpredictable variability within the AISMR and the lack of understanding of the ocean's role in AISMR variability. This implies that the persistent ambiguity on the impact of the slowly responding ocean surface to the extreme atmosphere–ocean coupled phenomena such as El Niño-Southern Oscillation (ENSO) during the antecedent months and its imprint on the rainfall variability of the following year.

This study looked into improve the understanding of impact of ENSO and Indian Ocean variability during antecedent months on monsoon precipitation in the following year, over various parts of India. This work showed that April-May Sea Surface Temperature (SST) and mean sea level anomaly (MSLA) over the southwest Indian Ocean affects forthcoming AISMR (Figure 5.16). However, SWIO impacts limits to the west coast of India (WCI), north India (NI) and central India (CI) rainfall, the rest of the land mass is not influenced by the SWIO variability. This association even becomes stronger with the removal of ENSO, which suggests SWIO even independently impacts WCI, NI and CI rainfall variability. The ENSO effect becomes prominent through SWIO over the northeast (NE) and eastern India (EI) rainfall variability. In most of the previous studies, it has been reported that ENSO affects AISMR as a whole. But this study shows that ENSO affects mostly the Northeast and Eastern India's monsoon rainfall through the SWIO. It has been also reported in many earlier studies that ENSO affects the southwest Indian Ocean. This study further linked the impact of ENSO on AISMR in a more quantified way. Despite increasing April–May SSTA and MSLA trends over SWIO and the western Indian Ocean, AISMR does not show any long-term secular change. However, the effect of long-term pre-monsoonal SSTA and MSLA shows decreasing rainfall trend over NI, NE, and EI in recent times. No such trends were observed over WCI and CI, thus making the rainfall excess or normal in the recent decade. Furthermore, the cooler SST (warmer) anomaly over the western Indian Ocean affects rainfall variability adversely (favorably) due to the reversal of the wind pattern during the pre-monsoon period (Figure 5.17).

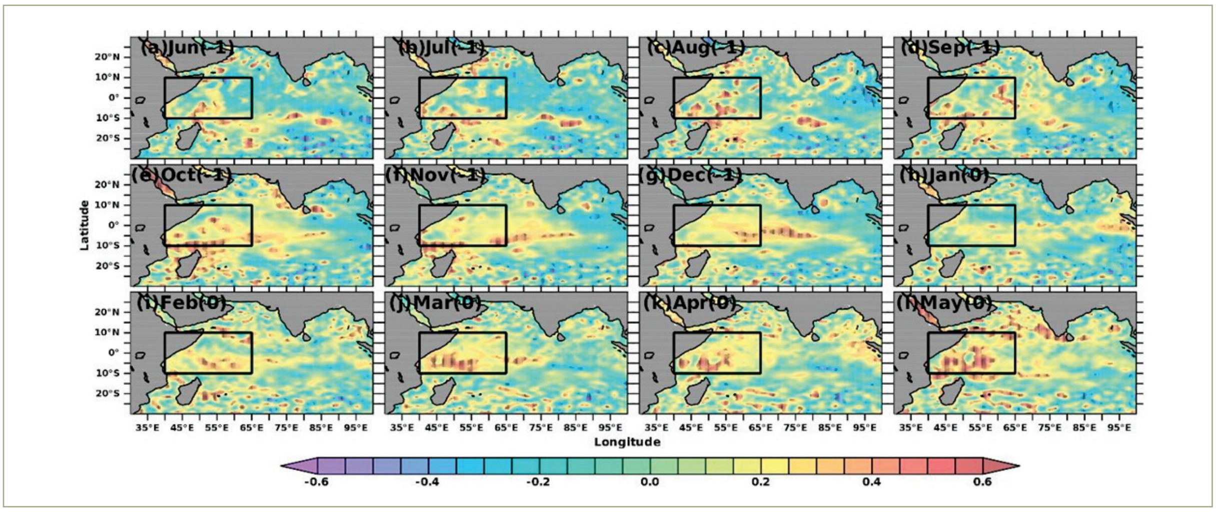


Figure 5.16: Lagged correlation of detrended AISMR SAI with detrended MSLA over the Indian Ocean. Areas over lapped with black dots are correlations with 90% significance.

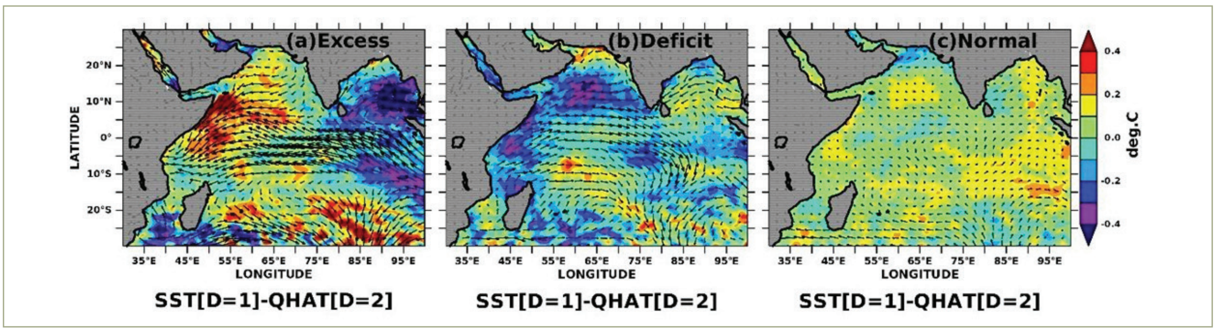


Figure 5.17: Composite of May month's detrended SSTA composite (shaded) overlaid with detrended ERA5 wind anomalies (vectors) over the Indian Ocean during (a) excess, (b) deficit, and (c) normal monsoon years

5.14 Distinct oceanic responses at Rapidly Intensified (RI) and Rapidly Weakened (RW) regimes of Tropical Cyclone

The response of the upper ocean to Tropical Cyclone (TC) Ockhi in its RI and RW regions was examined using simulations from the HYbrid Coordinate Ocean Model (HYCOM). The analysis revealed contrasting oceanic conditions between the RI and RW regions, including Sea Surface Temperature (SST), surface salinity, and the presence of a barrier layer. The RI region had warmer and fresher waters with a thick barrier layer, while the RW region had cooler and more saline waters with no barrier layer. The SST anomaly along the storm track showed minimal cooling in the RI region despite the slow storm speed, attributed to the presence of thick warm water and the barrier layer. In contrast, the RW region experienced pronounced cooling due to weaker stratification and faster storm movement.

Further, this study analyzed the mixed layer heat budget to assess the contributions of different physical mechanisms, such as surface thermal forcing, entrainment, horizontal advection, and vertical advection, in influencing the mixed temperature at the RI and RW locations (shown in Figure 5.18). The analysis revealed a slower rate of temperature cooling in the RI region compared to the RW region. Surface thermal forcing was the primary driver of temperature tendency in the RI region, while entrainment played a major role in the RW region. Horizontal advection had minimal influence on thermal changes in both regions. Vertical advection induced a significant negative temperature

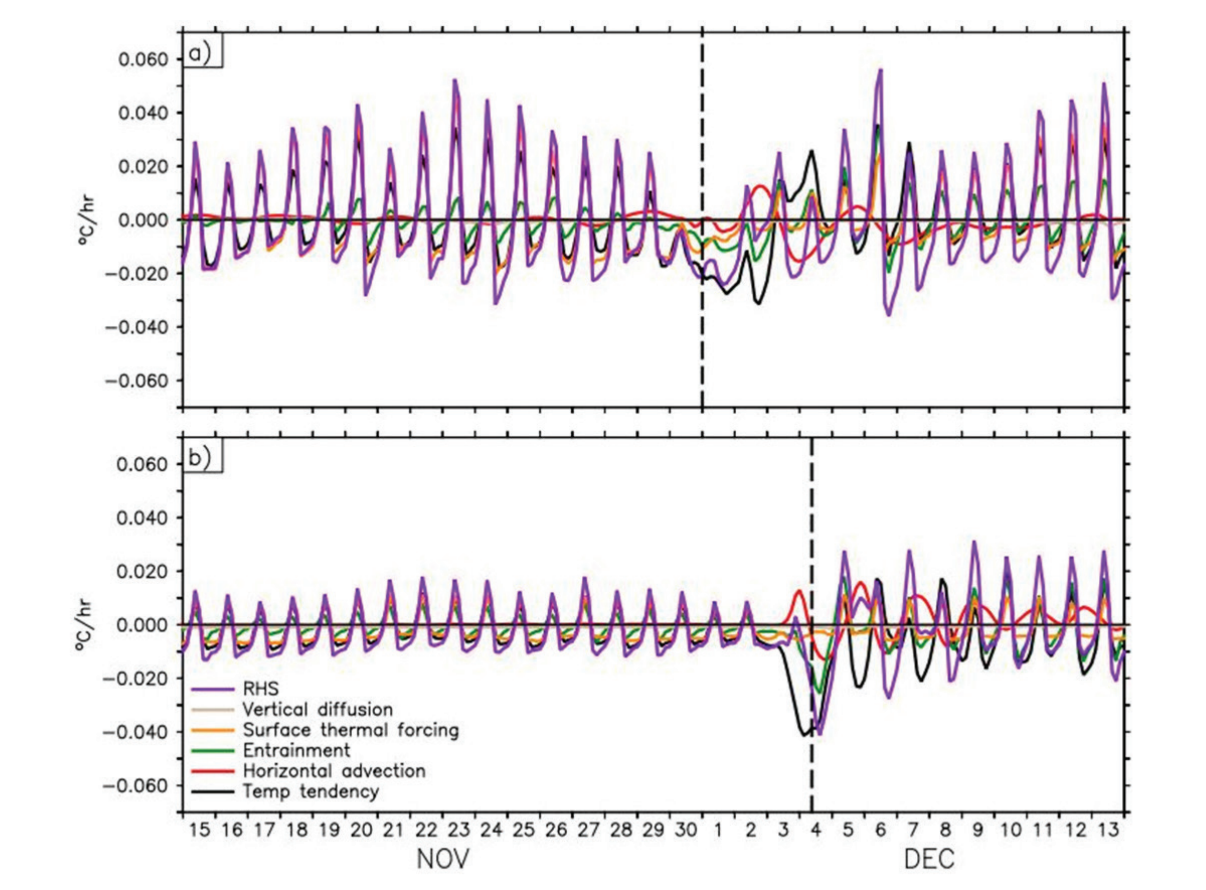


Figure 5.18 a) Temporal evolution of horizontal advection (0.5%), entrainment (48.4%), surface thermal forcing (53.5%) at RI b) At RW, horizontal advection (4.7%), entrainment (52%), surface thermal forcing (7.5%). The dashed line indicates the time of TC occurrence.

tendency below the mixed layer in the RW region, but its impact was negligible in the RI region. The differences in entrainment-induced cooling were attributed to the contrasting stratification characteristics in the RI (strong) and RW (weak) regimes. Also, the difference between the mixing length and the 26°C isotherm was significant in the RI region due to salinity stratification, while it was negligible in the RW region. This difference highlighted the importance of salinity stratification in determining the depth of mixing and suggested the need for accurate simulation of salinity stratification for better intensity forecasting of the cyclones.

5.15 Development of Search And Rescue Aid Tool – Integrated (SARAT-I)

To obtain the probable search areas for any object lost at sea, the Search And Rescue Aid Tool (SARAT) was developed by INCOIS and operationalized. The SARAT application requires the input of the Last Known Position (LKP) and Last Known Time (LKT) of the lost object 'at sea'. However, the SARAT application cannot be directly used to trace if an aircraft missing mid-air landed in the sea and drifted because the mid-air LKP and LKT of such an aircraft cannot be directly used as input to SARAT. Therefore, to address this issue, INCOIS developed an application called Search And Rescue Aid Tool – Integrated (SARAT-I) in collaboration with the Indian Coast Guard (ICG) and the Airports Authority of India (AAI). Through a series of calculations prescribed in the International Aeronautical and Maritime Search And Rescue (IAMSAR) manual, SARAT-I translates the mid-air LKP into the probable positions where the aircraft could have descended into the sea. These probable positions are then used to generate search regions by SARAT. The SARAT-I application was inaugurated by the Director General of the Indian Coast Guard on 17 November 2022. A detailed technical report, including operational instructions, has been handed over to the ICG and AAI for operational usage.

5.16 Consultancy Projects

Kalpasar Project was executed successfully, and deliverables were submitted. Ocean-met related consultancy projects were carried out/continued for M/s. ONGC Kakinada, M/s. Afcons House, and M/s McDERMOTT. A MOU was signed with DG-HC for serving improved, user-customised and location-specific high-resolution forecasts and warnings to various oil & natural gas offshore E&P companies. The details of the list of consultancy projects taken up during last one year are listed in Table 5.2.

Table 5.2 Details of the consultancy projects/ECF during last one year

Sl. No.	Industry/ firm	Project type	Amount earned-last 1 year (INR)	Remarks
1	M/S ONGC-KG Basin Kakkinada	Project on forecast and climatological trend analysis for KG basin development and operations	~ 20 Lakhs	Commenced in April 2018. 3+2 year project. (payment in 3-Monthly-basis). Daily operational forecasting for wells and 2-monthly trend analysis and delivery on request.

2	M/S AFCONS	Project on forecast for off Agalega Island, Mauritius for marinal operations	~13 Lakhs	Daily operationally pushed.
3	M/S AFCONS	Project on "hindcast analysis of wave, swell, winds and max wave height during the period 02 Jan to 22 Feb 2021	~4.5 Lakhs	One time delivery
4	DG Hydro Carbon	Consultancy in the form of a training and clarifications	1.33 Lakhs	One time two days training and consultancy
5	M/S ADANI-VIZHINJAM Port	Project on wave and current off Vizhinjam using Observational deployment and studies	46 Lakhs	Project was initiated and being executed

Efforts for the Expansion of consultancy projects

Aiming to expand the consultancy projects and making of user-customised and demanded value-added ocean-met products and also to make more awareness among offshore and coastal industries and clients regarding our all the services and its updates, which are suitable to them, leaflets/ brochures were conceived, prepared the matter and designed (with minor support from a Scientist and suggestions from all the concerned, and designing and printing in laisioning with rate contract firm of INCOIS). Considering the adequacy and relevance to each category of target users, it was identified and made seven types of leaflets/brochures for categories/titles given below.

1. Offshore Exploration & Production Companies
2. Port & Harbours
3. Shipping Industry
4. Insurance and Re-insurance Companies
5. Open Ocean Fishery
6. Information and Communication Technology (Industry innovations to make the best out of the data)
7. Observations (Where the industry can help INCOIS with indigenisation)

300 copies of each were printed and arranged to send the relevant brochures to 5 categories pertaining to 80 addresses of companies/client organisations/firms/HQs/representatives in hard-form and also in soft-form. Along with the brochures, the feedback cum survey form designed earlier were also sent/linked.

6

OCEAN OBSERVATION NETWORK (OON)

INCOIS maintained an extensive network of observation platforms in the Indian Ocean coastal and open ocean waters under its Ocean Observation Network (OON) project funded by the Ministry of Earth Science (MoES) to support operational forecast system development and its evaluation and improve our understanding on physical, biogeochemical, and ecosystem processes and interactions among them. Below is a summary of progress and current status of existing platforms under OON.

6.1. Argo programme

As part of the International Argo Program, INCOIS regularly deploys Argo floats in the Indian Ocean. To date, INCOIS deployed 494 floats in the Indian Ocean. 52 floats were active as of 31 March 2023, and transmitting data (Figure 6.1). The current array includes 18 biogeochemical floats and 34 core floats. New deployments will be restored from September 2023 onwards.

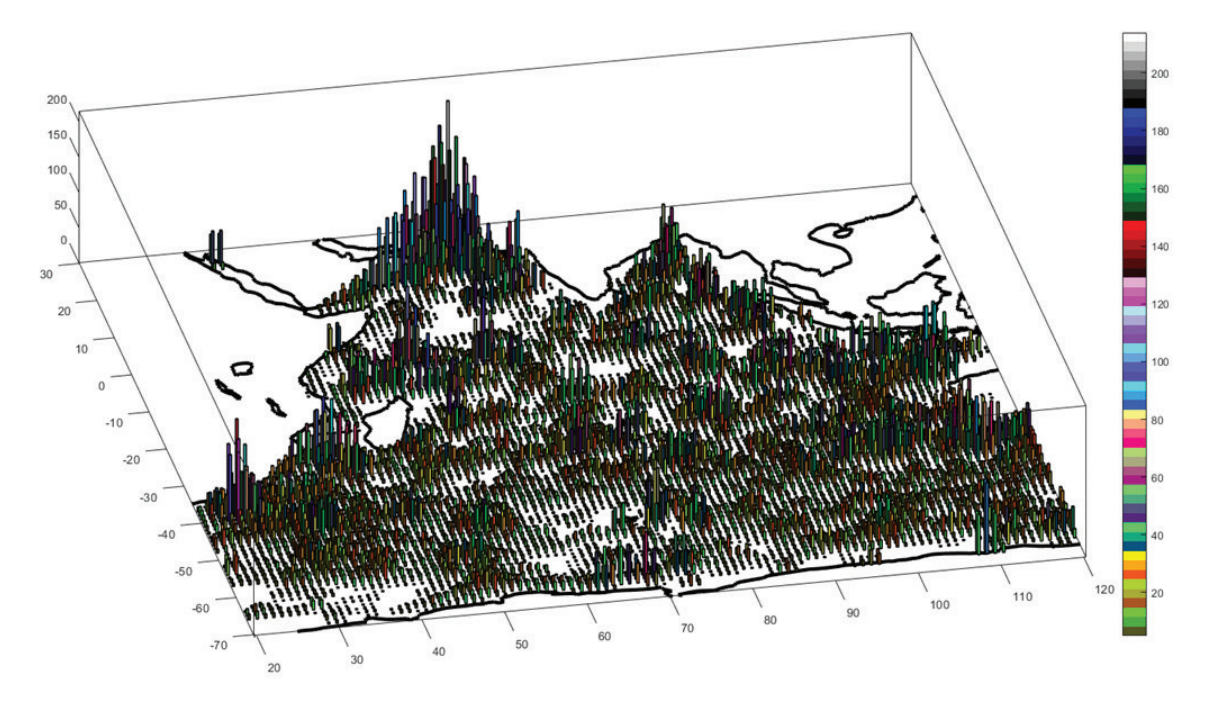


Figure 6.1. Spatial distribution of number of profiles collected from the Argo floats during Apr 2022 – March 2023 in every 3x3 box in the tropical Indian Ocean. Height and colour of the bar indicate the profile's density at the location.

6.2 Drifter buoy programme

INCOIS continued its contribution to the Global Drifter Programme (GDP) by deploying 15 satellite-tracked surface drifters as part of two scientific cruises in the Bay of Bengal. In the north Indian Ocean, right now, five Indian floats are functioning (Figure 6.2). INCOIS intends to continue this programme in the plan period 2023-24 by deploying indigenously produced drifters with INSAT communications. The drifting buoys collect sea surface temperature and barometric pressure with a one-hour temporal resolution and send it in real-time via satellite. Further, reliable float location information allows the scientific community to calculate near-surface current velocity. The data collected by these floats are used to improve the accuracy of atmospheric and ocean models.

6 OCEAN OBSERVATION NETWORK (OON)

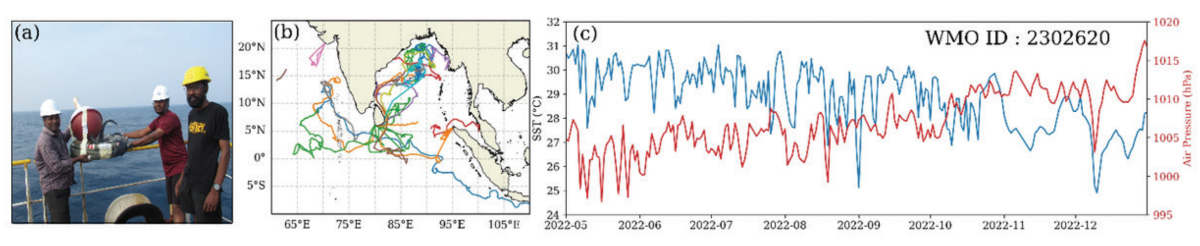


Figure 6.2. (a) Deployment of a Drifter buoy from Sagar Nidhi by INCOIS personnel. (b) The trajectories of INCOIS drifters during 2022-23. (c) The sea surface temperature (blue) and barometric pressure (red) measurements from drifting buoy (WMO ID 230620) during 2022-23.

6.3 Coastal and Equatorial Acoustic Doppler Current Profiler network

In partnership with NIO, Goa, INCOIS maintained 17 coastal Acoustic Doppler Current Profiler (ADCP) moorings along the Indian coast, which include 13 slope moorings and four shelf moorings, and another additional 3 ADCP moorings in the equatorial Indian Ocean (Figure 6.3). One scientific cruise was conducted onboard RV Sindhu Sankalp (SSK150) from 29 December 2022 to 14 January 2023 for servicing the west coast ADCP moorings. The maintenance activity of moorings on the east coast is scheduled in April 2023. The services of moorings along the equator are not completed due to the non-availability of ship time and are planned to be performed in August 2023.

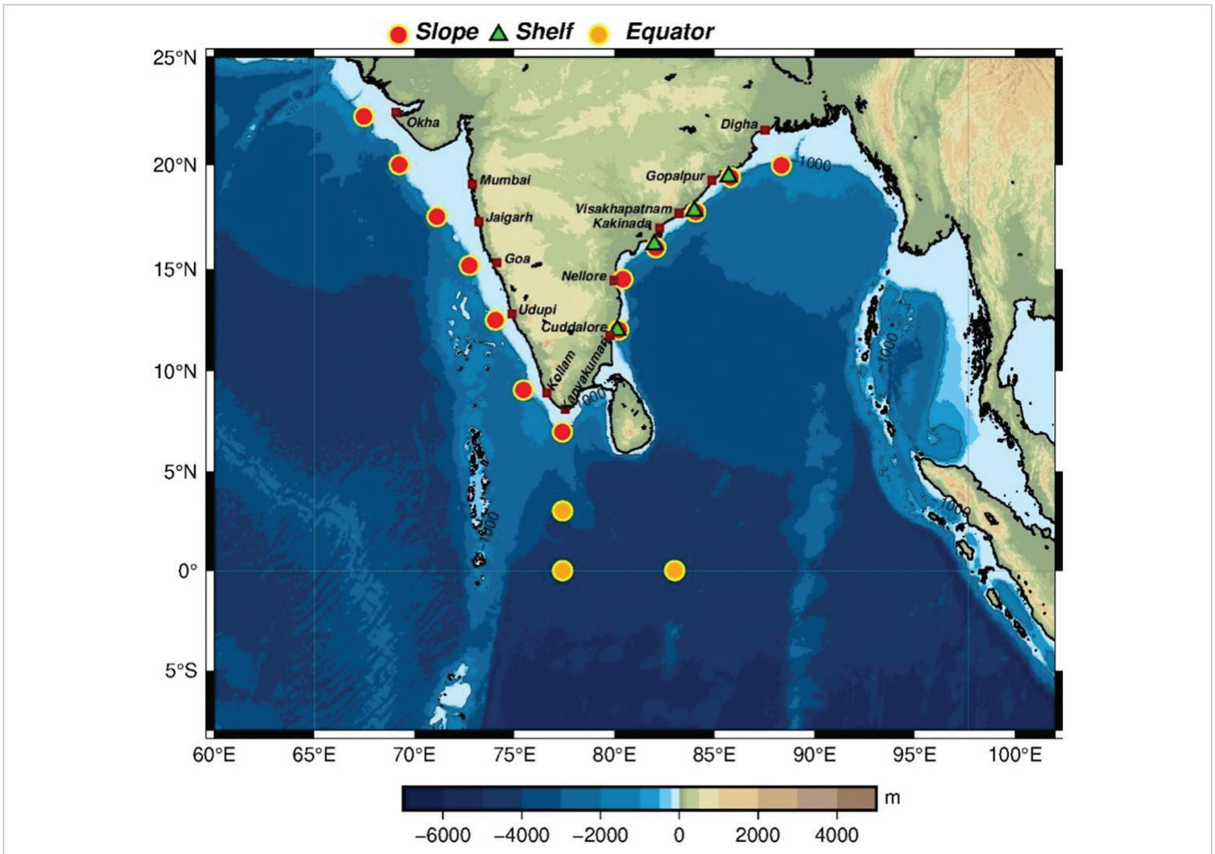


Figure 6.3 Location of 17 ADCP moorings (red-slope moorings and green-shelf moorings) along the Indian coast and additional 3 ADCP moorings in the equatorial Indian Ocean (orange circle).

6.4 Tsunami buoys

INCOIS maintained a network of three tsunami buoys with Bottom Pressure Recorder (BPR) deployed close to the tsunamigenic source regions in the Bay of Bengal and the Arabian Sea and received real-time data from these buoys (Figure 6.4). Additionally, INCOIS received real-time data from another tsunami buoy ITB06 (anchored in STB05 location) maintained by the National Institute of Ocean Technology (NIOT, Chennai). These high-precision buoys are capable of detecting very minor water level changes of 1 cm at water depths up to 6 km. The data from these buoys are transmitted in real-time to the Indian Tsunami Early Warning Centre (ITEWC) at INCOIS via satellites. In addition to these buoys, real-time data from around 50 tsunami buoys operated by other countries in the Indian and Pacific Oceans are also received at ITEWC. The real-time data from this network is used for issuing early tsunami warnings and it is also shared with NDBC-NOAA. For the maintenance and repairs of the STB01 buoy in the Bay of Bengal and the STB02 buoy in the Arabian Sea, INCOIS and Science Applications International Corporation (SAIC) inked a commercial purchase agreement. SAIC refurbished two tsunami buoy systems, which will be used in the upcoming maintenance schedule in the second part of 2023. Two moorings in the Arabian Sea (STB02 & ITB12) and two in the Bay of Bengal (ITB05 & ITB09) are now operational (Figure 6.4).

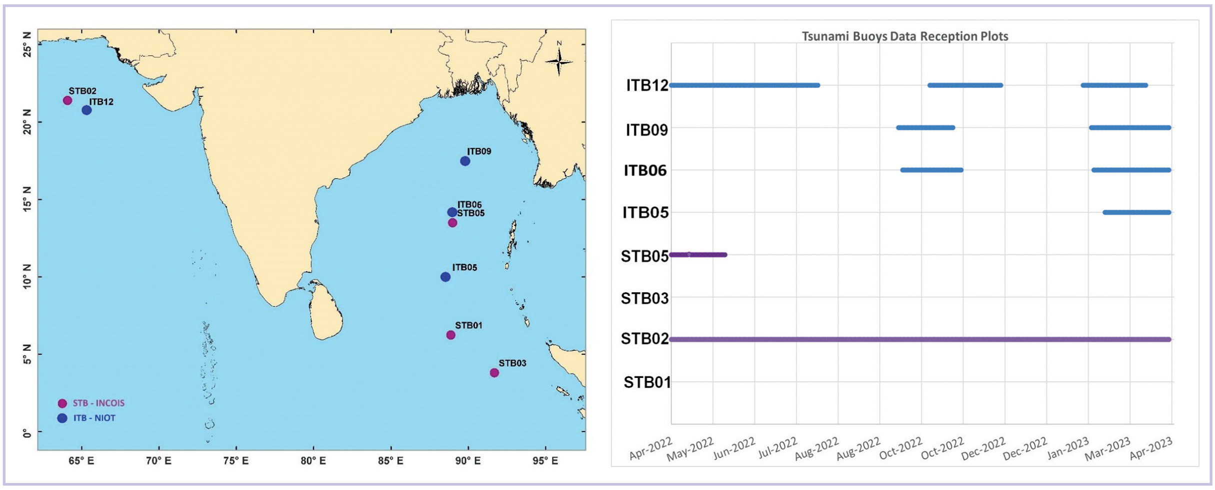


Figure 6.4: (top panel) Locations of the Sea level network of Tsunami Buoys and (bottom panel) data availability from Tsunami Buoys network during the reporting period.

6.5 eXpendable Bathy Thermographs (XBT) / XCTD transects

XBT/XCTD transects along commercial shipping routes were restarted in February 2023. Two transects were carried out along the Chennai-Port Blair and Port Blair-Visakhapatnam transects during the reporting period. Along the Chennai-Port Blair transect, 30 XBT profiles and 50 sea surface salinity (SSS) samples were collected, whereas 22 XBT profiles and 38 SSS samples were collected along the Port Blair-Visakhapatnam transect (Figures 6.5). In addition to the observations collected along the above-mentioned transects, in August 2022, weekly sampling for SSS at ten stations (Paradeep, Vizag, Penupalem, Suryalanka, Chennai, Nagapattinam, Tirnuchendur, Rameswaram, Kolachal, and Arambol) continued and collected 600 samples along the east coast of India (Figure 6.5a). Further, the laboratory testing of real-time XBT data transmission through the INSAT satellite was successfully performed. During the plan period until 2025, it is proposed to sustain XBT transects along Chennai-Port Blair, Port Blair-Visakhapatnam and Port Blair-Kolkata (PK) and to explore the possibilities of the Mumbai-Mauritius transect.

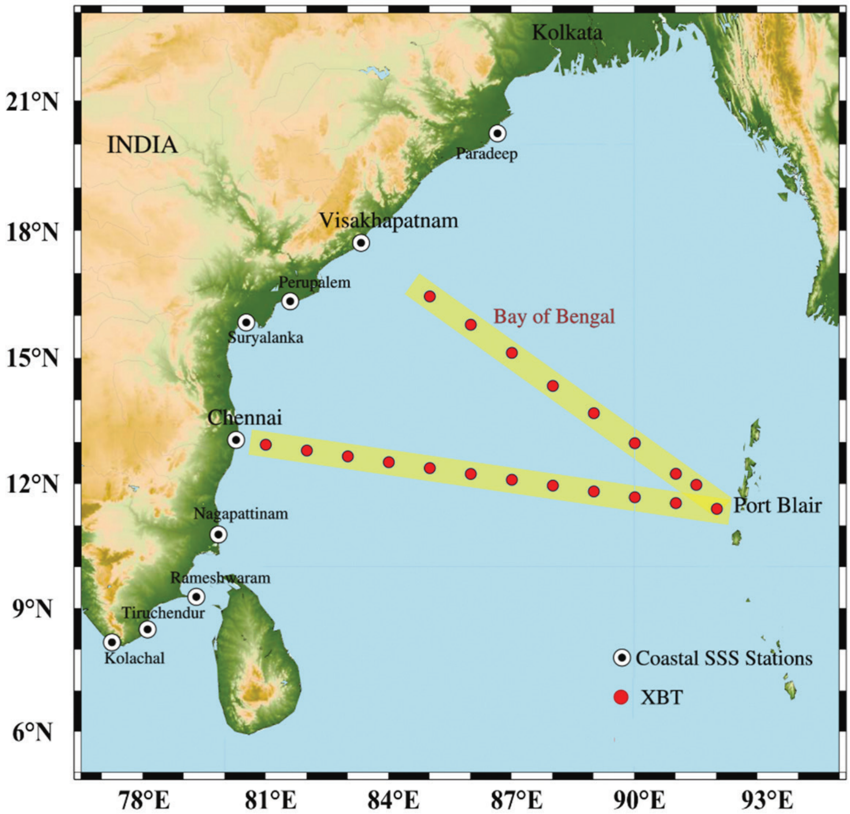


Figure 6.5. The location (red dots) of XBT profiles collected along the Chennai-Port Blair and Port Blair-Visakhapatnam transects (marked as a yellow strip) during April 2022-March 2023, and the black closed circle represents the location of ten SSS sampling stations (Paradeep, Vizag, Penupalem, Suryalanka, Chennai, Nagapattinam, Tirnuchendur, Rameswaram, Kolachal, and Arambol) along the east coast of India.

6.6 Tide Gauge Network

INCOIS maintained a tide gauge network at 36 locations around the coasts of the Indian mainland and islands to measure sea level during the reporting period (Figure 6.6). ITWEC at INCOIS received real-time data from 36 tide gauges through INSAT and GPRS modes of communication. In addition, INCOIS received near-real-time data from tide gauges installed and maintained by other countries. INCOIS also fed real-time data from eight tide gauges into the Intergovernmental Oceanographic Commission (IOC) Sea Level Monitoring Facility (Chennai, Kochi, Nancowry, Port Blair, Visakhapatnam, Minicoy, Marmagao, and Veraval). The tide gauge installed at Pondicherry was damaged due to a tropical cyclone which will be relocated to a new position in May 2023. The tide gauge at Digha has been decommissioned. A new tide gauge at Gopalpur and Orissa was successfully installed in April 2022. To ensure the availability of quality data from this network, 65 routine maintenance visits and 26 breakdown visits were performed during the reporting period. Local benchmark levelling operations were carried out at the tide gauge stations of Kochi, Baypore, and Kollam (Figure 6.6).

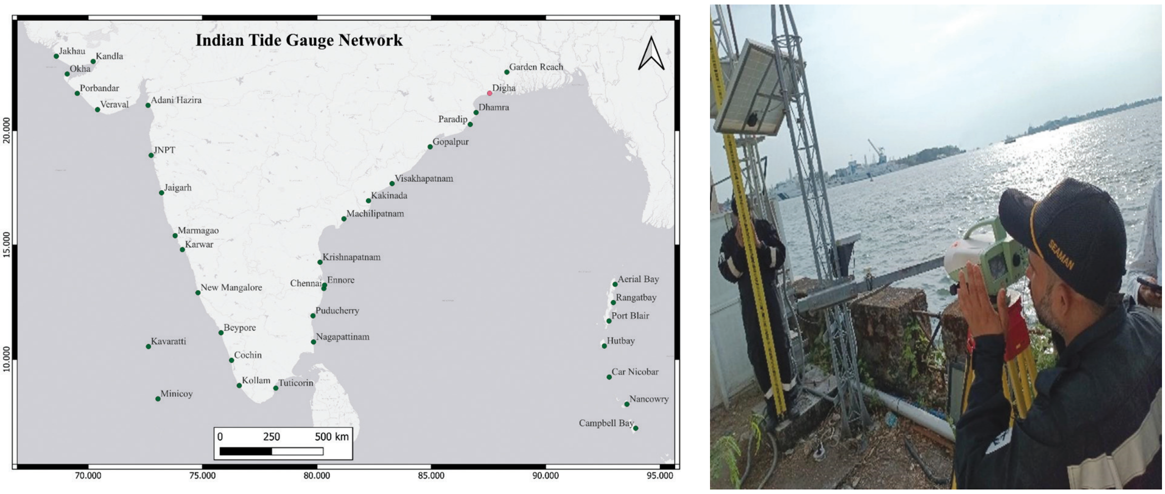


Figure 6.6 (left) Locations of INCOIS Tide Gauge network (right) Local Benchmark levelling at Kochi Tide Gauge station.

6.7 Wave Rider Buoy (WRB)

INCOIS maintained a network of 16 Wave Rider Buoys (WRB) to monitor ocean wave characteristics along Indian coastline waters and the propagation of Southern Ocean swells to the north Indian Ocean in near-real-time during the reporting period (Figures 6.7). The data from this network was used to test ocean state forecast products and to assimilate wave parameters into wave models. To assure the quality of data from these networks, regular calibration of the systems in prescribed intervals was undertaken. The indigenously developed INSAT-based buoy tracking mechanism assisted in the recovery of ten drifted buoys. These buoys were later redeployed at their original deployment locations. To ensure the continuous availability of quality data from these systems, 25 maintenance and re-deployment operations were performed on the existing WRB network.

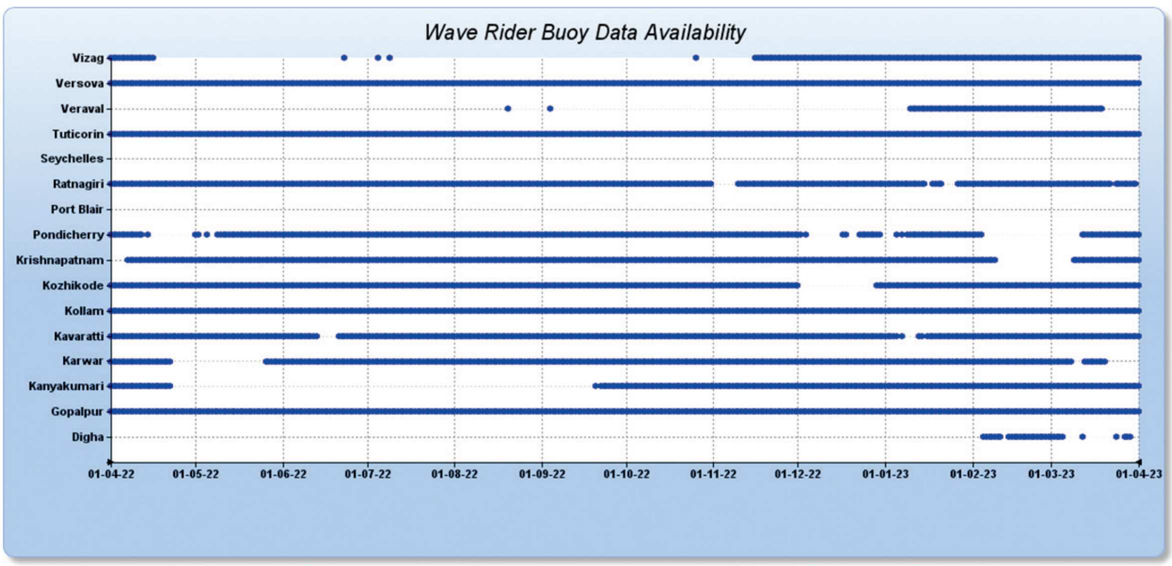


Figure 6.7 The data availability map from the wave rider buoy network from 01 April, 2022, to 31 March 2023.

OCEAN OBSERVATION NETWORK (OON)

6.8 Automatic weather stations

In collaboration with various national agencies, INCOIS maintained a network of 34 Automatic Weather Stations (AWS) in ships to measure wind speed and direction, air temperature, humidity, downwelling longwave radiation, downwelling shortwave radiation, rainfall, and barometric

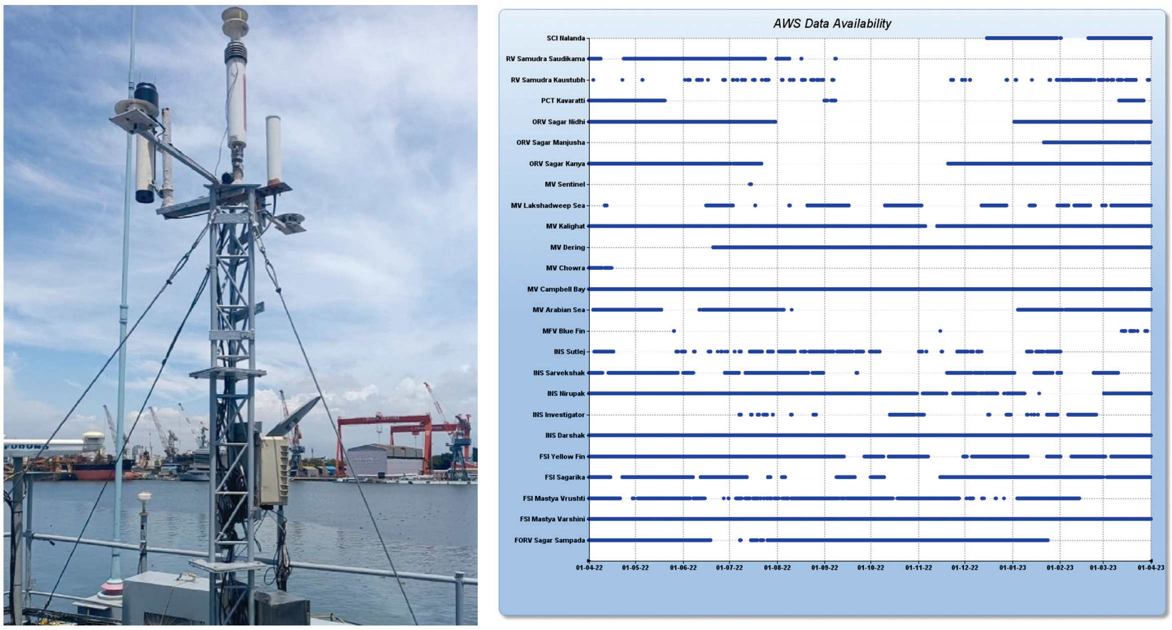


Figure 6.8 (left) The newly installed AWS onboard INS Investigator. (right) AWS data availability.

pressure in the Indian Ocean (Figures 6.8). The real-time data from this network is relayed to INCOIS via INSAT. The deployment of an AWS onboard the INS Investigator was successful. During the fiscal year, INCOIS renewed the annual maintenance and calibration contract, and the network is currently being revived. The AWS systems maintenance was carried out based on in-house monthly quality assessment statistics. During the fiscal year 2022-23, 42 preventive maintenance actions were carried out.

6.9 Coastal Water Quality Monitoring Buoy

With an aim to initiate nowcasting and forecasting of coastal water quality, INCOIS established two 'Coastal Observatories' at two locations (Kochi and Vishakapattanam) along the Indian coast. Dr Jitendra Singh, Hon'ble Minister for the Ministry of Earth Sciences dedicated this observatory to the nation on 27 July

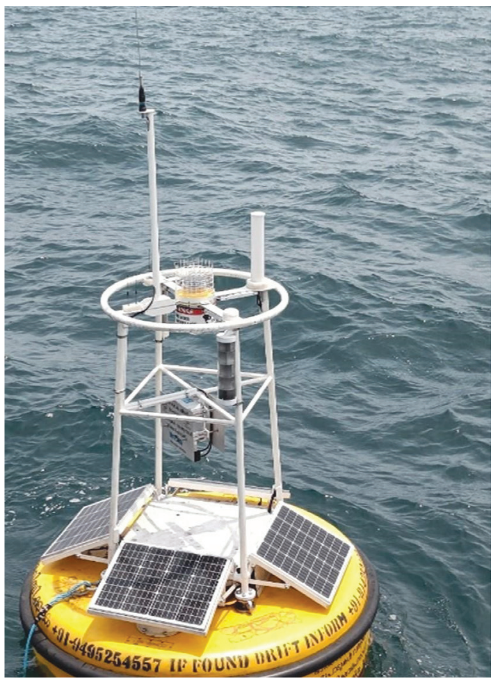


Figure 6.9 Coastal Water Quality Monitoring Buoy at Kochi

2022. The structure of coastal observatories is in the form of moored buoys equipped with multiple sensors to measure the physical (temperature, salinity, depth, surface current) and water quality (dissolved oxygen, nutrients, chlorophyll, turbidity, pH, pCO_2) parameters. The buoys deployed at approximately ~ 30 m water depth (~6-8 km from the coast). The measurement period of a buoy, after its deployment, is approximately three months, and the buoys are periodically replaced/redeployed. During 2022-23, the coastal observatory at Kochi was deployed in April, May, and October 2022 and at Visakhapatnam in June 2022. The real-time data of these buoys are made available on the INCOIS website.

6.10 GNSS& SMA Network maintained at Andaman & Nicobar Islands

INCOIS has planned to establish Global Navigation Satellite System (GNSS) and Strong Motion Accelerometer (SMA) network in Andaman and Nicobar Islands at 35 locations. Half-yearly preventive maintenance has been carried out successfully at all SMA stations in Andaman and Nicobar Islands. At present, the construction of the recording room at 32 sites is completed. During the reporting period, the GNSS receiver and its accessories were successfully commissioned and installed at Wandoor in January 2023. As of now, 31 GNSS sensors and 32 SMA sensors have been commissioned (Figure 6.10). The construction of the recording room at the remaining three sites is in progress.

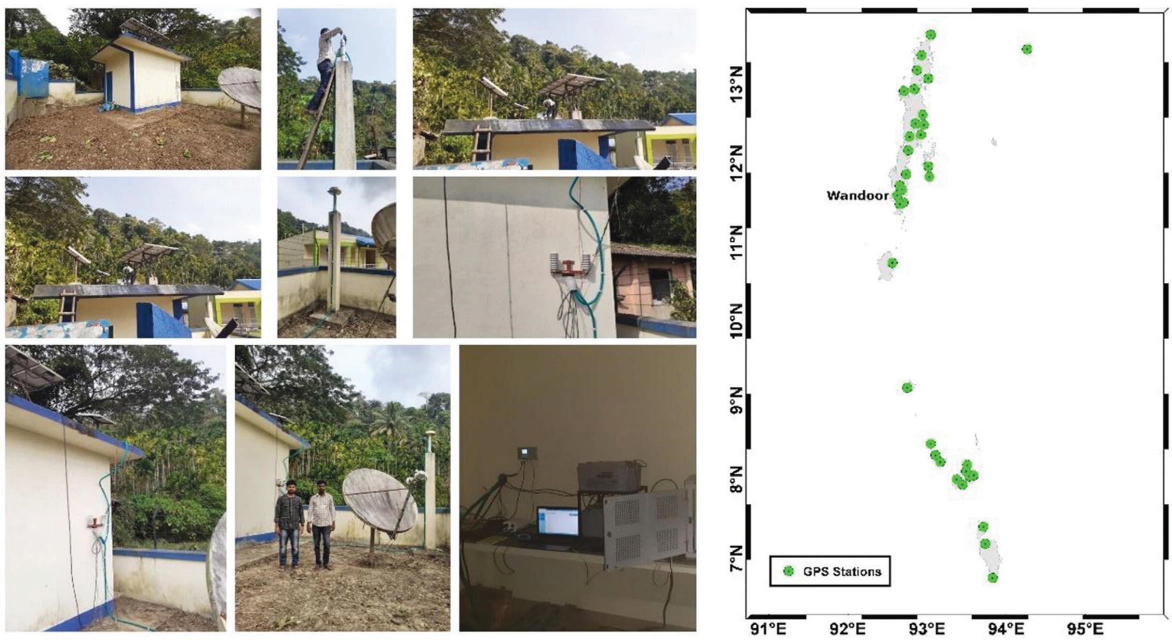


Figure 6.10. (left) Installation of GNSS receivers at Wandoor site during 16 to 20 January 2023. (right) Location map of GNSS and SMA network at Andaman and Nicobar Islands. The newly installed GNSS receiver at Wandoor is highlighted.

6.11 Deep Ocean Mission: Glider's operation in the Bay of Bengal

To achieve the objectives outlined under the Deep Ocean Mission's Ocean Climate Change Advisories development component, two Slocum Gliders (SG890 and SG891) were deployed in the Bay of Bengal on 08 March 2023 during the scientific cruise onboard ORV Sagar Manjusha (SAMA-14) (Figure 6.11). The gliders are capable of measuring physical and biogeochemical characteristics of the water column in the upper 1000 metres in the northern Indian Ocean. Vandalism compelled us to recover SG891 on 18 March 2023, however, SG890 is currently making a meridional transect along 88.5°E from 13°N to 5°S.

Figure 6.11. Deployment of Slocum gliders in the Bay of Bengal during March 2023.

6.12 Shipborne Eddy Covariance Flux Observations

INCOIS designed and constructed a bow mast onboard RV Sagar Nidhi as a permanent solution to fix the meteorological instruments onboard to collect data in October 2022. In January 2023, the Eddy Covariance Flux System (ECFS) was installed in the new bow mast onboard Sagar Nidhi (Figure 6.12a). With ECFS installation, RV Sagar Nidhi has become a unique oceanographic platform that collects high-accuracy and direct air-sea flux observations for oceanographic research applications. Currently,

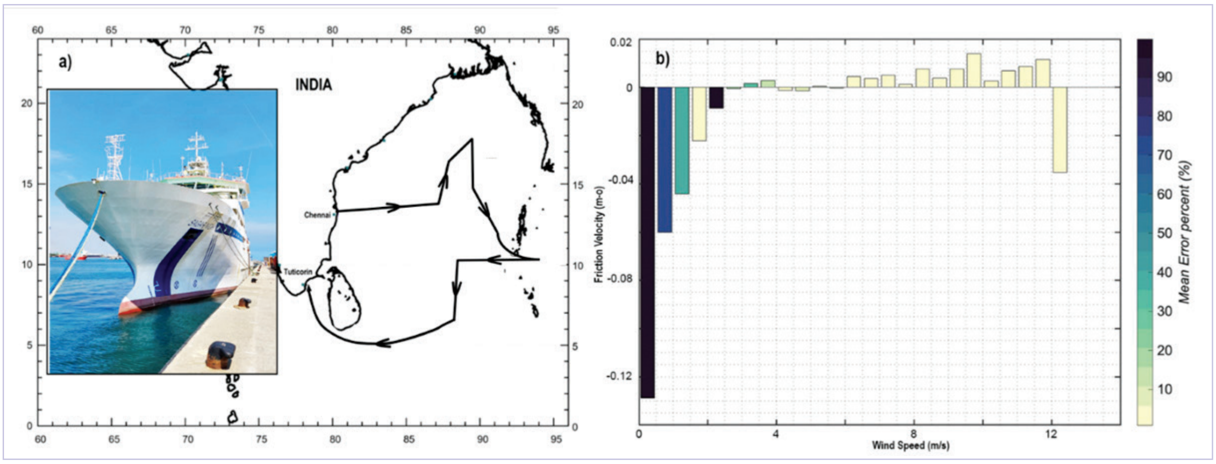


Figure 6.12. (a) The RV Sagar Nidhi cruise track (SN172) in the Bay of Bengal from 21 January 2023 to 21 February 2023. The inset map in panel (a) represents the newly constructed bow mast onboard Sagar Nidhi. (b) Bias in friction velocity between the estimation from Wave Watch III and ECFS measurements as a function of mean wind speed.

the ECFS continuously collects data from the north Indian Ocean basins. Efforts to upgrade the ECFS with additional sensors to collect concurrent bulk flux measurements are underway. The ECFS data collected as part of Sagar Nidhi cruise (SN172) from 21 January 2023 to 21 February 2023 are being processed to analyse the performance of wave forecasting models (Figure 6.12a). Preliminary results indicate that the Wave Watch III model, which INCOIS is using for wave forecasting applications, has an inherent limitation in forecasting accuracy in low winds (Figure 6.12b). This deficiency is due to the model's inability to parameterise the friction velocity accurately in low winds.

6.13 National Glider Operations Facility (NGOF)

INCOIS is in the process of acquiring a fleet of 12 gliders in the coming years to meet the need for various observational projects such as Deep Ocean Mission (DOM) and process-specific observational studies. After each mission, these gliders must be refurbished as soon as possible to get them ready for the next expedition. Considering this operational requirement, it is planned to construct a National Glider Operations Facility (NGOF) at INCOIS to avoid the delay between shipping the instrument to OEM and receiving it back. NGOF at INCOIS was inaugurated on 03 February 2023 by Dr. M. Ravichandran, Secretary, MoES, and it is operational now (Figure 6.13). The facility fosters simultaneous piloting of the glider fleet along with its testing, ballasting and routine maintenance. NGOF is capable of handling 20 to 25 Gliders regardless of what type of vehicle we are operating, and over a period, this centre may treasure the development of a new system.

Figure 6.13 (Top panels) Inauguration of NGOF on 03 February 2023 by Dr M. Ravichandran, Secretary, MoES and (bottom panels) inside view of NGOF at INCOIS.

7

OCEAN MODELING & DATA ASSIMILATION

7.1 Numerical Ocean Modeling and Data Assimilation for Operational Services

INCOIS has been augmenting the operational ocean state forecast system with targeted research in improving the performances in ocean forecast, analysis and reanalysis in the Indian Ocean. The operational ocean forecast/analysis system, named as Indian Ocean High Resolution Operational Ocean Forecast and reanalysis System (IO-HOOFS) comprises of the ocean general circulation model Regional Ocean Modeling System (ROMS) coupled with an ensemble-based data assimilation system called Local Ensemble Transform Kalman Filter (LETKF) and a marine ecosystem model.

7.1.1 Improvements in currents estimation with SLA Assimilation

The present operational data assimilation system RAIN (Regional Analysis of Indian OceaN) is augmented with assimilation of satellite track data of sea level anomaly (SLA). This assimilation has been done in two steps. In step one, all available in-situ temperature and salinity profiles along with satellite track data of SST are assimilated. Thereafter, the steric height from the analysis is estimated at all locations. Since the sea level anomaly output from ROMS does not contain steric height information, this steric height is deducted from the SLA observations and the residue is assimilated to the model using LETKF. Currents, that are independent variables, showed significant improvements with SLA assimilation (Fig. 7.1).

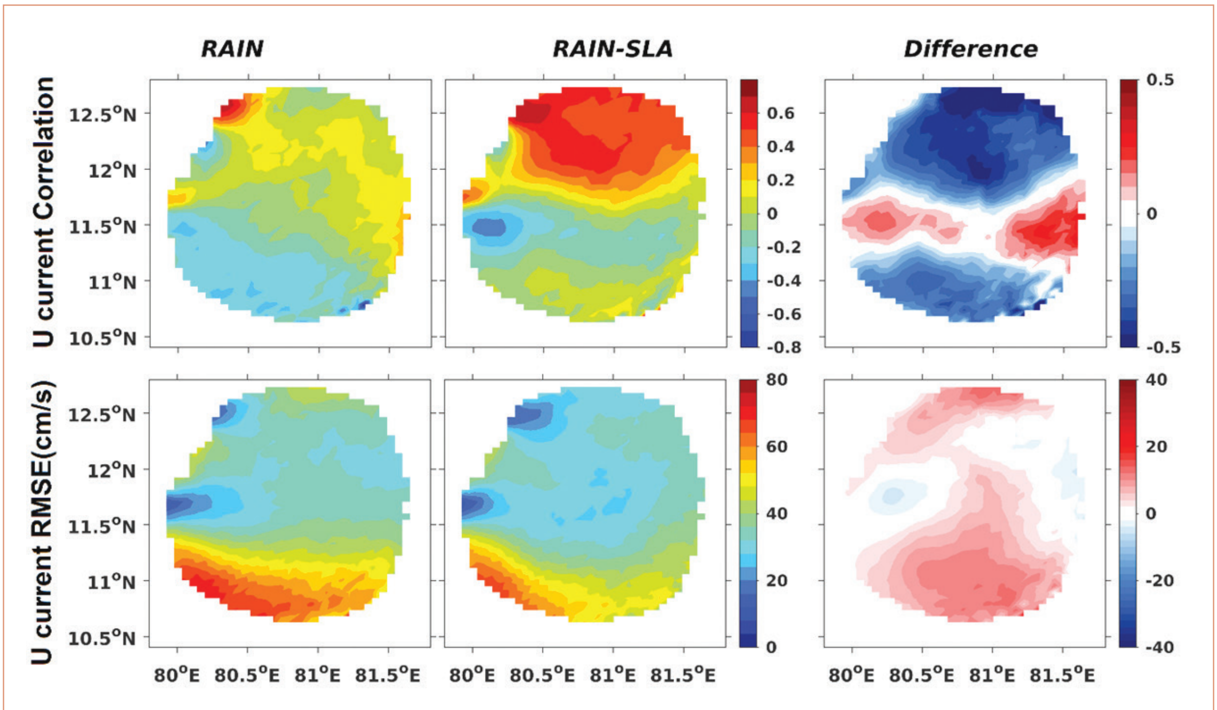


Fig 7.1 Correlation and RMSE (cm/s) of the zonal velocity near Tamil Nadu coast from RAIN and RAIN with SLA (RAIN-SLA) assimilation with respect to zonal velocity obtained from HF-RADAR. Negative (positive) difference in correlation (RMSE) indicates improvement (degradation).

Eddies are gyrating time-varying circulations of horizontal scale ranging from centimeters to around a few hundred kilometers, and a temporal scale ranging from seconds to several years. Eddies are one of the most important and dynamic features of oceanic circulation. They play a crucial role in transporting heat, salt, and nutrients across the oceans. The number of eddies over Arabian Sea (AS) and Bay of Bengal (BB) are underestimated by a free model with K Profile Parameterization (KPP) and Mellor-Yamada (MY). The free model (without data assimilation) underestimated the number of observed eddies by ~ 30-33% in the Arabian Sea and 12-15% in the Bay of Bengal. After the assimilation of sea level observations, the model managed to reproduce 91% of the number of mesoscale eddies in the Arabian Sea and 97% of the mesoscale eddies in the Bay of Bengal. This highlights the improvement in eddy estimation due to assimilation of sea level anomaly observations (Fig. 7.2). The assimilated system however still falls short in reproducing the location of eddies.

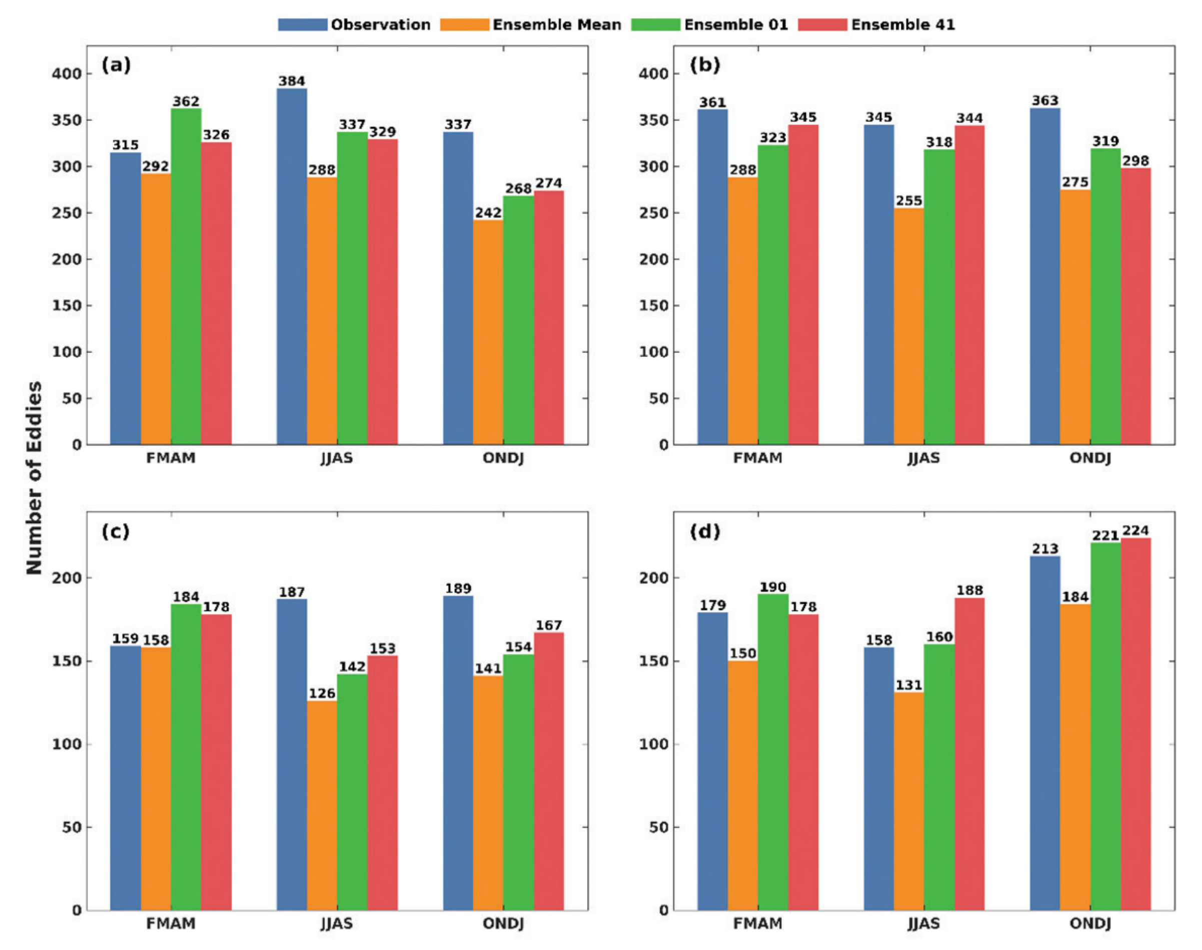


Fig 7.2 The number of anticyclonic and cyclonic eddies in the seasons FMAM (February-May), JJAS (June-September), and ONDJ (October-January) in AS (a and b) and BB (c and d) using AVISO SLA observation data and assimilated Model data of LETKF Ensemble member with KPP mixing scheme, member with MY mixing scheme, and the Ensemble mean for the period 2019 to 2021.

7.1.2 INCOIS- Global Ocean Analysis System (GODAS)

INCOIS-GODAS is a global ocean modelling system based on Modular Ocean Model (version 4.0) with a 3DVAR data assimilation system to assimilate all available quality-controlled T/S profiles. INCOIS continued to provide the initial conditions based on this INCOIS-GODAS analysis to force the CFS models of IITM and IMD, used for the extended and seasonal prediction of monsoon. Additionally, INCOIS provided climatic indicators such as NINO indices, IOD index, anomaly maps of Sea Surface

Temperature, and the longitude-depth section of temperature in the equatorial Pacific (Fig. 7.3), etc. generated based on INCOIS-GODAS to IMD for the preparation of climatic outlook. This information is critical for the seasonal prediction of monsoon. To support IMD's cyclone forecasting service, INCOIS also provides tropical cyclone heat potential estimates. In addition, INCOIS-GODAS also provides lateral boundary conditions to the regional IO-HOOFS modelling system.

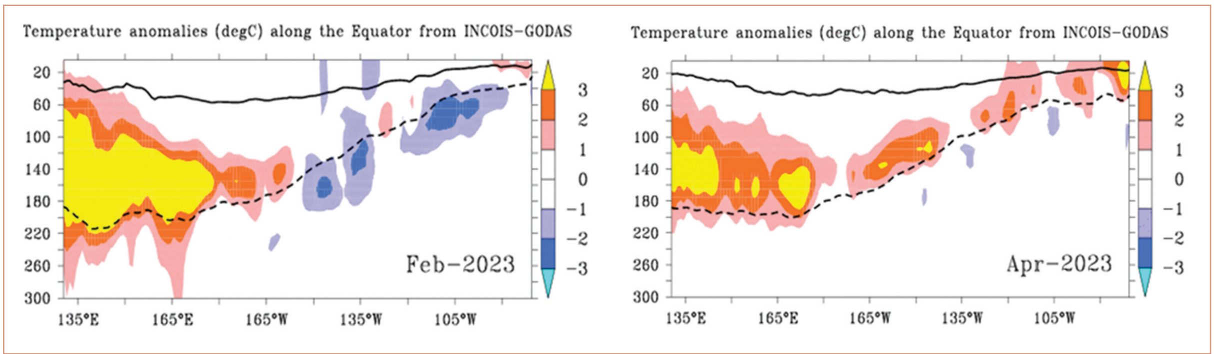


Fig 7.3 Depth-longitude section of the (5° S-5° N) region averaged temperature anomaly (ºC) for the month of February and April, 2023 for the Pacific Ocean longitudes. Anomaly is computed with respect to WOA09 monthly climatology. The solid black line represents the mixed layer depth whereas the dashed black line indicates thermocline depth (20° C isotherm). Subsurface temperature distribution in the equatorial Pacific during Feb 2023 shows warmer (cooler) than normal conditions in the western (eastern) parts. However, by April, positive anomalies extended to the eastern equatorial Pacific ndicating a possible gradual shift towards El-Nino phase.

7.1.3 Biogeochemical State of the Indian Ocean

The international carbon cycle research community is currently coordinating the largest, most comprehensive assessment in the form of 'REgional Carbon Cycle Assessment and Processes Phase 2 (RECCAP-2)' to assist IPCC. RECCAP-2 is coordinated by the Global Carbon Project and collects and synthesizes regional data for 14 large regions of the globe with a requirement of harmonization sufficient to be able to scale these budgets to the globe and to compare different regions.

Within the ocean-specific part of RECCAP-2, a global consortium of partners aim to better quantify and understand the CO_2 fluxes into and out of the ocean, the associated changes in ocean carbon storage beneath the sea surface, as well as the role of the ocean's biological pump. The international community had submitted global and regional models' simulated surface ocean pCO_2 levels, air-sea CO_2 fluxes, and surface and interior ocean properties of a list of ocean state variables to the FTP Server hosted at MPI Jena, Germany, under RECCAP-2.

Accordingly, a regional high-resolution (1/12 degree) coupled ocean-ecosystem model (INCOIS-BIO-ROMS) for the Indian Ocean region was configured following the 'RECCAP-2: Ocean Modeling Protocol' for the regional oceans to participate in the above-mentioned assessment process. The model simulated data for a period from 1980 to 2019 had been submitted to the MPI-BGC data server. To identify the best models reproducing the real scenarios in the Indian Ocean basin, the evaluation of surface ocean pCO_2 levels and air-sea CO_2 fluxes has now been completed against available observations by the RECCAP-2 Indian Ocean chapter.

According to the results, the regional model configured by INCOIS performed equally well or even better in a few instances compared to the other twelve global hindcast models and another regional hindcast model (Fig. 7.4). Overall, regional models perform better than the global models for obvious reasons.

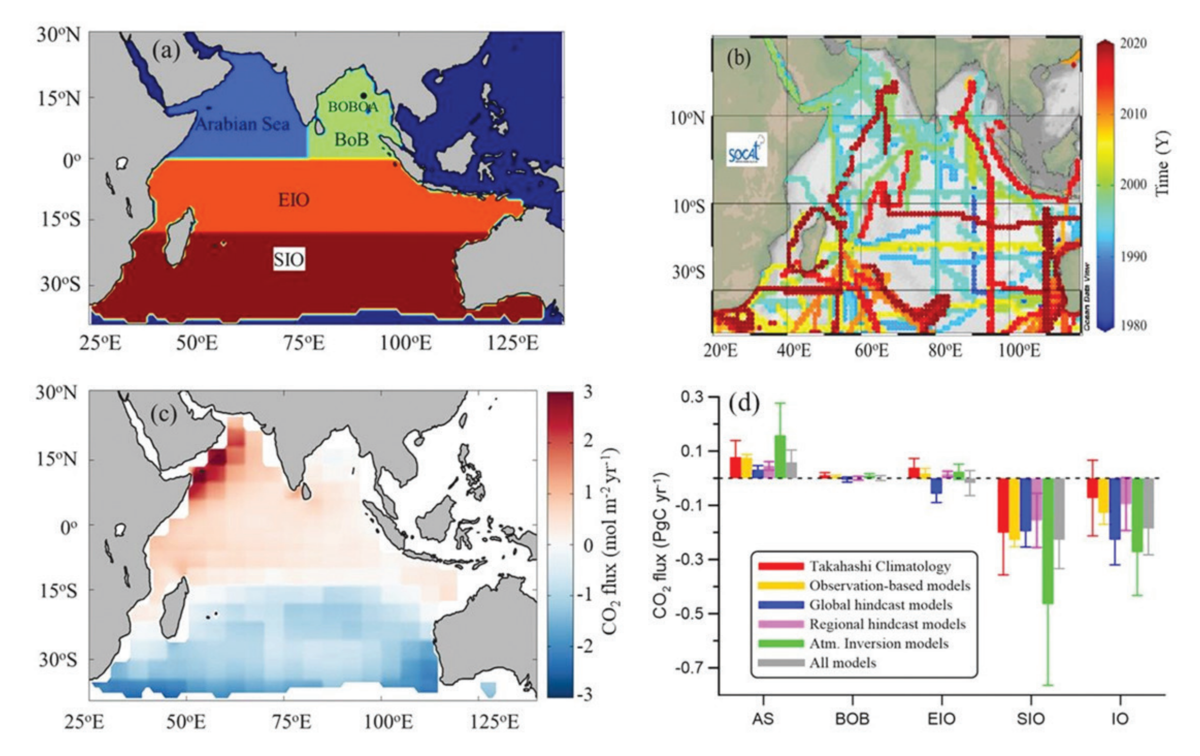


Fig 7.4: (a) Figure showing the sub-regions of the Indian Ocean used for synthesis: south Indian Ocean (SIO; Brown), equatorial Indian Ocean (EIO; red), Arabian Sea (AS; Blue) and Bay of Bengal (BoB; green). (b) Location of SOCAT observations of oceanic pCO_2 collected since 1958. (c) CO_2 flux climatology based on the observations and interpolated to a 4° × 5° grid and (d) annual mean uptake from climatology, hindcast, empirical and atmospheric inversion models (PgC yr^{-1}) for the reference year of 2002. The error bars represent the standard deviation. The negative (positive) values represent fluxes into the ocean (atmosphere).

7.2 Ocean Modeling Mission – Development of a Unified Operational Ocean Forecast System

INCOIS is bestowed with the responsibility of providing operational ocean forecasts and analyses. INCOIS envisaged an extensive modeling system overhaul to improve its services but limiting itself to the use of a smaller number of models and consequently drew up a unified ocean modeling system framework under its Modelling Mission that shall eventually replace the existing operational models. The Global Ocean model shall be based on Modular Ocean Model version 6 (MOM6). It will be used to provide oceanic conditions for atmospheric state estimations at short/medium/extended range and seasonal forecast models of the Indian summer monsoon, short-term ocean state forecasts as well as the datasets used for preparing climate indices. It shall also provide boundary conditions to the finer resolution regional Indian Ocean model based on MOM6. The Carbon, Ocean, Biogeochemistry and Lower Trophic (COBALT) ecosystem model will be used to model the biogeochemical and planktonic food web response. The regional ocean model, also based on MOM6 and coupled with data assimilation, shall provide an improved ocean state forecast/analysis of the Indian Ocean at a finer scale compared to the global model. INCOIS also has the onus to provide information/forecasts/ advisories for the coastal waters around the country which is of primary importance to the coastal population of India. For example, tsunami and storm surge predictions have significant implications on the life and livelihood of millions living along the coastal regions whereas the forecasts on coastal currents, waves, tides etc have a daily bearing on the livelihood of the coastal populace. Whereas the Tsunami and Storm Surge predictions will be carried out based on the ADCIRC model coupled with SWAN, it has been decided to proceed with WAVEWATCH III for wave forecasts. The near coastal oceanic state including the water quality shall be predicted/analysed using Finite Volume Community Ocean Model (FVCOM) coupled to an ecosystem model. The developments of all these models are in progress.

7.2.1 Development of global/regional models for ocean analysis/ reanalysis

INCOIS now intends to adopt MOM6 as its future workhorse for global and regional scale ocean modelling as part of its unified modelling framework. The major objective is to replace the operational regional Indian Ocean ROMS and GODAS with a very high resolution MOM6 that simulates ocean circulation from a regional scale to a planetary scale.

MOM6 is a complex ocean general circulation model compared to its predecessors. It uses vertical Lagrangian remapping, a variation of the Arbitrary Lagrangian-Eulerian (ALE) method, to permit the selection of either a sigma, isopycnal, geopotential, or Z vertical coordinate system, or a hybrid vertical coordinate system. It is based on a horizontal C-grid stencil. Therefore, a bottom-up strategy has been employed, starting with a basic setup and gradually increasing the complexity. Thus, an Indian Ocean regional 0.25°×0.25° model is configured with 75 hybrid vertical layers. Temperature and salinity were relaxed at the open south and eastern boundary using a sponge layer. For the barotropic (2D) and baroclinic (3D) dynamical components, radiation boundary conditions (Flather and Orlanski) were applied. Also, surface salinity is relaxed to climatological salinity with a timescale equivalent to 15 days. This set-up was spun-up using NCAR climatological forcing for 7 years and then interannual simulations were carried out using NCMRWF forcing. The model could simulate the seasonal surface circulations reasonably well such as EICC, WICC, Somali current, Wyrtki jet, South Equatorial Current, East Madagascar current, etc (Fig 7.5). However, the magnitude of the simulated currents is underestimated compared to OSCAR.

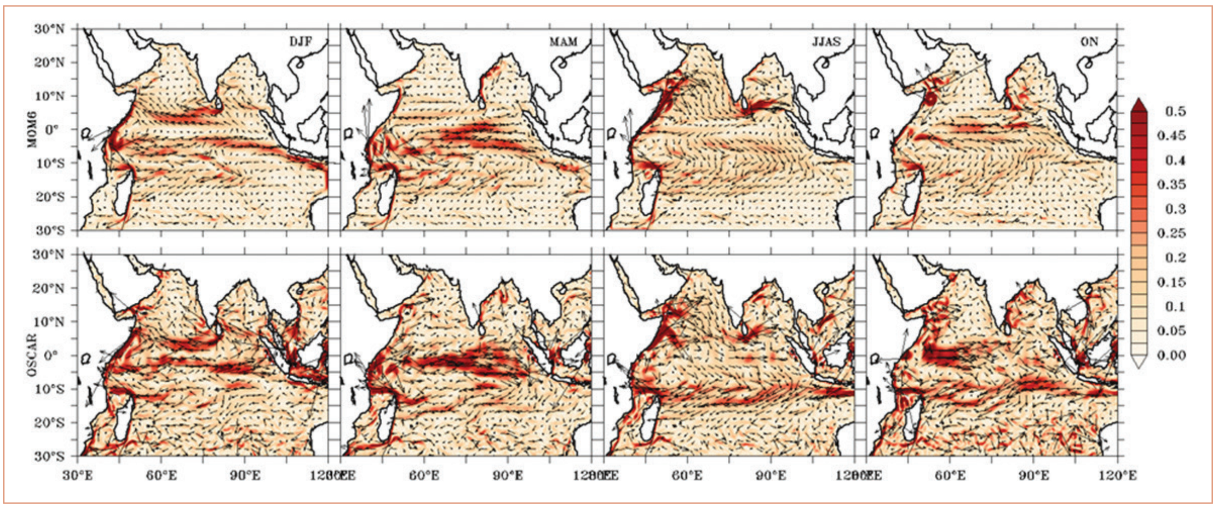


Fig 7.5 Seasonal surface current (m/s) from MOM6 (top) and OSCAR (bottom) for the year 2013.

River runoff from Dai and Trenberth (2002) climatology has recently been added to the system. The initial analysis shows a considerable improvement in the surface salinity. Furthermore, to identify the improvement of MOM6 over MOM5, a similar configuration is set-up and run using MOM5. A detailed comparison between these two model configurations is ongoing. We also initiated the development of a global 1/12° model in collaboration with Florida State University, under the Monsoon Mission.

7.2.2 Development of a global wave model

A high-resolution wave model was set up for the Global Ocean using WAVEWATCH III 6.07. This model has a grid resolution of 1/8° with a spatial extent of 0 – 360° E & 75° S – 65° N. The model grid uses Earth TOPOgraphy (ETOPO1) bathymetry and high-resolution coastline from Global Self-consistent Hierarchical High-resolution Shoreline Database (GSHSS). The propagation scheme used is third order Ultimate Quickest (UQ), while Ardhuin et al. source term package with no stability correction (ST4 STAB0) is selected for the model setup. The wave parameters such as significant wave height, periods, and wind speed were validated with available moored buoy data for the global ocean including the Indian Ocean. Satellite data was used for error estimation in two representative boxes – one in the central Arabian sea and another in the Southern Indian Ocean. The results of the evaluation show that the model performance is good with a high positive correlation ~0.9 for all the locations considered (Fig. 7.6). More validations are under way.

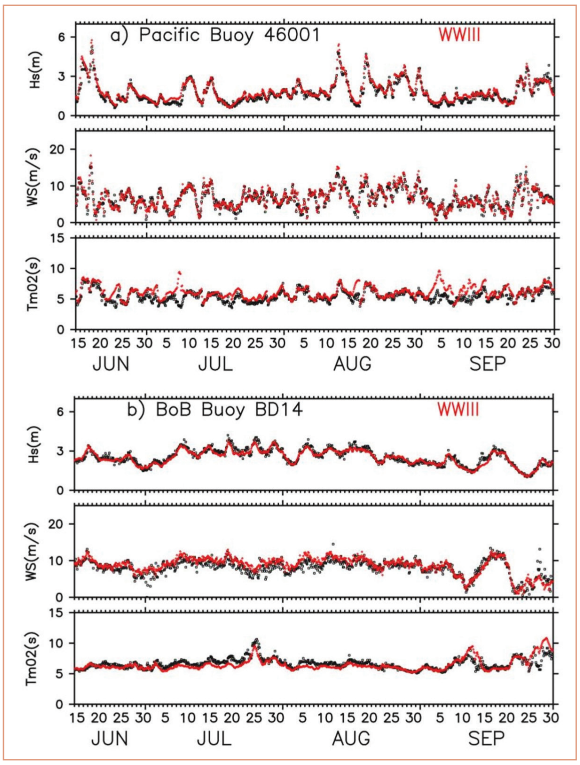


Fig 7.6: Evaluation of model performance at the (a) Pacific buoy 46001 and (b) Bay of Bengal buoy BD14 during June-September, 2018. The parameters compared are the significant wave height (Hs), wind speed (ws), and mean wave period (Tm02).

Table 7.1: Error statistics of significant wave height for two representative boxes in the central Arabian Sea and southern Indian Ocean using satellite data.

Region	Correlation coefficient	Bias (m)	RMSE (m)	Scatter Index
Central Arabian Sea	0.95	0.04	0.26	0.06
Southern Indian Ocean	0.92	-0.02	0.62	0.13

7.2.3 Development of coastal general circulation model

Finite-volume community ocean model (FVCOM) is a prognostic, unstructured-grid, Finite Volume, free-surface, three-dimensional primitive equations Community Ocean Model. Under the Ocean Modeling Mission of INCOIS to develop a Unified Operational Ocean Forecast System, FVCOM has been chosen to simulate the dynamics of Indian coastal waters. As a pilot study, a hydrodynamics model for Cochin coastal waters has been configured using FVCOM. The one-way nesting has been implemented for open boundaries using comparatively coarser NIO-HOOFS simulated hourly model outputs. A test run was conducted with this basic configuration. The details of the model configuration were reported earlier.

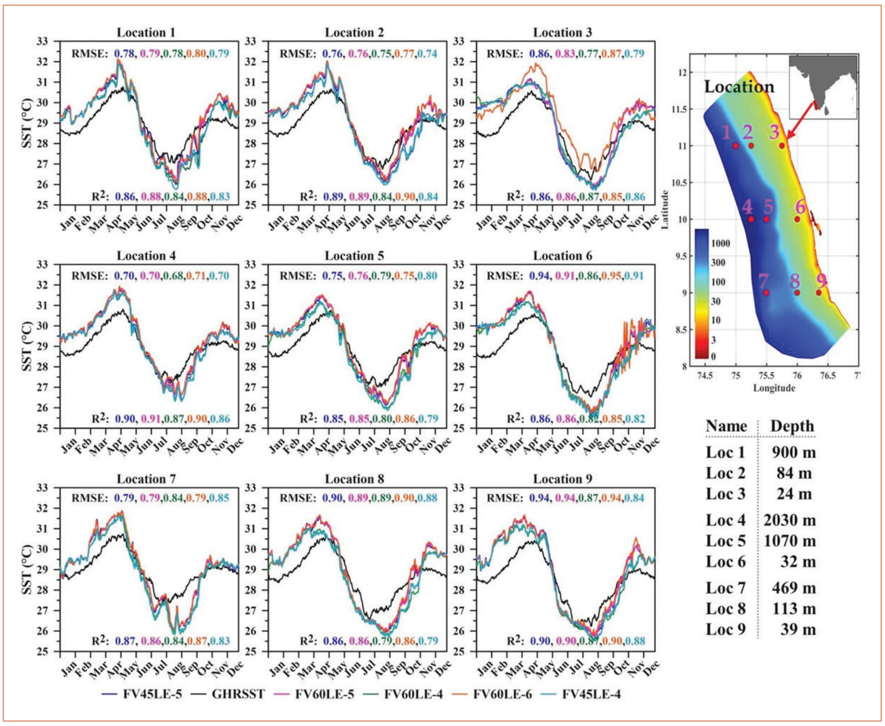


Fig 7.7: Temporal evolution of daily sea surface temperature (°C) obtained from GHRSST (black line), FVCOM with 60 vertical layers and vertical mixing coefficient 10^{-6} (orange line), FVCOM with 60 vertical layers and vertical mixing coefficient 10^{-5} (magenta line), FVCOM with 60 vertical layers and vertical mixing coefficient 10^{-4} (green line), FVCOM with 45 vertical layers and vertical mixing coefficient 10^{-5} (blue line) and FVCOM with 60 vertical layers and vertical mixing coefficient 10^{-4} (sky-blue line) at 9 different locations in the model domain (marked as red dots). The RMSE and R2 values calculated for the different FVCOM setups with respect to GHRSST are color coded accordingly.

To fine-tune the model state, several sensitivity experiments were conducted (Fig. 7.7). In these experiments, the model was forced with 3 hourly ERA5, JRA55 do, NCMRWF, and daily TROPFLUX atmospheric forcing fields such as 2 m air temperature, mean sea level pressure, relative humidity, zonal and meridional wind component, total precipitation, downward short-wave radiation and downward long-wave radiation. Out of the four atmospheric reanalysis products mentioned above, ERA5 performed relatively better in simulating the physical state of the ocean. Sensitivity experiments were done with varying horizontal and vertical mixing coefficients. Further, the hybrid vertical coordinates were changed to the general vertical coordinates capable of stretching surface and bottom depths. The model reproduced a relatively better ocean state with the general vertical coordinates. Additional model sensitivity experiments are underway with the general vertical coordinates to further fine-tune the model state. The horizontal and vertical mixing are prescribed, respectively, using Smagorinsky and Mellor and Yamada level 2.5 turbulence closure schemes. FVCOM could reproduce the observed seasonal cycle of physical state of the Cochin waters reasonably well.

7.2.4 Development of marine ecosystem models for regional and coastal applications

The European Regional Seas Ecosystem Model (ERSEM) is a very complex ecosystem model describing marine biogeochemistry, pelagic plankton, and benthic fauna. Its functional types are based on their macroscopic role in the ecosystem rather than species, and its state variables are the major chemical components of each type (carbon, chlorophyll a, nitrogen, phosphate, silicate and, optionally, iron). Although the integration of ERSEM with physical FVCOM configuration has been successfully done as a pilot study by enabling their coupling via a universal generic coupler, Framework for Aquatic Biogeochemical Models (FABM), this coupled set-up can't be used for understanding the coupled model dynamics through coupled model sensitivity experiments as it is extremely computationally expensive. Therefore, a relatively simple biogeochemical model based on NPZD/NPD dynamics has been chosen for conducting coupled model sensitivity experiments. The biogeochemical model has been integrated with physical configuration of FVCOM using Generalised Ecosystem Module. Considering the complexity of the coastal ecosystem dynamics, FVCOM-FABM-ERSEM coupled model sensitivity experiments will be carried out to adequately simulate the coastal marine ecosystem dynamics at a later stage. The same methodology will be extended to all the location-specific physical FVCOM configurations along the Indian coastal waters to meet the operational requirement of water quality forecasts.

7.2.5 Development of river forcing files for simulating the coastal marine ecosystem

Biogeochemical modelling is highly essential to understand the complex ecological processes, especially in the coastal zones, including estuaries. Additionally, accurate prediction of individual environmental parameters through biogeochemical modelling is the major input of different marine ecological services. To set up a well-performing biogeochemical model, regional parameterization with regional boundary conditions is highly essential. The Indian coastal waters are highly influenced

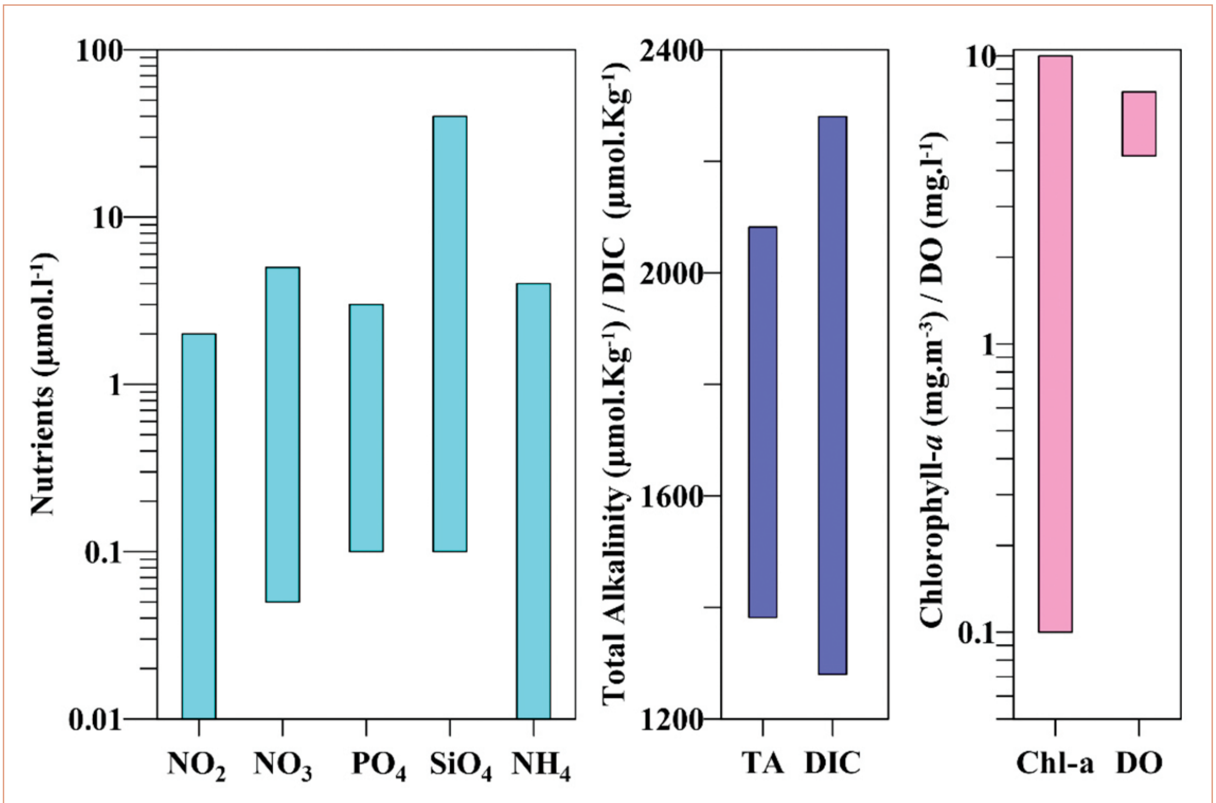


Fig 7.8: Dynamic range of biogeochemical variables based on frequency distribution analysis, in the Indian coastal waters (DO: Dissolved Oxygen; NO_2: NO_3: Nitrate, NH4: Ammonium; PO4: Phosphate; SiO4: Silicate; DIC: Dissolved Inorganic Carbon)

by the reversing monsoon currents, seasonal upwelling, river influx and terrigenous discharge. Therefore, it is essential to define the values of environmental parameters for defining the boundary by considering the controlling factors and seasonality. In order to accomplish this, frequency distribution analysis was carried out for the entire dynamic range of the key environmental parameters that have been reported over the years across a wide spatio-temporal scale in Indian coastal waters (Fig. 7.8).

7.3 Development of Ocean Climate Change Projections

INCOIS is spearheading 'Development of Ocean Climate Change Advisory Services (OCCAS)' underlined in the mission mode project known as the "Deep Ocean Mission" initiated by the Ministry of Earth Science (MoES) to ascertain the impacts on the ocean state due to climate change and enhance our understanding of the sustainable use of marine resources.

The OCCAS program aims to predict the long-term sea level changes, changes in the intensity of cyclones, storm surges and waves and consequently their impacts on the coastal community ranging from coastal erosion to the extent of inundation. This project shall eventually lead to improved policy decisions on how to mitigate coastal damages due to climate change. Another major thrust area is to assess the impact of climate change on the coastal marine ecosystem and create advisories on the likelihood of intensity and spread of Harmful Algal Blooms that may impact the future potential migration of fishing zones and adversely contribute to the marine-driven economy along the long coastline of India. The above-mentioned thrust areas are divided into five different modules for implementation with the help of well-designed observing and monitoring networks and a suite of modeling frameworks.

Finally, the outcomes of all the modules in terms of climate assessments will be provided through interactive GIS-based mapping applications so that they can be effectively utilized for coastal zone management and policy decisions.

7.3.1 Sea level Projections

As part of the Deep Ocean Mission, INCOIS has taken up the responsibility to provide robust sea level projections for the coastal waters of India using statistical downscaling and dynamical ocean models.

The dynamic sea level is one of the main contributors to the regional sea level change. Alteration in the ocean circulation and the steric effect cause the dynamic sea level to change. Coupled climate models (CMIP6) are used for global estimates of mean dynamic sea level change in the latest IPCC AR6 report. But, owing to their coarse resolution, these models are not useful for regional assessments. Hence, an improved estimate by downscaling the dynamical sea level projection using high-resolution ocean models is planned. This downscaling involves the following steps:

Selection of atmospheric forcing

In order to force the ocean model, atmospheric forcing fields are necessary. CMIP6 atmospheric projections are planned to be used for the same. However, all the CMIP6 models are not representative of the Indian Ocean conditions, and thus, using them for high-resolution ocean model simulations will be counterproductive. In order to avoid this problem, an exhaustive analysis of 27 CMIP6 models was carried out. Historical simulations from these models were compared with the observations from the Indian Ocean, and the best 10 models are selected for preparing the atmospheric fluxes to run the high-resolution ocean models.

Preparation of forcing

Atmospheric forcing from these selected models cannot be used directly for running the ocean models primarily because of two reasons: first, the mean of these atmospheric fluxes can be quite different than the forcing used for model spin-up and second, owing to their coarse resolutions, these model produce very weak intraseasonal variabilities which are important for internal variability of the ocean. Hence, a new set of projected atmospheric forcing fields are created by infusing atmospheric mean and intraseasonal fields from ERA5 reanalysis onto the CMIP6 projections using time-varying delta method (Fig. 7.9).

Model simulation

To test the projected forcing fields, existing operational Indian Ocean 1/12° ROMS is used. Currently, the model was run using two reconstructed CMIP6 atmospheric forcing fields from CNRM-CM6-1HR and HadGEM3-GC31-MM under SSP585 scenario. In comparison to the coarser CMIP6 model, the preliminary study indicates that ROMS is highly capable of capturing historical mean. The detailed analysis of the ROMS projections is underway.

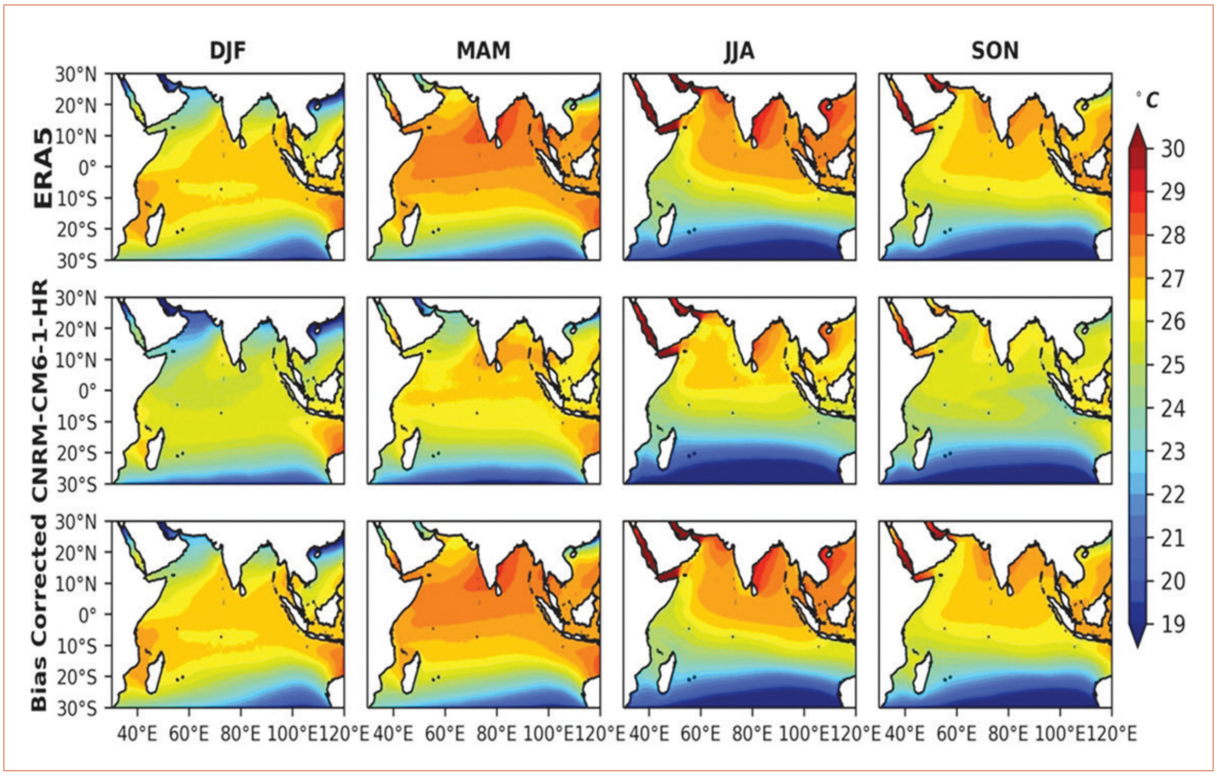


Fig 7.9: Comparison of mean seasonal average (1980-2010) of 2 m air temperature from ERA5, CMIP6 (CNRM-CM6-1-HR) and the bias-corrected field.

Steric effect

Seawater expansion, also referred to as steric effect, contributed ~49% of the observed sea level rise over the recent decades. However, this effect cannot be calculated by the CMIP6 models as they are volume-conserving. Hence, the model produced thermosteric expansion cannot be used directly for estimating the sea level change. Therefore, in the IPCC AR6 report, to produce projections of ocean heat content (OHC) and global mean thermosteric sea level (GMTSL) rise consistent with the equilibrium climate sensitivity and transient climate response, a two-layer energy budget emulator was employed.

These methods were explored in detail, and the expansion efficiency coefficient that relates GMTSL and OHC for the two-layer emulator was derived for the selected CMIP6 models. This enabled us to estimate the thermosteric effect on the sea level rise for each of these individual models. Currently, we have used CMIP6 simulations for deriving these coefficients but will be replaced by the high-resolution ocean model simulations once available.

7.3.2 Projections of Biogeochemical State of the Indian Ocean

The CMIP6 models provide a long-term prediction of the biogeochemical variables in the world ocean. One of the limitations of these models is their coarse resolution. These models cannot resolve high-resolution dynamical processes. The errors of the global models are not uniform over the globe. For example, the modeled sea surface temperature (SST) errors are often largest along the continental margins and shorter time-scale (seasonal). On the other hand, regional models have shown significant skill in modeling coastal processes. This creates the opportunity, and perhaps necessity, to develop multi-scale numerical solution schemes that adapt the resolution in specific areas of interest. One approach to achieve high-resolution climate-scale simulations in a given domain is the nesting of a high-resolution limited-area grid within a lower resolution large-scale numerical domain. With a nesting approach, information is downscaled from the coarser to the finer resolution region through an overlap in the domains. The high-resolution nest can explicitly resolve smaller scale features missing from the large-scale model simulation. Our goal is to develop a regional coupled high-resolution model to provide future projections of the biogeochemical state of the Indian Ocean along with uncertainties under different climate change scenarios.

The boundary conditions, initial conditions, and atmospheric forcing will be provided from the CMIP6 model to the regional ocean model for future predictions. Hence the initial job will be to select suitable models which could provide all the variables (physical oceanic, biogeochemical oceanic, and atmospheric). As these CMIP6 models have a coarse resolution

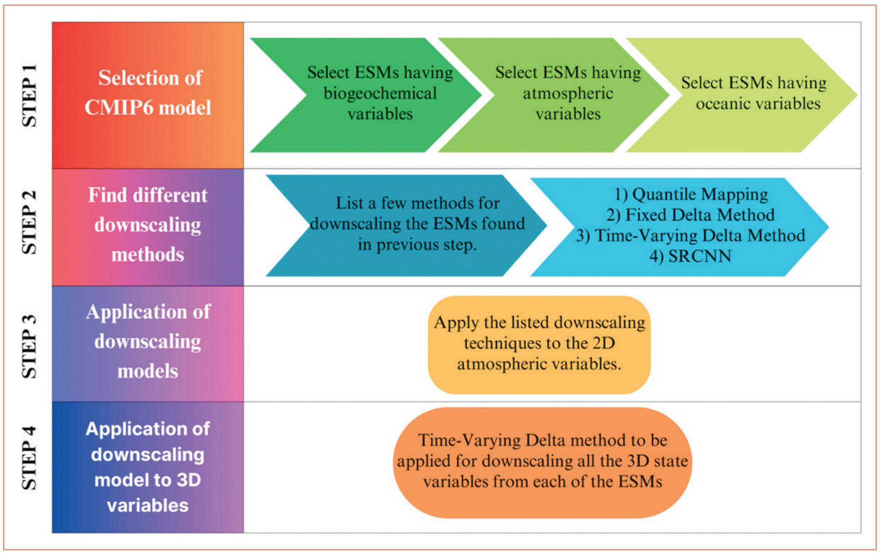


Fig 7.10 Schematic diagram shows selection of CMIP6 models and downscaling of forcing fields for the projections of biogeochemical state of the Indian Ocean.

OCEAN MODELING & DATA ASSIMILATION

so statistical downscaling (interpolation + bias correction) is necessary before providing the data from these models to general circulation models. The roadmap to select models from CMIP6 and how to downscale each of these models is shown below (Fig. 7.10).

7.3.3 Wave climate Projections

As part of the Deep Ocean Mission, INCOIS has taken up the responsibility to provide robust wave climate projections for the Indian Ocean (IO) region. Coupled climate models (CMIP6) do not provide ocean surface wave projections. Hence INCOIS need to come up with a WAVEWATCHIII (WWIII) model setup in the IO region for wave climate projection. This necessitated the evaluation of the source term packages in the WAVEWATCH III model for the Indian Ocean to identify the best scheme which works for the IO region under various conditions.

WWIII V6.07 were used and the model setup has four mosaic grids (Global (0°-360°, 80°S-70°N), Indian Ocean (30°E-120° E, 60°S-30°N), North Indian Ocean (32°E-100°E, 5°S-29°N) and Coastal (68.5°E-89°E, 3.8°N-24°N)) in a nested pattern. WWIII nesting ensures a two-way exchange of information between overlapping grids. The spatial resolution varies from a coarser 1° global grid to a finer 0.04° coastal grid, and the grids are prepared using an automated grid generation package V2.2. Grids are generated using ETOPO1 bathymetry (1' arc length global relief bathymetry dataset). The model is forced with 3-hourly European Centre for Medium-range Weather Forecast (ECMWF) winds of 0.25°x0.25° and 3-hourly resolution. The performance of four different source terms packages (ST2, ST3, ST4, and ST6) of the spectral wave model WAVEWATCH III (WWIII) and their four tuned versions (named ST4-Exp1, ST4-Exp2, ST4-Exp3, ST6-Exp1) in simulating the Indian Ocean wave conditions over a wide range of weather conditions were evaluated. The performance of various schemes is validated against a suite of ground truth data, including buoy wave spectra, buoy wave parameters, and altimeter data in different weather conditions, which makes the study different from previous works on similar lines for IO.

One takeaway point from this analysis is that ST4-Exp1 simulates the wave conditions reasonably well in all weather conditions in the Indian Ocean, while ST6-Exp1 reproduces the cyclonic wave conditions well. However, there are practical difficulties in doing multiple runs with different source term packages, especially for providing timely forecasts of the waves in severe weather conditions. Based on the analysis, the ST4 scheme with tuned wind–wave interaction parameters of ($\beta = 1.33$) is suggested for forecasting purposes (Fig. 7.11). Present INCOIS global WAVEWATCHIII operational forecast setup has also been modified based on the study.

In another sensitivity experiment, it is identified that the Southern Ocean (SO) ice impacts the IO wave climate through swells and it is decided to include ice fields for the accurate climate projections. The sea ice extent in different seasons in the Indian sector of the SO varies largely, from a minimum of 74,208.5 km^2 in December-February to a maximum of 1,08,308.75 km^2 in September-November, and a wave model without this large sea ice extent is likely to grossly overestimate the wave production. Hence any change in the ice extent in the SO will substantially impact north Indian Ocean (NIO) through the SO swells. Thus, the study recognizes sea ice concentration in the SO as a critical factor in modifying wave characteristics in the NIO and underscores the need to include it in wave modeling for climate simulations.

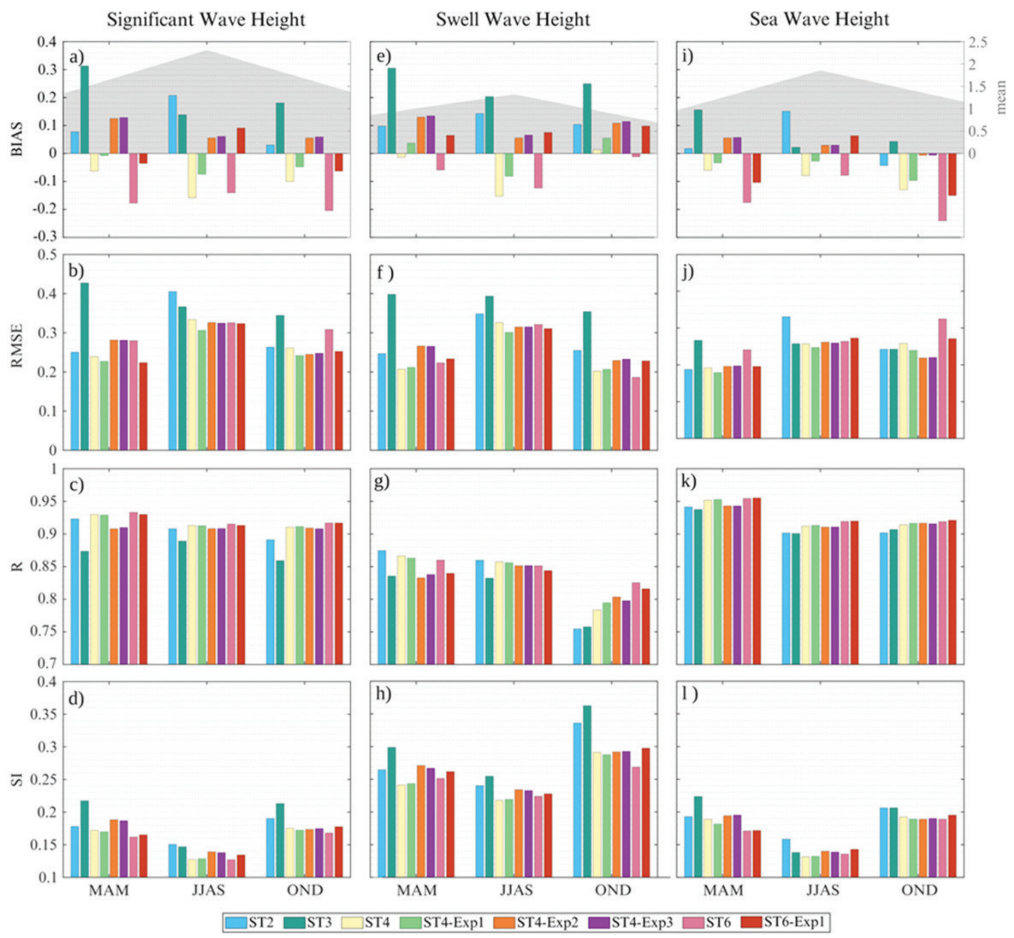


Figure 7.11: Model error statistics for significant wave height, significant swell height and significant sea height during different seasons (March-May (MAM); (June-September (JJAS); October-December (OND)) in north Indian Ocean.

The climate models do not provide ocean waves as a variable and hence identification of best CMIP6 wind fields for IO wave climate projection is compulsory and the work is in progress.

7.3.4 Future projections of storm surges and associated coastal inundation along the east coast of India

The tropical cyclones that make landfall along the Indian coasts have immense socio-economic implications. More than a hundred cyclones have hit the Indian coasts during the last five decades. The occurrence of tropical cyclones over the Bay of Bengal and Arabian Sea is therefore of great concern to India. Understanding the stochastic nature of extreme storm surges and their effects on coastal locations is crucial for efficiently designing coastal protection structures and planning for future coastal adaptations. A comprehensive study of storm surge projections considering climate change impacts is paramount for disaster preparation and future coastal infrastructure development activities. The current study analyzes storm surges and associated coastal inundation along the East Coast of India (ECI). The study utilized historical cyclone tracks over the past five decades. Synthetic tracks are projected for the next hundred years considering the impact of climate change. The ADCIRC model is used to compute storm surge heights and associated coastal inundation for historical and future cyclone tracks.

Figures 7.12(a) show the historic tracks that made their landfall along the ECI from 1972 to 2020 and Figure 7.12(b) shows the generated future synthetic tracks for the next 100 years (till 2120) that may land fall along the east coast of India. The generated synthetic tracks reveal that most coastal locations along the east coast of India will experience increased cyclone frequency and a 12% increase in peak wind intensity in the future projections due to climate change.

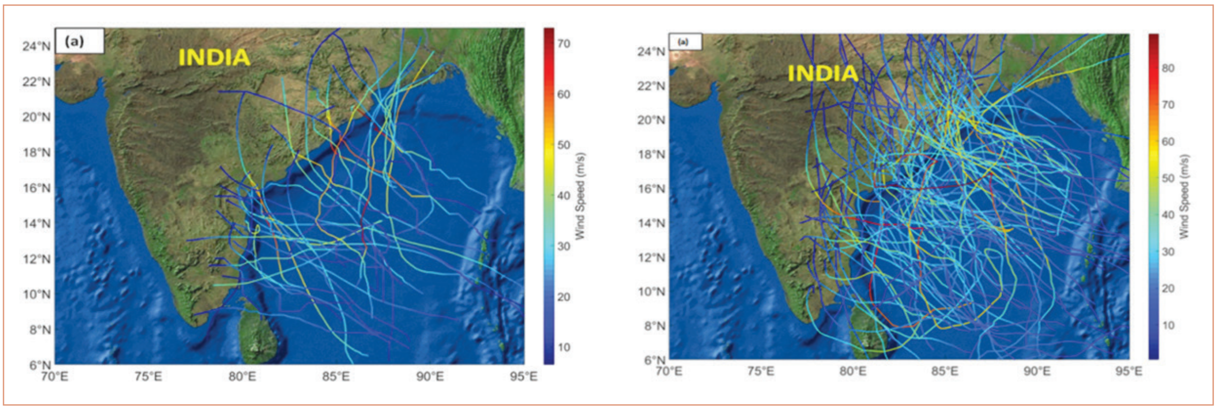


Figure 7.12: (a) Historic tracks that made their landfall along the ECI from 1972 to 2020 (b) Synthetic tracks generated for 100 years considering climate change.

Figures 7.13(a) and 7.13(b) show the storm surge composite maps for historical and future synthetic tracks obtained using ADCIRC. Figures 7.13(a) and 7.13(b) demonstrate that the coastal stretch that experiences storm surges greater than 2 m may grow drastically due to future cyclones. The inlet pie chart explains the percentage of the entire coastal stretch that experiences storm surge heights >0.5, >1, and >2 m; this chart is helpful for quick assessments.

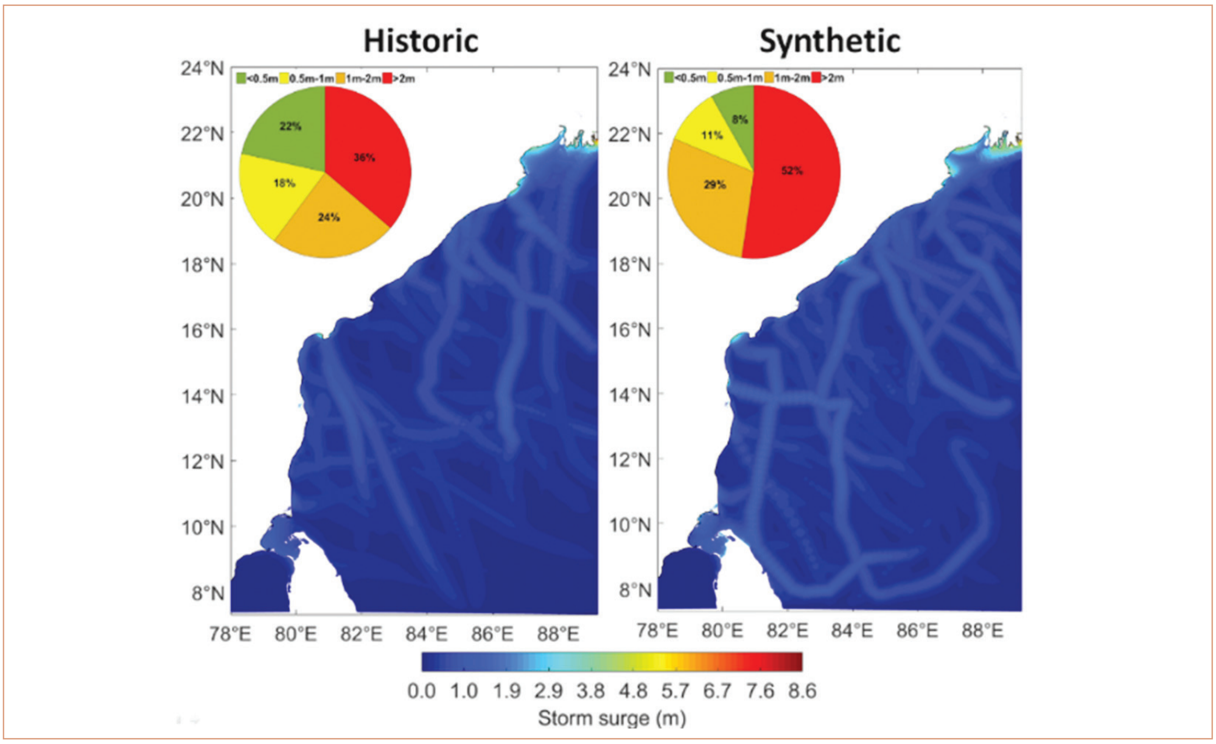


Figure 7.13: Storm surge composite maps using historical tracks that made their landfall along the east coast of India (ECI), and synthetic tracks that made their landfall along the ECI by 2120.

8

OUTREACH AND CAPACITY BUILDING

8 OUTREACH AND CAPACITY BUILDING

8.1 International Training Centre for Operational Oceanography (ITCOO)

During the reporting period, ITCOO conducted **12** training courses **(9 National and 3 International), 2 seminars** and **1 webinar**. In these courses, **669 persons** were trained, of which **550 (Male: 348, Female: 202)** are from India, and **119 (Male: 72, Female: 47)** are from 29 other countries. A short-term courses on "Advanced Operational Oceanography" for officers from Indian Navy were conducted successfully during 10 Oct 2022 to 28 January 2023.

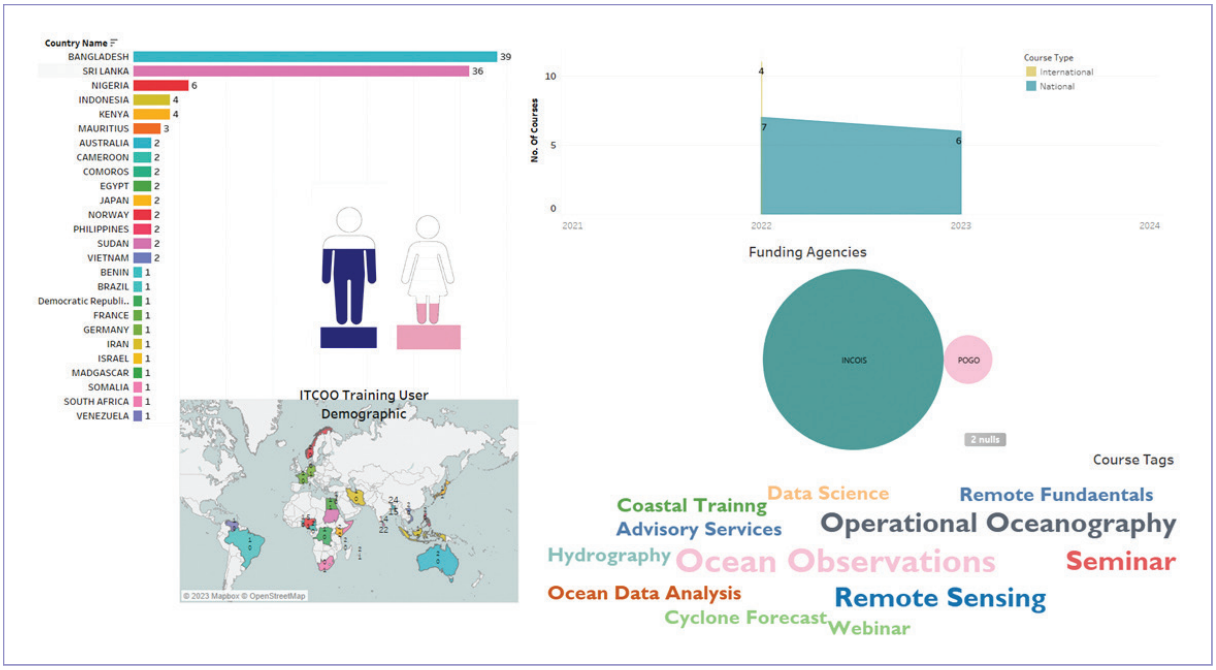


Figure 8.1 Analytics of the training courses conducted, topics covered, participant countries, agencies funded during the period April 2022 – March 2023

The third Governing Board meeting of **UNESCO Category – 2 Center** was held on **14 July 2022 online**.

The committee recommended the following activities:

- Feedback from member countries to be obtained to check their interest, local requirements, and design courses at ITCOOcean.
- On board scientific cruises-based trainings to be planned.
- Collaboration between ITCOOcean and RCOWA to be taken to a pragmatic level and joint programs to be taken up.
- Visiting professorship arrangements to be taken up.
- ITCOOcean to consider implementing action items proposed under MoU signed between IOC and IORA.
- New members from IOC member states are to be invited to be part of the Governing Board. Gender balance is to be maintained.
- Develop knowledge of the trainees to elevate their profile to make them part of policy-making in their respective countries.

The list of the training courses conducted during the year and brief details are given below:

- Training on **'Operational Oceanography, Marine Meteorology & Operational Ocean Forecasting, Warning and Advisory Services for offshore E&P industries (DG HC)' [13-14 June 2022].** This course was conducted to provide exposure to the National Institute of Hydrography Officers undergoing Advance Hydrography Course on the various products and services developed by INCOIS.
- The **"Advanced Operational Oceanography Course" 10 October 2022 – 28 January 2023**, As per MoU signed with Indian Navy for providing training support in the field of Operational Oceanography, Phase-I of Advanced Oceanography course for a duration of 16 weeks comprising of four officers was conducted between 10 October 2022 to 28 January 2023. The Phase-I focussed on theoretical and operational aspects of oceanography with special emphasis on Ocean State Forecasting Techniques, Dynamical oceanography and hands on with oceans models. The officers were taught and tested for their understanding by conducting mid-term and end-term exams, assignments, lab-visits, testing their programming knowledge. The officers were also made part of all international training conducted under the auspices of ITCOO and even made to take part in scientific cruise in Bay of Bengal. All the four officers were awarded certificates in the month of March 2023 marking the completion of their phase-I of their course.
- The **"Fundamentals of Remote Sensing and its Oceanographic Applications" 05 – 09 September 2022.** This course covered wide spectrum of subject dealing with how sensors capture Earth information and, how the atmosphere affects the data and how to correct it, how to quantify the ocean parameters with appropriate algorithms, and illustrate various oceanographic applications.
- The **"POGO - ITCOOcean Training Program on "Ocean Observations to Societal Applications", 31 October – 05 November 2022.** This course was conducted to develop capacity of Small Island Developing States (SIDS) from the Indian Ocean and the IO Rim countries including GOOS Members, POGO members, etc, to use ocean observations for societal applications.
- The **"OTGA-INCOIS Training Course: Ocean Color Remote Sensing, Data Processing & Analysis" 12 – 16 December, 2022.** This course was on ocean color analysis, a proven tool for determining the health of the ocean using oceanic biological activity through optical means.
- The **"Short Course on Data Science and AI", 16 – 23 February 2022.** This course was conducted to provide broad-based training in the tools and techniques that are basic to analyzing data that arise in several application areas.
- The **"Training Programme on Ocean Observation System and Models towards OSF, Coastal Dynamics, and PFZ" 20-23 February 2023.** This course was conducted to provide documentation on methodology, processes, and interpretation of various coastal process and model studies.
- **Report on Seminar: "The Oceanography of Tropical Cyclones", 08 August 2022.** Cyclones, or more generally Tropical Cyclones, have large impacts on subtropical coastal regions, particularly in North America and southern and eastern Asia. With climate change, we expect significant changes in these impacts.

8 OUTREACH AND CAPACITY BUILDING

- **Report on Seminar: "How will we measure the Ocean", 12 December 2022.** Over the last 50 years, many new tools have been developed to measure the ocean and its role in the overall climate system, including satellite remote sensing and robotic platforms of many types. Numerical models now assimilate some of this data to provide a real-time unified view of the ocean.
- **Report on Webinar: "Climate Change in the Indian Ocean region", 22 July 2022.** In this talk, Dr. Roxy Mathew Koll discussed how the Indian Ocean is rapidly changing and how it is affecting the food, water, and energy security of the region.

Figure 8.2. Advanced Operational Oceanography Course" 10 October 2022 – 28 January 2023

8.2 Webinars and Meetings

a) Tsunami Evacuation Planning Workshop

UNESCO-IOC implemented a multi-national project, "Strengthening tsunami early warning in the Northwest Indian Ocean region through regional cooperation," funded by United Nations ESCAP Trust Fund. A National Working Group for Tsunami Evacuation Planning (NWG-TEP) is constituted as

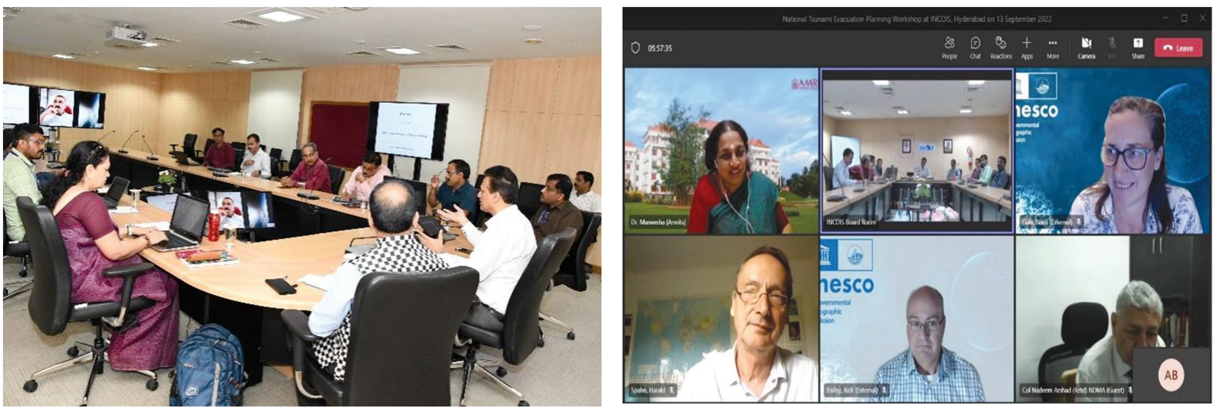


Figure 8.3. Tsunami Evacuation Planning workshop on 13 September 2022

part of the project, supporting the "Tsunami Ready" Program. In this connection, INCOIS conducted Tsunami Evacuation Planning (TEP) hybrid workshop on 13 September 2022. National stakeholders participated in the meeting onsite, and others participated online.

b) Tsunami SOP Workshop

The Regional Standard Operating Procedure (SOP) Workshop for National Tsunami Warning Centres (NTWCs), Disaster Management Organisations (DMOs), and Broadcast Media was conducted between 31 October and 03 November 2022 by IOTWMS. This is a part of the working process of the UNESCAP Project. The major goal is to improve warning services and organize the national warning chains with an end-to-end perspective and SOPs at each step to ensure timely warnings and effective community response, with due emphasis on self-protection for near source events. The workshop was conducted in a hybrid mode, including virtual meetings on the regional level combined with national face-to-face meeting in India.

A National Tsunami SOP workshop was conducted on-site at INCOIS, Hyderabad. The regional SOP workshop was conducted from 31 October to 03 November 2022 (4 days). INCOIS invited state disaster management officials and media representatives to attend the workshop. Day-1 and day-4 followed the regional SOP agenda, and day-2 and day-3 followed the national level by conducting national SOP sessions and tabletop exercise for DMOs and media.

Figure 8.4. Tsunami SOP Workshop for DMOs and Broadcasting Media participants

c) Webinar on Tsunami Awareness and Preparedness

INCOIS and the National Institute of Disaster Management (NIDM), Ministry Home Affairs jointly organized an expert webinar on "Tsunami Risk Reduction and Resilience" on 26 December 2022 to commemorate the 18th anniversary of the 2004 Indian Ocean tsunami. During the webinar, INCOIS Scientists explained about tsunami science, inundation mapping, warnings mechanisms, awareness & preparedness programs.

User Interaction Workshops/ Awareness campaigns

As part of Azadi Ka Amrit Mahotsav (AKAM), INCOIS, in collaboration with Project Investigators of INCOIS-funded projects, conducted 08 User Interaction Workshops/ Awareness campaigns at the field level in Kerala, Maharashtra, and Tamil Nadu. INCOIS Scientists& Scientific Assistants provided lectures and interacted with Fishermen/ user community during January to March 2023.More than 550 coastal users participated and provided their feedback.

Table 8.1. User interaction workshops conducted details.

Sl. No	Location	District	State/UT	Conducted Date
1	Neendakara	Kollam	Kerala	17 Jan 2023
2	Chettuva	Thrissur	Kerala	18 Jan 2023
3	Munambam	Ernakulam	Kerala	20 Jan 2023
4	Murad	Thane	Maharashtra	09 Feb 2023
5	Karaikal	Karaikal	Puducherry	08 Feb 2023
6	Tuticorin	Thoothukudi	Tamil Nadu	01 Feb 2023
7	Poompuhar	Mayiladuthurai	Tamil Nadu	14 Mar 2023
8	Keelakarai	Ramanathapuram	Tamil Nadu	16 Mar 2023




Figure 8.5. User interaction workshops participants at Tuticorin and Karaikal.

9

RESEARCH HIGHLIGHTS

9.1 Assessment of the forecasting potential of the WAVEWATCH III model under different Indian Ocean wave conditions

This study evaluated the performance of different wind input schemes (ST2, ST3, ST4, and ST6) in the Wave Watch III (WWIII) model used by INCOIS for wave forecasting in the Indian Ocean. Eight model experiments were conducted to examine the performance of different wind input schemes. The first four model experiments were conducted using the four wind input schemes. Next four experiments were done to tune the different schemes. The simulated waves were compared with Wave data obtained from the mooring observations. The results revealed significant errors in all wave simulations during low wind speeds, particularly in the pre-monsoon season. However, the errors were less prominent during medium and strong wind conditions in the post-monsoon and monsoon seasons. The accuracy of the wind forecasts did not influence these errors. The model experiments revealed that, the ST4 scheme performed well in reproducing wave characteristics across all seasons and conditions in the Indian Ocean. The ST6 scheme demonstrated the best performance for simulating waves during cyclonic weather conditions. The study concluded that switching the model's source term packages based on wind conditions is impractical due to the wide range of wind conditions throughout the year in the Indian Ocean. Instead, the study recommends selecting a scheme like ST4 that performs well in all conditions and fine-tuning it to improve its accuracy during cyclonic conditions.

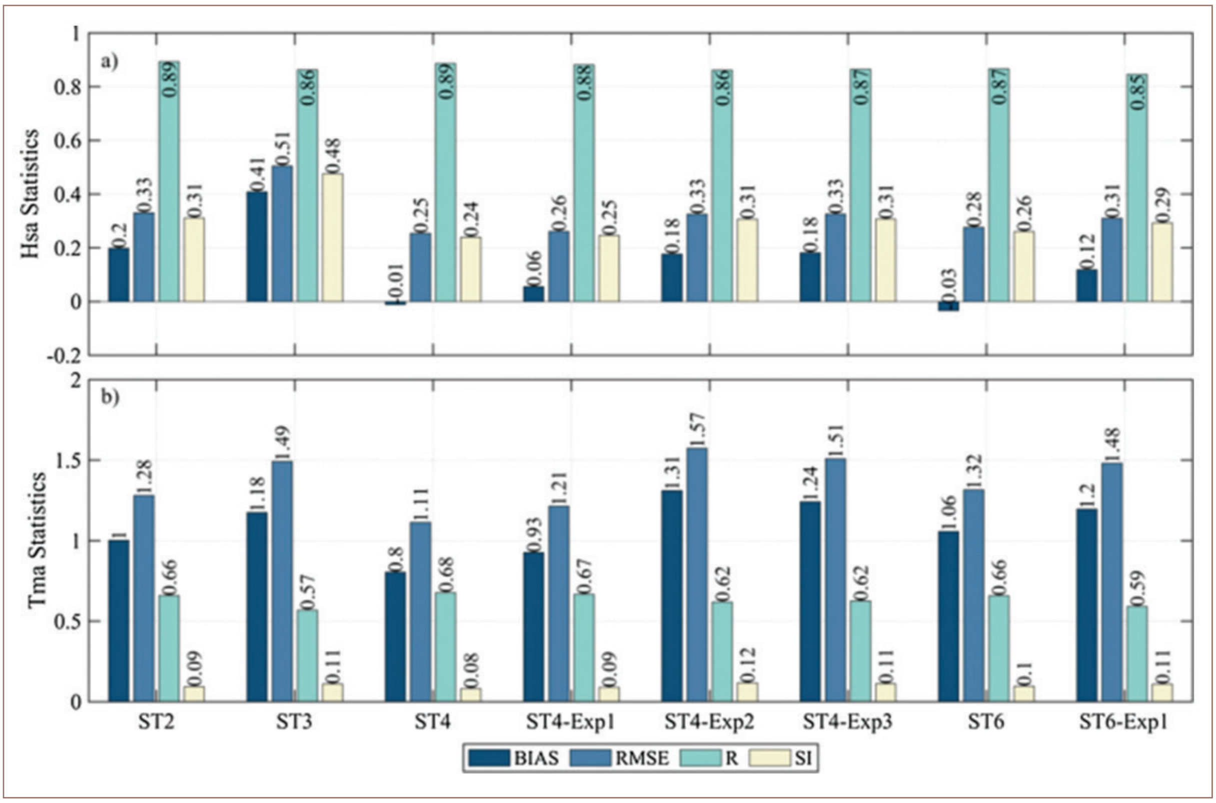


Figure 9.1: Error statistics of significant swell height (top panel) and swell period (bottom panel) of different wind input schemes of WWIII model compared to observations from moorings. ST4 scheme exhibits the least mean bias, root mean square error and scatter error and the highest correction among all schemes.

Ref: *Raj, A., Kumar B, P., Remya, P. G., Sreejith, M., & Balakrishnan Nair, T. M. (2023). Assessment of the forecasting potential of WAVEWATCH III model under different Indian Ocean wave conditions. Journal of Earth System Science, 132(32). DOI: https://doi.org/10.1007/s12040-023-02045-w*

9.2 Seasonal Variation of the Land Breeze System in the Southwestern Bay of Bengal and its Influence on Air-Sea Interactions

The land-sea breeze system, which occurs due to differential heating between the land and ocean surfaces, evolves over the course of a day and is a vital component of the climate system at least in coastal regions. The impact of the Land Breeze System (LBS) on the offshore region remains unexplored because of the limited availability of in-situ data. In this study, the seasonality of the LBS in the Bay of Bengal (BoB) is examined using OMNI moored buoy data, coastal radar data, atmospheric reanalysis data (ERA-5), and 6-hourly satellite-based Cross-Calibrated Multi-Platform (CCMP) wind velocity data. The prevailing zonal winds are a dominant factor in determining the annual variability in strength and geographical coverage of the LBS in the southwestern BoB. As a result of seasonally evolving large-scale winds, which are offshore during boreal summer and onshore during boreal winter, the land breeze signal in the southwestern BoB shows an annual variability with maximum amplitude (2 ms^{-1}) and geographical coverage during July and August (600 km offshore from the coast) and minimum during December and January. This diurnal variability of wind imparts a well-defined diurnal variability in latent heat flux (LHF) (35 Wm^{-2}) and near-surface current variability (12 cms^{-1}).

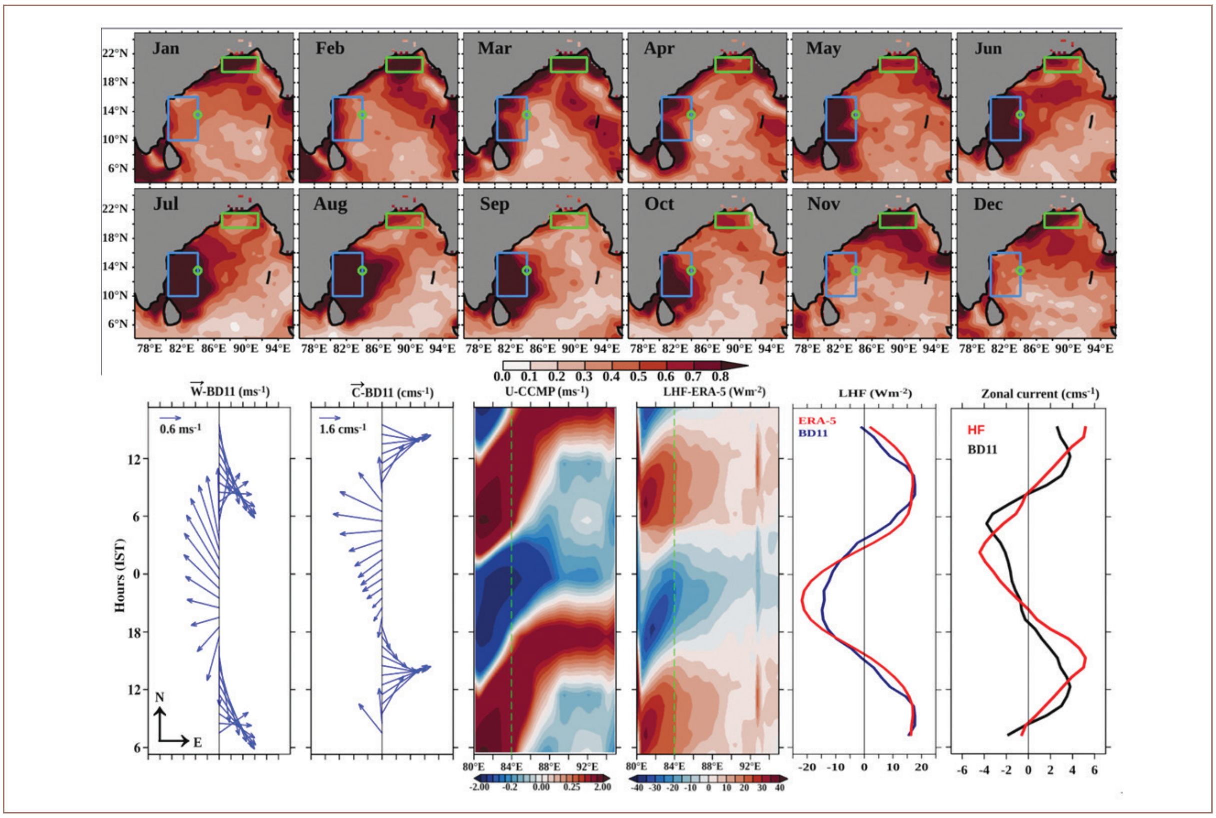


Figure 9.2: Monthly evolution of the diurnal amplitude of wind speed (ms^{-1}); composite of sub-daily evolution of wind vector anomaly; current vector anomaly; CCMP-zonal wind speed anomaly; ERA-LHF anomaly (Wm^{-2}); magnitude of LHF anomaly (Wm^{-2}) and magnitude of zonal current speed anomaly ($cm\ s^{-1}$).

Ref: *Athulya, K., Girishkumar, M. S., McPhaden, M. J., & Kolukula, S. S. (2023). Seasonal Variation of the Land Breeze System in the Southwestern Bay of Bengal and Its Influence on Air-Sea Interactions. Journal of Geophysical Research: Oceans, 128(2), e2022JC019477. https://doi.org/10.1029/2022JC019477*

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9.3 Response of Surface Ocean pCO_2 to Tropical Cyclones in Two Contrasting Basins of the Northern Indian Ocean

Tropical cyclones impart large amounts of energy into the upper ocean, enhancing vertical mixing under the influence of strong winds. The enrichment of nutrients and carbon due to upwelling of deeper waters enhance pCO_2 levels thereby facilitating biological productivity as a result of which CO_2 is consumed and net pCO_2 is reduced. This study examines the impact of two very severe cyclones on surface ocean pCO_2 variability associated with significant changes in the upper ocean structure in two contrasting basins – Arabian Sea and Bay of Bengal – of the northern Indian Ocean. It is found that in both basins physical processes like heat, water fluxes, air-sea exchanges of inorganic carbon and mixing contribute the largest in controlling the spatio-temporal variability of pCO_2 in response to the cyclones. Biological processes like carbonate production/dissociation and organic matter production/degradation impose weak control over this variability, especially in the Bay of Bengal. The contrasting biogeochemical response of both basins to tropical cyclones is attributed to the stratification in the upper layers and the vertical distribution of the inorganic carbon inventory inherent of the basins. We find that in comparison to the mean annual flux in our study region the impact of local fluxes in inducing pCO_2 variability during Ockhi is far more significant than Phailin.

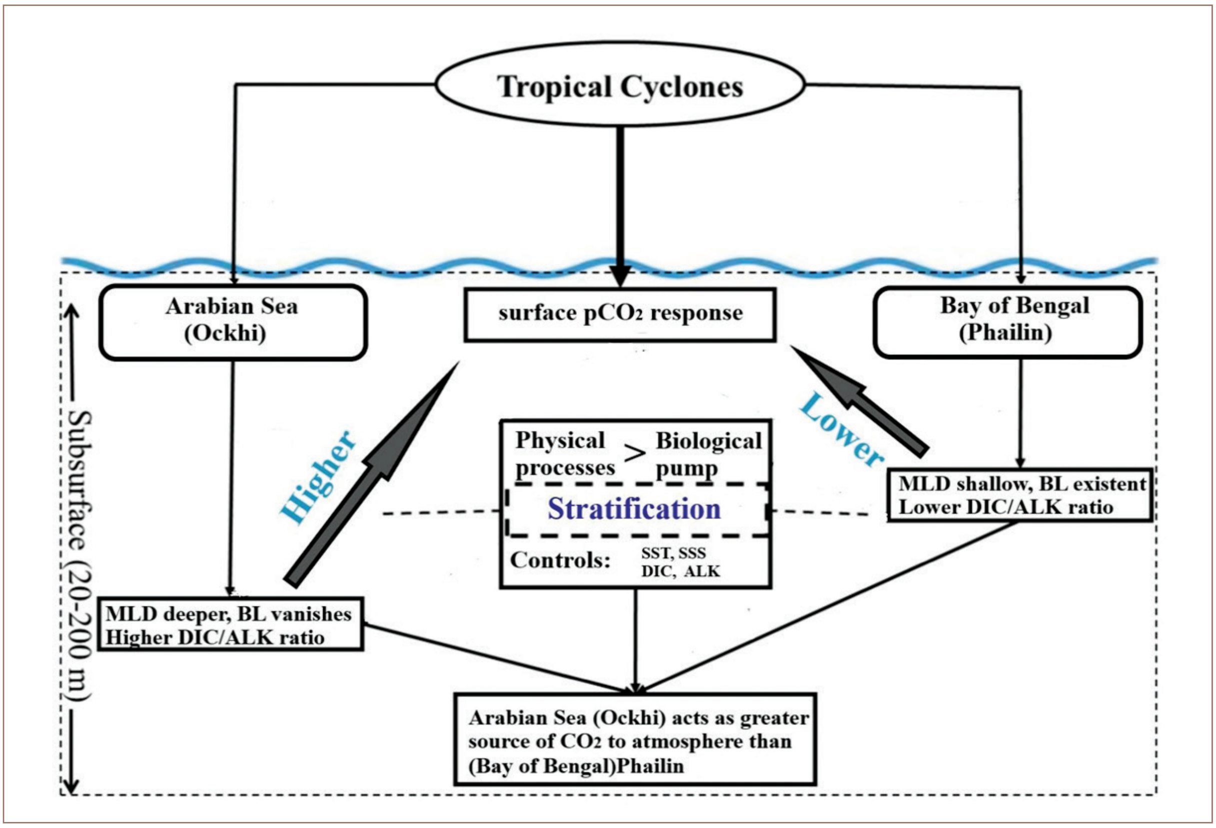

Figure 9.3: Conceptual diagram representing the differential surface pCO_2 response of the contrasting oceanic basins of the northern Indian Ocean. SST is sea surface temperature, SSS is sea surface salinity, DIC is dissolved inorganic carbon, ALK is total alkalinity, MLD is mixed layer depth and BL is barrier layer.

Ref: *Bhattacharya, T., Chakraborty, K., Ghoshal, P.K., Ghosh, J., Baduru, B. Response of Surface Ocean pCO2 to Tropical Cyclones in Two Contrasting Basins of the Northern Indian Ocean (2023) Journal of Geophysical Research: Oceans, 128 (4), art. no. e2022JC019058. DOI: https://doi.org/10.1029/2022JC019058*

9.4 The rapid increase in marine heatwaves in the Arabian Sea

Global oceans have been undergoing rapid anthropogenic warming in recent decades owing to the ongoing global climate change. Notably, the Indian Ocean, particularly the Arabian Sea, is warming much more rapidly than the other tropical basins. This enhanced warming trend and climate variability lead to extreme warming of the upper water column. These extreme warm events are referred to as marine heatwaves (MHW) and are responsible for widespread coral bleaching, loss of seagrass meadows, and harmful algal blooms. This study shows that the characteristics of the marine heatwave events (such as duration, frequency, and intensity) in the Arabian Sea have undergone rapid intensification during 1982-2019. Annually, the duration of heatwaves exhibits a rapidly increasing trend of ~20 days/decade, and the frequency has increased at a rate of 1.5-2 events/decade. The increasing trends are particularly conspicuous in the northern and northeastern Arabian Sea close to the coast of India during the spring and summmer seasons (Figure 9.4). We find that the accelerated trend of heatwaves in the Arabian Sea is driven primarily by the rapid rise in the mean sea surface temperature in the Arabian Sea. However, it is noted that prolonged and intense heatwave events are also associated with dominant climate modes. Among them, the Indian Ocean Basin Mode via the decaying phase of El Niño is the most influential mode contributing to more than 70%–80% of observed heatwave days in this basin. Further analysis shows a strong association between the increased prolonged heatwave events and the enhanced cyclogenesis in this basin

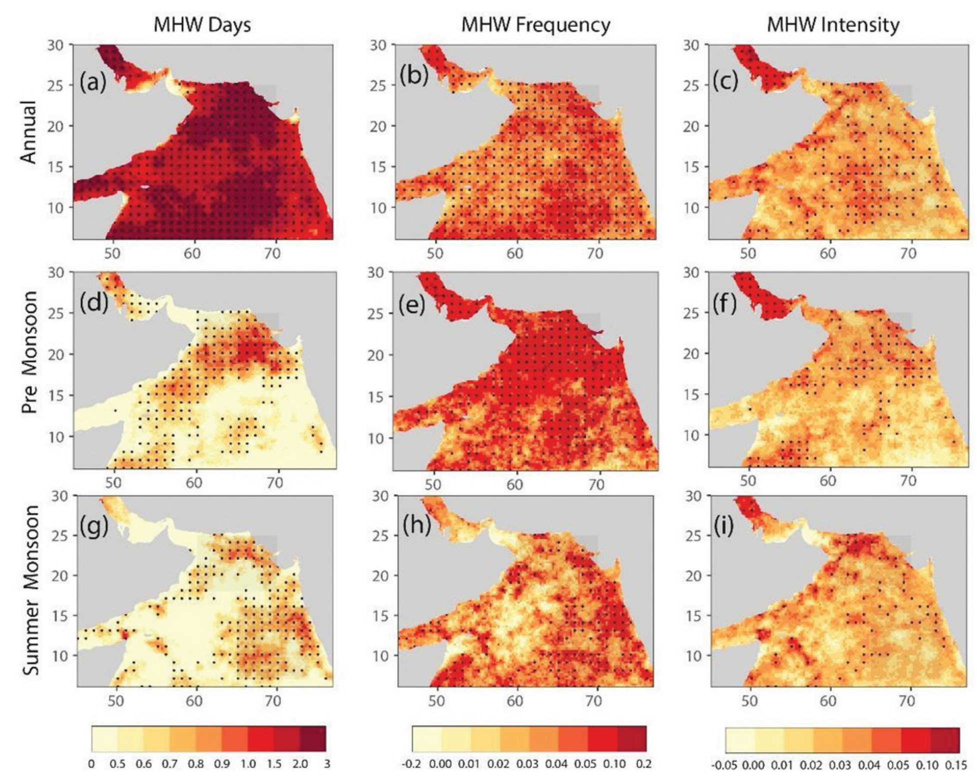

Figure 9.4: Trend for the MHW days (day yr^{-1}; a, d, and g), MHW frequency (events per year; b, e, and h), and MHW intensity (OC yr^{-1}; c, f, and i) for the annual (a–c), pre-monsoon (d–f), and summer monsoon (g–i) periods. The trends within the 99% confidence limit are marked by stippling. The trends are calculated for the period 1982–2019.

Ref: *Abhisek Chatterjee, Gouri Anil and Lakshmi R Shenoy: Marine heatwaves in the Arabian Sea. Ocean Sci., 18, 639-657, https://doi.org/10.5194/os-18-639-2022, 2022.*

during the recent past. Multiple instances of prolonged marine heatwave events accompanying an intense cyclone are observed.

9.5 Exploring the impact of southern ocean sea ice on the Indian Ocean swells

The Indian Ocean coastline is home to roughly 2.6 billion people - 40% of the global population - out of which one-third are located within 20 km of the coastline. One of the major factors affecting the coastline is wind-waves. Hence, any changes in wave climate have a substantial societal impact on their livelihood. For example, the long period swells from the Southern Ocean (SO) cause flash flooding along the Indian coastline, called the Kallakkadal events, creating much distress to the coastal community. The SO swells cause coastal inundations, hindrance to maritime operations, and possible damage to agriculture by contaminating freshwater reservoirs along coasts. The present study analyzes the impact of the SO sea ice concentration on the north Indian Ocean (NIO) wave

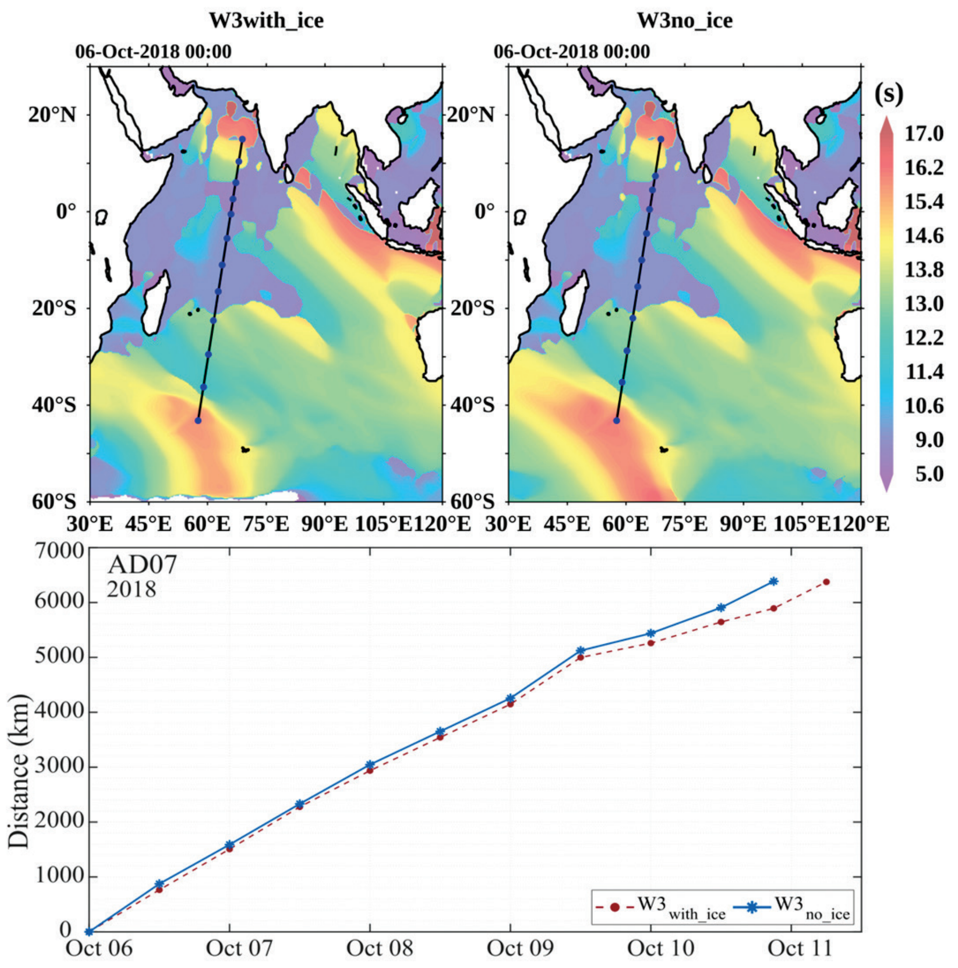

Figure 9.5: A SO swell system formed on 7th October 2018 and the distance line of swell from SO to AD07 mooring location from 07-Oct-2018 00hrs with blue dots representing 12-hour marks a) $W3_{with\_ice}$ and b) $W3_{no\_ice}$ simulations and c) shows the distance vs time of the swell system in $W3_{no\_ice}$ and $W3_{with\_ice}$ over the next few days until arrival at AD07 location.

Ref: *Sreejith, M., P. G., R., Kumar, B.P. et al. Exploring the impact of southern ocean sea ice on the Indian Ocean swells. Sci Rep 12, 12360 (2022). https://doi.org/10.1038/s41598-022-16634-0* fields through swells using six years (2016-2021) of WAVEWATCH III (WWIII) simulations. We did two experimental runs of WWIII, one with sea ice concentration and winds as the forcing ($W3_{with\_ice}$) and the other with only wind forcing ($W3_{no\_ice}$). Analysis shows the impact of the SO sea ice concentration on northward swell peaks in September-November, coinciding with the maximum sea ice extent in the Antarctic region of the Indian Ocean. *The absence of SO sea ice concentration in the model can introduce an error of ~12 hours in the timing of high swell events along NIO coasts and can potentially generate* false swell alerts along southeastern Australian coasts. A potential limitation of our analysis pertains to the absence of model validation in the Southern Ocean (SO) due to the unavailability of in situ observations in such remote regions. The extent of sea ice in the Indian sector of the SO exhibits significant variations across seasons, ranging from a minimum of 74,208.5 km^2 in DJF to a maximum of 1,08,308.75 km^2 in SON. A wave model that does not account for this substantial sea ice extent would result in a considerable overestimation of wave production. Nevertheless, the validity of our arguments in this article remains unaffected by the aforementioned limitation. It is important to note that any changes in the SO's ice extent will have a substantial impact on the North Indian Ocean (NIO) through the propagation of swells. Consequently, our study highlights the crucial role of sea ice concentration in the SO in modifying wave characteristics in the NIO. We emphasize the necessity of incorporating this factor into wave modeling for accurate forecasting and climate simulations.

9.6 Showcasing model performance across space and time using single diagrams

Model states are generally validated against observations to establish the veracity of the model. However, when a model state is compared with multiple in-situ observations scattered in space, it is challenging to showcase the statistical measure of correlation, root mean square error and the

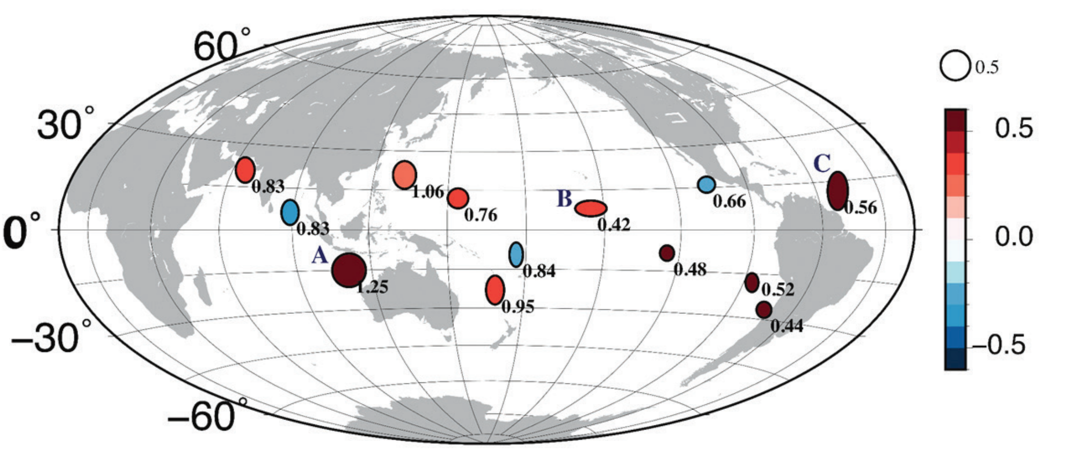

Figure 9.6: Schematic PAS diagram: Model performance in terms of correlation, RMSE (in arbitrary units) and ratio of standard deviation is shown with respect to observations at different locations in the globe. Three different locations represented by A, B and C in the eastern Indian Ocean, central Pacific Ocean and western Atlantic Ocean are highlighted. The zonal (meridional) axis of the ellipses represent the standard deviation of the model (observation). The scale of standard deviation is represented using a blank circle at the top right of this diagram. The color represents the correlation. The number at each location denotes the RMSE (in arbitrary units) of the model with respect to the observation at that location.

Ref: *Paul, A., Afroosa, M., Baduru, B., & Paul, B. (2023). Showcasing model performance across space and time using single diagrams. Ocean Modelling, 181, 102150.*

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standard deviations of the concerned variables across all the locations. It can be done using a Taylor Diagram but the sense of the spatial location is lost. We present a simple but efficient representation of correlation, root mean square error and standard deviation of the model and the observation across multiple in-situ locations in a single diagram keeping the sense of spatial location intact and name it as the "Performance Across Space (PAS)" diagram. We also present a diagram that showcases the comparison of model state and observation at a single location across multiple time windows in a single diagram and call it "Performance Across Time (PAT)" diagram. The PAS diagram can also be used to evaluate the efficacy of data assimilation as well. The PAS and PAT diagram are designed such that it can be used in any field that demands comparison of two time series.

9.7 Improved prediction of oil drift pattern using ensemble of ocean currents

Oil spill responders utilize the oil spill advisory services of INCOIS during the event of oil spills for setting the response operations. Modeled ocean currents have uncertainties due to model approximations, inaccurate initial and boundary conditions in the model setup. As ocean currents influence the oil drift and spread, they can transport the oil particles to undesired locations. To issue an appropriate advisory, an attempt was made to generate oil spill advisories using weighted ensembles of ocean currents. The oil spills trajectory model (GNOME) was forced using a weighted

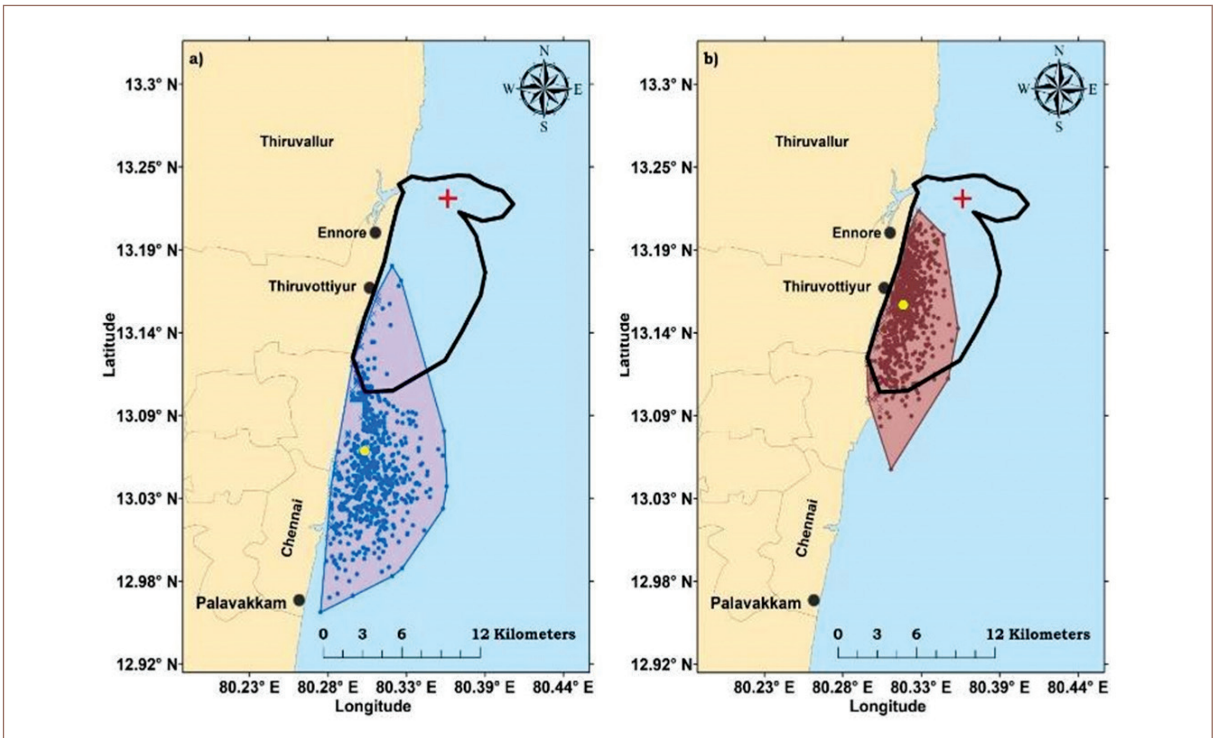

Figure 9.7. Comparison of HFO drift patterns with SAR data. The plus symbol in red denotes the HFO spill location. The black polygon is the zone of observed HFO remnants on 0600 hours of 29 January 2017. The yellow circle denotes the mean position of HFO particles. (a) The x (dot) denotes the beached (floating) status of drifted HFO while using operational Regional Ocean Modeling System (ROMS) currents. The blue polygon is the convex hull of oil particles of ROMS trajectory. (b) The brown x (dot) denotes the beached (floating) status of drifted HFO while using an ensemble of ocean currents. The brown polygon is the convex hull of oil particles while using an ensemble of ocean currents.

Ref: *SJ Prasad, TM Balakrishnan Nair & B. Balaji (2022). Improved prediction of oil drift pattern using ensemble of ocean currents. Journal of Operational Oceanography, 1-16. https://doi.org/10.1080/1755876X.2022.2147699* ensemble of ocean currents for the Heavy Furnace Oil (HFO) spill reported off Ennore port on 0400 hours (IST) of 28 January 2017. The inverse-variance weighting method was used to estimate weights by comparing zonal and meridional components of individual model ocean currents, with that of High Frequency (HF) Radar currents. The zone of HFO spread obtained while using an ensemble of ocean currents was compared with oil slick signatures obtained from Synthetic Aperture Radar (SAR) data on 0600 hours (IST) of 29 January 2017. It was noted that the trajectory patterns obtained from the weighted ensemble of ocean currents were well within the observed zone of oil slicks, compared to that of individual model ocean currents.

9.8 Wave induced coastal flooding along the southwest coast of India during tropical cyclone Tauktae

Globally, climate change has several adverse impacts on coastal areas. In the majority of coastal regions around the world, severe waves, storm surges, intense cyclones, and sea level rise are currently the main drivers of coastal vulnerability issues. The massive expansion of coastal urbanization, particularly in developing countries, poses key concerns about coastal vulnerability. India has a vast coastline covering nine states, and most of these coastal states are densely populated. One of the severe threats to these coastal areas is the intense tropical cyclones and associated coastal flooding and damage. The coastal flood during the tropical cyclone Tauktae, 2021, at Chellanam coast, Kerala, India, has invited wide attention as the wave overtopping severely affected coastal properties and livelihood. WAVEWATCHIII and XBeach were used together to analyze the coastline inundation during extreme waves. Even during low tide with a small surge height, the action of low-frequency waves and the rise in coastal water level due to wave setup caused the inundation at Chellanam. Wave setup raised the water level at the coast with a steep slopes to more than 0.6 m and peaked during low tide, facilitating wave breaking at the nearshore region. The coastal regions adjacent to these steep slopes were subjected to severe inundation. The combined effect of long and

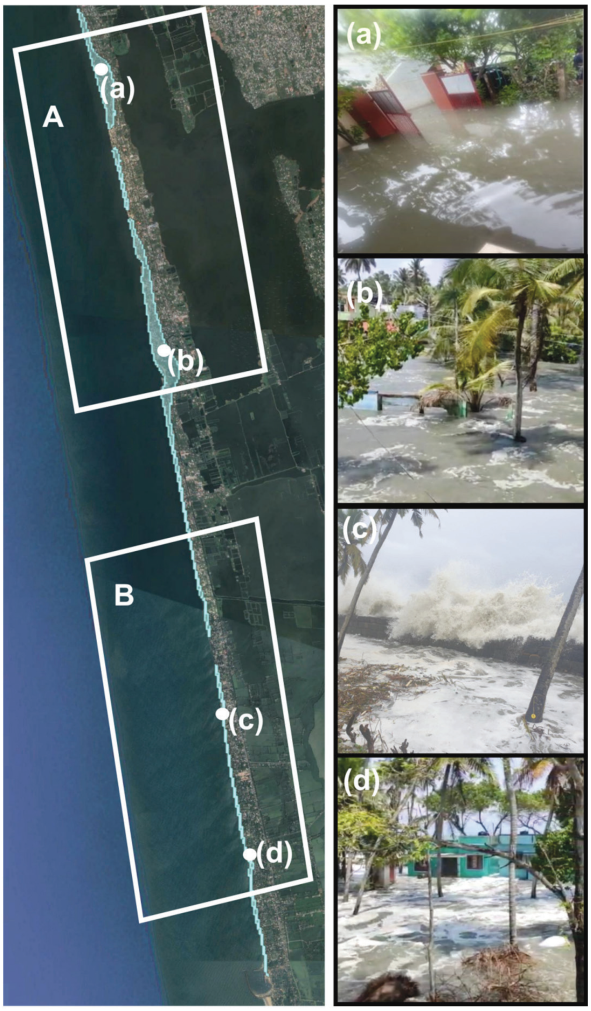

Figure 9.8: Simulated coastal inundation at Chellanam over Google Earth images. The point locations shown are (a) Cheriyakadavu, (b) Kannamali, (c) Velankanni, (d) Kandakkadavu and the corresponding photographs of inundation are shown in the right panel.

Ref: *Ramakrishnan, R., Remya, P.G., Mandal, A. et al. Wave induced coastal flooding along the southwest coast of India during tropical cyclone Tauktae. Sci Rep 12, 19966 (2022). https://doi.org/10.1038/s41598-022-24557-z* short waves over wave setup formed extreme wave runups that flooded inland areas. At gently sloping beaches, the longwave component dominated and overtopped the seawalls and damaged households along the shoreline. The study emphasizes the importance of longwave and wave setup and its interaction with nearshore bathymetry during the high wave in inundation outreach. The present study shall lead to the development of a coastal inundation prediction system for the low-lying hot spots using the combination of WAVEWATCHIII and XBeach models. The development of wave-induced inundation and erosion forecast systems for selected hotspots is the need of the hour as extreme waves may cause extreme damage to the coast, and in the anticipated climate change scenario, with increased storm surges; heavy rains and rising sea level, the impact on the coastal region may be extremely adverse.

9.9 Performance of mixing schemes in simulation of upper ocean properties in the tropical Indian Ocean in the HYbrid Coordinate Ocean Model (HYCOM)

The upper ocean is vital in determining ocean-atmosphere interactions at synoptic to interannual timescales. Due to an inadequate understanding of the upper ocean mixing processes and horizontal and vertical resolution limitations, ocean vertical mixing is often parameterized in Ocean General Circulation Models (OGCMs) such as HYCOM, ROMS, and MOM. The performance of different parameterization schemes in simulating the upper ocean properties in the Indian Ocean in HYCOM, one of the models used at INCOIS, is evaluated to adopt the best scheme in HYCOM.

This study evaluates the performance of three different mixing parameterization schemes available in HYCOM, namely, K-Profile Parameterization (KPP), Goddard Institute of Space Sciences (GISS), and Mellor-Yamada (MY). Their capability in simulating the upper ocean properties is evaluated against the observations. The sea surface temperature (SST) determines the exchange of information between the ocean and the atmosphere. The study shows that the simulated SST by these different schemes is generally warmer by 1–2°C than the observations. There is little difference in the simulated SST between the schemes. The Mixed Layer Depth (MLD), the thickness of the upper ocean layer of almost uniform density, determines the amount of heat stored in the ocean's upper layers, which can influence tropical cyclones, monsoon strength, etc. The study finds that the simulated MLD is generally deeper than observations in the tropical Indian Ocean, irrespective of the mixing scheme choice. However, this difference or bias in MLD simulation varies with time and location depending on the mixing scheme choice. None of the mixing schemes consistently simulated the MLD with minimal error at all locations and times in the tropical Indian Ocean. The study also presents a novel spatiotemporal map (Fig. 9.9) to show the best-performing scheme to guide further HYCOM studies. The bulk critical Richardson number (R_{ibc}) is a tunable parameter that controls the MLD in the KPP scheme, and changing its value from the often-used 0.25 to 0.15 can marginally improve MLD simulation. The results of this study can contribute to improving the ocean forecasts issued using the HYCOM model.

9.10 Characteristics of astronomical tides and their modulation on sea level extremes along the Indian coast

The long-term hourly sea-level records from 18 tide gauge stations during 1972–2007 were analyzed

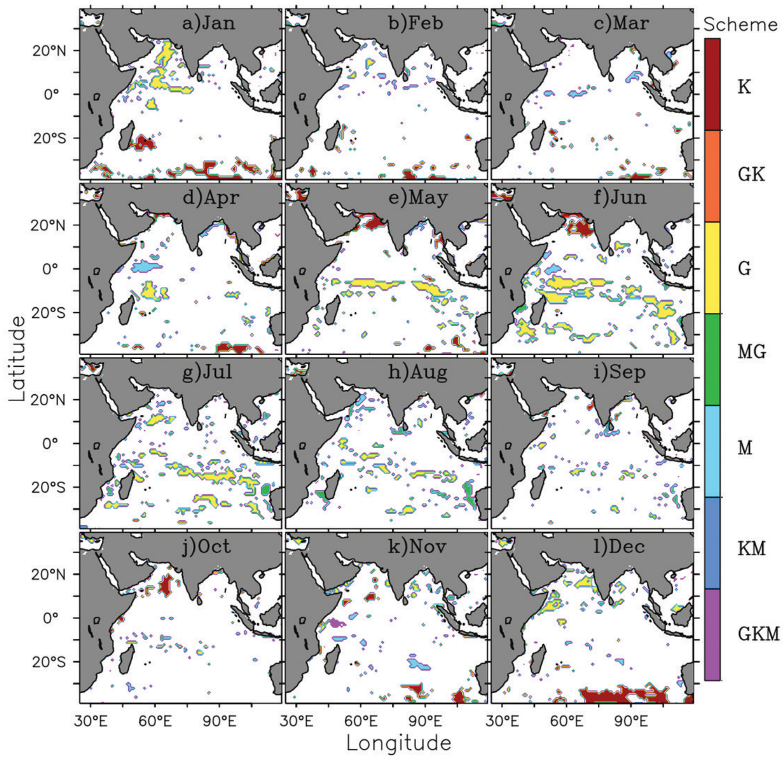

Figure 9.9: Spatiotemporal evolution of the performance of different mixing schemes in simulating the MLD in the tropical Indian Ocean, showing the best scheme(s) simulating the MLD with minimal error compared to the observation in each calendar month indicated on the corresponding subpanel. All possible combinations of three mixing schemes are shown on the color bar, with K, G, and M, indicating KPP, GISS and MY schemes, respectively. For instance, KM indicates the areas where KPP and Mellor-Yamada simulate the MLD equally well with minimal errors.

Ref: *Pottapinjara V, and Joseph S (2022): Evaluation of mixing schemes in the HYbrid Coordinate Ocean Model (HYCOM) in the tropical Indian Ocean, Ocean Dynamics. DOI:10.1007/s10236-022-01510-2.*

to study the characteristics of astronomical tides, sea-level trends, and extremes around India's mainland. The observed sea level depicts significant variability in daily, seasonal, and inter-annual time scales. Semidiurnal tides are the most dominant among the high-frequency tides along the northwestern and northeastern continental shelf and reduced towards south. The amplitude of diurnal tides is relatively weak at all the stations. The annual harmonics dominate the seasonal cycle along the east coast rather than the west coast of India. The amplitude of lunar nodal and perigee tides is significantly high (up to 25 mm) at several stations compared to the long-term global mean sea level trend (~3.3 mm/yr). Interaction between the semidiurnal tides and surges was intense at most stations, with a high probability of surge peaks during the fall-tide conditions in the northern continental shelf and at rising-tidal conditions for the south-eastern and western peninsula. The degree of tide-surge interaction increases from south to north with an increase in tidal range and significant nodal and perigee tidal modulation. The results would aid coastal authorities in developing a short and long-term disaster-management and vulnerability reduction action plan with respect to any high wind or cyclone events.

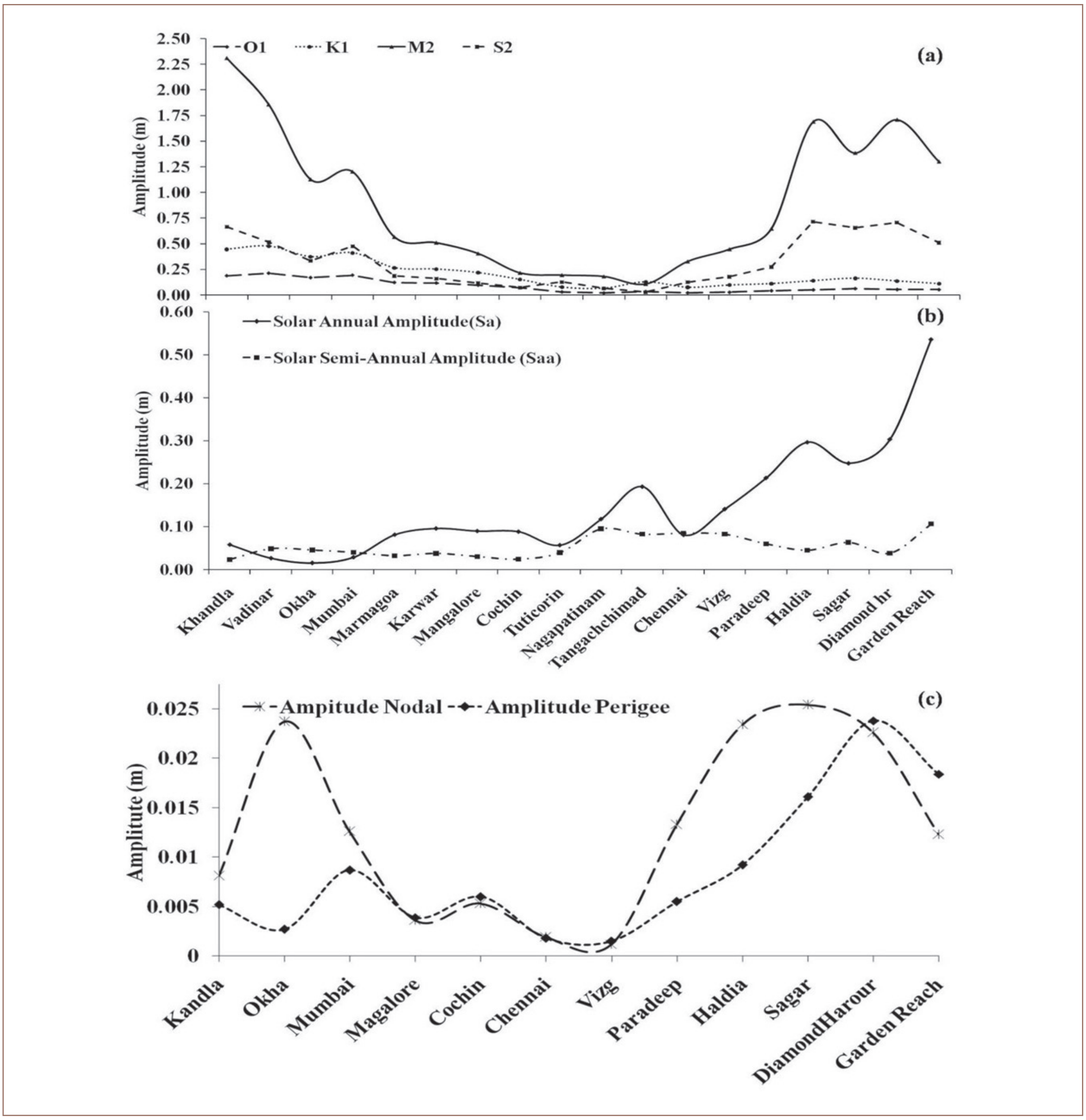

Figure 9.10: Variability of a) diurnal and semidiurnal tidal amplitudes around the Indian mainland from the northwestern tide gauge station at Kandla in Gujarat to the southern tip of India at Tuticorin in Tamil Nadu to the northeastern station Garden Reach on the West Bengal coast; b) the same as 'a' but for the annual and semi-annual amplitude; c) the same as 'a' but for the tidal amplitude associated with the lunar nodal cycle and perigee cycle.

Ref: *Mohanty P.C., Mahendra R.S., Nayak R. K., Manche S. S, Sudheer Joseph, T.M. Balakrishnan Nair, T. Srinivasa Kumar (2023). Characteristics of astronomical tides and their modulation on sea level extremes along the Indian coast. Ocean & Coastal Management, Volume 231*

9.11 Monitoring green Noctiluca bloom in the coastal waters

The southeastern coast of India recently witnessed an intense bloom of green Noctiluca scintillans (NS) that resulted in water discolouration, slimy-soupy surface layer, bioluminescent tides, and mass fish mortality. A probable basis for this algal bloom event and impact on water quality, was investigated using the Algal Bloom Information Service (ABIS) of INCOIS. ABIS could efficiently provide information on the spatial extent of the bloom from its occurrence to disintegration. The confinement of bloom to the coastal domain signified the localized evolution of green NS attributed to the regional onset of conducive conditions. Additionally, possible underlying factors responsible for fish mass-mortality associated with green NS bloom have been ascribed to a decline in dissolved oxygen concentration, increase in ammonia levels, and the clogging of fish gills causing asphyxiation. This study also reiterated the need for an autonomous coastal water quality observatory as a suitable alternative to field measurements to trace out the underlying factors responsible for the blooms and resultant harmful impacts on the ecosystem.

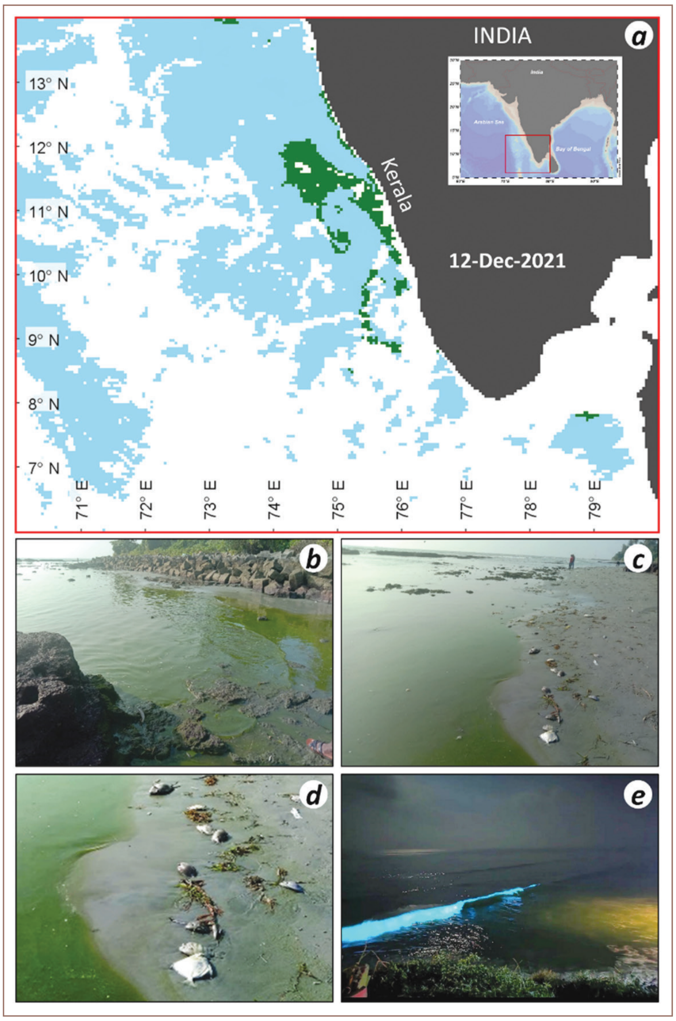

Figure 9.11: (a) Map of the study area showing the presence of green Noctiluca scintillans (deep green). Field photographs showing green Noctiluca scintillans bloom (b), and fish kill events (c-d) in coastal waters of Kerala at Kodikkal on 16 December 2021. (e) Bioluminescent green tide photographed at Varkala, Kerala on 14th December 2021

Ref: *Samanta, A., Baliarsingh, S.K., Lotliker, A.A., Joseph, S., & Balakrishnan Nair, T.M. (2023). Satellite-based detection of Noctiluca bloom in the coastal waters of the southeastern Arabian Sea: A case study implicating monitoring needs. National Academy Science Letters, https://doi.org/10.1007/s40009-023-01205-2*

9.12 Distinct Oceanic Responses at Rapidly Intensified and Weakened Regimes of Tropical Cyclone

This study examined the upper ocean responses to Tropical Cyclone (TC) Ockhi in its rapidly intensifying (RI) and rapidly weakening (RW) regions using simulations from the HYbrid Coordinate Ocean Model (HYCOM). The analysis revealed contrasting oceanic conditions between the RI and RW regions, including sea surface temperature (SST), surface salinity, and the presence of a barrier layer. The RI region had warmer and fresher waters with a thick barrier layer, while the RW region had cooler and more saline waters with no barrier layer. The SST anomaly along the storm track showed minimal cooling in the RI region despite the slow storm speed, attributed to the presence of thick warm water and the barrier layer. In contrast, the RW region experienced pronounced cooling due to weaker stratification despite faster storm movement.

Further, this study analyzed the mixed layer heat budget to assess the contributions of different physical mechanisms, such as surface thermal forcing, entrainment, horizontal advection, and vertical advection, in influencing the mixed temperature at the RI and RW locations (shown in Figure 9.12). The analysis revealed a slower rate of temperature cooling in the RI region compared to the RW region. Surface thermal forcing was the primary driver of temperature tendency in the RI region, while entrainment played a major role in the RW region. Horizontal advection had minimal influence on thermal changes in both regions. Vertical advection induced a significant negative temperature tendency below the mixed layer in the RW region, but its impact was negligible in the RI region. The differences in entrainment-induced cooling were attributed to the contrasting stratification characteristics in the RI (strong) and RW (weak) regimes. Also, the difference between the mixing length and the 26°C isotherm was significant in the RI region due to salinity stratification, while it was negligible in the RW region. This difference highlighted the importance of salinity stratification in determining the depth of mixing and suggested the need for accurate simulation of salinity stratification for better intensity forecasting.

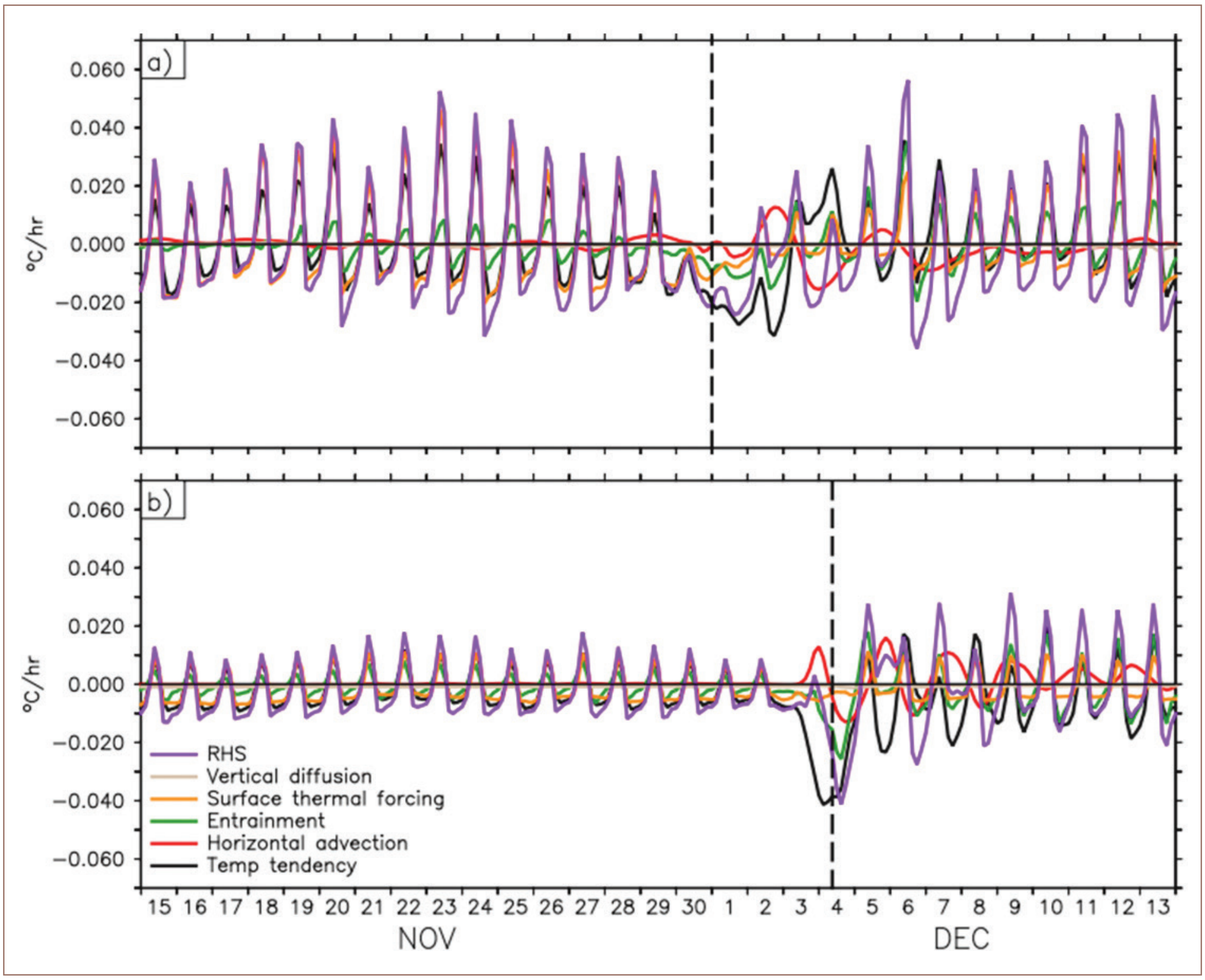

Figure 9.12: a) Temporal evolution of horizontal advection (0.5%), entrainment (48.4%), surface thermal forcing (53.5%) at RI b) At RW, horizontal advection (4.7%), entrainment (52%), surface thermal forcing (7.5%). The dashed line indicates the time of TC occurrence.

Ref: *Jyothi, L., Joseph, S., Huber, M., & Joseph, L. A. (2022). Distinct oceanic responses at rapidly intensified and weakened regimes of tropical cyclone Ockhi (2017). Journal of Geophysical Research: Oceans, 127(6), e2021JC018212.https://doi.org/10.1029/2021JC018212*

9.13 On the non-parametric changepoint detection of flow regimes in cyclone Amphan

The Bay of Bengal witnessed a severe cyclone named Amphan during the summer of 2020. The National Institute of Ocean Technology (NIOT), INDIA moorings BD08 and BD09 happened to be in the vicinity of the cyclone. The highly instrumented mooring recorded near-surface meteorological parameters like wind speed, sea surface temperature, and near-surface pressure. This article explores the possibility of using a non-parametric algorithm to identify different flow regimes using a one-month-long time-series data of the near-surface parameters. The changes in the structure of the time series signal were statistically segmented using an unconstrained non-parametric algorithm. The nonparametric changepoint method was applied to the time series of near-surface winds, sea surface temperature, sea level pressure, air temperature and salinity, and the segmentations are consistent with visual observations. Identifying different data segments and their simple parameterization is a crucial component, and relating them to different flow regimes helps in developing parameterization schemes in weather and climate models. The segmentations can considerably simplify the parametrization schemes when expressed as linear functions. Moreover, the usefulness of non-parametric automatic detection of data segments of similar statistical properties shall be more apparent when dealing with relatively long time series data.

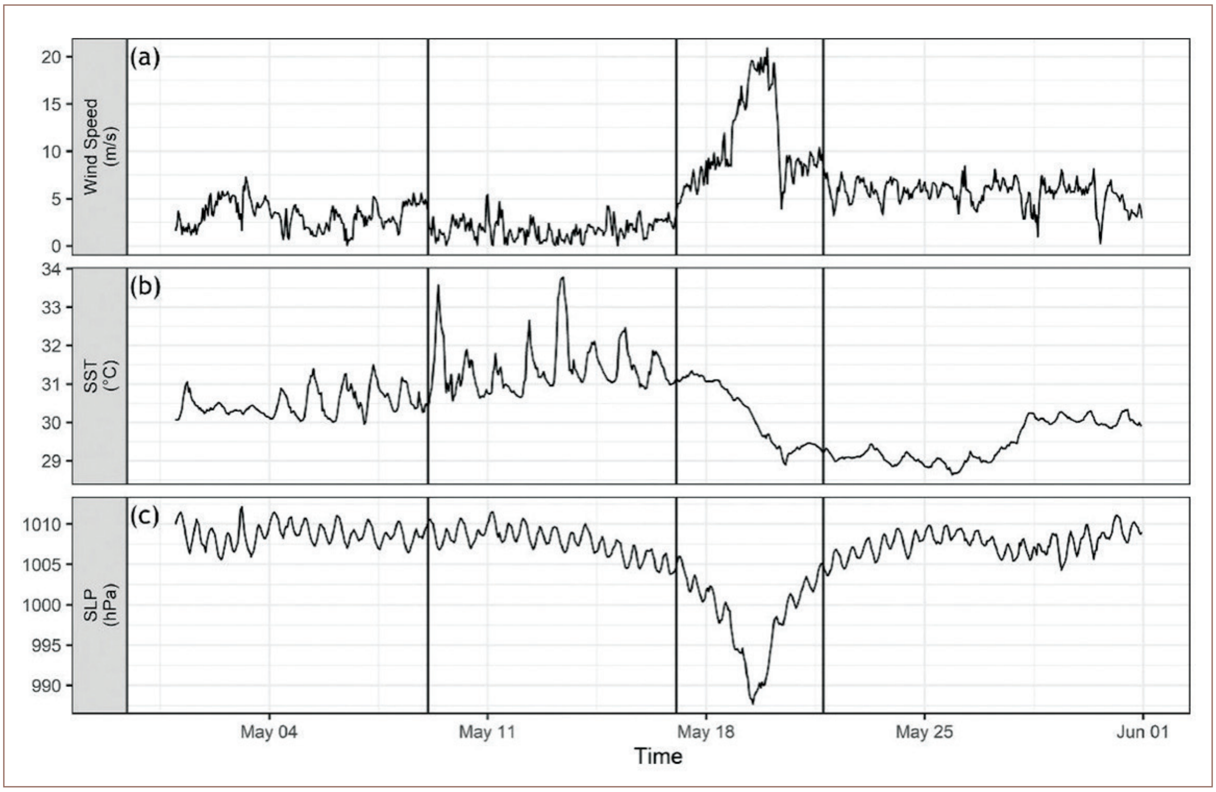

Figure 9.13: Time series of wind speed, sea surface temperature, sea level pressure, and location where there is a significant change in the signal.

Ref: *Venkat Shesu Reddem, Venkata Jampana, Ravichandran Muthalagu, Venkateswara Rao Bekkam, Pattabhi Rama Rao Eluri, Srinivasa Kumar Tummala. On the non-parametric changepoint detection of flow regimes in cyclone Amphan. Oceanologia, Volume 65, Issue 2, 2023. https://doi.org/10.1016/j.oceano.2022.07.006.*

9.14 Indian Ocean dynamic sea level, its variability and projections in CMIP6 models

Dynamic Sea Level (DSL) represents the change in the sea level due to thermal and halosteric changes along with dynamic processes such as ocean circulation. DSL plays a significant role in modulating regional sea level change and is thus responsible for the observed spatial deviation from the global mean. This study investigates the representation of the simulated mean DSL, its variability and climate projections over the Indian Ocean from the 27 coupled models of the Sixth phase of the Coupled Model Intercomparison Project (CMIP6). We show that these coupled models produce consistent positive mean sea level bias across the latitudinal range of the Indian Ocean, with the strongest bias in the western Arabian Sea in the north and along the subtropical front in the south. In the case of variability, most models fail to produce the observed variability. However, it is noted that the eddy-permitting models fare better in simulating the variability compared to the coarser models. Further, all models show easterly wind bias along the equatorial region, leading to strong IOD-like bias in the mean field and, therefore, strongly sensitive to IOD climate variability. Multi-model mean

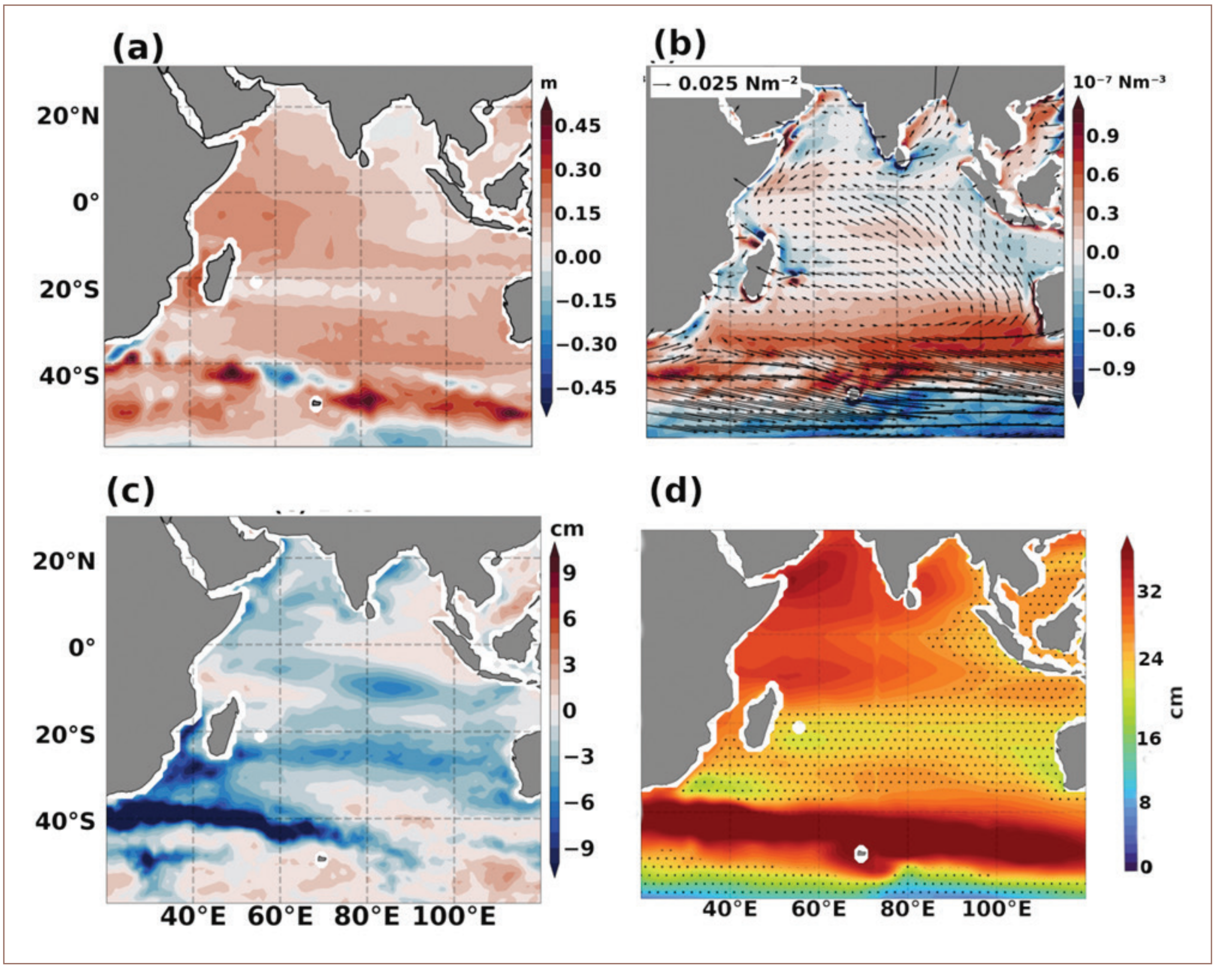

Figure 9.14: (a) Bias of the Multi Model Mean (MMM) for mean DSL for the time period 1994-2014. (b) Same as (a) but for wind stress curl overlayed by wind stress components. (c) Same as (a) but for variability. (d) Projected multi-model mean DSL change under SSP5-8.5 scenarios by 2100 relative to 1994-2014.

Ref: *Sajidh, C. K., & Chatterjee, A. (2023). Indian Ocean dynamic sea level, its variability and projections in CMIP6 models. Climate Dynamics, 1-24.https://doi.org/10.1007/s00382-023-06676-z* projected sterodynamic sea level shows a similar pattern for the mid (SSP2-4.5) and high (SSP5-8.5) emission climate scenarios with the fact that the sea level rise will be stronger for the high emission condition. Interestingly, an ensemble of the best-performing 10 models shows a weaker projected sea level rise than the complete multi-model ensemble.

9.15 Investigating the robustness of the intraseasonal see-saw in the Indo-Pacific barotropic sea level across models

This study focuses on evaluating the performance of several widely used ocean general circulation models (OGCMs) in capturing the see-saw phenomenon observed in the Indo-Pacific oceanic mass during boreal winters at intraseasonal timescales. The OGCMs evaluated include the Modular Ocean Model (MOM), the Nucleus for European Modeling of the Ocean (NEMO), Massachusetts Institute of Technology general circulation model (MITgcm), and the HYbrid Coordinate Ocean Model (HYCOM).

The main finding of the study is that regardless of differences in model physics, forcings, setup, and resolution, all the evaluated OGCMs were able to simulate the see-saw phenomenon in the Indo-Pacific oceanic mass, making it a robust oceanic phenomenon. The study emphasized the significance of horizontal resolution in accurately representing the see-saw. The models with horizontal resolutions ranging from 25 km to 9 km, particularly those with higher resolution, are more successful at simulating the see-saw characteristics. Accurate representation of the narrow Indonesian throughflow straits in the models is identified as a vital factor for a reasonable simulation of the see-saw. Furthermore, the inclusion of the polar ocean in the models does not significantly impact the structure of the see-saw, suggesting that semi-global domain OGCMs are suitable for capturing the see-saw dynamics.

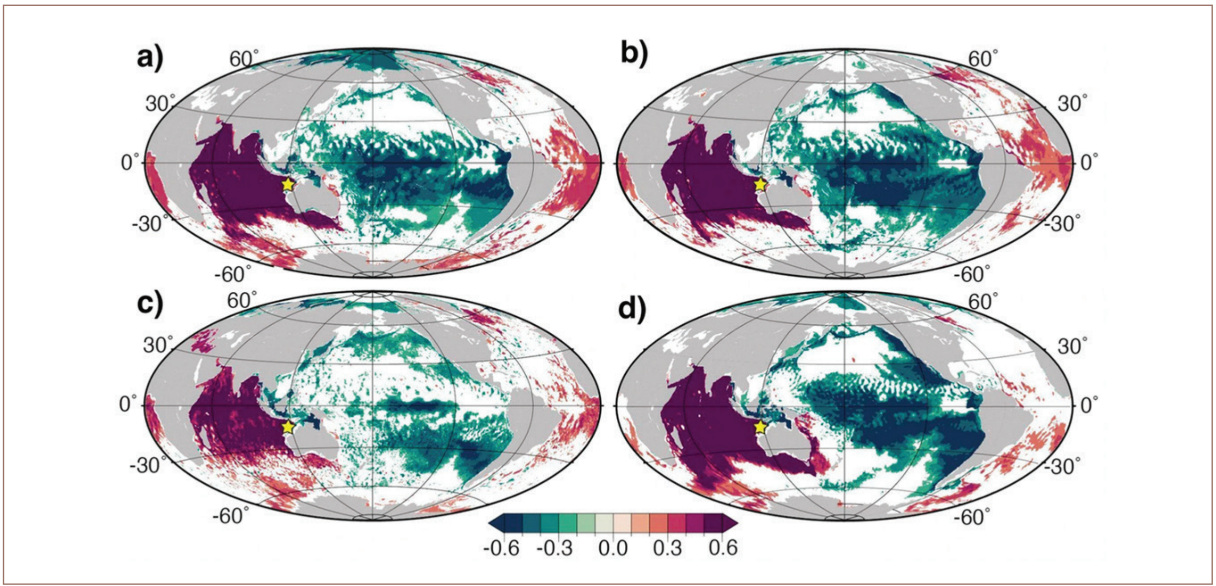

*Figure 9.15: Plot of correlation (> 90% significance) of model estimated BSL anomaly at the Maritime Continent (yellow star) with respect to BSL anomaly at all grid locations derived from **a** NEMO, **b** ECCO$_2$, **c** HYCOM, and **d** MOM5.1 during December to April from 2009 to 2016.*

Ref: *Afroosa, M., Rohith, B., Paul, A., Durand, F., Bourdallé-Badie, R., Joseph, S., ... & Shenoi, S. S. C. (2022). Investigating the robustness of the intraseasonal see-saw in the Indo-Pacific barotropic sea level across models. Ocean Dynamics, 72(7), 523-538.*

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9.16 Impact of initial and lateral boundary conditions in a Regional Indian Ocean Model and Salt transport in the Bay of Bengal

This study used seven years of (2003-2009) simulations from a nested basin-scale regional eddy-permitting Indian Ocean model, forced with CORE-II inter-annual forcing with different initial and lateral boundary conditions. Better initial and boundary condition shows significant improvement of thermocline temperature bias within a nested region (Figure 9.16). This study shows accurate initial and lateral boundary conditions are essential for the realistic simulation of the mean and the variability of temperature and salinity in the upper ocean over the Bay of Bengal (BoB). It has been reported in earlier studies that during the summer and winter monsoon the highly saline AS water intrudes into the south BoB. Most of the previous studies on salt transport into BoB are concentrated in the upper oceans (0-400 m). Therefore, any presence of pathways transporting salt into BoB deeper than 400 m has not been investigated. We studied salt transport along 8°N up to 2000 m depth. We reported for the first time about the coastally trapped narrow boundary current along the east coast of the Bay of Bengal at the thermocline depth (50-200 m). This coastally trapped narrow boundary current is absent in widely used global reanalysis products such as SODA3, ORAS5 GODAS. The regional models

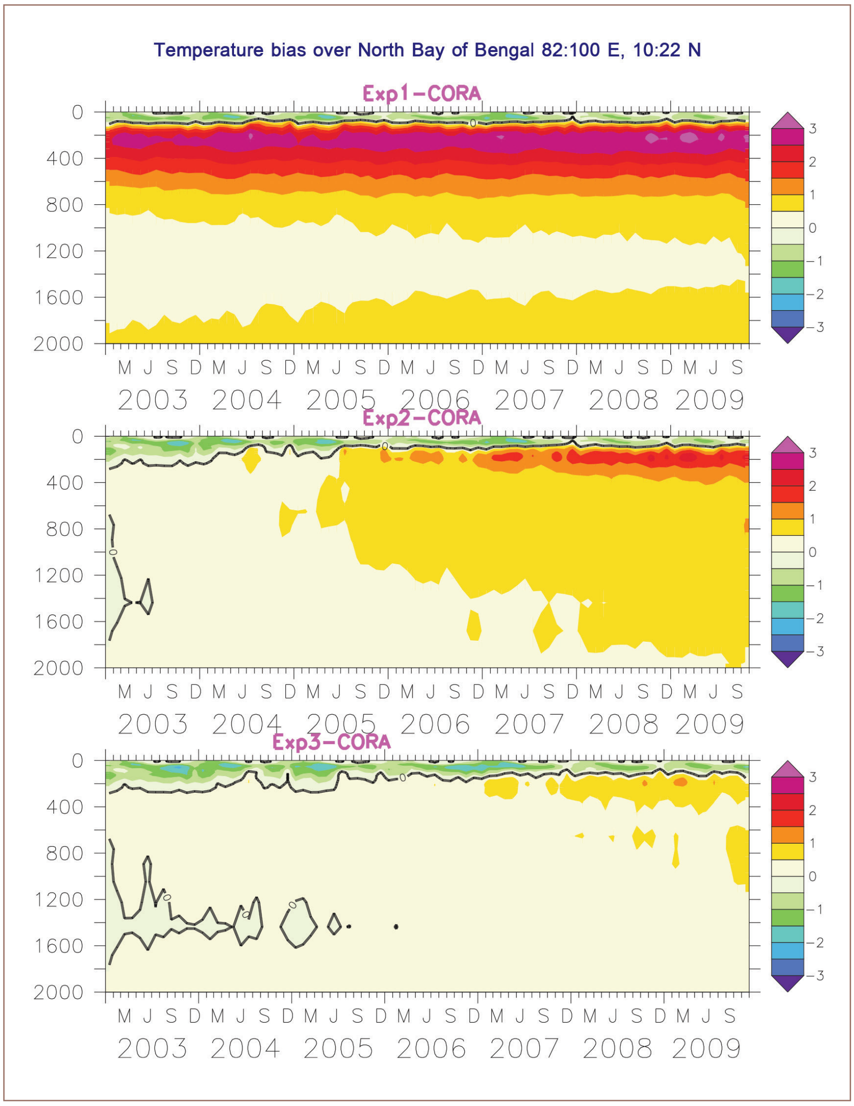

Figure 9.16: Depth vs time plots of the differences in temperature between the three simulations (Exp-1, -2, -3) and the observed gridded temperature over northern BoB. (1) Exp-1: Using initial and lateral boundary conditions from 1o MOM4p1 global model; (2) Exp-2: Using initial conditions for 2003 from INCOIS-GODAS reanalysis, but lateral boundary conditions from 1o MOM4p1 global model (Rahaman et al. 2014); (3) Exp-3: Using both initial and lateral boundary conditions from INCOIS-GODAS reanalysis.

Ref: *Rahaman, H., Kantha, L., Harrison, M., Raju, J. V. S., Nair, T. B., & Ravichandran, M. (2023). Impact of initial and lateral open boundary conditions in a Regional Indian Ocean Model on Bay of Bengal circulation. Ocean Modelling, 184, 102205, DOI: 10.1016/j.ocemod.2023.102205.*

accurately simulate the width of the EICC structure as seen in the observation. However, the widely used global reanalysis products such as SODA3, ORAS5 GODAS are unable to reproduce the narrow EICC structure. We identified new deeper pathways for salt intrusion at 300-1500 m depth along 82°E into the Bay of Bengal across 8°N. Integrated salt transport across 8°N in the southern Bay of Bengal shows large interannual variability with a very prominent seasonal cycle in the upper 0-200 m depth. This study provides first ever evidence of prominent intra-seasonal variability of salt flux across 8°N at deeper ocean depth.

9.17 Generation and Assessment of ARGO Sea Surface Temperature Climatology for the Indian Ocean Region

There are many SST products developed by various agencies viz., GHRSST, Optimally Interpolated SST, and HADISST using in-situ and remote sensing observations. However, ARGO near-surface temperatures were not used in the generation of these products. Argo data is available from 2001 and is nearly uniform both in space and time compared to all other sources of in situ data. Given the availability of temperature from Argo and its importance, an improved daily gridded SST product can be generated using Argo data. Accordingly a climatological product using two decades of data for the domain 30°E-120°E, 30°S-30°N was generated using Data Interpolation Variational Analysis (DIVA) method. An

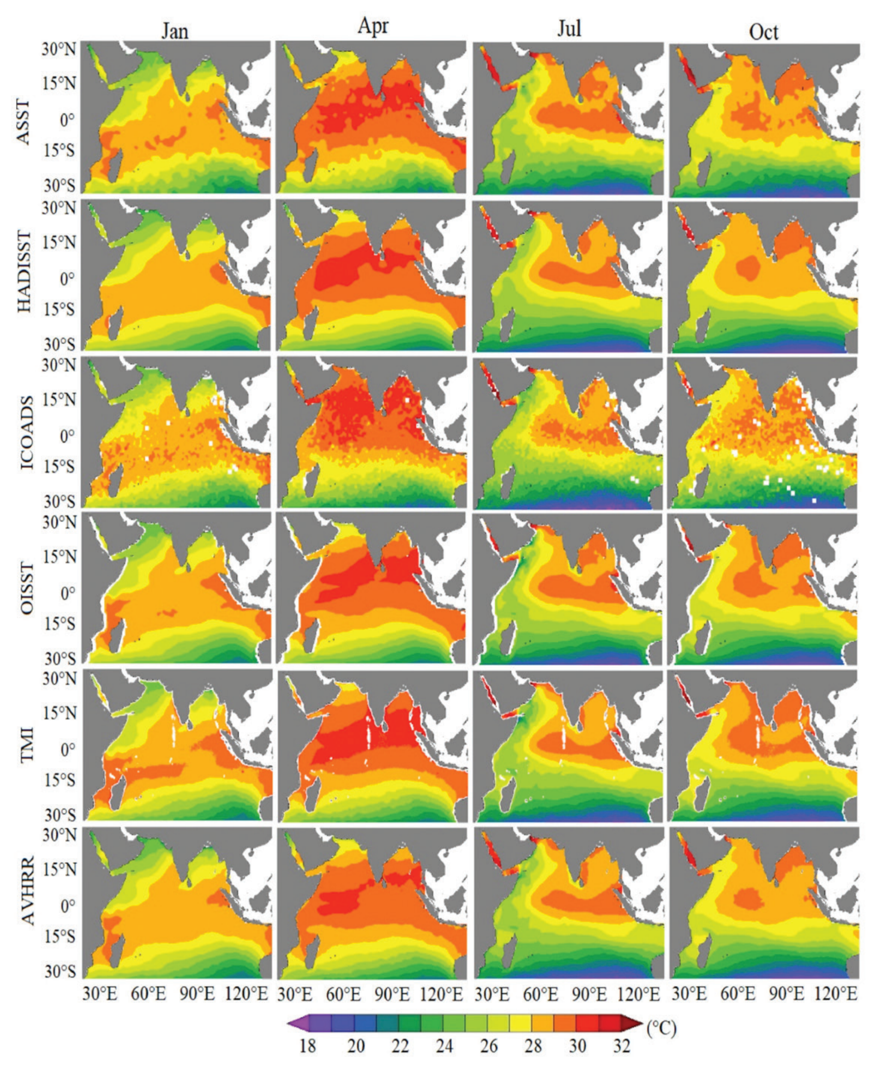

Figure 9.17 : Climatology of SST from ARGO, HADISST, ICOADS, OISST, TMI, AVHRR for the months of January, April, July, and October representing winter, summer, summer-monsoon and post-summer monsoon cycles.

Ref: *Ravi Kumar Jha, T.V.S. Udaya Bhaskar, Generation and Assessment of ARGO Sea Surface Temperature Climatology for the Indian Ocean Region,Oceanologia,Volume 65, Issue 2,2023,Pages 343-357,ISSN 0078-3234,https://doi.org/10.1016/j.oceano.2022.08.001.*

assessment of daily and weekly gridded products generated using Argo in situ data has been conducted against the existing SST products and the assessment was carried out on a climatological scale to establish the usability on all time scales.

As in-situ data sets are the main sources of validation of satellite and model products, data sets from RAMA and OMNI buoys were also used. Popular SST products viz., HADISST, ICOADS, OISST, TMI, and AVHRR for the period of Argo SST were used, and climatology was generated to assess Argo SST on a spatial scale. Those RAMA and OMNI moorings with continuous data matching the period of Argo SST were employed for validation at their respective locations. Using these in-situ and spatial SST data sets, various statistics like BIAS, RMSE, Correlation, Skill Score, conditional and unconditional biases were generated and analyzed for assessing the Argo SST product. The Argo SST product is observed to agree well with all the SST products except for ICOADS. Low BIAS in the range of -0.16°C to -0.01°C was observed between Argo SST and other SST products. RMSE less than 0.38°C was observed when compared with all SST data products except ICOADS. Both the non-dimensional biases are observed to be negligible, indicating high Skill Score and correlation. These statistics suggest that Argo SST is in near-perfect agreement with all the SST products used for validation. Hence, Argo SST data sets may be used to prepare high-quality SST products as it has uniform data coverage both spatially and temporally along with other in-situ data sets. Inclusion of SST from Argo will make the gridded products more robust.

9.18 LIST OF RESEARCH PUBLICATIONS DURING APRIL, 2022- MARCH, 2023

1. Afroosa, M., Rohith, B., Paul, A., Durand, F., Bourdallé-Badie, R., Joseph, S., ... & Shenoi, S. S. C. (2022). Investigating the robustness of the intraseasonal see-saw in the Indo-Pacific barotropic sea level across models. Ocean Dynamics, 72(7), 523-538. DOI: https://doi.org/10.1007/s10236-022-01518-8.
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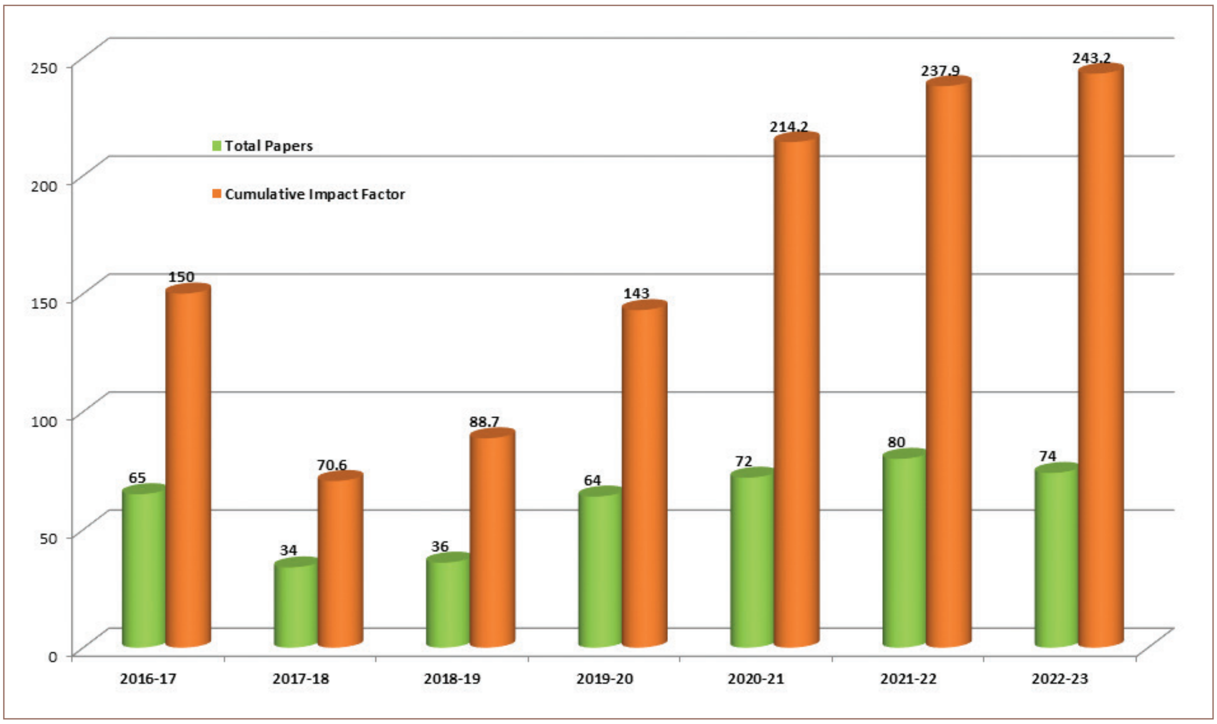

Figure 9.18 : Growth of publications in peer review journals and their cumulative impact factor.

RESEARCH HIGHLIGHTS

10

INVOLVEMENT IN INTERNATIONAL COORDINATION

10.1. Intergovernmental Oceanographic Commission (IOC)

The Director, INCOIS, as a member of the Indian delegation led by the Secretary of the Ministry of Earth Sciences (MoES), attended the 55th session of the Intergovernmental Oceanographic Commission (IOC) Assembly in Paris, France from 13-23 June 2022. During the session, India made several interventions on various topics, including the report of the Executive Secretary of the IOC, the status of IOCINDIO, the UN Decade of Ocean Science for Sustainable Development, ocean hazard warning and mitigation systems, the IOC State of the Ocean Report (StOR), and ocean observations in areas under national jurisdiction. India also provided updates on its progress and support for IOC activities and UN Ocean Decade initiatives.

10.2. World Meteorological Organization (WMO)

- INCOIS participated in the virtual WMO-IOC Joint Collaborative Board (JCB) meeting during 01-02 March 2022. Dr. T. Srinivasa Kumar, Director, INCOIS served as the Co-Chair of the JCB representing IOC. Discussions focused on the joint activities of WMO and IOC, the role of the JCB in enhancing collaboration on mutual interests, identifying gaps and potential areas of strengthened collaboration, and making recommendations to address these gaps.
- INCOIS has been designated as a Regional Specialized Meteorological Centre (RSMC) for numerical ocean wave prediction and global numerical ocean prediction in WMO's 76th Executive Council session (EC-76) held in March 2023. A proposal to designate INCOIS as an RSMC for Marine Environmental Emergency Response (MER) is currently under active consideration.

10.3. Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/ICG/IOTWMS)

- As a part of the ICG/IOTWMS of the IOC of UNESCO, INCOIS is acting as Tsunami Service Provider (TSP) and continued to provide tsunami services to the Indian Ocean Region together with TSPs Australia & Indonesia. TSP-India providing services to Australia, Bangladesh, Comoros, France (La Réunion), India, Indonesia, Iran, Kenya, Madagascar, Malaysia, Maldives, Mauritius, Mozambique, Myanmar, Oman, Pakistan, Seychelles, Singapore, South Africa, Sri Lanka, Tanzania, Thailand, Timor Leste, UAE and Yemen.
- INCOIS Scientists involved in various capacities (Vice-chairs and members) in the ICG/IOTWMS in Steering Group, Working Groups, Task Team and participated in related virtual meetings and contributed to related activities.
- INCOIS conducted 24th and 25th Communications (COMMs) tests of the ICG/IOTWMS on 08 June 2022 and 07 December 2022 to validate the dissemination processes. INCOIS issued tsunami test bulletins to 25 Indian Ocean rim countries as a Tsunami Service Provider. Different dissemination modes were tested.
- Tsunami Evacuation Planning (TEP) hybrid workshop was conducted at INCOIS on 13 September 2022 as part of IOC-UNESCO and UNESCAP project, Strengthening Tsunami Early Warning in the Northwest Indian Ocean Region through Regional Cooperation for North west Indian Ocean Region.

- INCOIS Scientists - Shri. E. Pattabhi Rama Rao and Ms. M V Sunanda have been, respectively, re-elected as a Vice-Chair of ICG/IOTWMS and the Sub-Regional Working Group for the North-West Indian Ocean for the second term. Mr. R. S. Mahendra, Mr. J. Padmanabham and Mr. B. Ajay Kumar have been, respectively, elected as a Vice-Chair of Working Group 1 on Tsunami Risk, Community Awareness, and Preparedness; Working Group 2 on Tsunami Detection, Warning, and Dissemination; Task Team on Indian Ocean Wave Exercises (IOWave23) during the 13th Session of IOC-UNESCO's Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) held at Bali Indonesia from 28 November - 01 December 2022.

Figure 10.1: 13th Session of IOC-UNESCO of ICG for the Indian Ocean Tsunami Warning & mitigation System at Bali, Indonesia.

10.4. UN Decade of Ocean Science for Sustainable Development

- The assessment of India's proposal to establish the Decade Collaborative Centre for the Indian Ocean Region (DCC-IOR) was carried out on 13 May 2022, and subsequently, it was approved by the IOC Decade Coordination Office. IOC endorsed the proposal on 19 October 2022 and a formal letter of exchanges to acknowledge and formalize the DCC-IOR is scheduled during the IOC Assembly session in June 2023.
- INCOIS participated in the bi-monthly meetings conducted by the IOC Decade Coordination Office with all National Decade Coordination Committees (NDCC) focal points to update and review the progress of national activities under UN Decade of Ocean Science for Sustainable Development, to discuss on the contributions of NDCs to the success of the decade, discussion on Global Stakeholder forum, etc.
- INCOIS partnered with UN Decade Collaborative Centre on Ocean Prediction and actively participated in its Kick-off meeting held through online platform during 11-12 January 2023. INCOIS is playing a major role in formulating and coordinating the formation of the Indian Seas Regional Team for Ocean Prediction.

- A project proposal by IIOE-2 Early Career 'Scientist' Network (ECSN) titled 'Devising Early-Career Capacity Development in the Indian Ocean region' has been endorsed as an Ocean Decade action under ECOPs programme in March 2023.
- Dr. Srinivasa Kumar, Director, INCOIS has been invited to be a Member of the Working Group on Ocean Cities for One year and he has also been the Co-Chair of the Working Group on Ocean Resilience.

10.5. Indian Ocean Rim Association (IORA)

- INCOIS submitted a proposal to Ministry of External Affairs (MEA), Government of India for being identified as the nodal institute/ centre for setting up the IORA Centre of Excellence: Digital Knowledge Hub in India.
- Director, INCOIS delivered a keynote talk on "Ocean Value Chain for Blue Economy – Observations to Services" at 2nd meeting of the IORA Working Group on Academic, Science, Technology & Innovation (WGSTI) at New Delhi, India on 30 September 2022.

10.6. Indian Ocean Global Ocean Observing System (IOGOOS)

- IOGOOS Secretariat at INCOIS successfully organised the 18th annual meeting of IOGOOS and its allied programmes such as Indian Ocean Regional Panel (IORP), Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER), IndOOS Resource Forum (IRF), International Indian Ocean Expedition (IIOE)-2 during 06-09 February 2023 at Perth, Western Australia.
- The 06th meeting of the Steering Committee (SC) of the IIOE-2 was organised virtually during 06-07 February 2023 at Perth, Western Australia by the IIOE-2 Project Office (JPO) located at INCOIS.
- INCOIS participated in the 14th meeting of the IndOOS Resource Forum (IRF) held virtually on 06 April 2022, and provided update on the ocean observation network of India and the resources allocated towards the same and collaborative efforts under NOAA-MoES.
- INCOIS participated in the GOOS Regional Alliances (GRA) Council meeting held virtually on 06 July 2022 to discuss on GRF-X report, GRA Success stories, Ocean co-lab, GRA Capability assessment across the value chain and on the new GOOS Regional policy.

10.7. Regional Integrated Multi-Hazard Early Warning System for Asia and Africa (RIMES)

- Under the MoU between MoES, Govt. of India and RIMES, INCOIS continues to provide the ocean state forecasts for Comoros, Madagascar, Maldives, Mozambique, Seychelles, and Sri Lanka. INCOIS also continues to receive seismic/GNSS data from Myanmar, Bhutan and Nepal established by RIMES and INCOIS.
- INCOIS has provided weekly updates including past week briefing and upcoming week forecast of Ocean State (Wave, Wind, Current, Swell, Sea Surface Temperature) for Indian Ocean under South Asia Hydromet Forum (SAHF) administrated by RIMES.

10.8. Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER) International Program Office

Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) is an international program co-sponsored by IMBeR (Integrated Marine Biosphere Research) and Indian Ocean Global Ocean Observing System (IOGOOS), with a focus on the Indian Ocean. The SIBER program aims to motivate and coordinate international interest in Indian Ocean research to improve the understanding of the role of the Indian Ocean in global biogeochemical cycles and the interaction between these cycles and marine ecosystem dynamics. Indian National Centre for Ocean Information Services (INCOIS), Hyderabad hosts International Program Office to coordinate the activities of SIBER.

Prof. Raleigh Hood from the University of Maryland, Cambridge, USA, and Dr. Gregory Cowie from the University of Edinburgh, UK, continue to serve as co-chairs of the SIBER Scientific Steering Committee (SSC). Dr. Aneesh Lotliker, Scientist-E & Divisional Head of the Ocean Observations Network (OON) at INCOIS, serves as the Executive Director of the SIBER International Program Office.

The 12th meeting of SIBER Scientific Steering Committee (SSC) was convened on 09 February 2023 at University of Western Australia, Perth. The primary focus of the meeting was to review the membership of the SIBER SSC, provide updates on the publications and to discuss the plans to continue SIBER beyond 2025. In during the SIBER SSC membership review, two members, Dr Jerry Wiggert and Dr Somkiat Khokiattiwong, were rotated off and one member, Dr Zainal Arafin was replaced by Dr Ocky Karna Radjasa. In addition, SSC includes one new member Dr Eric Raes from IIOE-2 ECSN. The co-chair provided updates on the SIBER products such as EGU Special Issue on IIOE-2, Deep-Sea Research Special Issues on IIOE-2 and Elsevier book on the Indian Ocean. The SSC members also presented the plans for biogeochemical observations in India, Germany, France, Australia, South Africa and United Kingdom. Subsequently, plans for SIBER post – 2025 were also discussed.

10.9. Second International Indian Ocean Expedition (IIOE-2) Joint Project Office (JPO)

The Second International Indian Ocean Expedition (IIOE-2) is a major global scientific program that engages the international scientific community in collaborative oceanographic and atmospheric research from coastal environments to the deep sea revealing new information on the Indian Ocean. The IIOE-2 program is co-sponsored by UNESCO-IOC, the Scientific Committee on Oceanic Research (SCOR) and IOGOOS. These international bodies, each involved in the science in the Indian Ocean, takes responsibility to facilitate funding and resources.

The IIOE-2 program was executed with the secretarial support from Joint Project Offices located at Australia (IOC Perth Program Office, PPO) and India (INCOIS, Hyderabad). The Australian IIOE-2 JPO Node ceased its operation on 30 September 2021, following the cessation of underpinning funding to PPO from the Western Australian State Government. Subsequently, the Joint Project Office - India continued IIOE-2 Project Office and provided secretarial support to execute the program. The major responsibility of IIOE-2 PO India is to maintain IIOE-2 Website, facilitate endorsement of projects, outreach activities in the form of Ocean Bubble and Monthly Newsletter, management of the data generated from IIOE-2 cruises, facilitate Early Career Scientist Network (ECSN) and social media.

Dr. Vladimir Ryabinin, Dr Marie-Alexandrine Sicre and Dr T. Srinivasa Kumar continued to be the co-chairs of the IIOE-2 Steering Committee (SC) and Dr Aneesh Lotliker as a coordinator of IIOE-2 PO India. Further, JPO-India continued to maintain the website (https://iioe-2.incois.gov.in) including timely updates on IIOE-2 expeditions and metadata portal. The website includes (1) IIOE-2 Online Discussions Forum to discuss about any scientific topics within the registered users under IIOE-2, (2) website for Early Career Scientist Network (ECSN) under IIOE-2 and (3) WebGIS Application for the IIOE-2 Endorsed Projects along with the Observations Network. In addition, Cyber Security audit was conducted through C-DAC, Hyderabad, India certified by CERT-In and the suggestions were incorporated to maintain the security of the IIOE-2 website and the data. Furthermore, 12 newsletters were published along with one issue of The Indian Ocean Bubble (Issue No 16).

The IIOE-2 PO India convened the sixth meeting of the steering committee (IIOE-2 SC6) at Indian Ocean Marine Research Centre (IOMRC), University of Western Australia (UWA) during 06-07 February 2023 along with meetings of IRF (15th major meeting), SIBER (13th major meeting), IORP (18th major meeting), IOGOOS (18th major meeting) and KUDOS Workshop as part of International Indian Ocean Science Conference (IIOSC 2023). The IOMRC provided venue and logistical support and CSIRO was the major sponsor in support of the conference's special events. The Western Australian Global Ocean Observing System Inc. (WAGOOS) provided sponsorship and administrative support and Wise Wine, Margaret River, Western Australia supported the opening reception event. The IIOSC-2023 Conference Information Booklet is available at https://iioe-2.incois.gov.in/documents/IIOE-2/IIOSC2023/InformationBooklet.pdf. The agenda of the Sixth meeting of the International Steering Committee of Second International Indian Ocean Expedition (IIOE-2 SC 6) is available at https://iioe-2.incois.gov.in/documents/IIOE-2/IIOSC2023/Draft%20Agenda_Sixth%20meeting_IIOE-2.pdf. During the meeting the co-chairs of National Committees, working groups and science themes reported the progress. In addition, flash talks were given by the members of the ECSN followed by the report from coordinator of IIOE-2 PO India.

IIOE-2 SC6 endorsed one project entitled "KIOST Indian Ocean Study: Korea-US Joint Observation Study of the Indian Ocean". The project has links to IIOE-2 ST-2 i.e. Boundary Current Dynamics, Upwelling Variability and Ecosystem Impacts. The project is funded by the Ministry of Oceans and Fisheries, Republic of Korea and has International Collaboration. The project duration is from 01 April 2022 – 31 December 2026, and adhere to the IIOE-2 Data Sharing Policy. The benefits from IIOE-2 endorsement are to increase the impact of research by sharing it with the IIOE2 community and create collaborations to oceanographers in foreign countries to extent the impact of research proposal.

The IIOE-2 SC6 noted that the tenure of IIOE-2 until 2025. For last seven-year IIOE-2 community has contributed significantly to the understanding of the Indian Ocean in terms of observation, research and capacity development along. Also there have been many international collaborations exchanging scientific ideas. In addition, the ECSN has gained momentum and discontinuing the program may have an impact on ECSN. Therefore, it was recommended formulating program aligning with UN Decade with more emphasis on coastal waters, consider priorities of the participating countries, best practices and establish linkages with other initiatives like IOGOOS, IORP, IRF, etc.

10.10. OceanPredict

OceanPredict is an international coordination of various international oceanographic centers for the coordination and improvement of global and regional ocean analysis and forecasting systems. It helps oceanographers to come together from around the world and exchange information that boosts and accelerates the improvements in operational oceanography. It builds the ocean prediction capacity of the future and endeavors to establish a seamless ocean information value-chain, from observations to end users, for economic and societal benefit. OceanPredict started in 1998 as the Global Ocean Data Assimilation Experiment (GODAE) which in 2009 transitioned to GODAE OceanView (GOV). GOV was renamed OceanPredict in 2019 to emphasize the science and development network for ocean prediction within an overall operational oceanography context. INCOIS scientists have been an active member of OceanPredict.

Whereas OceanPredict Science Team (OPST) with its 32 members is responsible for the implementation and execution of OceanPredict activities, OceanPredict (OP) contributes to the development of new science capabilities through active working groups, called the OP Task Teams. Dr. Arya Paul is the member of the OceanPredict Science Team from INCOIS and the Data Assimilation Task Team. Dr. Kunal Chakraborty from INCOIS is the member of the Marine Ecosystem Analysis and Prediction Task Team and Dr. Biswamoy Paul is the member of the Observing System Evaluation Task Team.

10.11. Partnership for Observation of the Global Ocean (POGO)

- INCOIS under the framework of ITCOOcean in partnership with Andhra University and financial support from POGO and INCOIS has conducted a training programme on "Ocean Observations to Societal Applications" at INCOIS during 30 October – 05 November 2022. The training

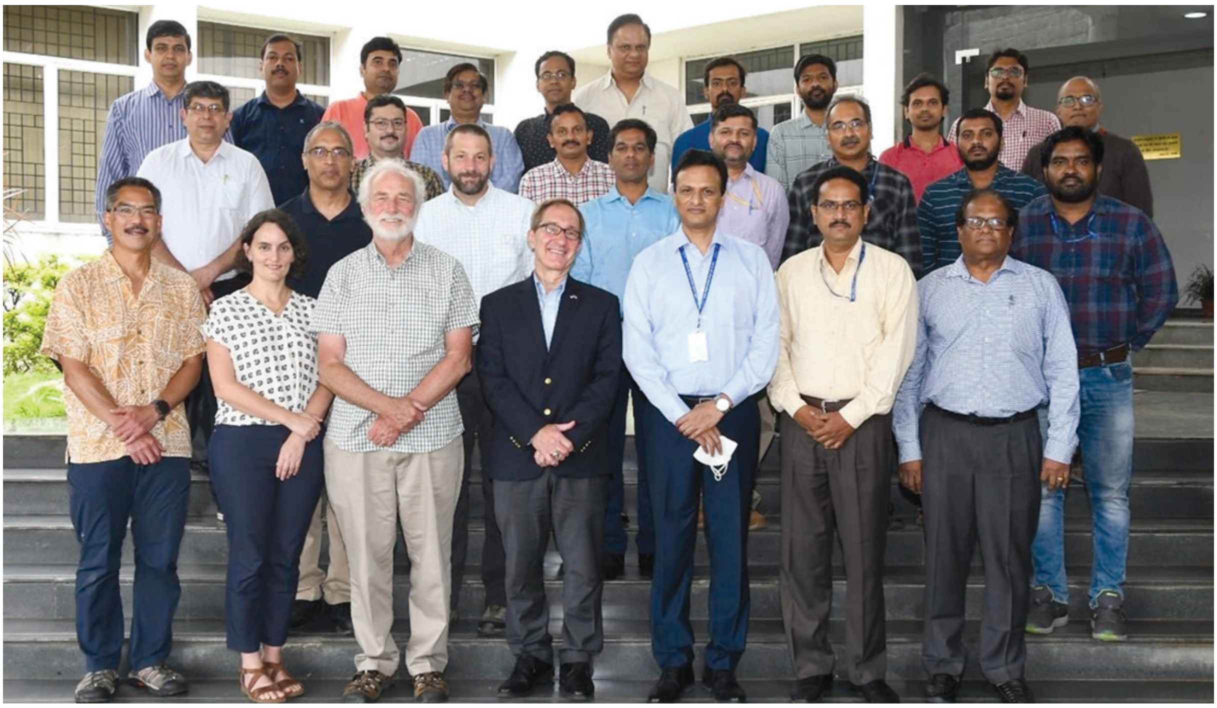

Figure 10.3: EKAMSAT science discussion meeting at INCOIS, 10-11 August 2022.

programme also aligns with the objectives of the UN Ocean Decade and contributes to the proposed outcomes of Ocean Decade on "A Predicted Ocean" and "A safe Ocean". 08 trainees from Bangladesh, Indonesia, Maldives, Mozambique, South Korea, Sri Lanka and Tanzania were able to join the training programme. 15 trainees across all over India have participated in the training. The Faculty were drawn from GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany, South African Environmental Observation Network /University of Cape Town, South Africa, University of Edinburgh, United Kingdom and national faculties from Andhra University, Indian Institute of Tropical Meteorology (IITM), Indian Meteorology Department (IMD), Indian National Centre for Ocean Information Services (INCOIS), Indian Ocean Regional Panel (IORP) of CLIVAR/GOOS, National Institute of Ocean Technology (NIOT) and Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER).

10.12. Science discussion meeting under EKAMSAT

- INCOIS hosted a two-day science discussion meeting during 10-11 August 2022 at Hyderabad, under Indo-US collaborative project titled "Enhancing Knowledge of the Arabian Sea Marine environment through Science and Advanced Training (EKAMSAT)". The meeting finalized the experimental design of the Arabian Sea field campaign to be carried out during the summer of 2023. The scientists from the institutions under the MoES, NOAA, ONR, and other institutions from India and the USA attended the meeting.

10.13. Other International and Bilateral Collaborations

- INCOIS participated in the first meeting of the Open-ended intersessional Working Group (OEIWG) on the status of the IOC Regional Committee for the Central Indian Ocean (IOCINDIO) held virtually on 28 February 2022 and discussed on the existing programmes, projects and activities in the IOCINDIO region.
- INCOIS participated in the 1st EDM – Climate Sustainability Working Group meeting of G20 held during 21-24 March 2022 at Indonesia. India provided its inputs on the concept note related to "Promoting Ocean based solution to climate change through enhanced cooperation in Science, Research and Innovation".
- INCOIS scientists delivered presentations on the services that are available to the members during the meeting of the Regional Subprogramme Management Team (RSMT) of SWFP-South Asia held virtually during 06-07 September 2022.
- Under the framework of the Memorandum of Understanding (MoU) by Government of India with Republic of Maldives, INCOIS scientists had a virtual meeting on 26 September 2022 with Ministry of External Affairs (MEA) of Govt. of India and representatives of Ministry of Fisheries, Marine resources and Agriculture, Republic of Maldives. The meeting discussed about the scope of the MoU, understand the requirements and discuss the road map for implementation of the collaborations under the scope of MoU.
- INCOIS scientists participated in virtual meetings with scientists of Centre for Environment, Fisheries & Aquaculture Science (CEFAS), UK to discuss on possible collaborations in the areas of Marine Pollution, Remote Sensing and Modelling. Scientists of CEFAS visited INCOIS on 20 September 2022 to discuss further on the possible collaborations under Ocean Country Partnership Programme (OCPP) of CEFAS.

10 INVOLVEMENT IN INTERNATIONAL COORDINATION

- INCOIS was successful in receiving the grants from Australia India Indo Pacific Ocean Initiative Partnership (AIIPOIP) during the second round of consultations for the proposal on "Predicting the Transport, Distribution, and Beaching Characteristics of Floating Microplastics in the Northern Indian Ocean". INCOIS will collaborate with University of Western Australia under this proposal.
- A virtual meeting was held on 11 October 2022 to explore areas of possible collaborations with research teams in Swedish Institutions under the call for proposals on Climate Advisory Services vertical of Deep Ocean Mission (DOM) of Government of India.
- Dr. Nimit Kumar was awarded the PORSEC Distinguished Service Award including an award-winning MOOC (IUCEL-2021 silver award) during the 15th PORSEC for his contributions. He is the first Indian to have received a PORSEC (science/service) award.
- INCOIS scientists participated in QUAD Space Working 'Group's technical workshop on extreme precipitation events, held virtually, 05-09 February 2023 (USA)/ 06-10 February 2023 (Australia, India, Japan).

11

GENERAL INFORMATION

11.1 Awards and Honours

11.1.1 WCDM-DRR Excellence Award for ITEWC

The ITEWC received the "World Congress on Disaster Management- Disaster Risk Reduction (WCDM-DRR) Excellence Award-2021" for the tsunami early warning services to the stakeholders of India and Indian Ocean countries. The award was conferred from Shri. G. Kishan Reddy, Hon'ble Minister of Tourism and Culture and Minister of Development of North Eastern Region, Government of India on 22 June 2022 at India International Centre, New Delhi.

Figure 11.1 WCDM-DRR award receiving for ITEWC on 22 June 2022

11.1.2 Anni Talwani Memorial Grant for Young Women Researcher-2022

Ms. Trishneeta Bhattacharya, Senior Research Fellow has received the Anni Talwani Memorial Grant for Young Women Researcher of Indian Geophysical Union (IGU) for the year 2022. The award was presented during the 59th Annual Convention of the IGU on "Geosciences of Himalaya for Sustainable Development" held at the Wadia Institute of Himalayan Geology, Dehradun, Uttarakhand during 16-18 November 2022.

Figure 11.2 Ms. Trishneeta Bhattacharya receiving the Anni Talwani Memorial Grant

11.1.3 PORSEC Service Award-2022

The 15th Pan-Ocean Remote Sensing Conference (PORSEC) was hosted by Universiti Teknologi Malaysia (UTM) on 7-8 December 2022 (preceded by the pre-conference tutorial during 03-06 December 2022). Dr. Nimit Kumar (Scientist, INCOIS) has been serving as a PORSEC board member since 2017 as Executive Secretary, and Chair for Membership, Education & Outreach. During the 15th PORSEC, he was awarded the 11th PORSEC Distinguished Service Award for his achievements including an award-winning MOOC (IUCEL-2021 silver award). He is also the first Indian to have received a PORSEC (science/service) award.

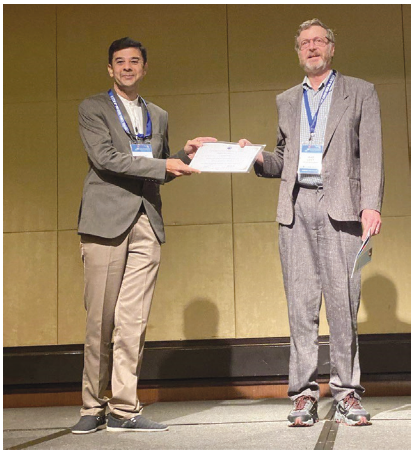

Figure 11.3 Dr. Nimit Kumar receiving the PORSEC Service Award-2022

11.1.4 Certificate of Merit 2022 by Ministry of Earth Sciences

Dr. T.V.S. Udaya Bhaskar, Scientist-F & Division Head, ODM was awarded Certificate of Merit 2022 for his outstanding contributions to Ocean Sciences during the 16th MoES Foundation Day Celebrations held at Prithvi Bhawan, New Delhi on 27 July 2022.

Figure 11.4 Dr. T.V.S. Udaya Bhaskar receiving the Certificate of Merit 2022 for his outstanding contributions to Ocean Sciences

11.1.5 ICTP's Associateship Scheme

Dr. Kunal Chakraborty has been selected as a 'Regular Associate' of the Abdus Salam International Centre for Theoretical Physics (ICTP) for a period of six years from 2023 until 2028. The Associateship Scheme, one of ICTP's oldest programmes, provides support for active scientists from developing countries to maintain long-term, formal contact with the Centre.

11.2 Awards of Doctor of Philosophy

Table 11.1 List of staff awarded the degree of Ph.D. during 2022-2023

Sl No	Name & Designation	Guides Name	Subject	University/ Department	Thesis Title
1	Dr. R. Venkat Shesu, Scientist E, INCOIS	Dr. M. Ravichandran, Secretary, Ministry of Earth Sciences, and co-supervision of Prof. B. Venkateswara Rao, Retd. Professor, Centre for Water Resources, JNTU, Hyderabad.	Earth & Atmospheric Science	Jawaharlal Nehru Technological University, Hyderabad	Application of Data Mining in Oceanographic Provincing
2	Dr. Lakshmi R Shenoy, Senior Research Fellow, INCOIS	Dr. Abhisek Chatterjee, Scientist E, INCOIS	Oceanography	INCOIS-KUFOS Joint Centre, Kerala University of Fisheries and Ocean Studies, Kochi	Deciphering the physical-biological interaction in the North Indian Ocean using Observation and Model
3	Dr. L Jyothi, Senior Research Fellow, INCOIS	Dr. Sudheer Joseph, Scientist G, INCOIS	Meteorology & Oceanography	INCOIS-Department of Meteorology and Oceanography, Andhra University, Visakhapatnam	Assessment of the upper ocean variability induced by the tropical cyclones over the north Indian Ocean
4	Dr. Jayashree Ghosh, Senior Research Fellow, INCOIS	Dr. Kunal Chakraborty, Scientist E, INCOIS	Oceanography	INCOIS-KUFOS Joint Centre, Kerala University of Fisheries and Ocean Studies, Kochi	Towards understanding spatio-temporal variability of the Indian Ocean carbon dynamics and its controlling factors

11.3 Memorandum of Understanding

Table 11.2 List of Memorandum of Understanding (MoUs) signed during 2022-23:

Particulars	Purpose
MoU between Indian Navy DNOM and INCOIS	Institutional Linkage for Training Towards Conduct of Various Courses
MoU between AMRITA and INCOIS	To carry out joint research and development activities, which are of mutual interest for both the organisations and R & D in operational oceanography for the development and validation of products required for the maritime community.
MoU between Spotflock Tech Pvt Ltd and INCOIS	To develop a collaborative framework for the utilisation of DeepTetch in the domain of Ocean Science and Services.
MoU between Infifresh Foods Pvt Ltd and INCOIS	To develop joint synergies by deploying mobile services like the Fishgram digital platform, having state-specific data in regional languages.
MoU between MRC and INCOIS	MRC – INCOIS shall jointly offer internship/fellowship programmes for graduate and postgraduate students.


Figure 11.5 Photos taken during signing of MoU between Indian Navy DNOM and INCOIS

11.4 Official Language Implementation

11.4.1 Inspection by the Parliamentary Committee on Official Language

The Second Sub-Committee of the Committee of Parliament on Official Language, Department of Official Language, Ministry of Home Affairs, Govt. of India inspected INCOIS, Hyderabad, on 18 June 2022. During the inspection, the committee, in the presence of the officials of INCOIS and the Ministry of Earth Sciences, reviewed the Implementation of the Official Language in the institution and appreciated the progress made by INCOIS in the implementation of the official language.

11.4.2 Hindi Training

A total of Fifty-three employees, including project staff, were registered for the Prabodh, Pragya and Parangat training sessions from January to May 2023. Training sessions are conducted at INCOIS by the Hindi Teaching Scheme, Department of Official Language, Ministry of Home Affairs, Hyderabad, in hybrid mode.

11.4.3 Hindi Workshop/Seminars

- Dr. Ravi Mishra, Scientist, National Centre for Polar and Ocean Research (NCPOR), delivered an invited lecture on 'Dissemination of Science & Language' as part of the Quarterly Hindi Workshop conducted on 29 June 2022.
- Shri Murarilal, Administrative Associate-3 (OL), conducted a workshop for the administrative staff on the topic 'Administrative Glossary & Noting' on 30 September 2022.

Figure 11.6 Photos taken during the 'Administrative Glossary & Noting' workshop

- Shri Ch. Subba Rao, Senior Hindi Officer, NGRI & Member Secretary, TOLIC (3), delivered a lecture on 'Role of e-Tools in the Official Language Implementation' during the workshop conducted on 23 December 2022.
- Shri Manoj Abusaria, Former Joint Director (OL), Ministry of Earth Sciences, delivered a lecture on the topic 'Inspection Questionnaire of Parliamentary Committee on Official Language' on 23 March 2023. The talk enlightened all the staff about the importance of Official Language Implementation.

11.4.4 Hindi Pakhwada (Fortnight) Celebrations

INCOIS celebrated Hindi Pakhwada during 01-14 October 2022. During the Pakhwada, various competitions like Essay, Noting/drafting and Scientific Presentation (PPT) were organised for the INCOIS staff. Also, a Hindi Poems competition was organized for the children of INCOIS employees. The winners of these competitions were felicitated with prizes during the concluding ceremony held on 14 October 2022 by the Chief Guest, Dr. D.D. Ojha, Senior Scientist.

Figure 11.7 Photos taken during the Hindi Pakhwada (Fortnight) Celebrations

11.4.5 Official Language Implementation Committee Meetings

The meetings of the Official Language Implementation Committee (OLIC) to evaluate the progress of work being done in Hindi were organized at regular intervals. Four meetings of the OLIC were conducted during the reporting period. Quarterly reports for the quarter ending on 30 June 2022, 30 September 2022, 31 December 2022 and the Annual Progress Report for the year ending on 31 March 2023 on the continuous use of Hindi in INCOIS was prepared and sent to MoES within the specified period. The Half Yearly Reports to the Town Official Language Implementation Committee (TOLIC) were submitted at regular intervals. The Annual programme and other orders/instructions by the Department of MoES and Department of Official Language regarding the implementation are being followed and implemented positively.

11.5 INCOIS Foundation Day

INCOIS celebrated its 25th Foundation Day on 03 February 2023. The Foundation Day talk was delivered by Dr. S. Chandrasekhar, Secretary - DST, on "13th - 21st Century: The Saga of Science." He also inaugurated the Oceansat-3 Data Acquisition and Processing Facility. Dr. M. Ravichandran, Secretary, MoES, the Chief Guest for the evening launched the National Glider Operations Facility and released a new Logo to mark the 25-year journey of INCOIS. Dr. K. Radhakrishnan Former Chairman, of Space

Figure 11.8 Collage image of Foundation Day celebration and inauguration of new facilities

Commission & Secretary, DoS, inaugurated the State-of-the-art E-Class Room Training facility at the International Training Centre for Operational Oceanography (ITCOO). The event was graced by the presence of Dr. SSC Shenoi, Former Director of INCOIS, who e-launched a new Marine Heat Wave Service for the Indian Ocean.

11.6 International Women's Day Celebrations

From 01-08 March, INCOIS celebrated International Women's Day with a wide range of events. On March 1, INCOIS staff showcased their hidden talents from dancing to singing to stand-up comedy in the 'INCOIS got talent' competition.

On 02 March, about 30 women students from the University of Hyderabad, Vallurupalli Nageswara Rao Vignana Jyothi Institute of Engineering &Technology and GokarajuRangaraju Institute of Engineering and Technology participated in an extempore speech competition and had an interactive session with the scientists and visited the various labs at INCOIS. A talk on "Career & Fellowship Opportunities for Students and Early Career Professionals" was delivered by Dr. Kunal Chakraborty.

On 03 March, INCOIS women staff were trained in basic self-defence techniques by N. Lakshmi Samrajyam, Founder of Rudramadevi Self Defence Academy. On 04 March, about 60 students from Vignan's Institute of Management and Technology for Women, Medchal visited the Tsunami Early Warning Centre and Operational Ocean Services Lab and interacted with INCOIS scientists.

On 06 March, INCOIS hosted Dr. P.V. Radha Devi, Director, of Advanced Data Processing Research Institute (ADRIN) and her team. Dr. Radha Devi shared her thoughts on "Celebrating Womanhood-Embracing Challenges for a Progressive Future."

Figure 11.8 Collage image of week-long International Women's Day Celebrations

On 07 March, Mr. Kishore, Vice President, Axis Bank enlighted INCOIS housekeeping women staff on the “Financial Literacy Programme” with a motto for financial empowerment of women. A rangoli competition was conducted for INCOIS women staff with the themes “Women in Science” and “Women Empowerment.”

On 08 March, K. Shilpavalli, Deputy Commissioner of Police (DCP) of Madhapur, Telangana Government joined the International Women's Day celebrations and delivered a talk on gender equality, feminism, and women's rights.

11.7 World Environment Day

On the occasion of World Environment Day, INCOIS celebrated 05 June 2022 as Open Day. As a part of this around three hundred (300) students from various colleges, schools, and public visited the INCOIS facilities, various labs and interacted with the scientists. This year's World Environment Day theme was "Only One Earth". It focuses on “Living Sustainably in Harmony with Nature”.

Figure 11.9 Collage image of World Environment Day Celebrations

11.8 World Ocean's Day

INCOIS open day was conducted on 08 June - World Ocean's Day. As a part of this, more than five hundred (500+) students from various schools to engineering colleges of Hyderabad and the public visited INCOIS facilities/labs and interacted with the scientists. The students were enlightened about the ocean's role in our weather and climate and about how it affects our daily life.

Figure 11.10 Collage image of World Ocean's Day Celebrations

11.9 International Yoga Day

INCOIS celebrated International Yoga Day on 21 June 2022. A Yoga Camp was conducted at INCOIS Multi-Purpose Hall by Yoga Chaitanya Trust (YCT) affiliated to Andhra University by following Covid-19 protocols and rules (wearing masks, social distancing, and sanitisation etc).

The volunteer provided the Yoga practices as per Ayush Protocol. Senior scientists and staff from INCOIS joined the session.

11.10 Rashtriya Ekta Diwas

INCOIS celebrated the birth anniversary of Shri Sardar Vallbhbhai Patel and observed 'Rashtriya Ekta Diwas' (National Unity Day) on 31 October 2022. Director, INCOIS took the pledge and read the same using the public address system. All staff followed the same and took the pledge from their respective desk.

11.11 Samvidhan Diwas

Director, INCOIS, and all staff of INCOIS took the preamble on 26 November 2022 as part of our National Constitution Day (Samvidhan Diwas) celebrations.

11.12 World Tsunami Awareness Day

On the occasion of the 7th World Tsunami Awareness Day (WTAD) on 05 November 2022, INCOIS open day was conducted to improve awareness on tsunamis. More than 200 school/college students and the public visited Tsunami Warning Centre to understand the services. Tsunami Awareness material was distributed to students.

(1) A National Tsunami Standard Operating Procedure (SOP) workshop conducted from 31 October – 03 November 2022 at INCOIS, Hyderabad. The workshop is part of the UNESCO-IOC and UNESCAP Project, "Strengthening Tsunami Early Warning in the North-West Indian Ocean through Regional Cooperation" focused on Disaster Management Organizations (DMOs) and Broadcast Media of Coastal States/UTs. The National Tsunami Ready Board meeting is also scheduled on 02 November 2022. Around 22 members attended the workshop from various coastal states/UTs of India

(2) Dr. T. Srinivasa Kumar, Director, INCOIS delivered an online talk on 'Applying risk information to strengthen the preparedness and early action' in Asia-Pacific: Early Warning and Early Action Before Every Tsunami conference on 04 November 2022 conducted by UNDRR, UNESCAP, UNDP and UNESCO.

(3) Tsunami Early Warning Centre, INCOIS conducted a mock tsunami drill in coordination with Odisha State Disaster Management Authority (OSDMA) and Odisha State Emergency Operation Centre. As part of a mock drill, ITEWC has simulated tsunami for an earthquake of M9.2 at Andaman & Nicobar Islands. Five coastal communities including two IOC-UNESCO Tsunami Ready communities actively participated and evacuated to test the Tsunami Ready indicators.

(4) Mr. B. Ajay Kumar, Scientist, INCOIS delivered an online lecture on "Tsunami Awareness and Tsunami Ready Programme" to the Alappad Community of Kerala as part of the community.

Figure 11.11 Students and public visit to ITEWC, INCOIS as part of WTAD on 05 November 2022

11.13 Vigilance and RTI Activities

Shri E. Pattabhi Rama Rao, Scientist 'G' & Group Director, ODICT continued as Vigilance Officer of INCOIS. No new complaints were received during the period 01 April 2022 to 31 March 2023.

In respect of the Right to Information Act (RTI) 2005, INCOIS related queries were regularly updated on the INCOIS website in prescribed format. Shri. M. Nagaraja Kumar, Scientist F & Division Head, Operational Ocean Services (OOS) functioned as the Public Information officer and Dr. T. Srinivasa Kumar, Director, INCOIS as the first appellate authority. During April 2022 – March 2023, 19 requests (14 through RTI Portal and 05 by Postal) were received under RTI Act and were disposed of within the time limit prescribed under the RTI Act, 2005.

As a pre-cursor to Vigilance Awareness Week 2022, prevention vigilance measures cum housekeeping activities were taken up during the 3 months campaign (16 Aug 2022 to 15 Nov 2022) that include property management, management of assets, record management, website maintenance and updation, identification of new areas for service delivery, updation of guidelines/circulars/manuals. Quarterly progress reports in respect of ongoing/completed procurement contracts were also prepared and submitted.

INCOIS observed "Vigilance Awareness Week 2022" from 31 October-06 November 2020 with the theme "Corruption free India for a developed Nation". As per the instructions of GoI guidelines, an Integrity Pledge was organized for all the staff of INCOIS on 31 October 2022. Dr. T. Srinivasa Kumar, Director, INCOIS led the pledge taking ceremony.

11.14 Azadi Ka Amrit Mahotsav Celebrations

INCOIS continued to organise various activities as part of Azadi Ka Amrit Mahotsav (AKAM) during 2022-23. These activities primarily focused on improving the outreach of 1) INCOIS activities and services and 2) India's achievements in the past 75 years in the field of Earth sciences with special emphasis on ocean sciences. The activities were grouped into the following mega-events.

11.14.1 Swachhata Pakhwada

INCOIS observed Swachhata Pakhwada during the first fortnight of July 2022 (01 – 15 July 2022). During this event, INCOIS carried out several activities such as plantation drives, awareness programmes, self-desk cleaning by employees and sanitisation on the campus.

11.14.2 Swachh Sagar, Surakshit Sagar/Clean Coast Safe Sea

The "Swachh Sagar, Surakshit Sagar/Clean Coast Safe Sea "campaign is a 75-day citizen-led campaign for improving ocean health through collective action. The campaign started on 05 July 2022 and ended on 17 September 2022. It had three strategic underlying goals that target transformation and environmental conservation through behaviour change. The three underlying goals of the campaign were to (i) Consume Responsibly (ii) Segregate waste at home and (iii) Dispose off Responsibly.

INCOIS organised the "Swachh Sagar, Surakshit Sagar" mega beach cleaning campaign on three beaches along the Andhra Pradesh Coast jointly with the Coast Guard and other participating government and social organisations. INCOIS teamed up with three universities — Andhra

University, JNTU Kakinada and Dr. BR Ambedkar University — to clean up RK Beach Vishakhapatnam, Kakinada, Srikakulam during 01-03 September 2022.

INCOIS also organised a scientific talk on "Swachh Sagar Surakshit Sagar" for the engineering students of JNTU Kakinada, followed by a painting competition for school students.

On 17 September 2022, 75-minute special simultaneous cleaning activities were conducted at 75 beaches along the coasts of India. INCOIS coordinated the cleaning activities on eight beaches (1. RK Beach, Visakhapatnam, 2. Yarada Beach, Visakhapatnam, 3. Rushikonda, Visakhapatnam, 4. Kakinada Beach, Kakinada, 5. NTR Beach, Kakinada, 6. Dhindi Beach, Nizampatnam, 7. Suryalanka Beach, Nizampatnam, 8. Manginapudi Beach, Machilipatnam). INCOIS scientists and about two thousand and two hundred volunteers participated in coastal clean-up activities during this 75-minute programme and the collected waste was segregated into plastic and non-plastic as part of data collection for the Marine Litter Program of MoES. Officers from the Indian Coast Guard, Marine police staff, NSS, NCC and college students also joined this mega beach cleaning program.

11.14.3 iConnect Event: 'Ocean Observations, Information and Advisory Services'

As a part of the 75 Industry Connects (iConnect) event organised by the Ministry of Science and Technology and Ministry of Earth Sciences to celebrate Azadi Ka Amrit Mahotsav and foster strong Atmanirbhar Bharat, INCOIS organised an iConnect event on 'Ocean Observations, Information and Advisory Services' organised under the theme 'Ecology, Environment, Earth & Ocean Science and Water' on 03 August, 2022. INCOIS showcased ocean information and advisory services and various activities during the event to stakeholders from different sectors and the potential areas of collaboration with the industry. About 150 delegates from Shipping, Ports, and Harbors, Oil and Gas Industry, the Offshore industry, Maritime Boards, the marine equipment industry, the fisheries industry, NGOs, Information and Technology etc. participated in the event organised in hybrid mode.

On this occasion, INCOIS signed three MoUs with industry partners to (i) develop a collaborative framework and applications for the utilisation of Deep Technology in the domain of Ocean Sciences and Services, (ii) undertake joint research projects, internship programmes, exchange of faculty / scholars and joint events and workshops and (iii) develop joint synergies by deploying the mobile services having state-specific data in regional languages for dissemination of information as desired by both parties, cooperate to provide desired services to the marine fishermen of the country. INCOIS also set up a Virtual Exhibition during the event showcasing various products and services.

11.14.4 Scientific Talk/ User interaction and awareness programme

As a part of Azadi Ka Amrit Mahotsav, INCOIS had adopted a government school in Bachupally, Hyderabad. Every Friday scientists from INCOIS visited the school and delivered lectures on science topics such as the basics of Ocean, Remote Sensing, Indian Summer monsoon, Earthquakes, Tsunamis etc.

As a part of Azadi Ka Amrit Mahotsav celebrations by INCOIS, a two-day event was organised in Mumbai in collaboration with Mangrove Foundation (an autonomous body under Mangrove Cell, Dept. of Forest, Govt. of Maharashtra).

On 14 July 2022, INCOIS scientists delivered talks on INCOIS Services and activities to the MF officials. Some of the key areas of cooperation found during this brainstorming were satellite telemetry, coastal vulnerability, coral bleaching alerts, and capacity-building training for MF staff at ITCOO. This was followed by a joint user interaction and awareness programme on 15 July 2022, hosted by Karanja Macchimar VKS Soc. Ltd. Uran, Raigad dist., Maharashtra. The awareness program was attended by fifty-three (53) fishermen and twenty (20) high school students, who were sensitised to India's advances in ocean information and advisory operational services as well as about the conservation of mangroves, sharks, turtles and other protected marine wildlife.

11.14.5 India International Science Festival (IISF) 2022

INCOIS participated in the India International Science Festival (IISF) held in Bhopal, Madhya Pradesh from 21 to 24 January 2023. IISF, an initiative of the Ministry of Science and Technology and Ministry of Earth Sciences (MoES) in association with Vijnana Bharati is an event for the celebration of science by all. The INCOIS stall (as part of the MoES booth) was visited by over 200 people including ministers, students, scholars, entrepreneurs, investors, and media persons. They were introduced to the various services provided by INCOIS such as Potential Fishing Zone advisories, Tsunami Early Warning System, Ocean State Forecasts, Storm Surge Warnings etc.

11.15 Campus Visit of Students

Over 5000 students from various schools, colleges, and universities visited INCOIS to learn more about our work and learn about the key role played by oceans in their daily lives. They were given a tour of our facilities such as the Tsunami Early Warning Centre, Operational Ocean Services Lab, Glider Facility, and Ground Station. The visits helped to raise awareness of our work and encourage young minds to enter the world of oceanography.

Table 11.3

Sl No.	Name of the Institute
1	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi
2	Kakatiya Institute of Technology & Science (KITSW), Warangal
3	VNR-Vignana Jyothi Institute of Engineering and Technology, Hyderabad
4	Silver Oaks Int. School, Hyderabad
5	Ahirkar Institute of Management Studies (AIMS), Nagpur
6	National Institute of Rural Development & Panchayati Raj (NIRDPR), Hyderabad
7	Vignan's Institute of Management and Technology for Women, Hyderabad
8	Marathwada Mitra Mandal College of Engineering, Pune
9	MVSR College of Engineering, Hyderabad
10	Glendale International Cambridge school, Hyderabad
11	Geological Survey of India Training Institute (GSITI), Hyderabad

12	Vardhman College of Engineering, Hyderabad
13	Meru International School, Hyderabad
14	JIVA Gurukulam School, Hyderabad
15	NASR Boys School, Hyderabad
16	Extension Education Institute (EEI), Hyderabad
17	Unicent School, Bachupally, Hyderabad
18	MNRI Exceed School, Kukatpally, Hyderabad
19	Govt. Polytechnic, Hyderabad
20	The Creek Planet School, Hyderabad
21	Surya Global School, Hyderabad
22	MLR Institute of Technology, Hyderabad
23	T.I.M.E. School, Hyderabad
24	St.Vincent Pallotti College of Engineering, Nagpur
25	Vignan Institute of Technology & Science, Hyderabad
26	Birla Open Minds Int. School, Hyderabad
27	Meridian School, Kukatpally, Hyderabad
28	Neo Geetanjali School, Pragathinagar, Hyderabad
29	CSIT, JNTU, Hyderabad
30	Samartha School, Mahbubnagar
31	CVR College of Engineering, Hyderabad
32	Nawab Shah Alam Khan College of Engineering & Technology
33	Geetanjali School, Hyderabad+Public Citizen
34	CVR College of Engineering+Public Citizen
35	Sreenidhi Institute of Engineering and Technology, Ghatkesar, Hyderabad
36	CISF-National Industrial Security Academy, Hyderabad
37	Centre for Earth, Ocean and Atmospheric Sciences, University of Hyderabad
38	JAIN (Deemed-to-be University), Kochi Campus
39	Durgabai Deshmukh Womens Govt. Training Inst.

11.16 Academic Projects/Internships carried out by students at INCOIS

Table 11.4

SL No	Name	Institute Name	Project Guide
1	Ms. Aswathy V.S.	Cochin University of Science and Technology (CUSAT), Kochi	Girish Kumar M.S.
2	Mr. Adithyanarayanan	Cochin University of Science and Technology (CUSAT), Kochi	Remya P.G.
3	Mr. Sriram A	Cochin University of Science and Technology (CUSAT), Kochi	Kunal Chakraborty
4	Ms. Theertha P	Cochin University of Science and Technology (CUSAT), Kochi	Abhisek Chatterjee
5	Mr. Athul C.R.	Cochin University of Science and Technology (CUSAT), Kochi	Arya Paul
6	Mr. R Sai Srikar	Vignan Institute of Technology & Science, Hyderabad	Udaya Bhaskar TVS
7	Mr. K Rishikesh	Vignan Institute of Technology & Science, Hyderabad	Udaya Bhaskar TVS
8	Mr. P Rajkumar	Vignan Institute of Technology & Science, Hyderabad	Udaya Bhaskar TVS
9	Ms. T Lalitha	Vignan Institute of Technology & Science, Hyderabad	Venkat Shesu R
10	Mr. T Praveen Reddy	Vignan Institute of Technology & Science, Hyderabad	Venkat Shesu R
11	Mr. Sri Hrudaya Sankalp	Manipal Institute of Technology	V Venugopala Rao
12	Mr. Sahil G	Vignan Institute of Technology & Science, Hyderabad	Venkat Shesu R
13	Mr. P Likhil	Amrita Vishwa Vidyapeetham, Kollam	Venkat Shesu R
14	Ms. V Leena Moukthika	Pondicherry University, Port Blair Campus, A&N	Sunanda M.V.
15	Mr. Jobin Raj M	Pondicherry University, Port Blair Campus, A&N	Sunanda M.V.
16	Mr. K Sai Lokesh	Pondicherry University, Port Blair Campus, A&N	Ajay Kumar B

17	Mr. Sarfas K	Pondicherry University, Port Blair Campus, A&N	Prakash Mohanty
18	Ms. Chhavi Goyal	Amity Institute of Marine Science & Technology	Arya Paul
19	Mr. M Sai Krishna	Central University of Haryana	Sidhartha Sahoo
20	Mr. M Ravi Kiran	Central University of Haryana	Sidhartha Sahoo
21	Mr. Kaustubh M	Indian Institute of Technology Kharagpur	Abhisek Chatterjee
22	Ms. Shradhha Motmal	University of Mumbai	Nimit Kumar
23	Ms. SharduliDalavi	University of Mumbai	Nimit Kumar
24	Mr. Shreyas Adsul	University of Mumbai	Nimit Kumar
25	Mr. K. Pavan Likith	Central University of Karnataka	Mahendra RS
26	Mr. M Yuvaraju	Central University of Karnataka	Mahendra RS
27	Mr. MSV Aravind	Central University of Karnataka	Prakash Mohanty
28	Ms. K. Nikita Namdev	Central University of Karnataka	Srinivasa Rao N
29	Mr. Noor Sabah M	Central University of Karnataka	Srinivasa Rao N
30	Mr. Rajchandra Trivedi	C.K Pithawala College of Engineering and Technology	Balakrishnan Nair T.M.
31	Mr. Dharmik Mangukiya	C.K Pithawala College of Engineering and Technology	Alakes Samanta
32	Mr. Kisan M Moradiya	C.K Pithawala College of Engineering and Technology	SJ Prasad

11.17 Deputation Abroad

Table 11.5

S. No	Name of the Officer/ Scientist	Country visited	Period of visit	Purpose of the visit
1	Dr. T. Srinivasa Kumar Director, INCOIS	Paris, France	13-23 June 2022	To attend the Meetings of the IOC Officers, 55th IOC Executive Council and Scientific Committee for the UN Ocean Decade Tsunami Programme.
		Paris, France	18-25 January 2023	To attend the meeting of the Scientific Committee for the UN Ocean Decade Tsunami Programme and IOC Officers.

GENERAL INFORMATION

		Perth, Australia	06-09 February 2023	To attend the Integrated Meetings of the IOGOOS, IIOE-2, SIBER, IORP and IRF.
2	Dr. T.M. Bala Krishnan Nair Scientist-G, Droup Director, OMARS, INCOIS	Geneva, Switzerland	26-28 October 2022	To attend the 1st meeting of WMO's Expert Team Met Ocean Requirements.
3	Mr. E. Pattabhi Rama Rao Scientist -G &Group Director, ODICT, INCOIS	Geneva, Switzerland	26-28 October 2022	To attend the 1st meeting of WMO's Expert Team Met Ocean Requirements.
		Bali, Indonesia	28 November- 02 December, 2022	To attend the 13th session of ICG/IOT WMS-XII.
		Perth, Australia	06-09 February 2023	To attend the Integrated Meetings of the IOGOOS, IIOE-2, SIBER, IORP and IRF.
4	Dr. Sudheer Joseph, Scientist-G & Division Head (ARO & MDA) INCOIS	Male, Maldives	21- 22 September 2022	To participate in the meeting of the National Focal Points (NFP's) of (SAACEP) on the Regional Project "PlASTIC FREE RIVERS AND SEAS FOR South Asia" (PLEASE PROJECT).
5	Dr. T V S Udaya Bhaskar Scientist- F DH-ODM, INCOIS	Paris, France	20-24 March 2023	To participate in the 27th session of the IOC Committee on international oceanographic data and information exchange held at France.
6	Mr. M. Nagaraja Kumar Scientist-F, Divison Head-OOS, INCOIS	Brussels, Belgium	23 January- 03 February 2023	To participate in the Training Program conducted under Exchange of Expertise on the Bay of Bengal.
		Perth, Australia	06-09 February 2023	To participate IOGOOS workshop and 18th Annual meeting to be held in conjunction with the meeting of SIBER, IRF, IOP, IIOE-2.

7	Dr. Aneesh A Lotliker Scientist -E & Division Head, OON, INCOIS	Lowestoft, United Kingdom	18-21 April 2022	As a member of the delegation led by MoES for discussion to have a possible research collaboration with the Centre for Environment, Fisheries and Aquaculture (CEFAS) in Marine Litter including remote sensing.
		Perth, Australia	06-09 February 2023	To participate IOGOOS workshop and 18th Annual meeting to be held in conjunction with the meeting of SIBER, IRF, IOP, IIOE-2
8	Mr. R.S. Mahendra Scientist-E, ARO, OMARS, INCOIS	Tehran, Islamic Republic of Iran	20-22 February 2023	To participate in the Third Phase of the Workshop Series on the Effects of Climate Change on the Indian Ocean Marine Environment.
9	Mr. Ch. Patanjali Kumar Scientist -E, ARO INCOIS	Mauritius	13-17 June 2022	To participate in IORA-UNITAR in-person Training Programme "Introduction to Geospatial Information Technology (GIT) for Operational Planning and Decision Making in Disaster Risk Management to be held in Mauritius.
		Japan	28 September 2022 - 16 September 2023	To participate in JICA Knowledge CO-Creation Program (KCCP) on "Seismology, Earthquake Engineering and Tsunami Disaster Mitigation (JICA-KCCP-JFY2022-NO202107994J001)".
10	Dr. Girish Kumar MS Scientist-E, OON, ODICT INCOIS	Washington DC, USA	15-16 March 2023	To attend an Indo-US collaboration research program in Washington DC, USA during 15-16 March 2023.

11	Dr. Kunal Chakraborty Scientist -E, MDA, INCOIS	ICTP, Trieste, Italy	15-17 August 2022	To Participate in the CLIVAR-GOOS workshop: from Global to Coastal: Cultivating New Solutions and Partnerships for an Enhanced Ocean Observing System in a Decade of Accelerating Change.
12	Mr. N. Kiran Kumar Scientist-E, ICT INCOIS	Perth, Australia	06-09 February 2023	To participate IOGOOS workshop and 18th Annual meeting to be held in conjunction with the meeting of SIBER, IRF, IOP, IIOE-2.
13	Ms. Vijaya Sunanda Scientist-E, ARO, INCOIS	Abu Dhabi, United Arab Emirates	14-16 November 2022	To attend the workshop on Makran Subduction Zone Science Strengthening Tsunami Warning and Preparedness to be held during 14-16 November, 2022.
14	J. Padmanabham Scientist-E, ICT, ODICT INCOIS	Bali, Indonesia	22 November – 02 December 2022	To attend Indian Ocean Tsunami Ready Workshop (ii) ICG/IOTWMS-XII session.
15	Dr. Abhisek Chatterjee Scientist-E, MDA Division, INCOIS	Belitung, Indonesia	13-15 December 2022	To participate in the Fifth Workshop on the Scoping of the next Assessment(s) of the United Nations Regular Process.
		Tehran, Islamic Republic of Iran	20-22 February 2023	To participate in the Third Phase of the Workshop Series on the Effects of Climate Change on the Indian Ocean Marine Environment.
16	Dr. Dipankar Saikia Scientist-D, ARO INCOIS	Abu Dhabi, United Arab Emirates	14-16 November 2022	To attend the workshop on Makran Subduction Zone Science Strengthening Tsunami Warning and Preparedness to be held during 14-16 November 2022.

17	Dr. Sanjiba Kumar Baliasingh Scientist-B, ARO, OMARS INCOIS	Jakarta, Indonesia	13 – 16 December 2022	To participate in the workshop Advanced Ocean Synergy Training Course 2023.
		Tehran, Islamic Republic Of Iran	20-22 February 2023	To participate in the Third Phase of the Workshop Series on the Effects of Climate Change on the Indian Ocean Marine Environment
18	Dr. Siva Srinivas Kolukula Scientist -C, MDA INCOIS	Abu Dhabi, United Arab Emirates	14-16 November 2022	To attend the workshop on Makran Subduction Zone Science Strengthening Tsunami Warning and Preparedness to be held during 14-16 November 2022.
19	Dr. Nimit Kumar Joshi Project Scientist - III, INCOIS	Morocco	12-16 September 2022	to attend as a faculty for the "Training Workshop on Space Oceanography" being organized by the Centre Royal de Teledetection Spatiale (CRTS), Morocco, and Committee on Space Research (COSPAR).
		Sylhet, Bangladesh	12-15 March 2023	To attend as a faculty for the 2023 NF-POGO Regional Training Programme on sustainable Marine Resource management from 12-25 March 2023 at Sylhet.
20	Ms. Sushmita Raulo, Project Scientist-I ARO, OMARS, INCOIS	Sylhet, Bangladesh	12-25 March 2023	To participate in the NFO-POGP regional trading program and international symposium on sustainable marine resource management.

GENERAL INFORMATION

11.18 Superannuation

Shri BVS Satyanarayan, Group Director, ICTD superannuated on 30 August 2022. He completed over 20 years of service at INCOIS having been a great support to the institute since its inception and formative years. He was fondly felicitated at a special farewell function in the presence of his family members. Staff members addressed him and shared their memories and experiences of working with him.

11.19 Estate Management and Other Infrastructure Services

- Rooftop solar electricity generated 800000 kWh, which is comparable to 200 tonnes of reduced carbon emissions.
- Efficient water management through the installation of water meters and the practices of water conservation techniques. For the previous two months, we have reduced total water consumption by 30% and are on our way to achieving “Zero water tankers,” campus.
- Geophysical surveys were conducted throughout the entire campus, and groundwater availability was investigated. This year, we will be drilling two new borewells. The work is still in progress.

Figure 11.12 INCOIS Director felicitating Shri BVS Satyanarayan

- Use of the ITCOOcean Hostel block and Canteen with all its amenities.
- Storage optimizers for the Purchase, Accounts, and Admin sections have been installed in the Main building FF Data Archival block.

11.20 INCOIS Human Capital

Regular positions:

Positions	Sanctioned posts	Staff-In-Position (In-situ)
Director	01	01
Scientist – G *	00	03
Scientist – F #	00	04
Scientist – E @	01	20
Scientist – D	01	07
Scientist – C	13	00
Scientist – B	26	01
Scientific Assistant	19	19
Administration	10	10
Total	**71**	**65**

Project Mode positions:

Position	Sanctioned posts	Staff in position
Project Scientist – D	12	4
Project Scientist – C	26	14
Project Scientist – B	53	46
Project Assistant (Technical/Non Technical)	63	21
Senior Assistant (Technical/Non Technical/Admin)	9	0
Administrative Officer	1	0
Research Fellow	34	19
Research Associates	7	1
Expert/ Consultant (Technical)	4	4
Expert/ Consultant (Admin)	1	1
Total	**210**	**110**

Note:

* Dr. T. Srinivasa Kumar, Scientist – G is on lien to INCOIS as Director.

Dr. Francis P.A, Scientist – F is on lien to University of Mumbai.

@ Mr. Ch. Patanjali Kumar is on deputation abroad to Japan.

Vacancies:

i) One post of Scientist - E & Two posts of Scientist – B are vacant due to Technical Resignation.

ii) One post of Scientist - C is vacant due to the death of an official in service.

ii) One post of Scientist - D is vacant due to Superannuation.

The above posts are advertised, and recruitment is under process.

12

ACRONYMS

ABIS	:	Algal Bloom Information Services
ADCIRC	:	ADvanced CIRCulation model
AIIPOIP	:	Australia India Indo Pacific Ocean Initiative Partnership
AKAM	:	Azadi Ka Amrut Mahotsav
ALE	:	Arbitrary Lagrangian-Eulerian
APNGCR	:	Asia-Pacific Network for Global Change Research
APSDMA	:	Andhra Pradesh State Disaster Management Authority
AS	:	Arabian Sea
BOB	:	Bay of Bengal
CBAS	:	Coral Bleaching Alert System
CEFAS	:	Centre for Environment, Fisheries & Aquaculture Science
Chl-a	:	Chlorophyll-a
CLIVAR	:	Climate Variability and predictability
CMIP6	:	Coupled Model Intercomparison Project Phase 6
COBALT	:	Carbon, Ocean, Biogeochemistry and Lower Trophic
COSPAR	:	Committee on Space Research
CRTS	:	Centre Royal de Télédétection Spatiale
DCC	:	Decade Collaborative Centre
DMO	:	Disaster Management Organization
DOM	:	Deep Ocean Mission
ECI	:	East Coast of India
ECMWF	:	European Centre for Medium-range Weather Forecast
ECOP	:	Early Career Ocean Professional
ECSN	:	Early Career Scientist' Network
EICC	:	East India Coastal Current
EKAMSAT	:	Enhancing Knowledge of the Arabian Sea Marine environment through Science and Advanced Training
ERA5	:	Fifth generation ECMWF Atmospheric Reanalysis
ERSEM	:	European Regional Seas Ecosystem Model
FABM	:	Framework for Aquatic Biogeochemical Models
FAST	:	Forecast Assessment Support Tool
FFMA	:	Fisher Friend Mobile Application
FVCOM	:	Finite-Volume Community Ocean Model
GEOMAR	:	Research Center for Marine Geosciences
GFZ	:	GeoForschungsZentrum
GMTSL	:	Global Mean Thermosteric Sea Level
GNSS	:	Global Navigation Satellite System
GODAS	:	Global Ocean Data Assimilation System
GOOS	:	Global Ocean Observing System
GRA	:	GOOS Regional Alliances
GTS	:	Global Telecommunication System

12 ACRONYMS

HPC	:	High performance computing
HySEA	:	Hyperbolic Systems and Efficient Algorithms
ICG/IOTWMS	:	Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System
ICT	:	Information & Communication Technology
IIOE	:	International Indian Ocean Expedition
IITM	:	Indian Institute of Tropical Meteorology
IMD	:	Indian Meteorological Department
INCOIS	:	Indian National Centre for Ocean Information Services
INGV	:	Istituto Nazionale di Geofisica e Vulcanologia (National Institute of Geophysics and Volcanology)
INSAT	:	The Indian National Satellite
IO	:	Indian Ocean
IOC	:	Intergovernmental Oceanographic Commission
IOCINDIO	:	IOC Regional Committee for the Central Indian Ocean
IOD	:	Indian Ocean Dipole
IOGOOS	:	Indian Ocean Global Ocean Observing System
IO-HOOFS	:	High Resolution Operational Ocean Forecast and reanalysis System.
IOR	:	Indian Ocean Region
IORA	:	Indian Ocean Rim Association
IORP	:	Indian Ocean Regional Panel
IOTWMS	:	Indian Ocean Tsunami Warning and Mitigation System
IPCC AR6	:	Intergovernmental Panel on Climate Change Sixth Assessment Report
IRF	:	IndOOS Resource Forum
ITCOOcean	:	International Training Centre for Operational Oceanography
ITEWC	:	Indian Tsunami Early Warning Centre
ITEWS	:	Indian Tsunami Early Warning System
IUCEL	:	International University Carnival on E-Learning
JCB	:	Joint Collaborative Board
JPO	:	Joint Project Office
JRA 55	:	Japanese 55-year Reanalysis
KPI	:	Key Performance Indicators
KPP	:	K Profile Parameterization
LETKF	:	Local Ensemble Transform Kalman Filter
MEA	:	Ministry of External Affairs
MER	:	Marine Environmental Emergency Response
MLD	:	Mixed Layer Depth
MoES	:	Ministry of Earth Sciences
MODIS	:	Moderate Resolution Imaging Spectroradiometer
MOM5	:	Modular Ocean Model version 5
MOM6	:	Modular Ocean Model version 6

MOOC	:	Massive Open Online Course
MSSRF	:	MS Swaminathan Research Foundation
MoU	:	Memorandum of Understanding
MY	:	Mellor-Yamada
NANO	:	NF-POGO Alumni Network for Oceans
NCAR	:	National Center for Atmospheric Research
NCESS	:	National Centre for Earth Science Studies
NCMRWF	:	National Centre for Medium Range Weather Forecasting
NCPOR	:	National Centre for Polar Ocean Research
NDBC	:	National Data Buoy Center
NDCC/NDC	:	National Decade Coordination Committee
NDMA	:	National Disaster Management Authority
NHO	:	National Hydrographic Office
NIDM	:	National Institute of Disaster Management
NIO	:	North Indian Ocean
NIO	:	National Institute of Oceanography
NIOT	:	National Institute of Ocean Technology
NOAA	:	National Oceanic and Atmospheric Administration
NWIO	:	North West Indian Ocean
OCCAS	:	Ocean Climate Change Advisory Services
OCM	:	Ocean Colour Monitor
OCPP	:	Ocean Country Partnership Programme
OEIWG	:	Open-ended intersessional Working Group
OHC	:	Ocean Heat Content
ONGC	:	Oil and Natural Gas Corporation
ONR	:	Office of Naval Research
OSCAR	:	Ocean Surface Current Analysis Real-time
OSDMA	:	Odisha State Disaster Management Authority
OSF	:	Ocean State Forecast
PFZ	:	Potential Fishing Zones
POGO	:	Partnership for Observation of the Global Ocean
PORSEC	:	Pan-Ocean Remote Sensing Conference
RAIN	:	Regional Analysis of Indian OceaN
RCOWA	:	Regional Education and Research Centre on Oceanography for West Asia
RCSTT	:	Regional Centre for Science and Technology Transfer
RECCAP	:	REgional Carbon Cycle Assessment and Processes
RIMES	:	Regional Integrated Multi-Hazard Early Warning System for Asia and Africa
ROMS	:	Regional Ocean Modeling System
RSMC	:	Regional Specialized Meteorological Centres
RSMT	:	Regional Subprogramme Management Team
SAHF	:	South Asia Hydromet Forum

12 ACRONYMS

SARAT	:	Search and Rescue Aid Tool
SCORI	:	Sustainable Coastal Ocean Research Institute
SDAP	:	Service Data Adaptation Protocol
SeaWiFS	:	Sea-viewing Wide Field-of-view Sensor
SIBER	:	Sustained Indian Ocean Biogeochemical and Ecological Research
SLA	:	Sea Level Anomaly
SMA `	:	Strong Motion Accelerometer
SOP	:	Standard Operating Procedure
SST	:	Sea Surface Temperature
SUST	:	Shahjalal University of Science and Technology
SVAS	:	Small Vessel Advisory Services
SWAN	:	Simulating WAves Nearshore
SWFP	:	Severe Weather Forecasting Programme
TEP	:	Tsunami Evacuation Planning
TSP	:	Tsunami Service Provider
TTF	:	Trust Fund for Tsunami
UN	:	United Nations
UNESCAP	:	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
UTM	:	Universiti Teknologi Malaysia
VECS	:	VSAT aided Emergency Communication System
VIIRS	:	Visible Infrared Imaging Radiometer Suite
VSAT	:	Very Small Aperture Terminal
WGSTI	:	Working Group on Academic, Science, Technology & Innovation
WICC	:	West India Coastal Current
WMO	:	World Meteorological Organization
WRF	:	Wave Rider Buoy
WTAD	:	World Tsunami Awareness Day
WQNS	:	Water Quality Nowcast System
WWIII	:	WaveWatch III

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FINANCE

K. PRAHLADA RAO & CO.
CHARTERED ACCOUNTANTS

H.No. 3-6-84/12&13, Flat # 402, Legend Venkatesha, Beside Taj Mahal Hotel,
Narayanguda, Hyderabad - 500 029. Telangana, India.
Phone : 040-40151768, E-mail: kprauditors@yahoo.com; www.kprandco.com

AUDITORS' REPORT

To
The Chairman and Members,
Governing Council,
INDIAN NATIONAL CENTRE FOR
OCEAN INFORMATION SERVICES,
Ocean Valley, Pragathinagar (B.O), Nizampet (S.O)
Hyderabad – 500090, India

We have audited the attached Balance Sheet of **INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES** as at 31st March, 2023, and also the Income & Expenditure Account and Receipts & Payments Account for the year ended on that date annexed thereto. These financial statements are the responsibility of the Society's Management. Our responsibility is to express an opinion on the financial statements based on our audit.

We conducted our audit in accordance with auditing standards generally accepted in India. Those Standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material mis-statements. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion and report that:

1. We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit.
2. In our opinion, proper books of account as required by the Society, have been kept by the Society so far as appears from our examination of such books.
3. The Balance Sheet, Income and Expenditure Account and Receipts and Payments Account are in agreement with the books of account.
4. In our opinion and to the best of our information and according to the explanations given to us and subject to the notes forming part of accounts, the Balance Sheet as at 31st March 2023, Income and Expenditure Account and Receipts and Payments Account for the year ended on that date, together with the Schedules and Notes on Accounts annexed therewith give a true and fair view of the state of affairs of the Society.

For **K. Prahlada Rao & Co.**
Chartered Accountants

(K. Prahlada Rao)
Partner
M.No.018477
FRN No: 002717S

Place : HYDERABAD
Date : 10.08.2023
UDIN : 23018477BGPXDD8881

BRANCH OFFICE : 47-3-28/19, FLAT NO. 2, II FLOOR, BHARAT TOWERS,
5th LINE, DWARAKA NAGAR, VISAKHAPATNAM - 530 016.

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES
(Ministry of Earth Sciences, Government of India)
"Ocean Valley", Pragathinagar (B.O.), Nizampet (S.O.), Hyderabad - 500 090

BALANCE SHEET AS AT 31st MARCH 2023

Particulars	Schedules	Current Year (2022-23) ₹	Previous Year (2021-22) ₹
CAPITAL FUND AND LIABILITIES			
Corpus fund	1	68,34,02,817	72,87,96,337
Earmarked funds	2	4,74,80,479	28,79,92,685
Current liabilities & Provisions	3	17,14,38,475	19,98,03,489
Total		**90,23,21,771**	**1,21,65,92,512**
ASSETS			
Fixed Assets	4	52,32,10,085	58,36,38,516
Current Assets, Loans & Advances	5	37,91,11,686	63,29,53,994
Total		**90,23,21,771**	**1,21,65,92,512**
Notes forming part of Accounts	11	-	-

As per our report of even date
For K. Prahlada Rao & Co.
Chartered Accountants

K. PRAHLADA RAO & CO., Chartered Accountants FRN No: 002717S Hyderabad

K. Prahlada Rao
Partner
M. No. 018477
FRN No: 002717S

Place : Hyderabad
Date : 10.08.2023

For and on behalf of
INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

10/8/23

(S. Nageswara Rao)
Senior Accounts Officer &
Head-ESS (Addl. Charge)

S Nageswara Rao
Senior Accounts Officer &
Head -ESS (Addl. Charge)

Indian National Centre for Ocean Information Services INCOIS Hyd

(Dr. T. Srinivasa Kumar)
Director, INCOIS

Dr. T. Srinivasa Kumar
Director, INCOIS

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES
(Ministry of Earth Sciences, Government of India)
"Ocean Valley", Pragathinagar (B.O.), Nizampet (S.O.), Hyderabad - 500 090

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 2023

Particulars	Schedules	Current Year (2022-23) ₹	Previous Year (2021-22) ₹
INCOME			
Income from Sales / Other Income	6	1,19,73,698	3,13,64,875
Interest Earned on Investments	7	30,61,214	25,33,461
Recurring Grants	8	23,36,36,881	22,78,00,000
TOTAL - A		**24,86,71,793**	**26,16,98,336**
EXPENDITURE			
Establishment Expenditure	9	14,57,28,760	13,26,78,122
Other Administrative Expenses	10	8,79,08,120	7,74,13,285
Depreciation	4	6,04,28,433	6,85,47,225
TOTAL - B		**29,40,65,313**	**27,86,38,632**
Excess of Income over expenditure (A-B)	1	**-4,53,93,520**	**-1,69,40,296**
Add / Less: Prior Period Items		-	51,69,349
Balance being net income / deficit transferred to Corpus Fund		**-4,53,93,520**	**-2,21,09,645**
Notes forming part of Accounts	11		

As per our report of even date
For K. Prahlada Rao & Co.
Chartered Accountants

K. Prahlada Rao & Co. Chartered Accountants FRN No: 002717S Hyderabad

K. Prahlada Rao
Partner
M. No. 018477
FRN No: 002717S

Place : Hyderabad
Date : 10.08.2023

For and on behalf of
INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

10/8/23

(S. Nageswara Rao)
Senior Accounts Officer &
Head-ESS (Addl. Charge)

S Nageswara Rao
Senior Accounts Officer &
Head -ESS (Addl. Charge)

INCOIS

(Dr. T. Srinivasa Kumar)
Director, INCOIS

Dr. T. Srinivasa Kumar
Director, INCOIS

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(Ministry of Earth Sciences, Govt. of India)

"Ocean Valley", Pragathinagar(BO), Nizampet(SO), Hyderabad - 500 090

RECEIPTS AND PAYMENTS ACCOUNT FOR THE YEAR ENDED 31ST MARCH 2023

RECEIPTS	CURRENT YEAR 2022-23 ₹		PAYMENTS	CURRENT YEAR 2022-23 ₹	
Opening Balance			**Establishment Expenses**		
INCOIS Current A/c-SBI-HAL Campus Br	4,57,43,580		Pay, Leave Salary Allowace	12,66,02,060	
UBI Savings A/c	76,81,217		NPS & CPF	1,37,11,863	
UBI Consultancy A/c	44,15,574		Staff welfare (Medical IP & OP)	28,33,249	
Short Term Deposits with SBI,HAL Campus	47,52,00,000		Leave travel consession expenses	25,81,588	**14,57,28,760**
INCOIS IOGOOS Secretariat- Local	9,01,151				
INCOIS IOGOOS Secretariat- Foreign	27,27,836		**Administrative Expenses**		
INCOIS- CPF Account	1,08,169		EL encashment during LTC	2,69,142	
Short Term Deposits with UBI (Consultancy)	3,00,00,000		Children Education Allowance	10,86,011	
Short Term Deposits with SBI,CPF Account	4,40,00,000		Telephone & Fax Expenditure	1,178	
INCOIS SBI GEM POOL A/C	66,07,003	**61,73,84,530**	Printing & Stationery	11,79,399	
			Travel expenses-Inland	96,655	
			Hornorarium to external experts	1,24,000	
Margin Money TDR Received			Advertising & Publicity	10,17,318	
Margin Money Reversal	1,30,21,000	**1,30,21,000**	Audit fee	23,600	
			Office expenses	10,98,759	
			General expenses	1,01,00,198	
Earmarked Funds			International Interface	10,51,642	**1,60,47,902**
OON	8,00,00,000				

ITCOO	4,77,84,134		**Operation & Maintenance**		
RIMES	27,01,882		Vehicle Hiring	4,84,332	
DOM	14,90,00,000		House Keeping, Plumbing & Garden Expenses	1,09,71,135	
OMAS	10,83,55,780		Security Expenses	1,61,34,385	
MSMN	97,33,166		Water Expenses	34,70,911	
OGR	18,01,801	**39,93,76,763**	Electricity Expenditure	3,08,49,608	
			Maintenance & Repairs	31,10,024	
			Material consumable	24,21,191	
Recurring Grants	23,36,36,881	**23,36,36,881**	HVAC & Electrical Operational & Maintenance charges	44,18,632	**7,18,60,218**
			OMAS		
Other Receipts:			Equipments	1,03,18,532	
Consultancy Projects:			Hardware/Software	4,57,06,680	
DGH	1,22,040		Technical Support	5,09,85,577	
Kalpasar Dam Project	17,43,700		Administrative Expenses	5,44,32,491	
Corromandel International Ltd	7,080		Travel	93,54,144	
Oil & Natural Gas Corporation Ltd	9,78,418		Consumable Materials/Data	2,43,84,742	
Public Work Department Chennai (INCOIS-NCCR Joint Consultancy Project)	20,35,200	**48,86,438**	Advance against subprojects	83,63,072	
			Advance for Purchase	56,86,512	**20,92,31,750**
Other Receipts:			**RIMES**		
Interest on Short Term Deposits	98,35,657		Technical Support	29,62,776	29,62,776
Interest on IOGOOS Foreign A/c	60,291				
Interest on IOGOOS Local A/c	25,607				
Interest on Savings A/c	2,79,024		**Ocean Observation Networks - OON**		
Interest on AB Consultancy A/c	1,64,128		Equipment	22,13,596	

Interest on SBI CPF A/c	55,233		Technical Support	56,73,649	
Vehicle Advance to Employees (Recovery)	45,000		Administrative Expenses	3,24,28,943	
Earnest Money Deposit	47,24,098		Travel	27,92,393	
Security Deposit	50,67,201		Consumable Materials/Data	1,63,51,948	
Income from Staff Qt	72,354		Advance against subprojects	14,06,555	
Income from Guest House	13,41,130		Advance for Purchase	68,48,636	
MoES Chair fellowship	18,01,802		Margin Money against LC	5,75,10,000	12,52,25,720
Dr PA Francis NPS Contribution	6,23,321				
GEM A/c	57,054	**2,41,51,900**			
IOGOOS			**International Training Centre (ITCOocean)**		
Interest received from savings accounts at banks			Equipments	3,58,03,995	
JP Morgan chase remittance Id 05341IR00242422	30,49,148		Technical Support	18,78,661	
Salary reimbursement from NCESS	20,65,566		Administrative Expenses	83,10,524	
CPF contributions	40,16,770	**91,31,484**	Travel	81,634	
			Consumable Materials/Data	12,36,451	
			Advance for Purchase	4,72,869	4,77,84,134
NODAL AGENCY BANK ACCOUNTS RECEIPTS					
CNA-INCOIS-OSMART Canara Bank Account	1,99,55,69,441				
CNA-INCOIS-REACHOUT Canara Bank Account	41,69,26,407				
CNA-INCOIS-ACROSS-BoM Account	1,38,00,000	**2,42,62,95,848**	**Monsoon Mission**		
			Administrative Expenses	80,49,392	
CPF - TDRs Interest	12,24,806	**12,24,806**	Travel	6,48,981	

			Advance for Purchase	10,34,793	97,33,166
IT Refund					
TDS Refund for AY 21-22	10,73,956				
Interest earned on CNA-INCOIS-OSMART	68,37,158		**Deep Ocean Mission (DOM)**		
Interest earned on CNA-INCOIS-REACHOUT	12,40,404	**91,51,518**	Equipments	1,83,06,179	
			Administrative Expenses	62,13,329	
GSLIS amounts received from LIC			Travel	33,72,083	
Dr. B.VS Satyanarayana, PLN Murthy & Dr. Ravichandran, Suprit Kumar	3,62,625	**3,62,625**	Consumable Materials/Data	27,46,833	
			Advance against subprojects	10,43,250	
Fellowships received for Research Fellows:			Advance for Purchase	1,17,56,185	
Inspire Fellowship Ms Anjana Srf	5,65,055	**5,65,055**	Margin Money against LC	21,32,62,000	25,66,99,859
Refund of Unspent Balances from PIs Sub-Projects					
Calcutta university	19,32,750		**Other Payments**		
NIO-Goa	49,099		LIC_FM GRATUITY	4,36,70,909	
CUSAT-Kerala	2,13,546		LIC_FM LEAVE ENCAMNT	5,32,80,285	
CSIR-NIO	2,54,352		CPF payment-Satyanarayana	68,98,744	
KUFOS	24,629		Inspire Fellowship (Regn. Fee, travel etc.)	9,52,794	
KOFUS	1,81,936		LTC Advance	1,39,500	
CIFT	54,873		Dept temp Cont Advan	1,22,298	
NIO-Goa	97,179		Medical Advance	1,70,000	
NIO-Goa	3,12,622		MoES Chair fellowship	18,01,802	
VIDYASAGAR UNIVERSITY	19,403	**31,40,389**	CPF to NPS transfer	1,40,11,734	
			National Post Doc Fellowship	5,08,050	

			TDS Payments	50,37,356	
			Interest Refund	1,65,10,349	
			Bank charges	2,697	
			Payment to Balmer Lawrie for tickets	3,64,610	14,34,71,128
			GSLIS amounts received from LIC		
			Dr. B.VS Satyanarayana, PLN Murthy & Dr. Ravichandran, Suprit Kumar	3,62,625	
			Dr. Suprit Kumar	5,81,663	
			Dr. M. Ravichandran	19,34,858	
			Mr. B.V. Satyanarana	20,00,000	
			SUPRIT KUMAR	5,97,461	
			DR M RAVICHANDRAN	29,35,710	
			SHRI BV SATYANARAYANA	27,81,358	1,11,93,675
			NODAL AGENCY Bank Accounts		
			Interest refunded to CFI on CNA-INCOIS-OSMART	68,37,158	
			Interest refunded to CFI on CNA-INCOIS-REACHOUT	12,40,404	
			Expenditure met from CNA-INCOIS-OSMART	1,57,15,76,961	
			Expenditure met from CNA-INCOIS-REACHOUT	29,62,56,815	
			Expenditure met from CNA-INCOIS-ACROSS BoM Account	97,33,166	1,88,56,44,504
			Closing Balance		
			INCOIS Current A/c-SBI-HAL Campus Br.	18,81,39,959	

			UBI Savings A/c	36,65,468	
			UBI Consultancy A/c	84,77,102	
			INCOIS IOGOOS Secretariat- Local	9,26,757	
			INCOIS IOGOOS Secretariat- Foreign	54,98,474	
			INCOIS- CPF Account	2,91,09,819	
			Short Term Deposits with UBI (Consultancy)	3,00,00,000	
			INCOIS SBI GEM POOL A/C	1,63,960	
			CNA-INCOIS-OSMART Canara Bank Account	42,39,92,480	
			CNA-INCOIS-REACHOUT Canara Bank Account	12,06,69,592	
			Canara Bank (INCOIS-NCCR Joint Consultancy Project)	20,35,200	
			CNA-INCOIS-ACROSS BoM Account	40,66,834	81,67,45,645
Total	**3,74,23,29,237**	**3,74,23,29,237**	**Total**	**3,74,23,29,237**	**3,74,23,29,237**

As per our report of even date
For K. Prahlada Rao & Co.
Chartered Accountants

K. Prahlada Rao
Partner
M. No. 018477
FRN No: 002717S

Place : Hyderabad
Date : 10.08.2023

For and on behalf of
INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(S. Nageswara Rao)
Senior Accounts Officer &
Head-ESS (Addl. Charge)

S Nageswara Rao
Senior Accounts Officer &
Head -ESS (Addl. Charge)

(Dr. T. Srinivasa Kumar)
Director, INCOIS

Dr. T. Srinivasa Kumar
Director, INCOIS

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES
(Ministry of Earth Sciences, Government of India)
"Ocean Valley", Pragathinagar (B.O.), Nizampet (S.O.), Hyderabad - 500 090

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31st MARCH 2023

SCHEDULE 1 – CORPUS FUND

Particulars	Current Year (2022-23) ₹	Previous Year (2021-22) ₹
Corpus Fund at the beginning of the year	72,87,96,337	11,83,97,544
Add: Building fund balance amount capitalised	-	63,25,08,439
Add: Net income transferred from Income & Expenditure Account	-4,53,93,520	-2,21,09,645
BALANCE AS AT THE YEAR END	**68,34,02,817**	**72,87,96,337**

As per our report of even date
For K. Prahlada Rao & Co.
Chartered Accountants

K. Prahlada Rao
Partner
M. No. 018477
FRN No: 002717S

Place : Hyderabad
Date : 10.08.2023

For and on behalf of
INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(S. Nageswara Rao)
Senior Accounts Officer &
Head-ESS (Addl. Charge)

S Nageswara Rao
Senior Accounts Officer &
Head -ESS (Addl. Charge)

(Dr. T. Srinivasa Kumar)
Director, INCOIS

Dr. T. Srinivasa Kumar
Director, INCOIS

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 2 - EARMARKED FUNDS

(Amount in ₹)

PARTICULARS	PIN-OMAS	Ocean Observation Networks	ITCOO	Monsoon Mission	RIMES	Deep Ocean Mission	TOTALS Current Year (2022-23)	TOTALS PreviousYear (2021-22)
a) Opening balance of the funds	7,83,60,883	4,52,25,720	2,521	-	2,60,894	16,41,42,667	28,79,92,685	10,69,28,671
b) Additions to the Funds:								
i. Grants	10,71,82,254	8,00,00,000	4,77,81,613	97,33,166	27,01,882	14,90,00,000	39,63,98,915	58,98,00,000
ii. Interest if any			-	-	-		-	
a) Interest Apportioned during2022-23	15,35,726	7,25,080	-	-	-	71,82,379	94,43,185	1,63,17,584
b) Interest credited Direct to projects2022-23	6,98,893	68,083	-	-	-	3,86,473	11,53,449	1,92,765
iii. Advance for sub projects utilised/refund	3,24,55,216	-	-	-	-	-	3,24,55,216	24,73,275
iv. Advance for purchase Utilised	1,16,26,767	-	-	-	-	-	1,16,26,767	2,40,99,036
v. Margin Money Reversed	-	-	-	-	-	-	-	1,94,00,000
vi. Deposit Advance Utilized/refund	-	-	-	-	-	-	-	-
vii. Mobilization Advance Reversed	-	-	-	-	-	-	-	-
viii.Other Revenue	-	-	-	-	-	-	-	32,69,558
TOTAL (a+b) - A	**23,18,59,739**	**12,60,18,883**	**4,77,84,134**	**97,33,166**	**29,62,776**	**32,07,11,519**	**73,90,70,217**	**76,24,80,889**
c) Utilisation/Expenditure								
i. Capital Expenditure								
W.I.P	-	-	27,81,290	-	-	-	27,81,290	5,49,67,408
Architect fee	-	-	-	-	-		-	-
Equipments	1,03,18,532	22,13,596	3,30,22,705	-	-	1,83,06,179	6,38,61,012	12,85,76,550
Computers / Software	4,56,14,282	-	-	-	-	-	4,56,14,282	2,93,35,719
Other Assets	92,398	-	-	-	-	-	92,398	-
Total (i)	**5,60,25,212**	**22,13,596**	**3,58,03,995**	**-**	**-**	**1,83,06,179**	**11,23,48,982**	**21,28,79,677**
ii. Revenue Expenditure								
Technical support	5,09,85,577	56,73,649	18,78,661	-	29,62,776	-	6,15,00,663	6,21,41,041
Adminisrtrative expenses	5,44,32,491	3,24,28,943	83,10,524	80,49,392	-	62,13,329	10,94,34,679	6,74,00,311
Travel	93,54,144	27,92,393	81,634	6,48,981	-	33,72,083	1,62,49,235	4,63,237
Consumable Materials / Data	2,43,84,742	1,63,51,948	12,36,451	-	-	27,46,833	4,47,19,974	1,88,37,134
Total (ii)	**13,91,56,954**	**5,72,46,933**	**1,15,07,270**	**86,98,373**	**29,62,776**	**1,23,32,245**	**23,19,04,551**	**14,88,41,723**
iii. Others								
Advance against subprojects	83,63,072	14,06,555	-	-	-	10,43,250	1,08,12,877	2,16,83,661
Advance for Purchase	56,86,512	68,48,636	4,72,869	10,34,793	-	1,17,56,185	2,57,98,995	2,89,12,296
Deposit Works (APWD & RITES)	-	-	-	-	-	-	-	36,37,874
Margin Money against LC	-	5,75,10,000	-	-	-	21,32,62,000	27,07,72,000	-
Total (iii)	**1,40,49,584**	**6,57,65,191**	**4,72,869**	**10,34,793**	**-**	**22,60,61,435**	**30,73,83,872**	**5,42,33,831**
TOTAL (i+ii+iii) - B	20,92,31,750	12,52,25,720	4,77,84,134	97,33,166	29,62,776	25,66,99,859	65,16,37,405	41,59,55,231
Amount Refunded- C (Unspent Bal)	2,03,93,370	-	-	-	-	89,62,329	2,93,55,699	4,20,22,623
Interest to be refund - D (outstanding liability)	15,35,726	7,25,080	-	-	-	71,82,379	94,43,185	1,65,10,349
as per 238 of GFR	6,98,893	68,083	-	-	-	3,86,473	11,53,449	-
NET BALANCE AS AT THE PERIOD END {A -(B+C+D)}	**-**	**-**	**-**	**-**	**-**	**4,74,80,479**	**4,74,80,479**	**28,79,92,685**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE - 3 CURRENT LIABILITIES & PROVISIONS

Particulars	Current Year (2022-23) ₹	Previous Year (2021-22) ₹
A. CURRENT LIABILITIES		
Earnest Money Deposit	54,88,650	22,01,860
Security Deposit	1,13,01,011	63,98,512
Outstanding Expenses	2,58,52,139	2,12,35,913
INSPIRE/DISHA/NPDF Fellowship	8,26,786	40,38,736
Sundry Creditors	2,46,91,370	4,46,69,673
Other Bank Liability	46,23,465	2,43,07,601
Total – A	**7,27,83,421**	**10,28,52,295**
B. PROVISIONS		
Gratuity	4,45,63,020	4,36,70,909
Accumulated Leave Encashment	5,40,92,034	5,32,80,285
Total – B	**9,86,55,054**	**9,69,51,194**
Total (A+B)	**17,14,38,475**	**19,98,03,489**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE – 4 FIXED ASSETS

2022-23 (Amount in Rs.)

Description (% of Depreciation)	Rate	Gross Block				Depreciation			Net Block	
			Additions During The Year							
		As on 31.03.2022	>180 Days	<180 Days	As at 31.03.2023	As at 31.03.2022	For the Year 2022-23	As at 31.03.2023	As at 31.03.2023	As at 31.03.2022
1. Land (0%)	0.00%	1,000	-	-	1,000	-	-	-	1,000	1,000
2. Plant, Machinery & Equipment (15%)	15.00%	4,62,23,555	-	-	4,62,23,555	4,53,63,244	1,29,047	4,54,92,291	7,31,264	8,60,311
3. Furniture & Fixtures (10%)	10.00%	1,72,67,084	-	-	1,72,67,084	1,38,37,742	3,42,934	1,41,80,676	30,86,408	34,29,342
4. Office Equipment (15%)	15.00%	34,84,725	-	-	34,84,725	30,53,297	64,714	31,18,011	3,66,714	4,31,427
5. Computer / Peripheral (40%)	40.00%	12,92,44,815	-	-	12,92,44,815	12,72,63,284	7,92,612	12,80,55,897	11,88,919	19,81,531
6. Electric Installations (10%)	10.00%	20,98,406	-	-	20,98,406	16,06,361	49,204	16,55,566	4,42,841	4,92,045
7. Library Books (40%)	40.00%	8,39,08,143	-	-	8,39,08,143	7,97,22,657	16,74,195	8,13,96,851	25,11,292	41,85,487
8. Other Fixed Assets (15%)	15.00%	70,60,861	-	-	70,60,861	53,09,629	2,62,685	55,72,314	14,88,547	17,51,232
9. Vehicles (15%)	15.00%	22,23,774	-	-	22,23,774	9,75,228	1,87,282	11,62,510	10,61,264	12,48,546
10. Building(10%)	10.00%	63,25,08,439	-	-	63,25,08,439	6,32,50,844	5,69,25,760	12,01,76,603	51,23,31,836	56,92,57,595
Total		**92,40,20,802**	**-**	**-**	**92,40,20,802**	**34,03,82,286**	**6,04,28,433**	**40,08,10,719**	**52,32,10,085**	**58,36,38,516**
Previous Year		**29,14,74,544**	**13,820**	**63,25,32,438**	**92,40,20,802**	**27,18,35,061**	**6,85,47,225**	**34,03,82,286**	**58,36,38,516**	**1,96,39,483**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE -4A -EARMARKED FIXED ASEETS **(Amount in Rs.)**

	Description of the Assets	Gross Block					Depreciation					Net Block	
Sl. No	Name of the Fund/ Project	As on 01-04-2022	Additions 2022-23	Transfers to Fixed Assets based on prior approval of MoES	Grant Utilized/ Received till 31-3-23 (G/A -Gen/Capital)	Total Amount as on 31-03-2023	As on 31.03.2022	For the Year 2022-23	Diff. of Previous Years Dep	Total Depreciation for the year	As at 31.03.2023	As at 31.03.2023	As at 31.03.2022
i)	Building Fund	-	-	-	-	-	-	-	-	-	-	-	-
ii)	MDC & Equipment Fund	6,59,21,618	-	-	-6,59,21,618	-	-	-	-	-	-	-	-
iii)	Ocean Information and Advisory Services (OASIS)	2,05,08,95,387	-	-	-2,05,08,95,387	-	-	-	-	-	-	-	-
iv)	Computational Facilities	15,28,06,467	-	-	-15,28,06,467	-	-	-	-	-	-	-	-
v)	INDOMOD & SATCORE Projects	52,60,47,361	-	-	-52,60,47,361	-	-	-	-	-	-	-	-
vi)	Ocean Observation Networks	82,03,38,249	22,13,596	-	-82,25,51,845	-	-	-	-	-	-	-	-
vii)	International Training Center- ITCOocean	70,90,35,884	3,58,03,995	-	-74,48,39,879	-	-	-	-	-	-	-	-
viii)	O-MASCOT (HROOFS)	6,54,19,251	-	-	-6,54,19,251	-	-	-	-	-	-	-	-
ix)	IT & E Governance Fund	5,88,34,380	-	-	-5,88,34,380	-	-	-	-	-	-	-	-
x)	HPC Systems - Others	1,33,61,57,396	-	-	-1,33,61,57,396	-	-	-	-	-	-	-	-
xi)	CSS	14,37,371	-	-	-14,37,371	-	-	-	-	-	-	-	-
xii)	V SAT Node	17,44,71,627	-	-	-17,44,71,627	-	-	-	-	-	-	-	-
xiii)	Ernet India	72,00,000	-	-	-72,00,000	-	-	-	-	-	-	-	-
xiv)	IOAS	51,25,986	-	-	-51,25,986	-	-	-	-	-	-	-	-
xv)	MH Vulnerability	28,30,738	-	-	-28,30,738	-	-	-	-	-	-	-	-
xvi)	Monsoon Mission	16,59,62,545	-	-	-16,59,62,545	-	-	-	-	-	-	-	-
xvii)	RIMES	4,85,36,951	-	-	-4,85,36,951	-	-	-	-	-	-	-	-
xviii)	Coastal Monitoring (CMI/SATCORE)	1,80,60,121	-	-	-1,80,60,121	-	-	-	-	-	-	-	-
xix)	NCS	13,73,259	-	-	-13,73,259	-	-	-	-	-	-	-	-
xx)	OMAS	-	5,60,25,212	-	-5,60,25,212		-	-	-	-	-	-	-
xi)	Deep Ocean Mission	-	1,83,06,179	-	-1,83,06,179								
	Total	**6,21,04,54,591**	**11,23,48,982**	-	**-6,32,28,03,573**	-	-	-	-	-	-	-	-
	GRAND TOTAL (PREVIOUS YEAR)	**6,92,15,57,897**	**84,54,25,935**	**63,25,08,439**	**-5,28,64,33,789**	**-54,672**	**-27,18,35,061**	**-6,85,47,225**	**-34,03,82,286**	**-54,672**	**-58,36,38,516**	**-1,96,39,483**	-

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE - 5 CURRENT ASSETS, LOANS & ADVANCES

Particulars	Current Year (2022-23) ₹		Previous Year (2021-22) ₹	
A. CURRENT ASSETS				
1. Inventories (Valued at cost)	11,45,557	11,45,557	15,05,621	15,05,621
2. Cash & Bank Balance :				
a) With Scheduled Banks – Current Account				
State Bank of India HAL CAMPUS A/c	18,56,41,591		4,37,63,197	
Union Bank Pragathinagar SAVINGS A/c	36,65,468		73,65,178	
Union Bank Pragathinagar-Consultancy A/c	84,77,102		44,15,039	
State Bank of Indian - CPF Savings A/c	2,91,09,819		1,08,169	
State Bank of India - IDBPS Savings A/c	-		-	
CNA REACHOUT A/c	-		-	
CNA OSMART A/c	-		-	
Canara Bank 70804 A/C				
(INCOIS-NCCR JOINT CONSULTANCY)	20,35,346		-	
State Bank of India - GeM Pool Account (GPA)	1,63,960	22,90,93,286	66,07,003	6,22,58,586
b) Short Term Deposits with CPF A/c		-	4,40,00,000	
c) Short Term Deposits with SBI		-	47,52,00,000	
d) Short Term Deposits with Union Bank Consultancy		3,00,00,000	3,00,00,000	54,92,00,000
3. LIC_FM GRATUITY		4,45,63,020	-	-
4. LIC_FM LEAVE ENCAMNT		5,40,92,034	-	-
5. Sundry Debtors		36,57,720	11,64,660	11,64,660
TOTAL A:		**36,25,51,617**		**61,41,28,867**

B. LOANS, ADVANCES & OTHER ASSETS				
1. Deposits				
a) Telephone	1,73,186		1,73,186	
b) Electricity	70,16,374		70,16,374	
c) Gas	13,100	72,02,660	13,100	72,02,660
2. Advances & other amounts recoverable in cash or in kind or for value to be received				
a) Interest Accrued	6,50,702		6,50,702	
b) Advance for Purchase	-		-	
c) Tour Advance	49,907		65,246	
d) LTC Advance	1,39,500		-	
e) TDS				
Opening Balance - Rs.74,93,354				
Less: Refund received - Rs. 10,73,956				
Add: Current year accumulation - Rs. 20,15,542				
Add: TDS Adjustment Entry	84,34,940		74,93,354	
f) Margin Money against Bank Guarantee	82,360	93,57,409	34,13,165	1,16,22,467
TOTAL B: (1+2)		**1,65,60,069**		**1,88,25,127**
GRAND TOTAL (A + B)		**37,91,11,686**		**63,29,53,994**

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SCHEDULE 6 - INCOME FROM SALES / OTHER INCOME

Particulars	Current Year (2022-23) ₹	Previous Year (2021-22) ₹
a) Other Receipts	33,57,186	60,07,516
b) Consultancy Services	85,44,158	2,49,44,289
c) Income from staff quarters	72,354	4,13,070
TOTAL	**1,19,73,698**	**3,13,64,875**

SCHEDULE 7 - INTEREST EARNED

Particulars	Current Year (2022-23) ₹	Previous Year (2021-22) ₹
a) Interest on Deposits & Others	25,16,008	8,61,669
b) Bank Accounts	5,00,206	16,11,792
c) Interest on Vehicle Advance	45,000	60,000
TOTAL	**30,61,214**	**25,33,461**

SCHEDULE 8 - IRRECOVERABLE GRANTS & SUBSIDIES RECEIVED

Particulars	Current Year (2022-23) ₹	Previous Year (2021-22) ₹
a) Central Government (Recurring Grant received from MoES)	23,36,36,881	22,78,00,000
TOTAL	**23,36,36,881**	**22,78,00,000**

SCHEDULE 9 - ESTABLISHMENT EXPENDITURE

Particulars	Current Year (2022-23) ₹	Previous Year (2021-22) ₹
a) Salaries, Wages & Allowances	12,66,02,060	11,97,66,760
b) Staff Welfare Expenses	28,33,249	21,29,821
c) Contributory Provident Fund	21,21,442	10,03,260
d) New Pension Scheme	1,15,90,421	91,21,107
e) Leave Travel Concession	25,81,588	6,57,174
TOTAL	**14,57,28,760**	**13,26,78,122**

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SCHEDULE 10 - OTHER ADMINISTRATIVE EXPENSES

Sl No.	Particulars	Current Year (2022-23) ₹	Previous Year (2021-22) ₹
1	Electricity & Power Expenses	3,08,49,608	2,57,53,528
2	Water Charges	34,70,911	37,74,726
3	Operation & Maintenance expenses	92,05,424	50,16,682
4	Garden Expenses	4,84,332	3,75,777
5	Vehicle Hiring Expenses	1,46,717	5,41,922
6	Postage, Telephone, Fax & ISDN Charges	1,178	4,80,045
7	Printing & Stationery	11,79,399	9,87,686
8	Travelling Expenses (Inland)	96,655	-
9	Seminar/Workshops Expenses	-	-
10	General Expenses	1,11,98,957	1,13,21,659
11	Audit Fee	23,600	25,370
12	House Keeping & Plumbing	1,04,86,803	78,93,902
13	Security Expenses	1,61,34,385	1,58,39,414
14	Advertisement & Publicity	10,17,318	6,16,973
15	Internet Expenses	-	8,90,364
16	Legal Expenses	16,000	-
17	Papers & Periodicals	-	-
18	Material /Consumable	24,21,191	29,85,246
19	International Interface	10,51,642	8,63,991
20	Others (Honorarium to External Experts)	1,24,000	46,000
	TOTAL	**8,79,08,120**	**7,74,13,285**

SCHEDULE NO.11

NOTES FORMING PART OF ACCOUNTS:

1. Significant Accounting Policies:

a) Basis of Accounting:

The Society follows the mercantile system of accounting and recognizes Income and Expenditure on accrual basis. The accounts were prepared on the basis as a going concern.

b) Income Recognition:

The Grant-in-aid was received by the Society from Ministry of Earth Sciences in the form of recurring grant and ear-marked funds.

The Grant-in-aid received from Ministry of Earth Sciences for the purpose of meeting revenue expenditure is treated as Income to the Society and to the extent utilized for capital expenditure is added to the Corpus Fund. During the year 2022-23, the Society received Rs.23,36,36,881/- towards Recurring Grant as shown in the Schedule-8.

The remaining Grant-in-aid of Rs.39,63,98,915/- received from Ministry of Earth Sciences is being utilized for specific purposes for which they were intended to and are disclosed under the Earmarked Funds- Schedule-2.

c) Fixed Assets and Depreciation:

i. Fixed Assets Register maintained by the Society.

ii. The management verified the assets physically by appointing a committee.

iii. The additions to the fixed assets during the period of audit were stated at cost.

iv. Depreciation on Fixed Assets was provided on written down value, as per the rate prescribed under the Income Tax Rules.

d) Inventories:

Inventory of stores, stationery items and other material of significant value are valued at cost, and the same are taken as certified by the management.

e) Employee Benefits:

i) Gratuity:

The present value of the INCOIS obligations under Gratuity is recognized on the basis of an actuarial valuation given by the LIC of India Ltd., as on 31 March 2023.

ii) Leave encashment:

The present value of the INCOIS obligations under Leave encashment is recognized on the basis of an actuarial valuation made by the LIC of India Ltd., as on 31 March 2023.

iii) NPS & CPF:

Periodical contributions made towards Contributory Provident Fund (CPF) and New Pension Scheme (NPS) are charged to revenue.

f) Interest on Deposits:

The Society invested surplus funds from time to time in Short Term Deposits in Nationalized Banks. For the year 2022-23, an amount of Rs.99,33,606/- was earned as interest on the Short

Term Deposits in the bank. Since, the interest received on Short Term Deposits, relate to the grants accruing to the various projects and recurring grants received by INCOIS, the management decided to spread the interest on Short Term Deposits to such projects and INCOIS Society.

a. Interest transferred to Ear-marked Funds - Rs. 94,43,185.00

b. Interest transferred to various other funds (Such as DST-DPWS, DST-NPDF and SERB) - Rs. 3,26,293.00

c. Interest transferred to Society - Rs. 1,64,128.00

Total Rs. 99,33,606.00

In addition to the apportioned interest amount of Rs.94,43,185/- for various earmarked funds in Schedule 2, the funds earned interest directly also credited to the relevant funds and such amount is worked out to Rs.11,53,449/-. As the interest refund is to be deposited to the Consolidated Fund of India (CFI), under the compliance of Rule-230(8) of GFR-2017, a liability was created in the FY 2022-23 and the same will be deposited in the CFI.

However, interest is not being charged on excess utilized funds (funds that are in negative balance) used for the Earmarked funds to the respective grants. The programmes those were closed and interest and unspent balances were refunded for compliance of GFR were also not apportioned the interest.

The details are furnished below: -

(Amount in Rs.)

a.	Interest earned on regular STDRS closed in FY 2022-23 SBI	90,50,725.00
b.	Add: Net Interest accrued GEM Pool A/c FY 2022-23	57,054.00
c.	Add: Net Interest accrued in UBI SB A/c FY 2022-23	4,43,152.00
d.	Add: Net Accrued Interest for the F.Y 2022-23 on SBI	-
e.	Add: TDS on closed and accrued TDRs on SBI as per 26 AS 2022-23	10,73,834.00
f.	Less: Transfer of outstanding Accrued Interest for the F.Y 2021-22	6,91,159.00
	Total Interest Earned for the FY 2022-23	**99,33,606.00**

2. Notes on Accounts:

a. EARMARKED FUNDS:

The Society during the year 2022-23, received Rs.39,63,98,915/- as Grant-in-aid towards Earmarked Funds from the Ministry of Earth Sciences (MoES) and other institutions in the form of Recurring and Non-Recurring grants as specified under Schedule -2.

Ministry of Earth Sciences has issued the Administrative Order for the umbrella scheme for the OSMART on 07.11.2022 and accordingly the sub-schemes such as OASIS, Coastal Monitoring, O-MASCOT, MH Vulnerability, IIOE2 & IIOSC are brought under the scheme of OMAS and accordingly the opening the balance of OMAS is being considered of all these said schemes of closing balance as on 31.3.2022.

Details of closing balance as on 31.3.2022

Sl. No.	Scheme name mentioned in the Schedule-2 of FY 2021-22	Audited closing balance as on 31.3.2022 (Amount in Rs.)
1.	OASIS	4,64,28,828.00
2.	Coastal Monitoring by INCOIS	2,17,77,619.00
3.	O-MASCOT	65,28,044.00
4.	IIOE2 & IIOSC	36,26,392.00
	Opening Balance of OMAS as on 01.04.2022 matching to the amount of Schedule-2	**7,83,60,883.00**

The amounts advanced to various Earmarked Funds under Schedule-2, shall initially be shown as Advances to Sub Projects under "Others" category in the Earmarked Funds Schedule, and, on receipt of Utilisation Certificates from the respective project heads, the utilized amounts are transferred to either Capital expenditure or Revenue expenditure based on the nature of utilization.

INCOIS is making payments for the acquisition of equipment for the various projects classified under Earmarked Funds of Schedule-2. These payments are initially shown as 'advance for purchase' under Schedule-2, and later, on completion commissioning of the equipment and contractual/warranty obligations, the total value of equipment is transferred to equipments under the same Schedule. An amount of Rs.1,41,72,229 of advances was adjusted and the value of "Advance for Purchase" as on 31-03-2023 was only Rs.11,73,87,937.

The accumulated value of the capital expenditure as on 31-03-2023 (excluding advances to sub- projects and advances for purchases), incurred in each year and specified in the Earmarked Funds under Schedule - 2, are stated below. A separate schedule has been added at Schedule 4A.

Sl No	Name of the Fund/ Project	As on 01-04-2022 Rs.	Capital Expenditure incurred during 2022-23 ₹	Transfers to Fixed Assets based on prior approval of MoES	Total Amount as on 31-03-2023 ₹
i)	MDC & Equipment Fund	6,59,21,618	-	-	6,59,21,618
ii)	**OMAS** OASIS : 2,05,08,95,387 CF : 15,28,06,467 HROOF : 6,54,19,251 IT & EG : 5,88,34,380 MHVM : 28,30,738 CMI : 1,80,60,121 INDO : 52,60,47,361 **Total : 2,87,48,93,705**	2,87,48,93,705	5,60,25,212	-	2,93,09,18,917

iii)	Ocean Observation Networks	82,03,38,249	22,13,596	-	82,25,51,845
iv)	International Training Center- ITCOocean	70,90,35,884	3,58,03,995	-	74,48,39,879
v)	HPC Systems – Others	1,33,61,57,396	-	-	1,33,61,57,396
vi)	CSS	14,37,371	-	-	14,37,371
vii)	V SAT Node	17,44,71,627	-	-	17,44,71,627
viii)	Ernet India	72,00,000	-	-	72,00,000
ix)	IOAS	51,25,986	-	-	51,25,986
x)	Monsoon Mission	16,59,62,545	-	-	16,59,62,545
xi)	RIMES	4,85,36,951	-	-	4,85,36,951
xii)	NCS	13,73,259	-	-	13,73,259
xiii)	Deep Ocean Mission	-	1,83,06,179	-	1,83,06,179
	TOTAL	**6,21,04,54,591**	**11,23,48,982**	**-**	**6,32,28,03,573**

b. PROJECTS AND UTILISATION CERTIFICATES:

The Committees comprising the heads of respective projects and other technical/scientific experts are monitoring the status of the various projects, including the financial budgets etc. The recommendations of the committee are being reviewed from time to time by the competent authority.

The various assets of the projects and sub projects purchased either by the INCOIS or by the respective sub projects, are located at such projects and sub projects. The confirmations of the assets held by them are being submitted from time to time.

The respective project heads submitted the utilization certificates for the year ending 31st March of each financial year and these certificates are received by the INCOIS during the subsequent financial year. Hence, the management had decided to pass the entries relating to the Utilisation Certificates actually received upto 31st March of each financial year.

c. NOMINATION OF INCOIS AS NODAL AGENCY FOR CNA SCHEMES:

Nomination of INCOIS as a Nodal Agency for the CNA Schemes as per the MoF, GoI guidelines

Management has received communication from the Ministry of Earth Sciences nominating INCOIS as the Nodal Agency for the OSMART and REACHOUT Programmes and accordingly opened the CNA Bank Account with the designated bank i.e. Canara Bank, Pragathi Nagar, Hyderabad. These accounts are being operated on behalf of MoES and brought the matter in to Receipts and Payment Account only.

d) Contingent Liabilities:

i Contingent liabilities not provided for:

a) In view of the non-fulfillment of the contractual obligation for Rs.9,50,000/- of Bank Guarantee submitted by M/s Gaian (FY2018-19) was encashed. Depending upon the satisfactory fulfillment, amount will be refunded in future.

ii. Estimated amount of Contracts remaining to be executed on capital account-NIL

iii. Claims against the company not acknowledged as debts-NIL

e) The Society had placed an order with M/s. Victory Genset Pvt. Ltd. for purchase of two 600 KVS DG sets in the year 2009 and released 90% payment by irrecoverable LC as per terms agreed. But, M/s. Victory Genset Pvt. Ltd. had supplied only one DG set. The society claims that the documents were fabricated by supplier as if two DG sets have been supplied and hence, filed a criminal and civil suit in 2009 against the supplier.

The III Additional Chief Judge of City Civil Court, Hyderabad, had passed a decree for Rs. 64,89,747/- plus damages Rs. 5,00,000/- with future interest till the date of payment by the firm vide their Order OS No. 69 of 2010, dated 18-04-2012. During the proceedings of the case, an amount of Rs. 18,50,907.98 was blocked through injection petition in the current account of M/s. Victory Genset Pvt. Ltd. Maintained at SBI, Versova Branch, Mumbai.

Upon grant of decree by Hon'ble court, the society on the advice of legal advisor had requested SBI, Versova Branch, Mumbai to transfer the available amount to INCOIS and to provide the details of assets of M/s. Victory Genset Pvt. Ltd. to file the petition to recover the balance amount. As SBI, Versova Branch refused to honour the court decree; the society had written letters to Governor, Reserve Bank of India & Secretary, Ministry of Finance, Govt. of India complaining against the SBI, Versova Branch for not adhering to the court decree. No response is received from the above.

Society now filed a Executive petition at III Additional Chief Judge of City Civil Court, Hyderabad for recovery of the amount available in the bank account of M/s. Victory Genset Pvt. Ltd at SBI, Versova branch and also to take steps by seizing his properties available in the Mumbai for recovering the decreed amount. As per the orders of the above Hon'ble court, the case has been transferred to the City Civil Court, Mumbai at Dindoshi (Borivali Division), Goregaon Mumbai. The case is in progress.

INCOIS filed criminal complaint against M/s Victory Genset Pvt. Ltd. at Dundigal Police Station, Hyderabad on October 5, 2009 and Police filed a Charge Sheet vide 173 of Cr: PC (Section 420 IPC) at VI Metropolitan Magistrate Court, Medchal, Hyderabad against the firm.

INCOIS has provided all the relevant documents related to the case to the concerned police officials. After final arguments and actual records available by the court, the Hon'ble Judge on 31.08.2018 had declared that Mr. Nanda Kumar is convicted in the case and issued Non Bailable Warrant as he has not attended to the court in spite of clear-cut instructions / orders issued by the Hon'ble Judge.

The Police officials along with INCOIS official were went to Mumbai on 05/02/2019 for execution of NBW. They searched for Mr. Nanda Kumar at his residence and office addresses. But already he had vacated from the both the addresses.

As the case is long pending, Director, INCOIS had sent a letter to Commissioner of Police, Hyderabad for his interfere for its closure.

Again, Police officials from Dundigal Police stations & Commissioner's office and also INCOIS official were went to Mumbai on 18/05/2019 and arrested Mr. Nanda Kumar in Boisor (120 Kms away from Mumbai) and brought to Hyderabad.

The Police were produced Mr. Nanda Kumar before Hon'ble court on 20.05.2019. The Hon'ble Judge had questioned the convicted person Mr. Nanda Kumar, Managing Director of M/s Victory Genset Pvt. Ltd. about his acceptance whether he is going to accept the allegations made by INCOIS against him or not. In reply to the question Mr. Nanda Kumar accepted all the allegations and also requested the Hon'ble Judge to grant time of one month for settlement / payment of dues to INCOIS to get rid of the case. The Hon'ble Judge has recorded the statement of Mr. Nanda Kumar in the file and pronounced the Judgment as "03 years of rigorous imprisonment and fine of Rs.10,000/- if, Mr. Nanda Kumar fails to pay the fine he has to undergo two more months of imprisonment". The Judgment copy also received from the Hon'ble Court.

f) Input Tax Credit of GST

INCOIS is being a Scientific Organization mandated with providing ocean data, information and advisory services to the society, industry, the Government and Scientific Community. There is an imbalance of payment of GST against the Purchases made and services obtained against input tax credit claimed. The matter is discussed with GST Department. Since Input GST is not agreed by the GST Department as credit allowable, GST is treated as part of expenditure and GST collected as output GST, is treated as Income in the books of Accounts whereas while filing GST return, we claim ITC and set off against Output GST.

g) Figures have been regrouped/rearranged wherever necessary.

h) Paise had been rounded off to the nearest rupee.

As per our report of even date
For K. Prahlada Rao & Co.
Chartered Accountants

K. PRAHLADA RAO & CO. Chartered Accountants FRN No: 002717S Hyderabad

(K. Prahlada Rao)
Partner
M.No. 018477
FRN No. 002717S

Place: Hyderabad
Date: 10-08-2023

For and on behalf of
INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

10/8/23

(S. Nageswara Rao)
Senior Accounts Officer &
Head-ESG (Addl. Charge)

S Nageswara Rao
Senior Accounts Officer &
Head -ESS (Addl. Charge)

(Dr.T.Srinivasa Kumar)
Director, INCOIS

Dr. T. Srinivasa Kumar
Director, INCOIS

INCOIS Indian National Centre for Ocean Information Services Hyd

FINANCE

Indian National Centre for Ocean Information Services

(An autonomous body under the Ministry of Earth Sciences, Govt. of India)

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