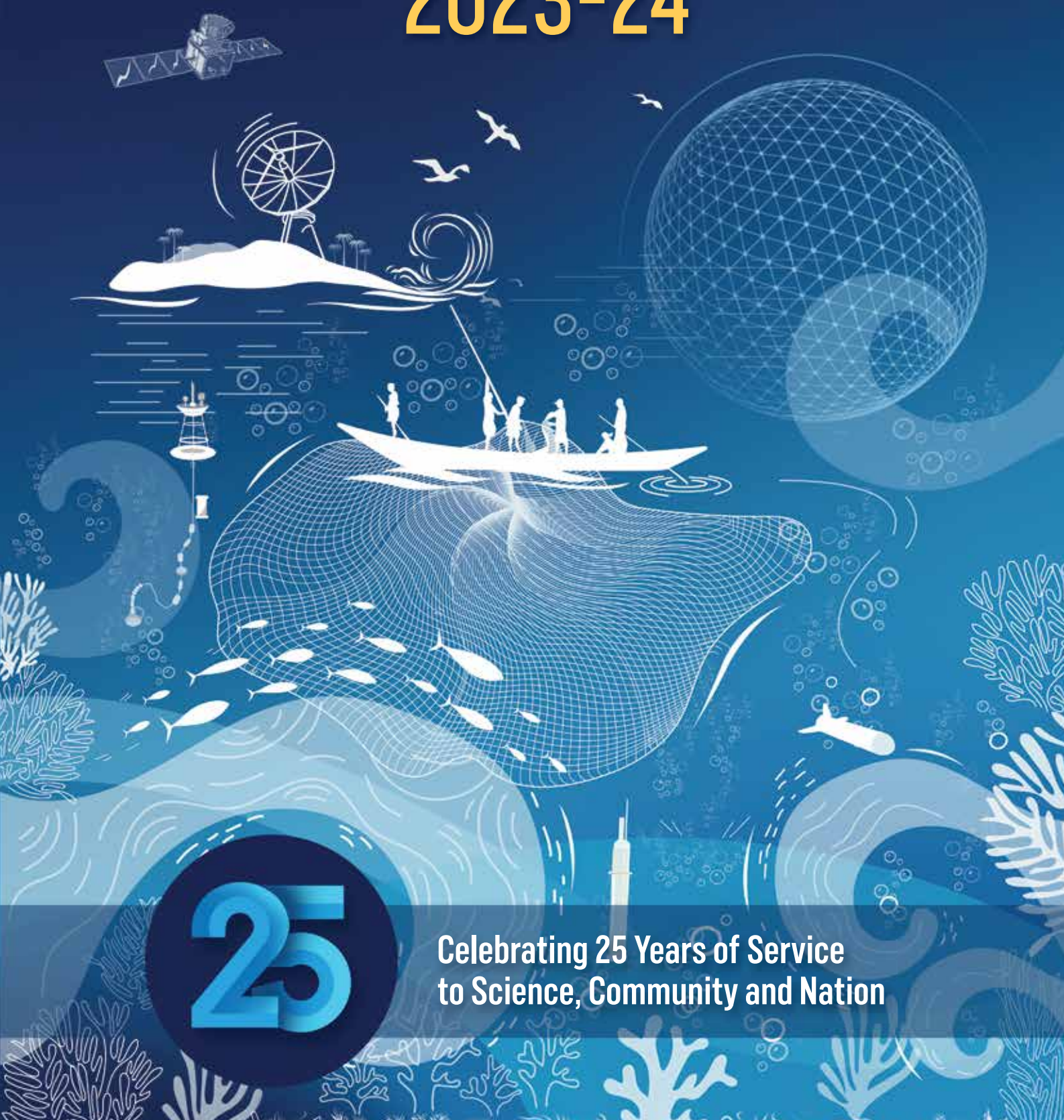
ANNUAL REPORT 2023-24



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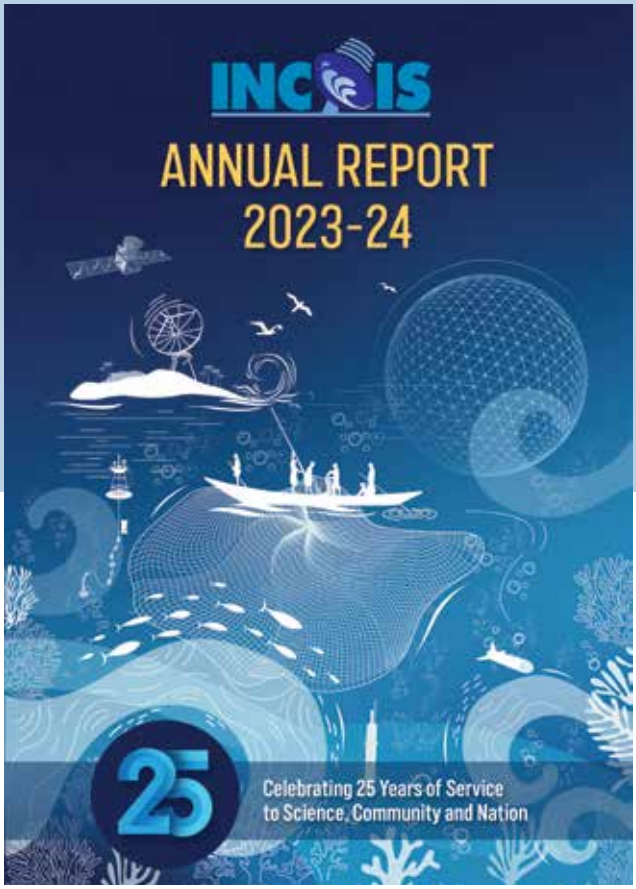
Celebrating 25 Years of Service
to Science, Community and Nation



Cover

The cover design of the INCOIS Annual Report 2023-24 effectively represents the organization's comprehensive range of services dedicated to ocean science. The use of vibrant blue hues evokes the vastness of the ocean, mirroring the depth of INCOIS's research and its commitment to understanding and preserving marine ecosystems. Central to the design are various technological tools and monitoring systems, such as satellites, ocean buoys, and underwater sensors, which symbolize INCOIS's advanced capabilities in ocean observation and data collection. These elements underscore the organization's role in providing accurate and timely ocean information, crucial for disaster management, maritime safety, and environmental protection. The inclusion of ocean modeling and the depiction of coral reefs further emphasize the focus on ecosystem services and the sustainable management of marine biodiversity. Further, it depicts the commitment of INCOIS to use data driven models for developing new services and improving its existing services.

Celebrating 25 years of service, the cover art also highlights INCOIS's continuous contributions to science, the community, and the nation. The imagery of waves, fish, and coral reefs signifies the institute's dedication to maintaining marine biodiversity and providing essential ecosystem services. The representation of scientists and fishermen underscores the collaborative efforts between research and local communities, which are vital for effective ocean governance. Key services depicted in the design include the oceanographic data, potential fishing advisories, tsunami and storm surge early warnings, and ocean state forecasts. Additionally, the emphasis on ocean-based energy solutions and the intricate marine life network showcases the institute's commitment to promoting sustainable ocean resource use. By integrating these elements, the design not only marks a significant milestone in INCOIS's journey but also reaffirms its mission to provide information and advisory services to the nation and Indian Ocean rim countries, enhancing societal resilience against ocean-related hazards.

Back

The establishment of the International Training Centre for Operational Oceanography (ITCOOcean) in 2013 is one of the important steps taken by INCOIS on the capacity development front. ITCOOcean conducts short- and long-term training programs for students, researchers, and officials on focused topics. Over the period of the last ten years since the establishment of ITCOOcean, INCOIS has organized more than 100 training programs in which 6457 persons, including 1869 from 96 foreign countries, were trained. Considering the importance of ITCOOcean activities, UNESCO has recognized ITCOOcean as a Category-2-Centre for operational oceanography.

Annual Report 2023-24

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

Contents

Director's Desk (2023-24)

This year's Annual Report is remarkable as it emphasizes the incredible journey of Indian National Centre for Ocean Information Services (INCOIS) over the past 25 years, showcasing its growth and contributions to operational oceanography. It fills me with immense pride and joy to have been part of this journey from its early days in various capacities. I have witnessed with great satisfaction how the organization has expanded to touch every aspect of ocean services in India and the Indian ocean, contributing to nation building in so many ways. Over these two and half decades, INCOIS has evolved into a dynamic, multifaceted institution, shaping the ocean services landscape across diverse areas including technology, innovation and sustainability.

The early days of the INCOIS were marked by foundational efforts to establish the organization as a key player in oceanographic research and services. INCOIS was established on 03 February 1999, under the Ministry of Earth Sciences (formerly the Department of Ocean Development). Its inception was part of a broader vision to harness oceanic resources and ensure the safety and security of India's coastal and maritime sectors. The primary objectives of INCOIS in its early days included providing ocean information services, supporting research on coastal and marine ecosystems, and offering solutions for disaster management, particularly concerning ocean-related hazards. To meet these objectives, INCOIS invested in setting up state-of-the-art facilities and infrastructure necessary for ocean data collection, analysis, and dissemination. This included establishing a data center equipped with the latest technologies for processing and modeling oceanographic data. Recognizing the need for skilled manpower, INCOIS invested on training and capacity building. It organized workshops, seminars, and training programs to develop expertise in oceanography and related fields. In its initial phase, INCOIS focused on creating awareness and providing training to the fishing community, gradually extending its efforts to the maritime industry, and disaster management authorities, emphasizing the importance of ocean information for these key stakeholders. The early days of INCOIS laid a strong foundation for its future growth and success. The organization's commitment to innovation, collaboration, and service has made it a crucial part of India's efforts in oceanographic research and services. After the devastating 2004 Indian Ocean tsunami, INCOIS played a crucial

role in developing an early warning system. The Indian Tsunami Early Warning Centre (ITEWC) was set up in 2007, which has since been instrumental in issuing timely warnings for tsunamis. Soon after ITEWC was recognized as one of the Tsunami Service Providers (TSP), and started providing tsunami advisories to 28 member states of the Indian Ocean region under the framework of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) of IOC-UNESCO. Around the same time INCOIS delved into ocean modeling to issue basic ocean state forecasts which subsequently graduated into an advanced service at par with the best oceanographic centers in the world. The year 2023-24 is particularly noteworthy as it commemorates the silver jubilee of INCOIS. Since its inception 25 years ago, INCOIS has grown into a premier institution, offering an extensive array of ocean information services and playing a pivotal role in the sustainable management of ocean resources.

During 2023-24, INCOIS introduced several innovative products and new services. In a bid to strengthen its Ocean Observing capacities, INCOIS established a 2.4 m X/L band satellite data reception and processing system, commissioned a buoy-based autonomous water quality observatory at Visakhapatnam and dedicated the GNSS and SMA network in the Andaman & Nicobar Islands to the nation. One of the key achievements was the development and launch of the 'SAMUDRA' mobile application on 17th MoES Foundation Day, designed to offer comprehensive information on all ocean-related services, catering specifically to seafarers and the fishing community. On February 14, 2024 INCOIS unveiled the state-of-the-art Synergistic Ocean Observation Prediction Services (SynOPS) facility, equipped with an advanced network operations center and a 3-D visualization system designed to enhance ocean monitoring and provide integrated ocean services.

In the realm of advancements and developments in oceanographic monitoring systems and models, INCOIS made significant strides during the reporting period. The Oil Spill Advisory System was upgraded with cutting-edge GIS and predictive capabilities, enhancing its operational effectiveness. Additionally, INCOIS is in the final stage of integration of HF-RADAR surface currents into the Indian Ocean Regional Ocean Modeling System (ROMS). INCOIS also configured a model for the Indian Ocean using WAVEWATCH III to develop wave climate projections. Further, an ADvanced CIRCulation (ADCIRC) model was developed, featuring a mesh resolution of 2 km in shallow waters and 20 km in deeper waters, enabling more accurate tsunami predictions. The high-resolution global Modular Ocean Model 6 (MOM6) was configured, along with a variable spatial resolution coastal physical-biogeochemical model (FVCOM) for the coastal waters of the southeastern Arabian Sea, marking another significant achievement in INCOIS's ongoing efforts to enhance oceanographic forecasting and monitoring capabilities.

During the reporting period, INCOIS continued its unwavering commitment in providing critical ocean information and advisory services around the clock. These services included tsunami and storm surge alerts, Ocean State Forecasts (OSF), Potential Fishing Zone (PFZ) advisories, coral bleaching alerts, and algal bloom information, among others. The Tsunami Early Warning Centre (TEWC) at INCOIS

diligently monitored global seismic activity, including one tsunamigenic earthquake of magnitude greater than 6.5 Mw in the Indian Ocean. In response, 'No Threat' messages were promptly issued to India and Indian Ocean countries, while all tsunami events in the South Atlantic and Pacific Oceans were also closely observed. Additionally, INCOIS provided storm surge and inundation advisories for six cyclones–Mocha, Biparjoy, Tej, Hamoon, Midhili, and Michaung–through the India Meteorological Department (IMD). Over the year, INCOIS issued a total of 1,904 High Wave/Swell Alerts/Warnings and rough sea alerts, alongside daily Ocean State Forecasts for India and six Indian Ocean countries. Notably, INCOIS issued swell surge alerts for the event in Kerala on 31 March 2023, which led to flooding in low-lying areas and reported damages. In addition to these efforts, INCOIS provided 346 Potential Fishing Zone advisories and 104 Yellowfin Tuna advisories. It also issued 122 advisories related to coral bleaching, including nine warnings and 23 watches. INCOIS monitored algal blooms daily for 354 days, issuing 26 alerts in selected ecological hotspots. Furthermore, INCOIS disseminated daily Marine Heatwave Advisories, encompassing 19% watch, 14% alert, and 2.5% warnings.

Throughout the reporting period, INCOIS maintained active participation in several prominent international programs, such as the Indian Ocean Global Ocean Observing System (IOGOOS), the United Nations Ocean Decade for Sustainable Development (Ocean Decade), the IOC Regional Committee for the Central Indian Ocean (IOCINDIO), the Partnership for Observation of the Global Oceans (POGO), the Regional Integrated Multi-Hazard Early Warning System for Asia and Africa (RIMES), the Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER), the Second International Indian Ocean Expedition (IIOE-2), and the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS), among others. The global presence of INCOIS continued with the re-election of the Director, INCOIS, as the Vice-Chairperson IOC-UNESCO's Electoral Group IV for another term of two years (2023-25) and Group Director, ODICT, was elected as the member of the WMO-IOC Data Buoy Cooperation Panel. INCOIS played a key role in organizing different activities related to Ocean Dialogue under India's G20 Presidency and contributed immensely to the G20 Chennai High Level Principle for a Sustainable and Resilient Blue Economy.

A significant milestone was achieved on 23 August 2023, when the office of the UN Ocean Decade Collaborative Centre for the Indian Ocean Region (DCC-IOR) was inaugurated at INCOIS, having been endorsed by the Intergovernmental Oceanographic Commission (IOC) of UNESCO. Further enhancing its global engagement, the DCC-IOR at INCOIS organized the Indian Ocean Regional Decade Conference (IO-Con 2024) from 01-03 February 2024. INCOIS was also recognized as a Regional Specialized Meteorological Centre (RSMC) under the World Meteorological Organization (WMO), for Ocean Wave Prediction and Global Numerical Ocean Prediction, and initiated products to the Indian Ocean Rim countries starting on 23 August 2023. Additionally, since 22 May 2023, INCOIS has extended its ocean services to 14 Pacific Island Countries under the auspices of the Sustainable Coastal and Oceania Research Institute (SCORI) at the University of the South Pacific, Fiji.

Furthermore, since 07 December 2023 INCOIS has started providing ocean services to the member countries of the Colombo Security Conclave (CSC).

Alongside its oceanographic services and research, INCOIS is deeply committed to educating the next generation of oceanographers. Over the past year, the International Training Center for Operational Oceanography (ITCOOcean) at INCOIS continued to deliver high-quality training, offering a total of 17 international and national training courses in both offline and online formats. As in previous years, INCOIS conducted a specialized four-month advanced oceanography course tailored for Indian Navy officials. To enhance tsunami preparedness, INCOIS organized a series of initiatives, including tsunami mock exercises, awareness campaigns, and the Indian Ocean Tsunami Exercise IOWave23 under the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS).

As part of the Azadi Ka Amrit Mahotsav (AKAM) initiative by the Government of India, INCOIS conducted various outreach activities throughout 2023-24. These activities were designed to highlight the achievements of INCOIS and India's progress in Earth Sciences, with a special focus on ocean sciences over the past 75 years. INCOIS hosted over 6,000 students from schools, colleges, and universities at its facilities, inspiring young minds and raising awareness about the vital services it provides. Moreover, 69 students from various universities and institutes across India completed their academic projects and internships under the expert guidance of INCOIS scientists during 2023-24, further nurturing future leaders of oceanography. As part of its Silver Jubilee commemoration, INCOIS orchestrated five mega user workshops across five coastal states, engaging over 2,300 fishermen. Additionally, user interaction workshops were organized in 237 coastal villages, reaching over 9,000 fishermen across ten coastal states. The institute spearheaded the 'Swachh Sagar, Surakshit Sagar' campaign in 37 locations within 12 coastal districts of Andhra Pradesh and organized educational visits for students to the Ocean Research Vessels Sagar Nidhi, fostering a deep appreciation for oceanic research among the youth. INCOIS also conducted various scientific, art and oratory competitions for school students, hosted multiple Open Days for the general public, arranged a mega sports tournament for MoES inter-institutional teams, and organized popular science talks by eminent experts. Highlights of the Silver Jubilee celebrations included the unveiling of the 'INCOIS My Stamp', release of a book titled 'INCOIS 25-Years and a Mural themed 'Ocean & Life'.

During 2023-24, INCOIS scientists have published 61 research papers in several peer-reviewed journals, with a cumulative impact factor of 193. INCOIS scientists/researchers/services have been conferred with several awards/honors such as 'Journal of the Indian Society of Remote Sensing's Best Publication Award-2022', "Best Research Award" by the National Graduate Institute for Policy Studies (GRIPS) and Building Research Institute (BRI), institutes of Japan, 'Best Paper Award' at the World Ocean Science Congress-2024, and selection of research scholar under ICTP/IAEA Sandwich Training Educational Programme (STEP).

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 (FC) for 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 Shesu, Girish, Arya, Padmanabham, Ajay, Dipankar, Rohith, Sanjiba, Dhanya and Sidhartha. I thank them for doing a wonderful job.

As we celebrate glorious 25 years of our existence, our future vision for 2047 focuses on contributing towards a Viksit Bharath.

Jai Hind

Dr. Srinivasa Kumar Tummala

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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. Dy CAG	Member (Expert)
8.	Senior Finance Officer, INCOIS	Member Secretary (Ex-Officio)

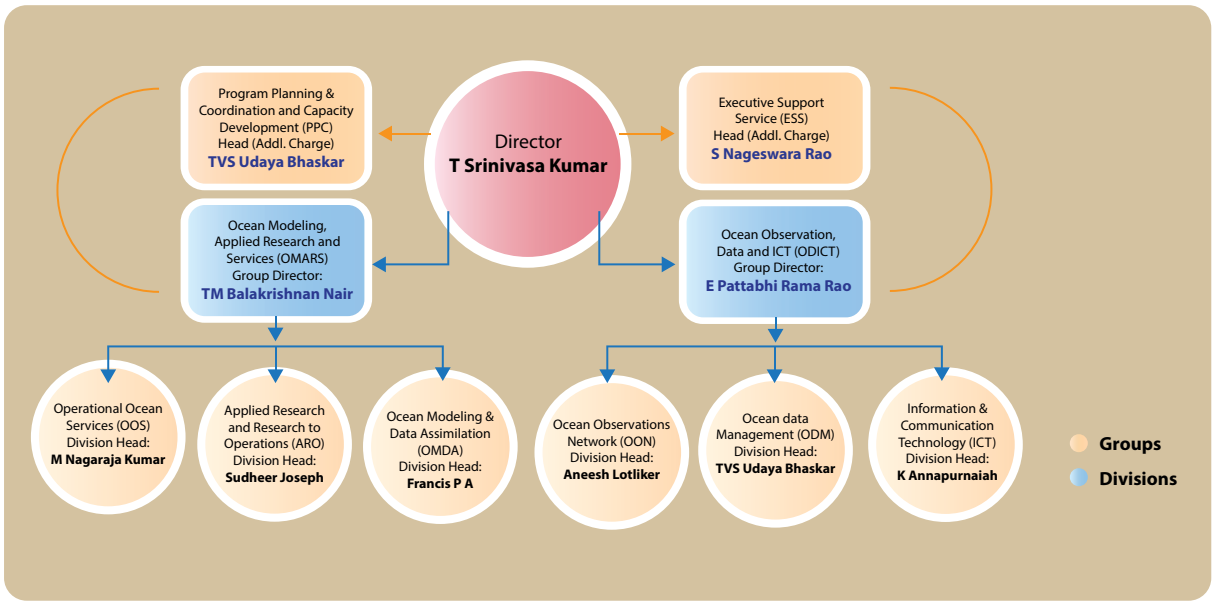
2.4 INCOIS Research Advisory Committee

1.	Dr. Satish R Shetye, Former Vice Chancellor, Goa University	Chairperson (Expert)
2.	Cdr. P K Srivastsava, 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 two major Scientific Groups headed by respective Group Directors, and each group has three divisions headed by respective Division Heads. In addition to the scientific groups, there are two divisions: one to support the program planning & coordination and capacity building and another to tender the administrative support for the organisation's functioning.



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.

HIGHLIGHTS

Highlights during April 2023 to March 2024

Launch of New Infrastructure Facilities, Observations, Products and Services

- **SynOPS Facility:** Launched on 14 February 2024, by Shri Kiren Rijiju, the Hon'ble Union Minister of Earth Sciences, Govt. of India, a state-of-the-art Synergistic Ocean Observation Prediction Services (SynOPS) facility is equipped with an advanced network operations center system for enhanced ocean monitoring and integrated ocean services.
- **Satellite Data Acquisition and Processing Facility** inaugurated by Dr Vijay Kumar Saraswat, Member, NITI Aayog, Govt. of India, equipped with a 2.4 m X/L band antenna for enhanced satellite data reception and processing on 03 February 2024.
- **Global Navigation Satellite System (GNSS) & Strong Motion Accelerometer (SMA) Network** in Andaman & Nicobar Islands, established for improving tsunami early warning services of INCOIS, was dedicated to the Nation on 14 February 2024 by Shri Kiren Rijiju.
- **Commissioned a Coastal Buoy** for observing water quality off Visakhapatnam on 23 August 2023 by Dr M. Ravichandran, Secretary, Ministry of Earth Sciences, Govt. of India.
- **'SAMUDRA' mobile application** launched 27 July 2023 during the 17th MoES Foundation Day by Shri Kiren Rijiju, provides comprehensive information on all ocean-related services and is helpful for both seafarers and the fishing community.
- **Released a customized 'INCOIS My Stamp'** on the occasion of INCOIS Foundation Day (Silver Jubilee) celebrations by Dr Vijay Kumar Saraswat on 03 February 2024.
- Dr Vijay Kumar Saraswat also **released Hindi and English versions of the book on 'INCOIS 25-Years Journey'** on the INCOIS Foundation Day (Silver Jubilee) celebrations on 03 February 2024.
- **Mural on 'Ocean & life'** installed at the entrance of INCOIS's main building was inaugurated on 14 February 2024 by Shri Kiren Rijiju to symbolizes the theme '*Ocean & Life*.
- **UN Ocean Decade Collaborative Centre for the Indian Ocean Region (DCC-IOR)**, endorsed by the Intergovernmental Oceanographic Commission (IOC) of UNESCO, was inaugurated by Dr Ravichandran on 23 August 2023 at INCOIS.
- **Regional Specialized Meteorological Centre (RSMC) of WMO** was inaugurated on 23 August 2023, by Dr M Ravichandran, which provides ocean services on Numerical Ocean Wave Prediction and Global Numerical Ocean Prediction to the Indian Ocean Rim countries, reflecting INCOIS's global role in delivering ocean services.
- **The ocean services on Numerical Ocean Prediction**, which INCOIS has been providing to 14 Pacific Island Countries since 22 May 2023 under the Sustainable Coastal and Oceania Research Institute **(SCORI)** at the University of the South Pacific, Laucala Campus in Suva, Fiji, were officially inaugurated on 23 August 2023 by Dr. M. Ravichandran.
- **Ocean Services for Colombo Security Conclave (CSC) countries** have been initiated by INCOIS from 07 December 2023.

Ocean Observation, 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.
- **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.

- **OSF Advisories:** INCOIS provided Ocean State Forecast advisories on waves, winds, currents, swell, tides, SST, MLD, D20, etc. daily during the reporting period.
- **Storm Surge Early Warnings:** INCOIS provided Storm surge and inundation advisories for six cyclones (Mocha, Biparjoy, Tej, Hamoon, Midhili, and Michaung) through IMD.
- **OSF during Cyclones:** INCOIS monitored the evolution of the sea state during the passage of six cyclones (Mocha, Biparjoy, Tej, Hamoon, Midhili, and Michaung) and provided 191 INCOIS-IMD joint bulletins to issue high-wave alerts and warnings to the public.
- **High Wave/Swell and Rough Sea Warning/Alert:** INCOIS issued a total of 1904 High Wave/Swell Alerts/Warnings and rough sea alerts, in addition to the daily Ocean State Forecasts for India and 6 Indian Ocean Countries.
- **Swell Surge Alert:** INCOIS issued swell surge alerts for the swell surge event that happened in Kerala on 31 March 2023, in which low-lying areas flooded and damages were reported. INCOIS team surveyed the impacted areas.
- **Small Vessel Advisory Services:** INCOIS provided Small Vessel Advisory Service advisories daily during the reporting period to fisherfolks and seafarers.
- **PFZ Advisories:** INCOIS provided 346 Potential Fishing Zones advisories and 104 Yellowfin Tuna advisories and disseminated widely through multiple platforms, including 09 broadcast channels on the TELEGRAM platform.
- **Coral Bleaching Alerts:** INCOIS provided 122 advisories (including 9 warnings and 23 watches) on Coral Bleaching Alerts for Andaman, Nicobar, Lakshadweep, Gulf of Kutch, and Gulf of Mannar.
- **Algal Bloom Information:** INCOIS monitored algal blooms on a daily basis for 354 days and issued 26 alerts in select ecological hotspots of the Indian coastal waters.
- **Marine Heatwave Advisory Services:** INCOIS issued daily Marine Heatwave Advisories (19% watch, 14% alert, and 2.5% warning out of the total number of advisories) for the Indian Ocean during the reporting period.
- **Upgradation of Oil Spill Advisory System:** INCOIS upgraded Online Oil Spill Advisory System (OOSA) to Version 5.0 with Advanced GIS and Predictive Capabilities.
- **Integration of Multi-hazards Early Warnings through CAP-SACHET:** INCOIS integrated multi-hazard early warning services with NDMA CAP (National Disaster Management Authority-Common Alerting Protocol) platform 'SACHET' and disseminated SMS alerts about 6.6 cr. through CAP-SACHET.
- **Services for SAHF:** INCOIS provided weekly briefings on ocean state forecast information for Indian Ocean region to South Asia Hydromet Forecaster Forum (SAHF) through the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES).
- **Revival of Ocean Observations Network:** INCOIS sustained its ocean observation network and resumed the procurement and deployment activities, bringing most in-situ ocean observation platforms close to their proposed targets during the reporting period.
- **Glider Transects Fully Operational:** INCOIS made the open ocean glider transects in the Arabian Sea fully operational for the first time.
- **OSICON-23 and IO-CON-24 Conferences (Websites):** INCOIS developed webpages for the National Conference of Ocean Society of India (OSICON-23) and Indian Ocean Regional Decade

Conference (IO-CON-24) events to advance operational oceanography and marine sciences through global collaboration and innovation.

- **Regional Sea Level Projection:** INCOIS assessed the Regional Sea level projection for all along the coast of India for the SSP585 scenario (high emission scenario) using the available global datasets.
- **Climate Outlook:** INCOIS-Global Ocean Data Assimilation System (GODAS) has been providing climate outlooks on an operational basis.
- **Data Assimilation:** INCOIS developed the assimilation of HF-RADAR surface currents in Indian Ocean Regional Ocean Modeling System (ROMS), which has shown promising results.
- **Wave Climate Projections:** INCOIS configured a model for the Indian Ocean using WAVEWATCH III for developing wave climate projections under the Deep Ocean Mission.
- **Biogeochemical Projections:** INCOIS identified three Global Earth System Models (GFDL, UKESM, and CNRM) for developing downscaled biogeochemical projections for the Indian Ocean.
- **Tsunami Modeling:** INCOIS developed an ADvanced CIRCulation (ADCIRC) model with a mesh resolution of 2 km in shallow waters and 20 km in deeper waters that accurately and efficiently predict tsunamis.
- **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 completed the configuration of a high-resolution global Modular Ocean Model (MOM6) and a varying spatial resolution coastal Finite Volume Community Ocean Model (FVCOM) for the coastal waters off Cochin.
- **Indian Ocean Acidification:** INCOIS analyzed the present status of Indian Ocean acidification using the available field observations, reconstructed data sets, and model simulations.
- **Research Publications:** INCOIS scientists published 61 research papers during the reporting period with a cumulative impact factor of 193.8.

Capacity Building, Education & Training

- **Trainings:** International Training Centre for Operational Oceanography (ITCOOcean) of INCOIS conducted 17 training programs (9 International and 8 National), 4 seminars and trained 1025 persons, of which 807 (Male: 506, Female: 301) are from India, and 218 (Male: 146, Female: 72) are from 25 other countries.
- **Advanced Oceanography Course for Indian Navy Officials:** INCOIS conducted a four-month course on Operational Oceanography exclusively for the second batch of officers of the Indian Navy from 09 October 2023 to January 25, 2024.
- **Tsunami Mock Exercise:** INCOIS conducted a tsunami mock drill for Odisha stakeholders on 05 November 2023 (World Tsunami Awareness Day). A total of 30 coastal villages of 6 districts actively participated. Approximately 20,000 people evacuated and tested Tsunami Ready indicators.
- **Tsunami Awareness Campaigns:** INCOIS conducted week-long events in Kerala in collaboration with Amrita University as a part of tsunami awareness campaigns. The event included Tsunami awareness sessions, Drawing competitions, and a Scavenger hunt, wherein about 365 students from various schools participated.

- **COMM Tests:** The 26th Communications test of the IOC-UNESCO Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) was conducted on 07 June 2023 to validate the Tsunami Service Providers (TSPs) dissemination process to National Tsunami Warning Centres (NTWCs) and to validate the dissemination processes for tsunami notification messages.
- **ICG/IOTWMS IOWave23 Tsunami Exercise:** INCOIS conducted the Indian Ocean Tsunami Exercise IOWave23 of ICG/IOTWMS during October 2023. As aTSP, The Indian Tsunami Early Warning Centre (ITEWC) issued test bulletins to 3 scenarios for Indian Ocean countries. At the National level, 44 coastal villages from 13 districts of 4 coastal States participated and evacuated about 40,000 people.
- **Tsunami Ready progress:** INCOIS has been supporting the implementation of tsunami-ready measures in 24 villages of Odisha and nine coastal villages of Kerala, which is progressing well.
- **Azadi ka Amrit Mahotsav:** As part of the Azadi Ka Amrit Mahotsav (AKAM) initiative of the Government of India, INCOIS continued to organize various activities during 2023-24. These activities primarily focused on improving the outreach of INCOIS activities and services and India's Achievements in the past 75 years in the field of Earth Sciences with special emphasize on ocean sciences.
- **Campus Visit of Students:** INCOIS hosted over 6000 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 69 students from various Universities and Institutes across India completed their academic Projects/Internships under the guidance of INCOIS scientists during 2023-24.

Important International Activities

- **UNFCCC:** INCOIS participated and contributed to the **28th Conference of Parties (COP)** to the UN Framework Convention on Climate Change (UNFCCC) held in Dubai, UAE.
- **G20:** INCOIS played a key role in organizing different activities under related to Ocean Dialogue under India's G20 Presidency, and contributed immensely to the G20 Chennai High Level Principle for a Sustainable and Resilient Blue Economy.
- **IO-Con 2024:** Within months of its formal launch, the UN Ocean Decade Collaborative Centre for Indian Ocean Region (DCC-IOR) at INCOIS organized the Indian Ocean Regional Decade Conference (IO-Con 2024) during 01-03 February 2024 as an official prelude to the 2024 UN Ocean Decade Conference scheduled at Barcelona, Spain in April 2024.
- **OceanPredict DCC's Indian-seas Regional Team Meeting:** INCOIS organized the first Indian-seas regional team meeting of OceanPredict DCC (Mercator Ocean) virtually on 03 May 2023. Users from the scientific community, NGOs, fishermen community, etc., from member institutes/countries participated in this meeting.
- **SIBER-International Programme Office:** INCOIS continued to host an International Programme Office to coordinate the activities of the Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER).
- **IIOE-2 Project Office:** IIOE-2 Project Office of INCOIS hosted a brainstorming meeting of distinguished researchers and policymakers across the globe engaged in various forums in the Indian Ocean, such as IOGOOS, IORP, IRF, SIBER, IOCINDIO, and SCOR, on 28-30 November 2023

to discuss and prepare an addendum to IIOE-2 science plan and revised implementation strategy for extension of IIOE-2 tenure till 2030.

- **Ocean State Forecast to RIMES Member States:** INCOIS has been providing the ocean state forecast services to Comoros, Madagascar, Maldives, Mozambique, Seychelles, and Sri Lanka as a part of the MoU between the Ministry of Earth Sciences, Govt. of India, and Regional Integrated Multi-Hazard Early Warning System for Asia and Africa (RIMES).
- **IIOSC 2024:** INCOIS scientists actively participated in the integrated annual meetings of Global Ocean Observing System in the Indian Ocean (IOGOOS) and its allied programs (IORP, SIBER, IRF, IIOE-2, IOCINDIO) held under the central theme of 'International Indian Ocean Science Conference (IIOSC)-2024' on 04-08 March 2024 at Lombok, Indonesia.
- **ITCOOcean-POGO International Training Course:** ITCOOcean of INCOIS hosted a Partnership for Observation of the Global Ocean (POGO)-funded international training programme on 'Ocean Observations for Coastal Applications' from 29 January to 07 February 2024.
- **ICG/IOTWMS Steering Group and WG-3 Meetings:** INCOIS hosted the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) Steering Group and Working Group(WG-3) meetings attended by around 20 officials, including international representatives from Australia, Indonesia, and Iran.

Foundation Day (Silver Jubilee) Celebration

- **Mega User Workshop:** INCOIS conducted 05 Mega workshops across five coastal states, engaging over 2,300 fishermen.
- **User Interaction Campaigns:** INCOIS hosted User Interaction Workshops at 237 coastal villages in partnership with various organizations, engaging over 9,000 fishermen from 10 coastal states.
- **Swacch Sagar, Surakshit Sagar/Clean Coast Safe Sea Campaign:** INCOIS, in collaboration with Matsyakara Samkshema Samiti, hosted the Swachh Sagar, Surakshit Sagar/Clean Coast Safe Sea Campaign across 37 locations in 12 coastal districts of Andhra Pradesh.
- **Exposure to ORV Sagar Nidhi:** INCOIS arranged a visit of 91 students from 12 colleges, universities, and institutes based in Chennai to the Ocean Research Vessels (ORV) Sagar Nidhi to educate young students about ocean research and the capabilities of ORV on 24 June 2023.
- **World Tsunami Awareness Day:** On World Tsunami Awareness Day, INCOIS organized Drawing/ Painting, Extempore, and Science Exhibition/model-making competitions for the school students of Telangana to raise awareness about tsunami preparedness, learn about INCOIS cutting-edge research, and understand the vital role of oceans in daily lives. 439 students, along with 58 teachers and parents from different schools/colleges based in Hyderabad & over 550 general public, visited INCOIS on 05 November 2023.
- **Open House Programme for Students & Public:** INCOIS hosted three Open Days on multiple occasions, attracting more than 1,050 visitors from the general public on each occasion. These open-day events allowed visitors to explore INCOIS facilities, learn about INCOIS's ocean research and services, and engage with INCOIS scientists.
- **MoES Inter-institutional Sport Tournament:** INCOIS organized a mega sports tournament for MoES inter-institutional teams. A total of 180 players participated in the tournament, including 48 women and 132 men from various institutes under the Ministry.

- **Outreach Lecture Series:** INCOIS scientists delivered seven enlightening lectures to schools and colleges across Telangana to cultivate and encourage student's interest and passion in ocean science and popularize INCOIS services.
- **Popular Science Talks:** INCOIS organized six popular science talks delivered by distinguished experts from various fields on critical environmental and scientific issues as a part of INCOIS's 25th Anniversary Celebrations.
- **Competition for School Students:** As a part of the Silver Jubilee Celebrations (1999-2024), INCOIS organized a series of competitions, including a Science exhibition, Quiz, and Drawing/Painting competition, inviting enthusiastic students from various schools across Telangana. 245 students from 28 different schools located in 9 districts of Telangana participated in these competitions.

Awards/Honors/ Recognition

- **Vice-Chairperson IOC-UNESCO:** Dr. T. Srinivasa Kumar, Director, INCOIS, has been re-elected as Vice-Chairperson from Electoral Group IV of the Intergovernmental Oceanographic Commission (IOC) for another term of two years (2023-25).
- **Member of the WMO-IOC Data Buoy Cooperation Panel:** Shri. Pattabhi Rama Rao, Scientist 'G' & Group Director, ODICT, elected as a Member of the WMO-IOC Data Buoy Cooperation Panel (DBCP) for International Cooperation and Partnership.
- **JISRS Best Publication Award- 2022:** Mr. Sivaiah Borra, Project Scientist, won the 'Journal of the Indian Society of Remote Sensing's Best Publication Award-2022' by the Indian Society of Remote Sensing (ISRS).
- **Best Research Award:** Dr. Ch. Patanjali Kumar, Scientist-E, INCOIS awarded with "The Best Research Award" in the Disaster Management Policy Program, Tsunami Disaster Mitigation Course, 2022-2023 by the National Graduate Institute for Policy Studies (GRIPS) and Building Research Institute (BRI), institutes of Japan.
- **ICTP/IAEA Sandwich Training Educational Programme (STEP):** Ms. Trishneeta Bhattacharya, Senior Research Fellow at INCOIS under the guidance of Dr. Kunal Chakraborty, selected to participate in the ICTP/IAEA Sandwich Training Educational Programme (STEP).
- **WOSC-2024 Best Paper Award:** Dr. Sanjiba Kumar Baliarsingh & Dr. Dhanya M Lal won the 'Best Paper Award' under the theme 'Ocean services: what is existing and what is required' at the World Ocean Science Congress-2024.


4
SERVICES

4.1 Multi-Hazard Early Warning Service

4.1.1 Tsunami Early Warning Service (TEWS)

The Indian Tsunami Early Warning Centre (ITEWC) monitored 29 earthquakes of magnitude ≥ 6.5 during the reporting period. Out of 29 earthquakes, only one earthquake occurred in the Indian Ocean region. The ITEWC carefully assessed the situation during the earthquakes and declared that there would not be any tsunami threat to India and the Indian Ocean. Being the Tsunami Service Provider (TSP) for the Indian Ocean, the necessary bulletins were also sent to 26 Indian Ocean rim countries through E-mails, GTS, FAX, and SMS. The locations of these earthquakes are shown in Figure 4.1.1.

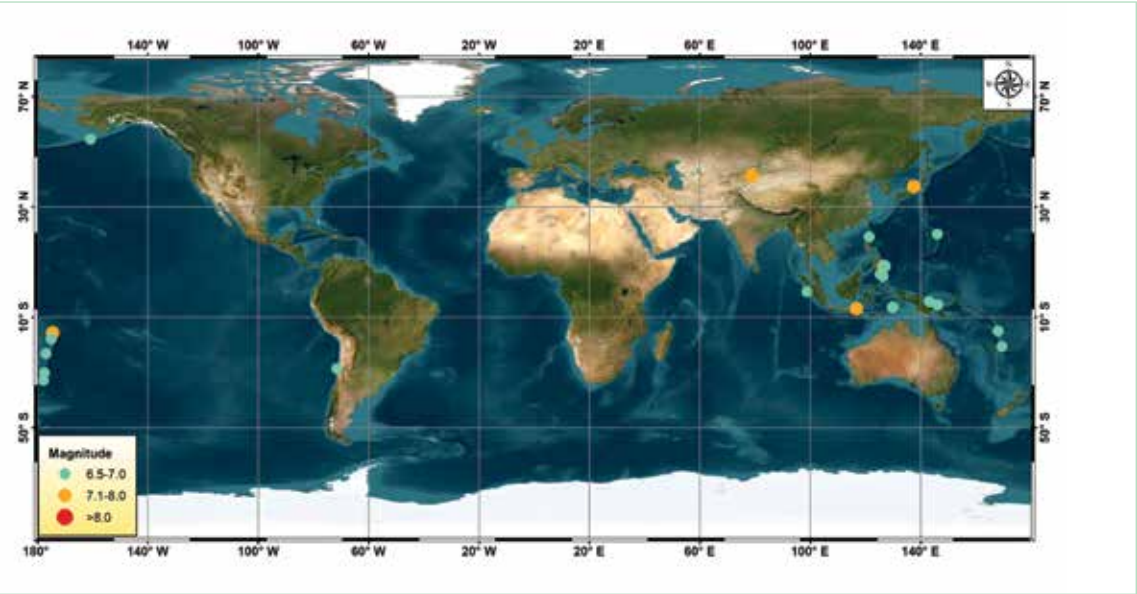


Figure 4.1.1. Location map of earthquakes of magnitude ≥6.5 monitored at ITEWC during 2023-24

4.1.1.1 Key Performance Indicators (KPI) of ITEWC

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

Table 4.1 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	10.8
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	23.3
KPI 5	Accuracy of earthquake hypocenter location in comparison with Final USGS parameters	30 Km	22.4
KPI 6	Elapsed time from the earthquake to the issuance of the first Threat Assessment Bulletin	20 Min	22

4.1.1.2 Monitoring of Tsunamigenic Earthquakes

In the Indian Ocean, an earthquake of magnitude 6.8 occurred in Southern Sumatra, Indonesia, on 24 April 2023 at 20:00 UTC (25 April 2023 at 01:30 IST). The epicentre of the event was at 0.69° S, 98.71° 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. ITEWC issued a second bulletin for this earthquake, 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.

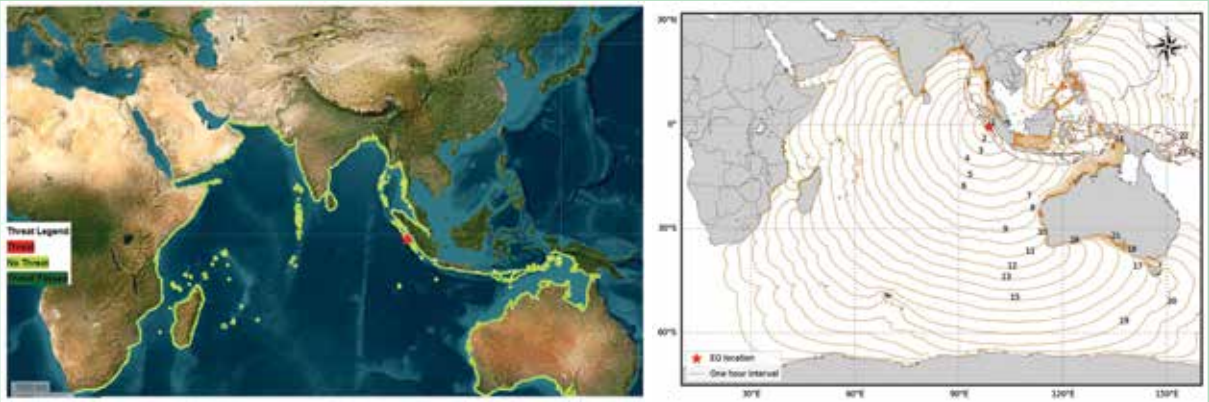


Figure 4.1.2. Tsunami Threat details and Travel time Map for Southern Sumatra, Indonesia earthquake on 24 April 2023

4.1.1.3 Tsunami Mock Exercises

IOWave23 Exercise

India has participated in a major Indian Ocean Tsunami Exercise IOWave23 during October 2023 by the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) of Intergovernmental Oceanographic Commission (IOC), UNESCO. IOWave23 exercises four scenarios on the 04, 11, 18 & 25 October 2023 including a volcanic eruption scenario (on 18 October 2023). The collage image of coordinated activities at various levels as part of IOWave23 tsunami exercise on 04 October 2023 is shown at Figure 4.1.3. As a Tsunami Service Provider (TSP), ITEWC issued bulletins for Indian Ocean countries for three scenarios, details mentioned in table 4.2 below.

Table 4.2 Scenarios details for IOWave20 Exercise

	Scenario 1 – Andaman Trench	Scenario 2 – Makran Trench	Scenario 3 – Java Trench
Date:	Wednesday, 04 October 2023	Wednesday, 11 October 2023	Wednesday, 25 October 2023
Time:	09:30 IST	11:30 IST	07:30 IST
Magnitude:	9.0 M	9.0 M	9.1 M
Depth:	10 km	10 km	10 km
Latitude:	7.20° N	24.80° N	10.40° S
Longitude:	92.90° E	58.20° E	112.80° E
Location:	Nicobar, India	Off Coast of Iran	South of Java

The IOWave23 exercise involved enacting three scenarios on (i) 4th October with an earthquake of magnitude 9.0 in Nicobar, India, (ii) 11th October with an earthquake of magnitude 9.0 off coast of Iran and (iii) 25 October with an earthquake of magnitude 9.1 South of Java. During the exercise, ITEWC generated and issued 15 test tsunami bulletins/notifications in 12 hours duration to both its National & Regional (IOTWMS) contacts through GTS, email, fax, SMS as well as website.

At the National level, the IOWave exercise was conducted on 04 October for the east coast of India and Andaman & Nicobar Islands and on 11 October west coast of India and Lakshadweep Islands. All the coastal states participated in the tsunami exercise. A few coastal provinces participated up to the community level and other coastal provinces participated up to DMOs/Organisation levels with tabletop and functional exercises. In addition, the Indian Navy, Coast Guard, NDRF, Nuclear power plants and Port & Harbours, Fisheries departments, etc. also participated in the exercise. Overall, 44 coastal villages from 13 districts of 4 coastal States/UTs of Odisha (32 villages), Andaman (5), Puducherry (4), and Tamil Nadu (3) were involved and evacuated during the exercise. About 40,000 people were evacuated to shelters/safe places during mock exercises, and community people, school students, elderly personnel, etc. were involved in the evacuations. During the exercise, Tsunami ready indicators were tested at 32 coastal villages of Odisha.

Figure 4.1.3. Community participation during IOWave23 tsunami exercise on 04 October 2023

For Odisha: On 05 November 2023, a tsunami mock exercise was conducted in coordination with the Odisha State Disaster Management Authority (OSDMA), 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 9.0 in Nicobar Islands. During the drill, 7 test bulletins were issued in 4 hours duration. A total of 30 coastal villages under 18 Blocks of 6 Districts actively participated and approximately 20,000 People evacuated to test the Tsunami ready indicators (Figure 4.1.4).

Figure 4.1.4. Odisha community participation during tsunami mock drill on 05 November 2023

4.1.2 Storm Surge Early Warning Service

During 2023-24, INCOIS successfully monitored 06 Cyclonic Storms, namely, ESCS Mocha, ESCS Biparjoy, VSCS Hamoon, CS Midhili, SCS Michaung, and a deep depression, and issued 85 timely storm surge and inundation advisories through Indian Meteorological Department (IMD). Storm surge and inundation forecasts for cyclones are shown in Figure 4.1.5.

Table 4.3. Cyclones and deep depressions during 2023-24

Sl. No.	Cyclone Name	Dates Active	No. of Advisories / Graphic products issued
1	Extreme Severe Cyclonic Storm Mocha	10 – 14 May 2023	23
2	Extreme Severe Cyclonic Storm Biparjoy	10 – 15 June 2023	25
3	Deep Depression in Bay of Bengal	01 August 2023	01
4	Extreme Severe Cyclonic Storm Tej and Hamoon	22 – 25 October 2023	08
5	Cyclonic Storm Midhili	16 – 17 November 2023	07
6	Severe Cyclonic Storm Michaung	02 – 06 December 2023	21

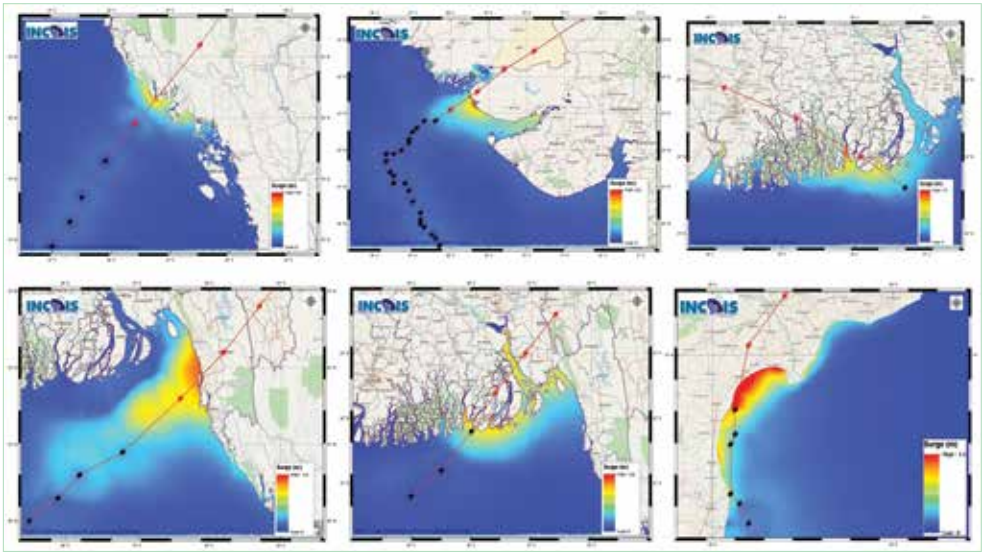


Figure 4.1.5. Real-time storm surge and inundation forecast for Mocha, Biparjoy, Deep Depression, Hamoon, Midhili and Michaung cyclones, respectively

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, Sea Surface Temperature (SST), Mixed Layer Depth (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 defense authorities. INCOIS also provided daily OSF data to Sri Lanka, Maldives, Seychelles, Comoros, Mozambique, and Madagascar.

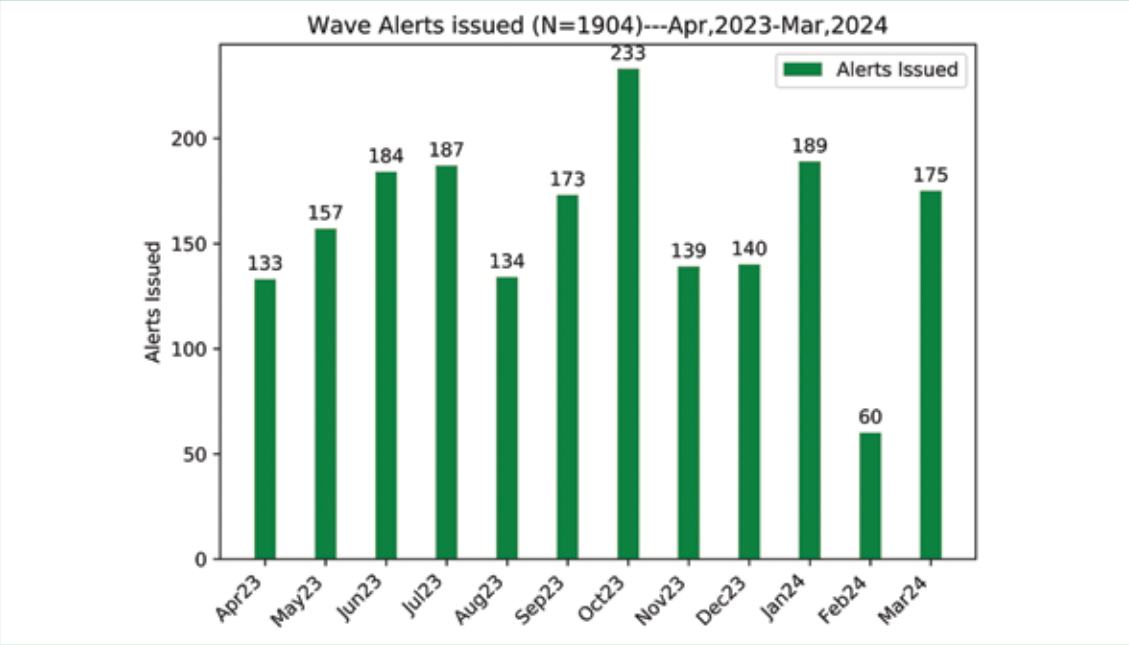


Figure 4.1.6. Number of high wave/swell/ rough sea alerts issued during Apr 2023 – Mar 2024

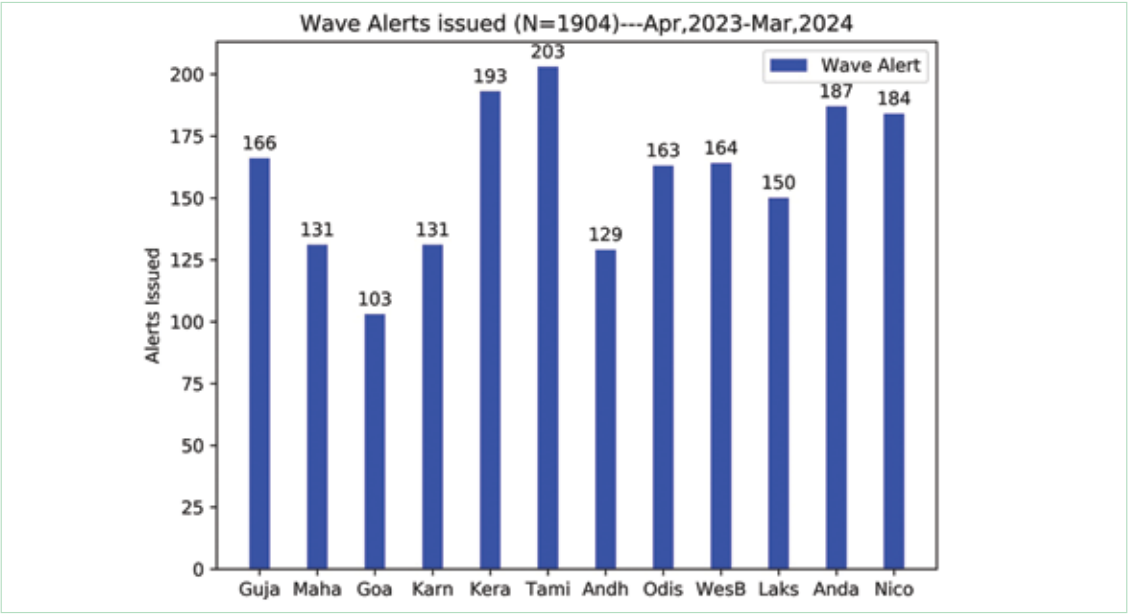


Figure 4.1.7. State-wise distribution of the high wave/swell/rough sea alerts during the period

During the reporting period, INCOIS issued OSF services seamlessly, supporting the operational requirements and safety of a diverse and large user community through multiple dissemination modes. INCOIS issued 1904 wave-related alerts (high wave alerts, high swell alerts, rough sea alerts and swell surge alerts) from April 2023 to March 2024. The maximum alerts were issued during the month of October 2023 and the least during February 2024. Month-wise and state-wise alerts are shown in Figures 4.1.6 and 4.1.7, respectively. The highest number of alerts was issued for Tamil Nadu and the lowest for Goa.

INCOIS issued Swell surge/ Rough Sea Alerts to Kerala, Lakshadweep, and Tamil Nadu during 29-31 March 2024. A swell Surge happened on 31 March 2024 at a few coastal places of Kerala

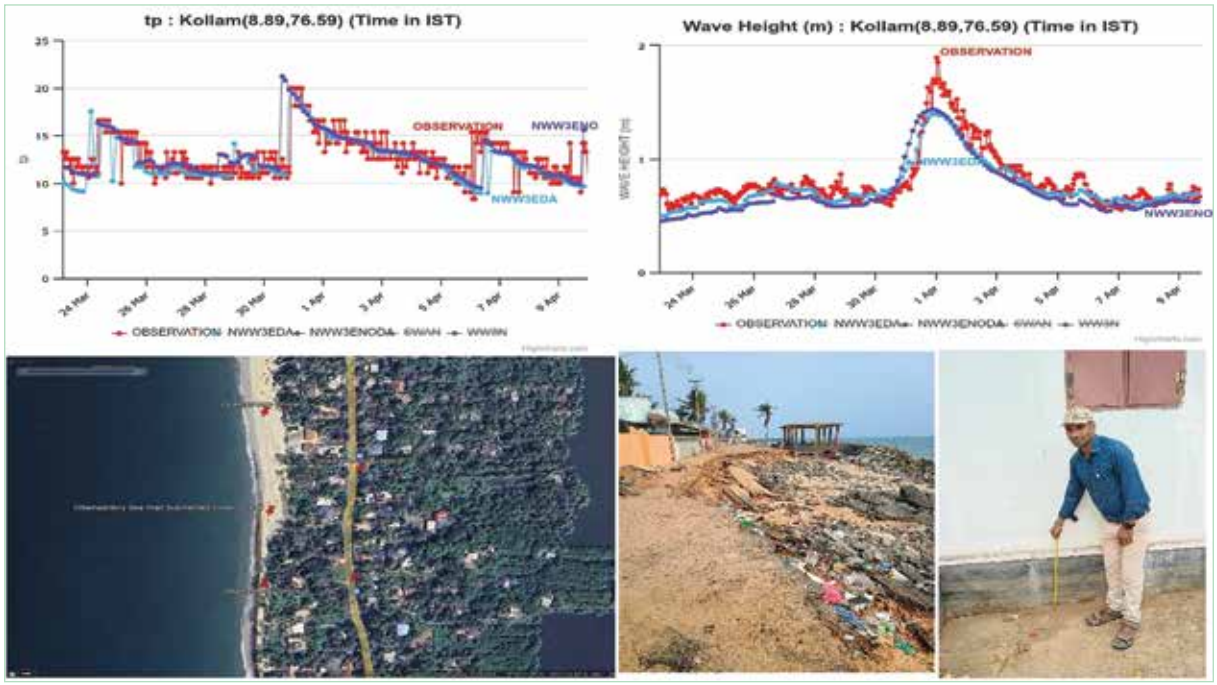


Figure 4.1.8. Swell Surge observations and field survey in impacted areas in Kerala coast

and Tamil Nadu. Low-lying areas got flooded and damages were reported in a few scattered coastal districts. The swell peak wave period observed was 20 sec and the wave height observed was 1.8 m in WRB & Moored buoys off Lakshadweep and Kerala. INCOIS team surveyed the impacted areas in Kerala and observed 120 m maximum inundation at Adimalatura and 1.2 m maximum wave height at Pozhiyoor (Figure 4.1.8).

INCOIS continued extending the necessary support required to the users through customization and location-specific services (including a large

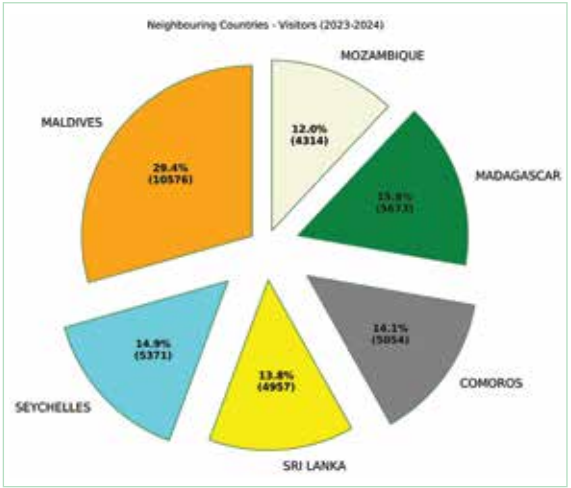


Figure 4.1.9. Ocean forecast services to RIMES member states and countries wise visitors list

number of fish landing centers). INCOIS provided ocean state forecast services to McDermott, ONGC, etc. 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 in addition to the access provided to multiple users through registration.

INCOIS is supporting the RIMES countries of Maldives, Sri Lanka, Seychelles, Comoros, Madagascar and Mozambique on a daily basis. However, the users from Maldives heavily dominated the user base as seen in Figure 4.1.9.

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 ESCS Mocha, ESCS Biparjoy, ECSC Tej, VSCS Hamoon, CS Midhili and SCS Michaung using models, in-situ instruments as well as satellite observations. Extreme events during the period are displayed in the table below, including all the phases of the events, e.g., depression – cyclone – depression, and its dissemination statistics. A total of 191 bulletins were issued for the eight extreme events, as listed in table 4.4 below.

The maximum significant wave height was in the range of 3.5 – 7.7 m in the six cases, the maximum being to the right of the cyclone path.

Table 4.4. OSF forecast for cyclones and depressions during the reporting period

Extreme weather event	Period	Number of bulletins issued	States/UTs/Countries affected
Extremely Severe Cyclonic Storm Mocha	10 – 14 May 2023	32	Andaman and Nicobar Islands, West Bengal (India), Sri Lanka, Myanmar, Bangladesh,
Extremely Severe Cyclonic Storm Biparjoy	6 – 16 Jun 2023	75	Gujarat, Maharashtra, Goa, Karnataka, Lakshadweep, Kerala (India), Pakistan
Deep Depression BoB 01	1 – 2 Aug 2023	4	West Bengal, Odisha (India), Myanmar, Bangladesh
Depression ARB 01	30 Sep – 01 Oct 2023	3	Goa, Maharashtra, Karnataka (India)
Extremely Severe Cyclonic Storm Tej & Extremely Severe Cyclonic Storm Hamoon	20 – 25 Oct 2023	33	Kerala, Tamil Nadu, Lakshadweep (India), Socotra, Yemen, Oman; West Bengal, Odisha, Andhra Pradesh (India), Bangladesh
Cyclonic Storm Midhili	15 – 17 Nov 2023	14	Odisha, West Bengal (India), Bangladesh
Severe Cyclonic Storm Michaung	01 – 06 Dec 2023	30	Tamil Nadu, Andhra Pradesh, Odisha, West Bengal (India), Bangladesh

Spatial plots of the forecast waves during the Biparjoy and Michaung cyclones are presented in Figure 4.1.10.

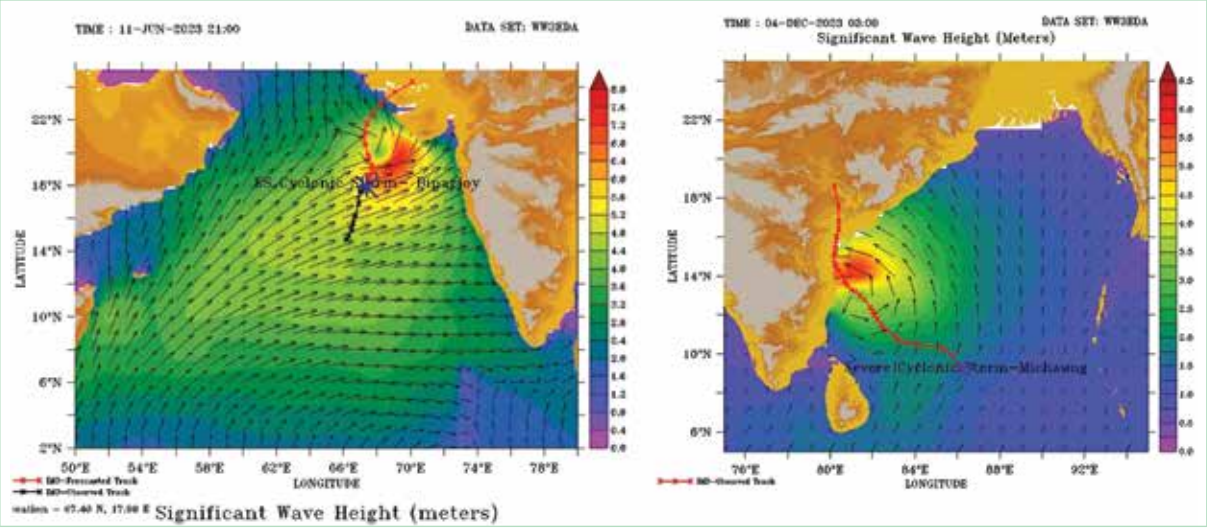


Figure 4.1.10. Spatial plots of significant waves height for Biparjoy and Michaung cyclones

INCOIS monitors the real-time conditions over the sea using a suite of instruments. The validation of Significant Wave Height at Wave Rider Buoys (WRB) and Moored Buoy during Biparjoy (Veraval and BD06) and Michaung (Krishnapatnam and BD11) cyclones is shown in Figure 4.1.11.

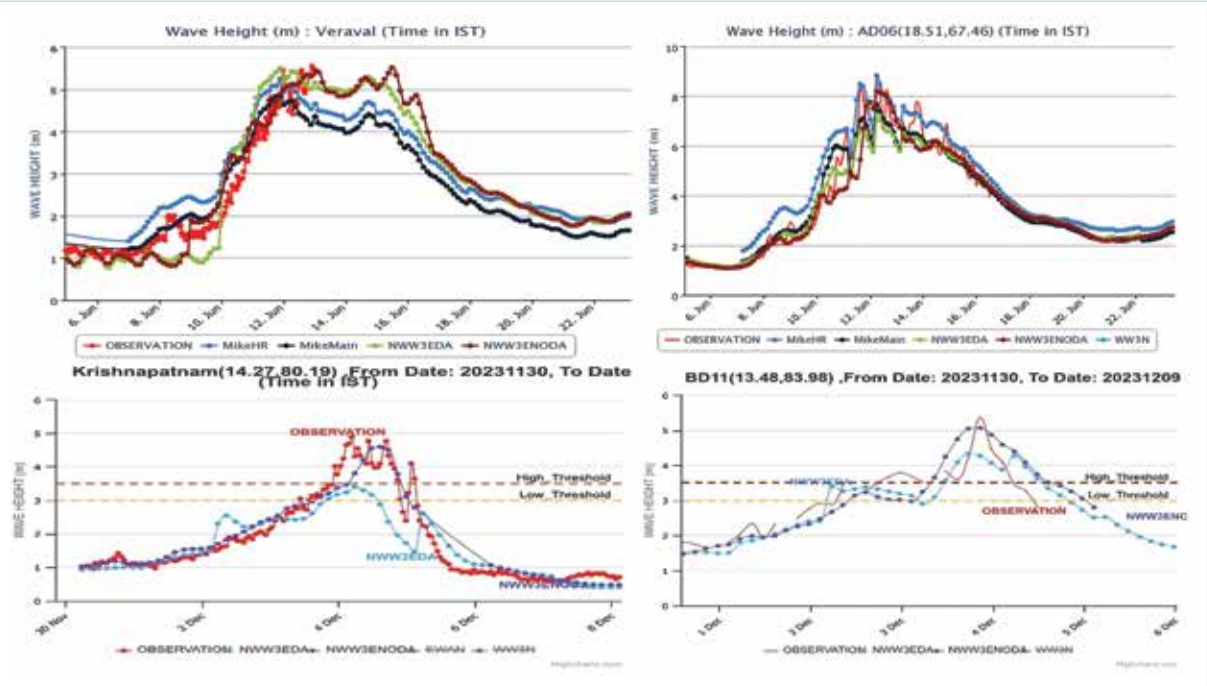


Figure 4.1.11. Validation of forecast wave with WRB and MB observations during cyclones

The number of INCOIS-IMD joint bulletins issued and States/UTs affected during cyclones, shown in figure 4.1.12. The states of West Bengal and Odisha were affected maximum, by 5 and 4 of these events, respectively.

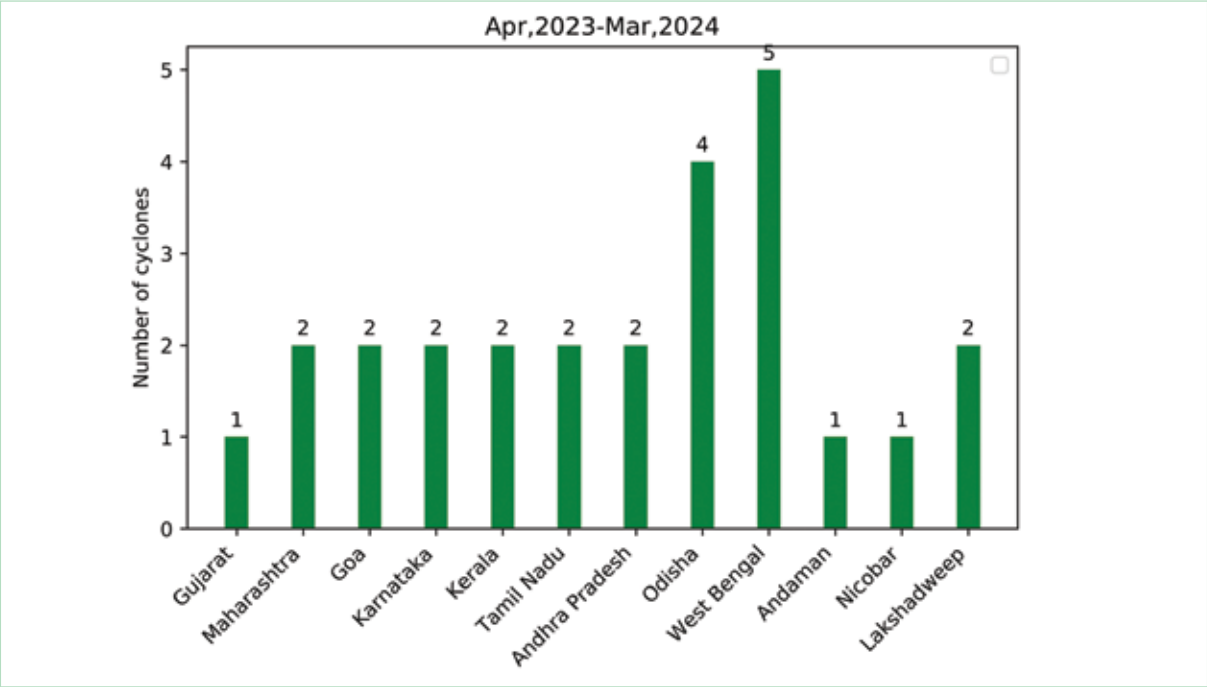


Figure 4.1.12. Number of States affected for Cyclones during 2023-24

Along with IMD, INCOIS was also closely monitoring the movement of all Cyclones and alerts/ warnings were issued well in advance to the user community for their information and action. INCOIS disseminated information through websites, e-mail, SMS, mobile app, Navic, social media, CAP-SACHET application, etc.

4.1.3.2 Oil-spill trajectory advisories

INCOIS provides oil spill advisories to coastal communities during oil spill incidents. During the reporting period, INCOIS provided Oil Spill Trajectory based on the requests. Online Oil Spill Advisory System (OOSA) is available (https://oosa.incois.gov.in) for users and utilized OOSA service by users.

4.1.3.3 Search and Rescue Aid Tool

During the reporting period, Search And Rescue Aid Tool (SARAT) advisories were provided for Maritime Rescue Coordination Centre Mumbai for Man Overboard from IFB Jai Vaishnavi Devi (14 May 2023), and various others based on the request. Users also utilized the SARAT services through online weblink https://sarat.incois.gov.in/sarat/home.jsp.

4.1.3.4 Small Vessel Advisory Service

INCOIS issued Small Vessel Advisory Services (SVAS) 365 days to fisherfolks and seafarers at sea. The SVAS warns potential zones where vessel overturning can occur ten days in advance, which helps fishermen avoid such unfortunate incidences. This warning system is based on the Boat Safety Index derived from wave model forecast outputs such as significant wave height, wave steepness, directional spread, and wind at sea. SVAS was categorized according to the beam width of the vessel up to 7 m. This limit covers the entire range of beam widths of the fishing vessels used in all nine coastal states and union territories of India.

4.1.3.5 Marine Heatwave Advisory Service

INCOIS issued Marine Heatwave Advisory Service (MAHAS) on a daily basis for 365 days. The Marine heatwave is a discrete, prolonged, anomalously warm water event. These advisory services provided through a web interface for the Indian Ocean rim countries can help understand the impact of Marine habitat and the frequency and intensity of disaster events in the region.

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 tsunamis, high waves, swell surges, strong ocean currents, and storm surges. The same information was integrated with the National Disaster Management Authority (NDMA) dissemination platform Common Alert Protocol (CAP) Sachet application for mass dissemination of advisories. INCOIS utilized CAP-SACHET platform for the first time for Biparjoy cyclone and alerts were issued through SMS about 5.62 cr. numbers.

4.2 Ecosystem-based Service

4.2.1 Marine Fisheries Advisory Service (MFAS)

4.2.1.1 Potential Fishing Zones (PFZ) and Tuna PFZ Advisories

Potential Fishing Zone (PFZ) advisory has become part of the value chain of the fishing community of India. INCOIS continued to provide advisories on 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 2023 to March 2024, multilingual PFZ advisories and Yellowfin Tuna advisories were provided for 346 and 104 days, respectively. PFZ and TUNA advisories issued figures are shown in 4.2.1 and 4.2.2, respectively.

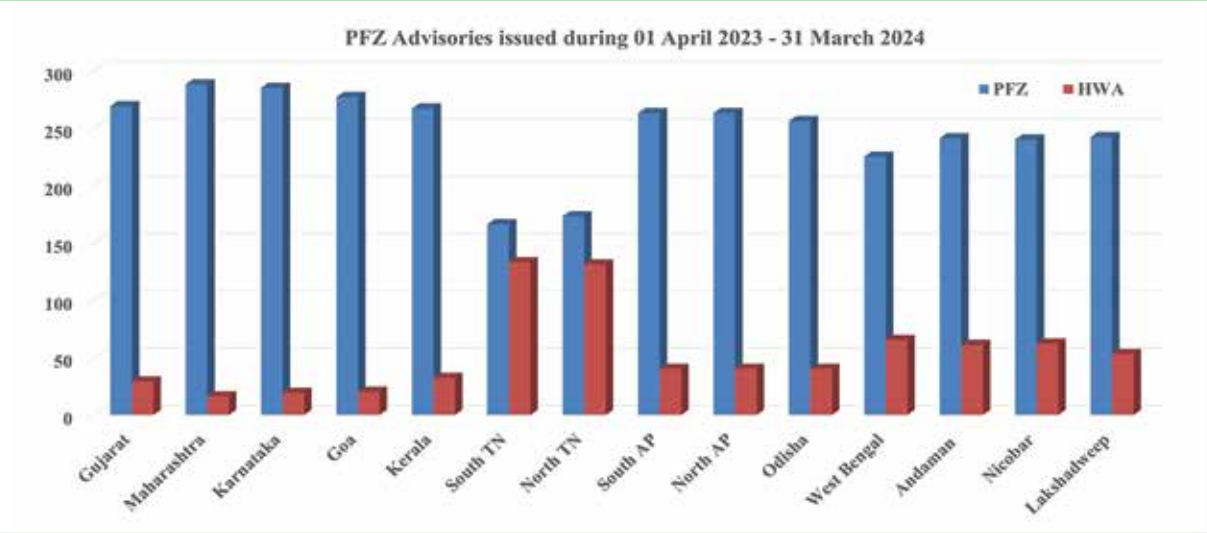


Figure 4.2.1. Number of PFZ advisories issued during 2023-24

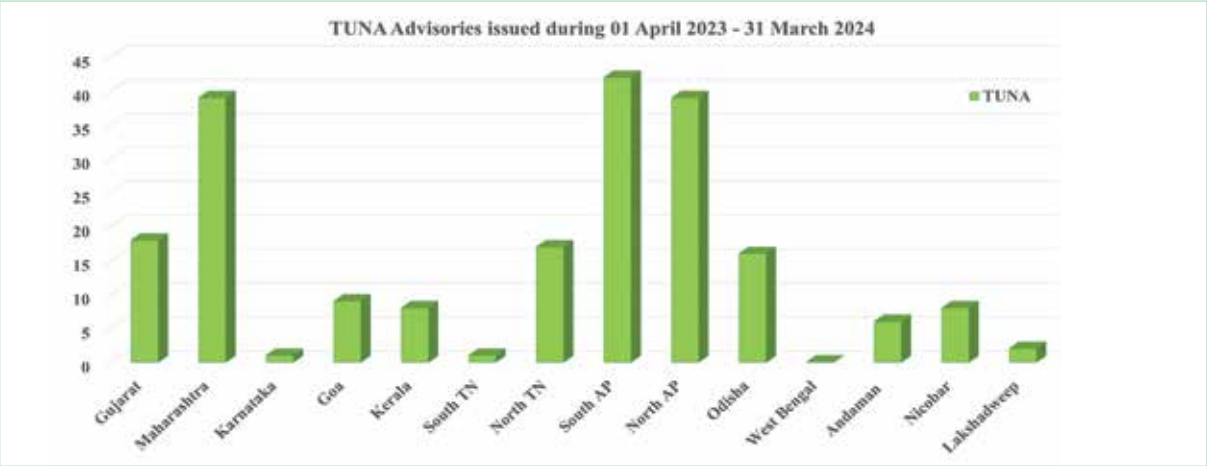


Figure 4.2.2. Number of Tuna PFZ advisories issued during 2023-24

Separate PFZ advisory generated to Goa and Karnataka coast for the INCOIS-funded project to validate PFZ advisory gradients (for nearshore region < 100km).

4.2.2 Coral Bleaching Alert System

Coral Bleaching Alert System (CBAS) provided 122 advisories on Coral Bleaching Alerts for Andaman, Nicobar, Lakshadweep, Gulf of Kutch, and Gulf of Mannar from April 2023 to March 2024. These advisories comprise HotSpots (HS) and Degree of Heating Weeks (DHWs) estimated using SST anomalies derived from satellite data on bi-weekly basis. During the period, 9 warnings and 23 watches were recorded, and most of them were for Lakshadweep. Coral bleaching advisories issued, and Hotspot values are shown in figures 4.2.3 and 4.2.4, respectively.

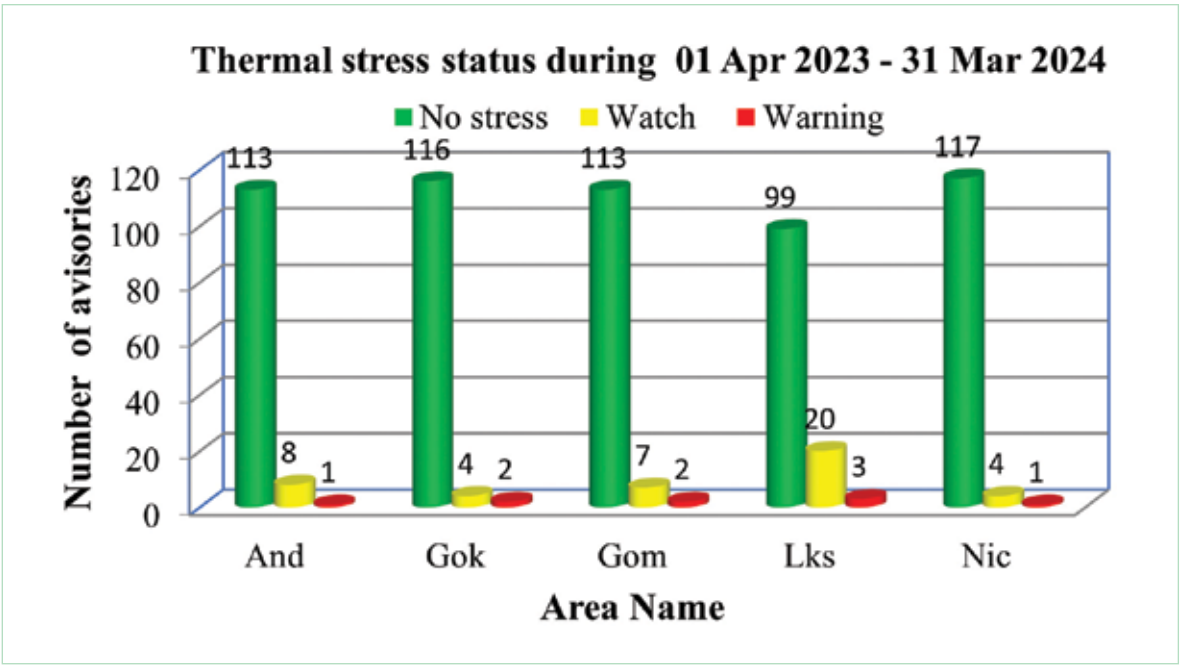


Figure 4.2.3. Total number of coral bleaching advisories generated and their alert status

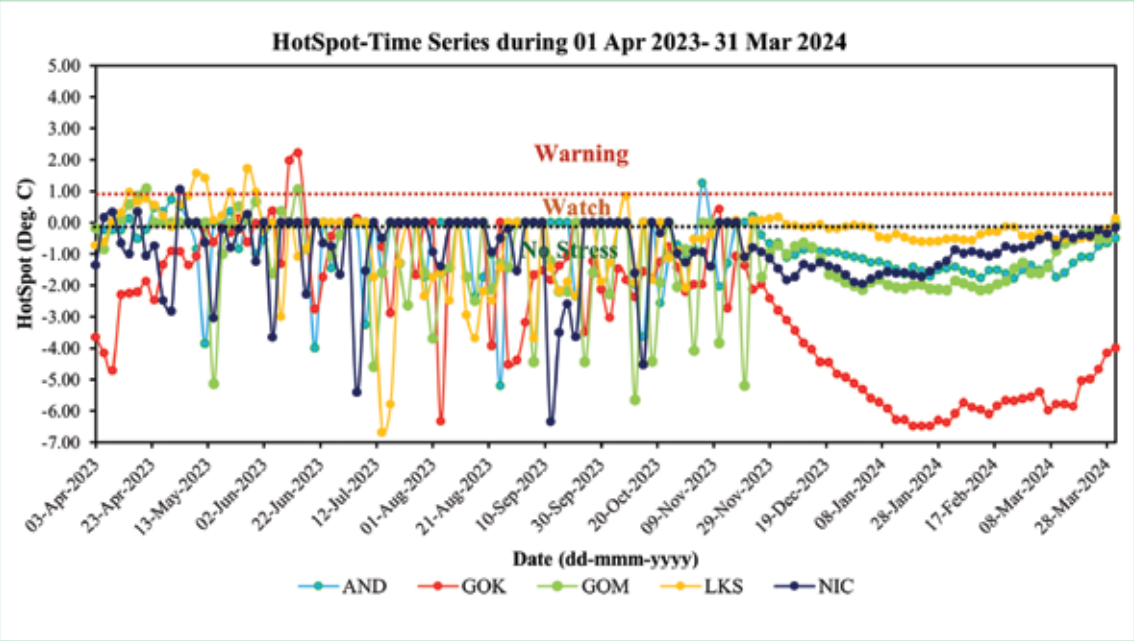


Figure 4.2.4. Line chart depicting variations of HotSpot (HS) values pertaining to Indian coral environs

4.2.3 Algal Bloom Information Service (ABIS)

Ocean colour satellite products are generated and disseminated in real-time 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 ha been disseminated daily. ABIS advisories are provided for four bloom hotspots i.e., North-eastern Arabian Sea, Kerala Coast, Gulf of Mannar and Coast of Gopalpur.

ABIS Product Generated	354 days
Alert issued	26 days

4.3 Data Service

Oceanographic data plays a key role in understanding the oceans around us. INCOIS is designated as the National Oceanographic Data Centre (NODC) by the International Oceanographic Data Exchange (IODE) Programme. INCOIS serves as a central repository and distribution hub for a wide variety of oceanographic datasets, catering to the needs of various stakeholders (Figure 4.3.1) through collaboration with the Ministry of Earth Sciences (MoES), other government organisations, Indian Ocean Rim Countries, and Universities. By sharing this data, INCOIS promotes sustainable ocean management, informed policy-making, and dynamic decision-making.

4.3.1 Management of In-Situ Oceanographic Data

Data management centre maintained and enhanced acquisition and processing of in-situ data from multiple platforms, including Argo floats, moored and drifting buoys, XBT/XCTD, coastal ADCPs, current meter moorings, wave rider buoys (WRB), tide gauges and automatic weather stations

(AWS). Data from newly deployed coastal water quality buoys off Visakhapatnam and Kochi were quality controlled and integrated into Water Quality Nowcast System to improve its utility.

Data processing chain was developed for twenty-nine newly deployed INCOIS wave drifters. To ensure data preservation and accessibility, a systematic archiving and inventory process was established for data collected from Equatorial ADCPs, RCMs, Coastal ADCPs, and XBT/XCTDs obtained from the National Institute of Oceanography (NIO), meteorological departments, and the Naval Operations Data Processing and Analysis Centre (NODPAC), Kochi (detailed in Table 4.5). Real-time location information of in situ ocean observation platforms are shared with PDNOM, NODPAC and other naval units for their operations.

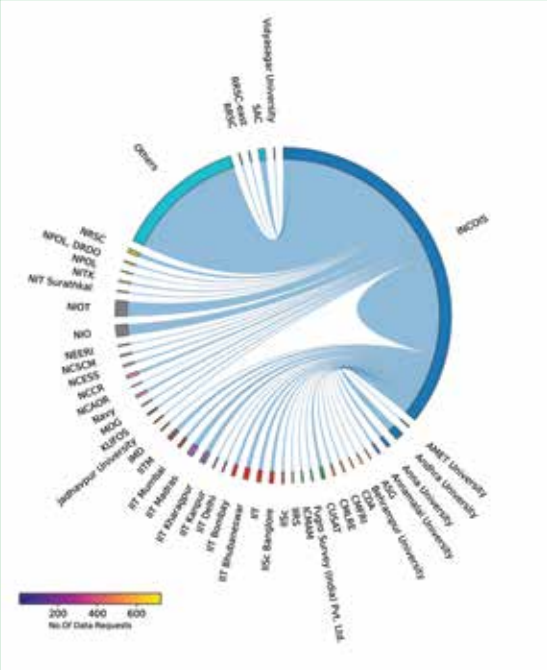


Figure 4.3.1 INCOIS Data Sharing Network

Table 4.5. Details of data acquired between April 2023 to March 2024

Institute / Programme	Parameters	No. of Platforms / Stations Reported	Status
INCOIS (Argo CTD)	Temperature and Salinity	29637 profiles	Added to the database
NIOT - NDBP (Moored buoys)	Met-ocean parameters	17 buoys	Added to the database
INCOIS (Drifting buoys)	Met-ocean parameters	51 buoys	Added to the database
INCOIS (Ship-mounted AWS)	Met parameters	20 stations	Added to the database
INCOIS (Coastal Water Quality Monitoring Buoy)	Phy-Bio-Geo-Chem	02 stations	Added to the database
INCOIS (Wave rider buoys)	Wave parameters	18 stations	Added to the database
INCOIS (Tide gauges)	Sea level	36 stations	Added to the database
NIO (Coastal ADCP)	Currents	18 stations	Added to the database

NIO (Equatorial Current Meter and ADCP)	Currents	03 stations	Added to the database
NIO (XBT / XCTD)	Temperature &Salinity profiles	134 profiles	Added to the database
INCOIS-NIOT (Tsunami Buoy)	Sea level	06 stations	Added to the database
NIOT (HF RADAR)	Currents	03 pairs of stations	Added to the database
NODPAC (Met Observations along Ship track)	Surface met parameters	3229 observations	Archived

4.3.2 Satellite Data Acquisition and Processing System

Data obtained from MetOp-B, MetOp-C, NOAA-18, NOAA-19, Suomi NPP, NOAA-20, and NOAA-21 satellites through the newly established X/L Direct Broadcast Processing System is being successfully used for in house operational services. Data acquired from Advanced Data Collection System (A-DCS) is being shared with Kinéis, France and real-time meteorological data is being transmitted to the Global DBNet for use in numerical weather prediction (NWP) models.

Software installation and testing for EOS-06 OCM-3 ground station was successfully completed. Efforts are underway for enhancing, validating and checking the quality of Level-2 products in collaboration with ISRO.

4.3.3 Oceanographic Data Processing, Analysis, and Applications

Significant improvements have been made in enhancing the processing, analysis, and application of oceanographic data. An AI/ML-based alternative to Delayed Mode Quality Control (DMQC) procedure was developed and evaluated to address salinity degradation issues. A machine learning model capable of estimating Dissolved Oxygen (DO) using temperature and salinity data was developed and its performance was compared to that obtained from SAGE_QC tool. Similarly, Sea Surface Temperature (SST) quality control system was constructed, featuring a user-friendly graphical user interface (GUI) based on data obtained from World Ocean Data (WOD). To provide continuous and reliable Chlorophyll-a data for Potential Fishing Zone (PFZ) operations, DINEOF and DINCAE algorithms have been operationalised for effective gap-filling.

A Data analytics as a Service (DaaS) dashboard (Figure 4.3.2) was established to empower decision-makers with comprehensive insights from diversified ocean datasets. This platform aims to support sustainable ocean management and informed policy development. An alternative method for Sonic Layer Depth (SLD) estimation using Artificial Neural Networks (ANN) based on Argo float temperature profiles in Bay of Bengal data was developed, which showed improved accuracy in estimating SLD which is used in naval operations and safe submarine operations.

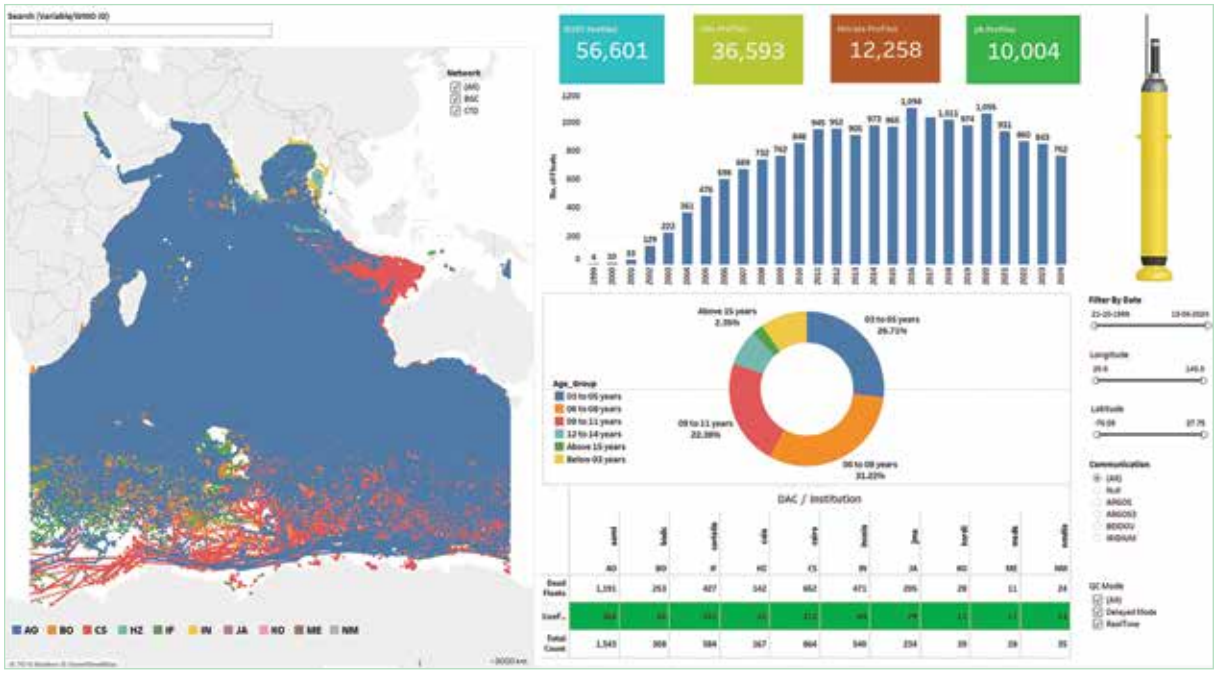


Figure 4.3.2. Data analytics as a Service (DaaS) dashboard

4.3.4 Quality Control and Analysis of Moored Buoy Subsurface Data

Improved quality control checks (inversion and gradient test) have been applied to the subsurface data from OMNI buoys. A climatology-based standard deviation trimming approach was employed for depth remapped data, resulting in increase of quality data return (Figure 4.3.3) from the buoys. An Evaporation Duct Height (EDH) climatology was developed (Figure 4.3.4) using marine-met observations. Along with this, correlations with key atmospheric boundary layer parameters such as air-sea temperature difference (positive correlation), air-sea specific humidity difference (positive correlation), sea level pressure (negative correlation), atmospheric humidity (positive correlation), and momentum transfer coefficient (negative correlation) was carried out.

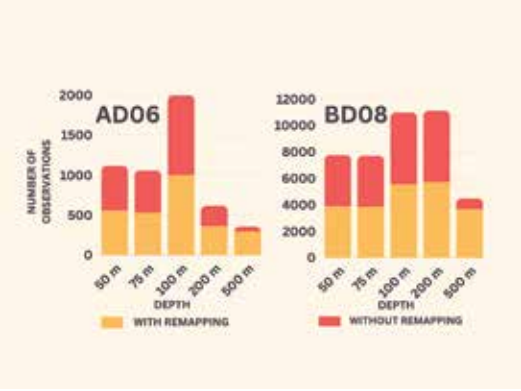


Figure 4.3.3. Increased no. of quality observations after depth remapping

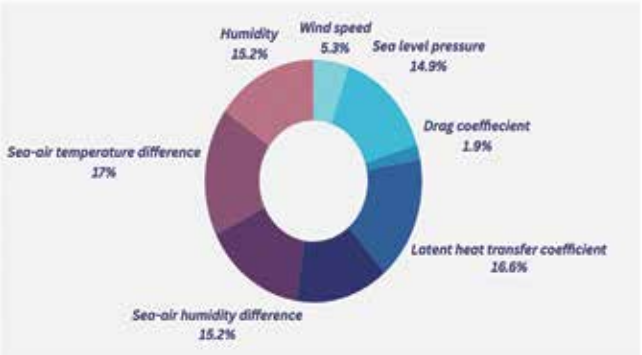


Figure 4.3.4. Percentage contribution of different MABL parameters to EDH

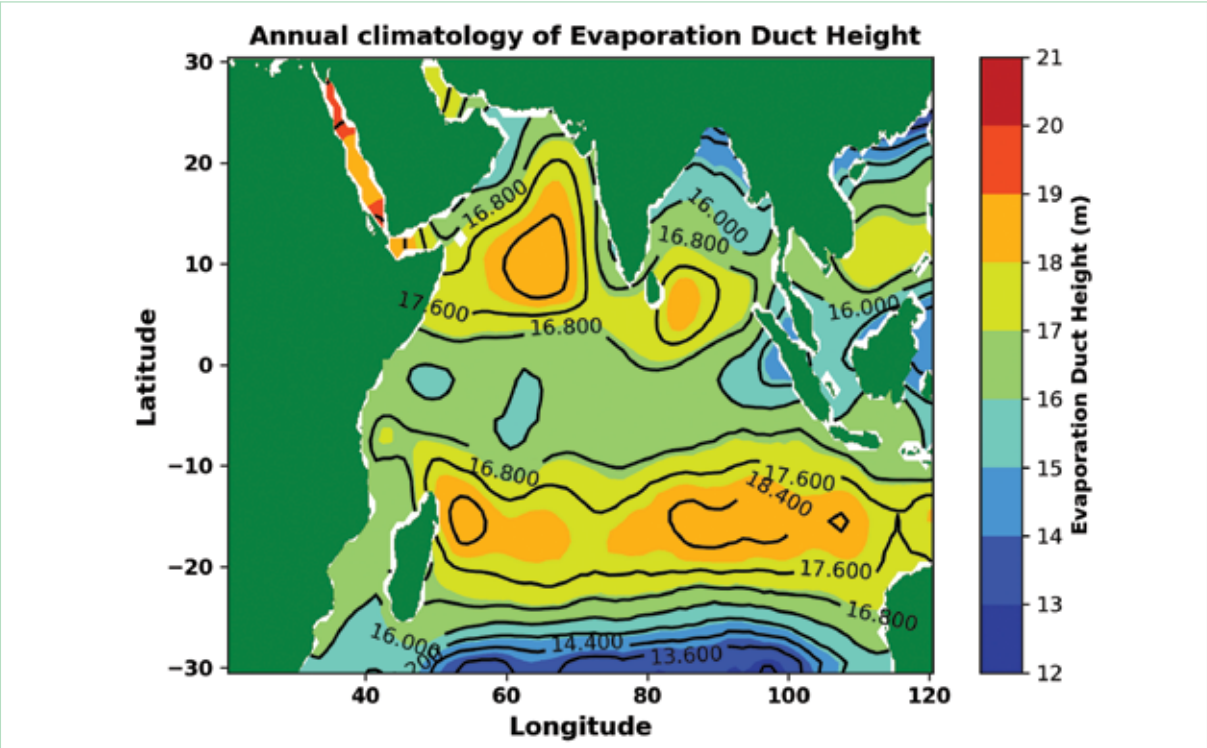


Figure 4.3.5. Annual climatology of EDH from marine-met data

4.3.5 Quality Control of Tide Gauge and Wave Rider Buoy Data

Systematic quality control (QC) procedure was applied to tide gauge data collected from five Indian stations between 2010 and 2023 (Figure 4.3.6). This process involved identifying and flagging outliers,

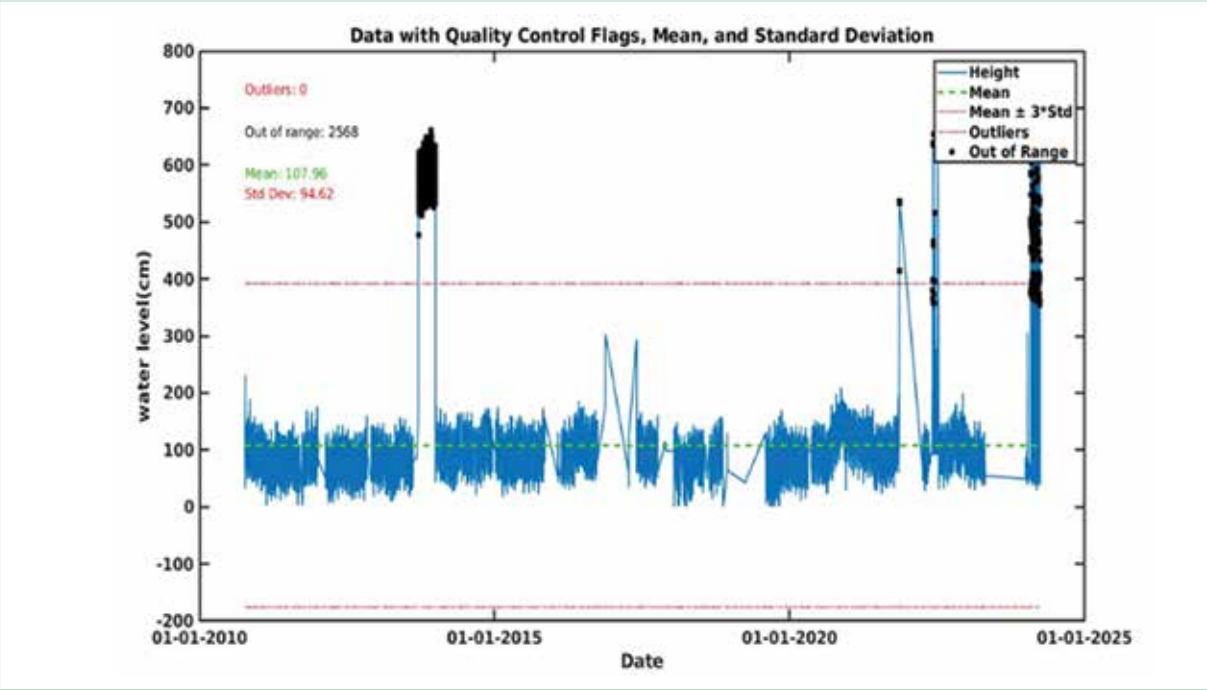


Figure 4.3.6. Tide Gauge data for Chennai showing Quality Control flags for the period 2010-2023

spikes, and data anomalies that deviated from expected ranges. These automated tests, assign QC flags, with '1' indicating data of good quality and other specific flags denoting specific issues. Visual plots were employed to aid in identification of flagged data points and generate summary statistics quantifying the percentage of flagged data which ensured the reliability for subsequent analysis. Similar QC procedures were developed and implemented for Wave Rider Buoy data.

4.3.6 Data Infrastructure and Applications

As per the new data storage policy, a data transfer application was developed to facilitate the seamless movement of data from centralized storage to operational systems. For ensuring uninterrupted data delivery and high reliability, Spring Boot, React JS, and Apache NiFi was used in data pipeline management.

To optimize code utilization a centralised GitLab was established for code management, along with an automated monitoring system that tracks server uptime and sends alerts. Automated data transfer between INCOIS and IMD for facilitating real-time DBNet data exchange was successfully implemented.

4.3.7 Collaboration with the Indian Navy for Enhanced Maritime Domain Awareness

A collaborative initiative between INCOIS and the Indian Navy which aims to enhance maritime domain awareness through the operational monitoring of ship movements in the North Indian Ocean was established. This collaboration utilised Visible Infrared Imaging Radiometer Suite (VIIRS-DNB) data to detect, characterise, and track ship locations, identify vessel movements.

4.4 Information & Communication Technology (ICT) Infrastructure

The ICT Division's mission is to deliver information and communication technology services that enable the operations, R&D, and activities 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 Facility

ICT provides mission-essential enterprise-wide computing services such as web hosting, administrative computing, networking, security monitoring, High-Performance Computing systems and supercomputing support for INCOIS research and forecasting missions. INCOIS data centres hold the capacity for more than 150+ high-end servers and 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. The ICT division initiated various tenders for upgrading enterprise storage, Computing Infrastructure of Operational Ocean Services, and technology refreshment of the existing INCOIS Web Environment.

4.4.2 Application Software Development

4.4.2.1 Launch of INCOIS Mobile Application "SAMUDRA"

On 27 July 2023, the 17th Foundation Day of the Ministry of Earth Sciences (MoES), Shri Kiren Rijiju, Hon'ble Union Minister of Earth Sciences, launched the INCOIS mobile application "SAMUDRA" (Smart Access to Marine Users for ocean Data Resources and Advisories). This innovative app is a one-stop solution for accessing all ocean-related services provided by the Indian National Centre for Ocean Information Services (INCOIS).

To enhance the dissemination and utilization of its services, INCOIS developed the SAMUDRA app to provide users with easy access to critical ocean data (Figure 4.4.1).

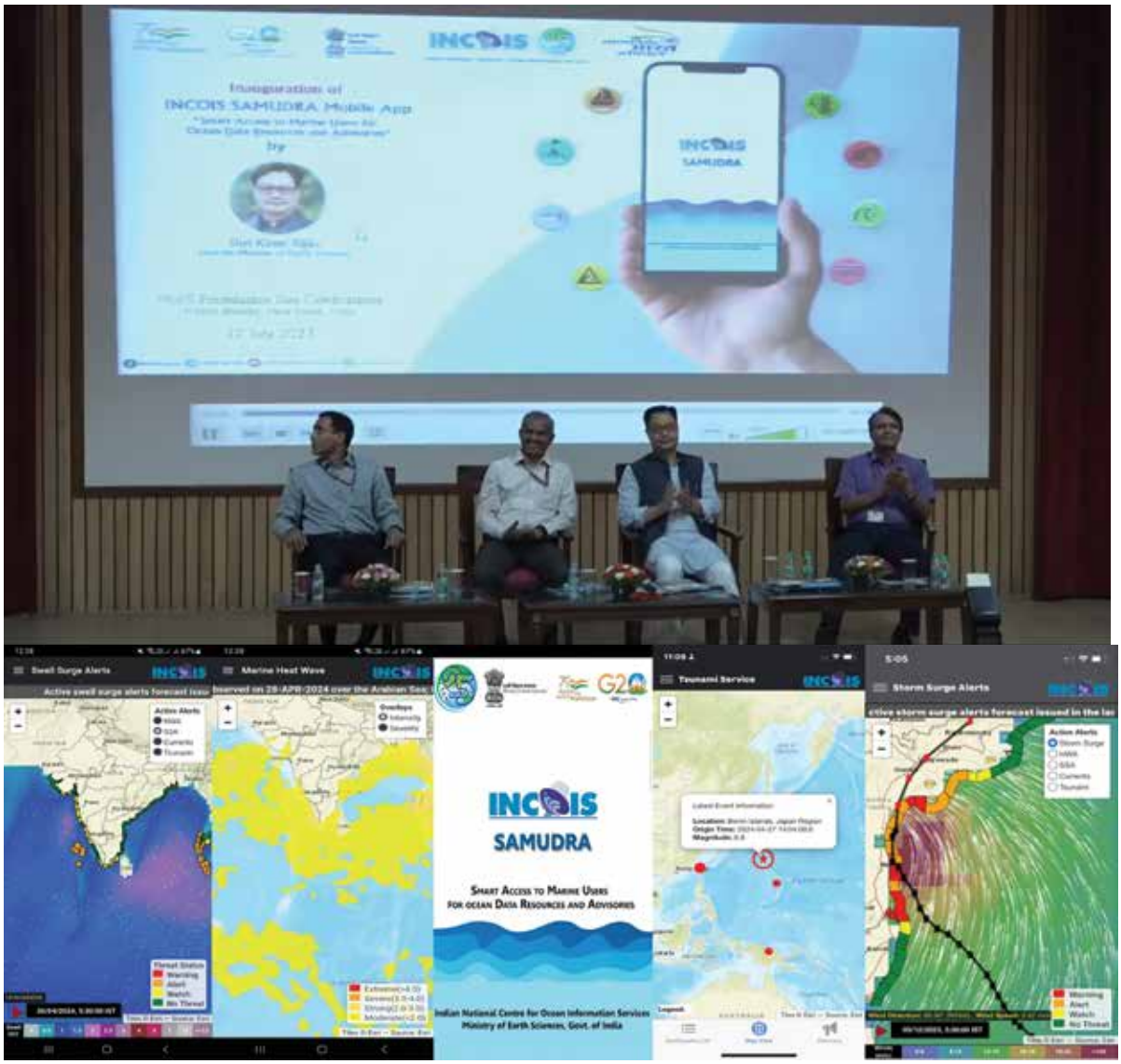


Figure 4.4.1. Shri Kiren Rijiju, Hon'ble Union Minister of Earth Sciences, launching the SAMUDRA mobile App (top) and SAMUDRA app glimpse (down)

Leveraging state-of-the-art technologies, the app delivers a seamless user experience across Android, iOS, and Progressive Web Applications (PWA). It empowers users with real-time updates and critical alerts on oceanic disasters such as tsunamis, storm surges, high waves, and swell surges, ensuring timely precautions to protect lives and property.

The SAMUDRA app also offers invaluable services to the fishing community by providing Potential Fishing Zone (PFZ) advisories that guide fishermen to probable fish aggregation locations, thereby maximizing catch rates and improving livelihoods. Additionally, the app features five-day advanced Ocean State Forecasts, enabling mariners, fishermen, and coastal communities to plan their activities in advance, mitigating risks and optimizing operations based on predicted ocean conditions. Interactive maps, charts, and animations within the app enhance the comprehension of complex oceanic phenomena, making SAMUDRA an essential tool for all marine users.

4.4.2.2 INCOIS Website

INCOIS website (https://www.incois.gov.in/) is the primary medium through which ocean information on products/services is disseminated. This responsive website enables the web-based online delivery system to facilitate users across multiple languages. It has WebGIS capabilities to deliver ocean information and advisory services on different spatial and temporal resolutions. INCOIS Website and Its Statistics are shown in figure 4.4.2.

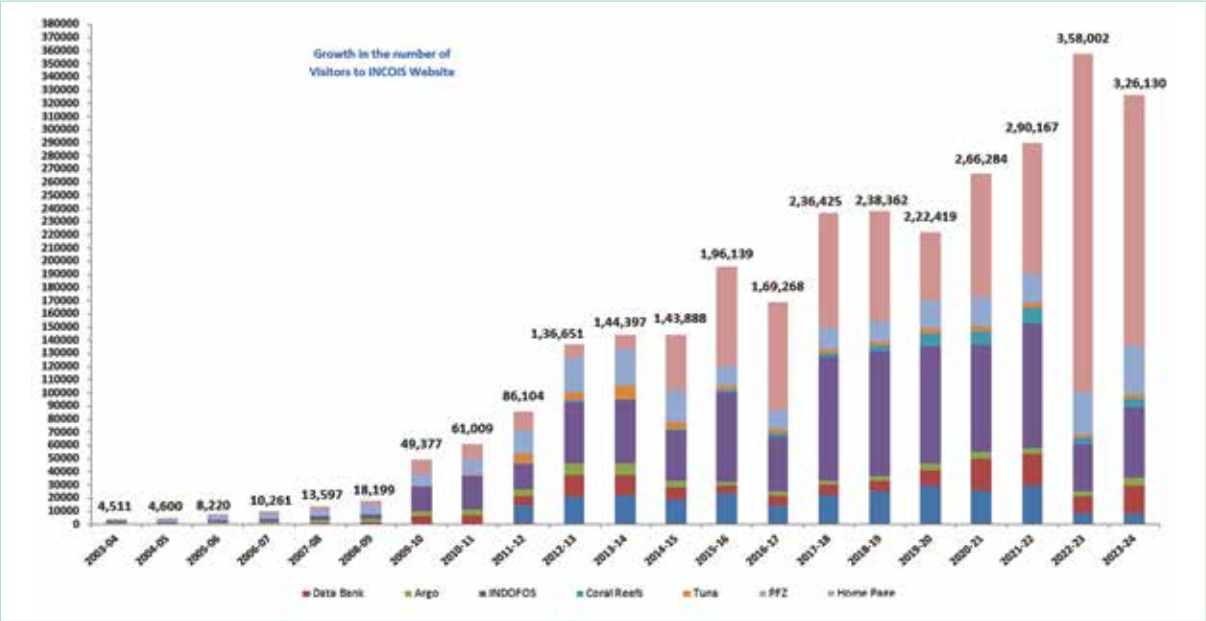


Figure 4.4.2. INCOIS Website applications and Statistics

4.4.2.3 Android App for Fishermen Feedback

INCOIS designed a FISH 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). INCOIS has received several fish catch photos from fishermen through FISH mobile app, a few photos are shown in Figure 4.4.3. Geolocated photos from FISH app were validated with advisories.

Figure 4.4.3. Fish catch photos at Kerala (off MunakkaKadavu and Maruthadi)

4.4.2.4 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 26 Indian Ocean rim countries (Figure 4.4.4). The Tsunami website is the primary platform for disseminating this information (https://tsunami.incois.gov.in).

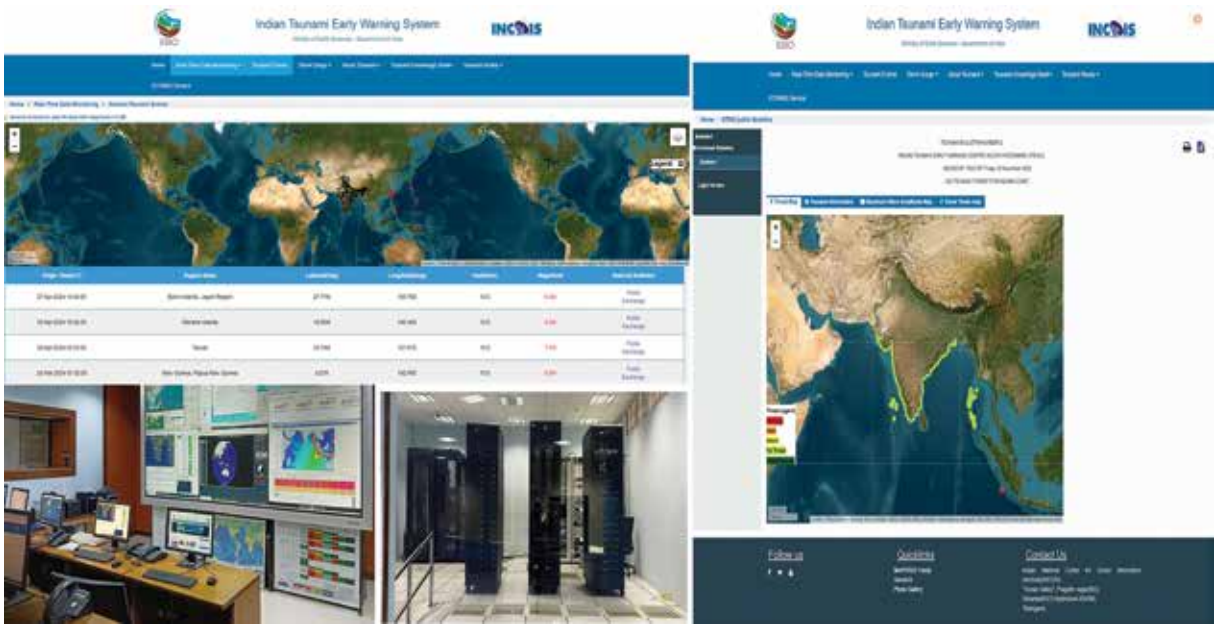


Figure 4.4.4. Tsunami Website showing no threat information for the event of M6.8 at Southern Sumatra, Indonesia

During the reporting period, the tsunami application software 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 contributing 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.

4.4.2.5 Dedicated website development for various national and international collaborative initiatives and Conferences

INCOIS ICT team developed dedicated website portals for various international collaborative initiatives and Conferences as listed below

- Regional Specialized Meteorological Centre (RSMC) for Numerical Ocean Wave Prediction and Global Numerical Ocean Prediction
- Ocean Services Portal for countries of Colombo Security Conclave (CSC) by incorporating Ocean State Forecast Products and advanced WebGIS functionalities.

- Decade Collaborative Centre Indian Ocean Region (DCC-IOR) to showcase all activities related to the UN Ocean Decade under the DCC-IOR.
- Eighth National Conference of Ocean Society of India OSICON-23 Conference.
- Indian Ocean Regional Decade Conference (IOCON-24).

4.4.2.6 Online Oil Spill Advisory System (OOSA)

INCOIS has upgraded the Online Oil Spill Advisory System (OOSA) to Version 5.0 and hosted at https://oosa.incois.gov.in (Figure 4.4.5). This revamped system harnesses the power of Geographic Information System (GIS) tools for enhanced mapping and integrates GNOME software for predictive oil spill modeling.

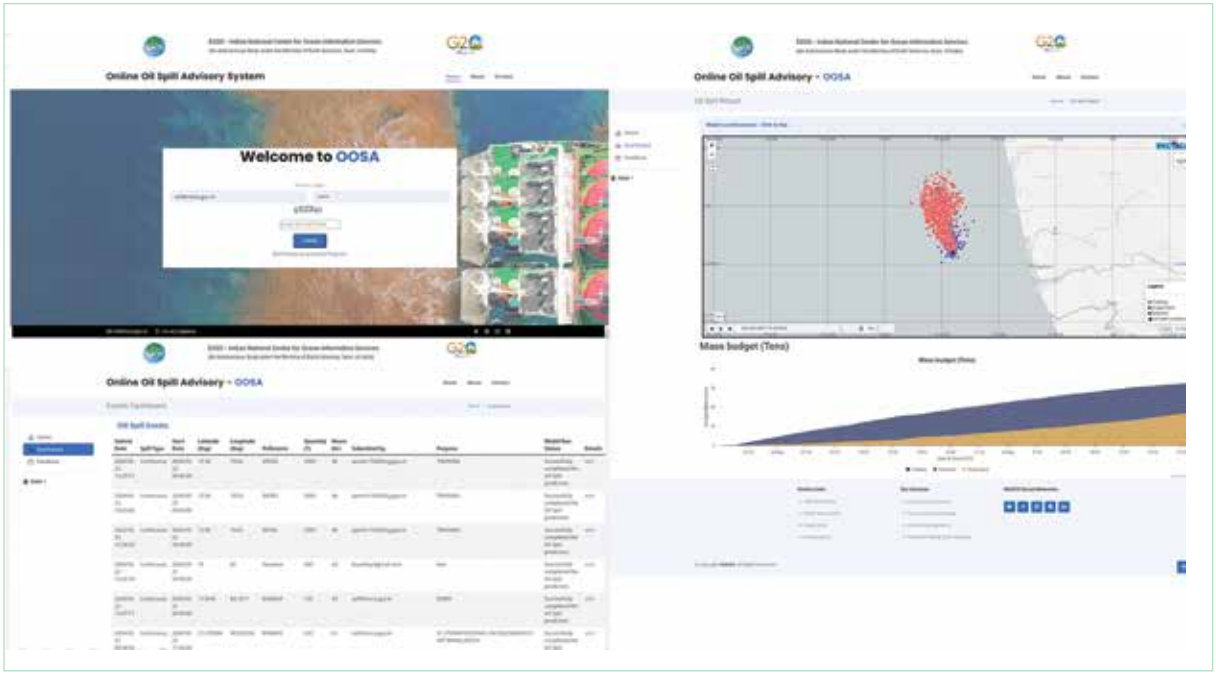


Figure 4.4.5. Online Oil Spill Advisory System web interface

Key Features:

Robust Backend: Powered by Python for real-time, accurate advisories;

Historical Data Visualization: Tracks and analyzes past oil spill patterns using the Time Dimension plugin with Leaflet;

Responsive Design: Ensures seamless access across all devices;

Velocity Layer on Leaflet: Provides vital insights into oil spill dynamics.

This upgrade demonstrates INCOIS's ongoing commitment to marine safety and environmental protection.

4.4.2.7 Online Recruitment Portal for MoES Institutions

INCOIS continues to host recruitment portals for various posts/vacancies of INCOIS, MoES, NCPOR, NCMRWF, NCESS, IMD, and NIOT (Figure 4.4.6).

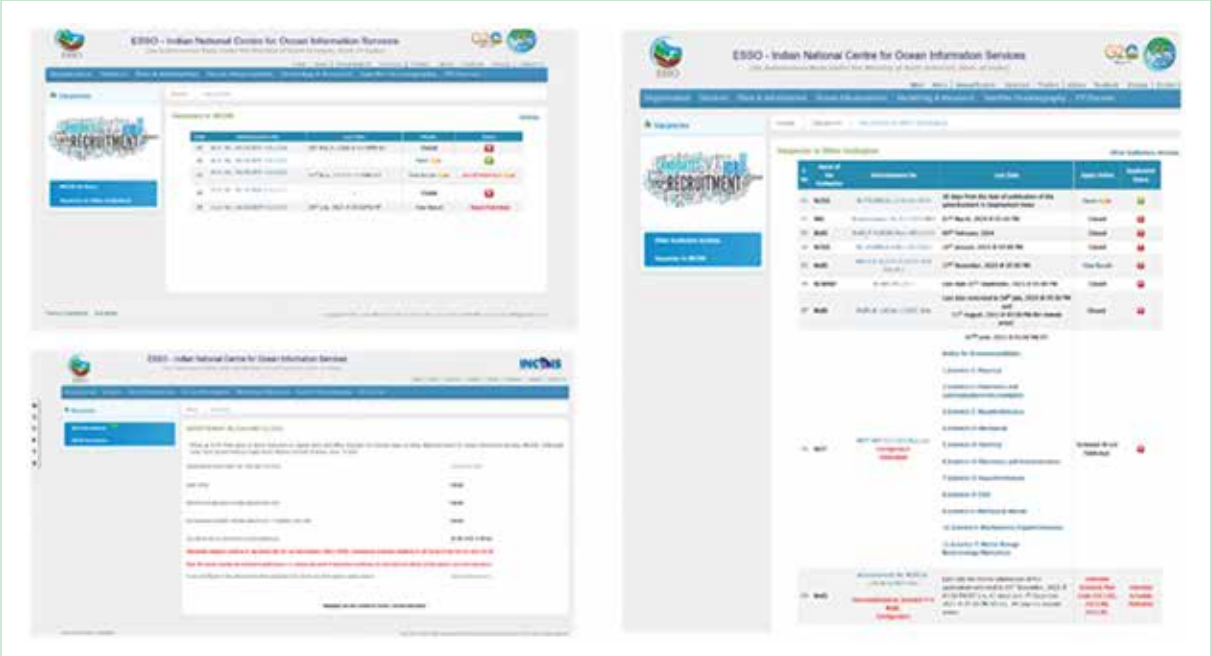


Figure 4.4.6. Recruitment Portal view

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

- On behalf of the WG-3, Project Office, India, through the ICT Division at INCOIS, Hyderabad has been responsible for the development, hosting and maintaining the IIOE-2 Website. The web page related to IIOE-2 and statistics are shown in Figure 4.4.7.
- Facilitates a user-friendly environment for the clear presentation of the diverse activities under IIOE-2 and their progress.
- 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.
- Refinements to Online Interface for IIOE-2 Endorsed Projects.
- New Website for Early Career Scientist Network (ECSN).
- Endorsed 54 scientific projects that align with the IIOE-2 objectives. (https://iioe-2.incois.gov.in/IIOE-2/Endorsed_Projects.jsp).

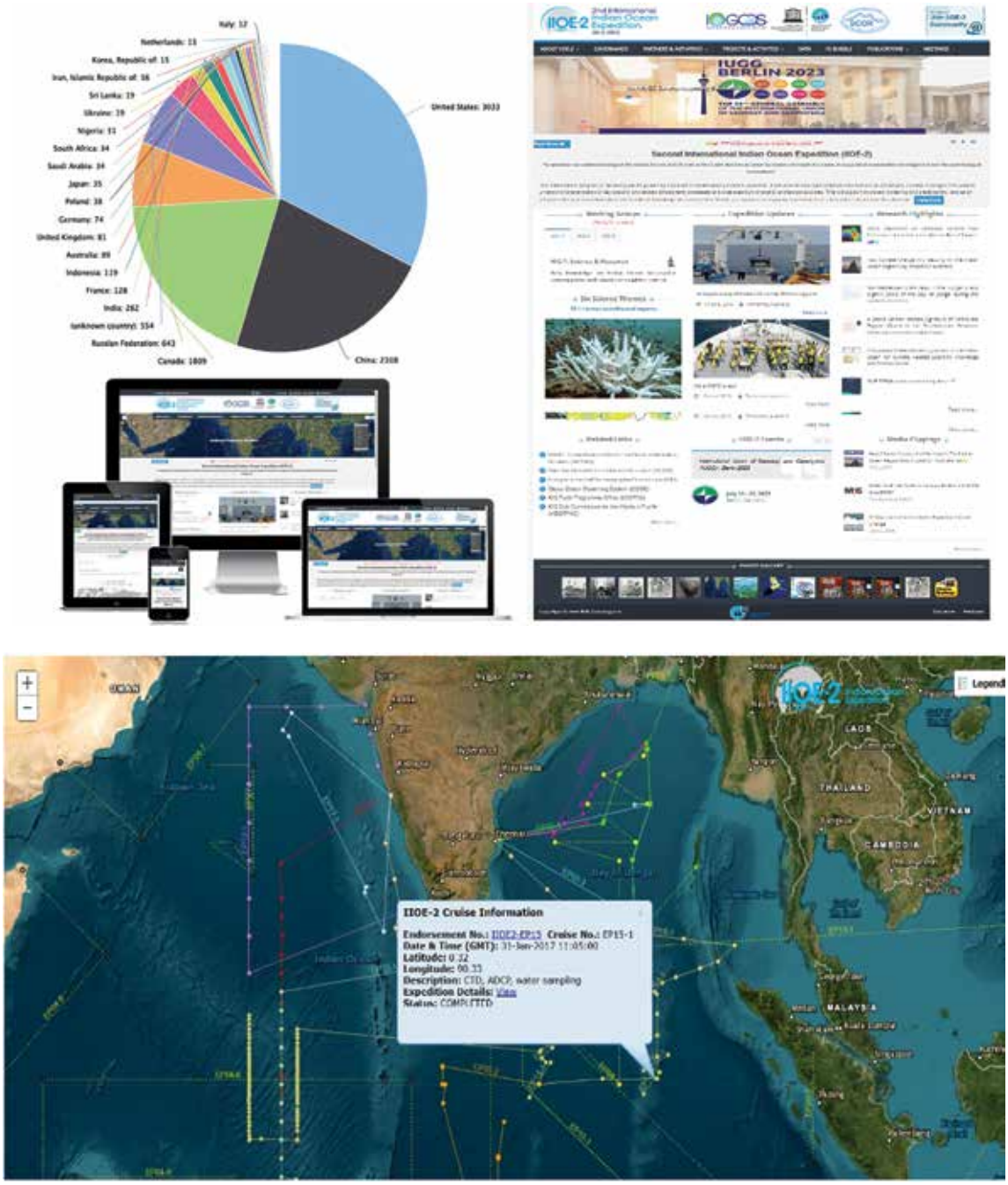


Figure 4.4.7. IIOE2 related webpages and statistics

4.4.2.9 Other developments / Enhancements

- **SARAT (Search And Rescue Aid Tool) Version 2.0:** Enhanced search region accuracy, new trajectory overlays, and improved PDF generation.
- **SARAT-I (SARAT-Integrated) Updates:** Deployed on a production server, fixed format issues, and added new overlays and PDF enhancements.
- **SSFS Improvements:** Fixed wind forcing input, updated grid, and set up automated daily analysis script.

- Technical reports published for SARAT and SARAT-I changes - ESSO-INCOIS-OMARS-TR-02(2024)
- PFZ Dissemination: INCOIS issued 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. During the field level user interaction workshops, INCOIS collected users' mobile numbers, and the same were added to PFZ dissemination list to enhance the user database.

4.4.3 Communication, NOC and AV Facilities

4.4.3.1 Establishment of SynOPS (Synergistic ocean Observation Prediction Services) NOC Facility at INCOIS

The SynOPS **(Synergistic ocean Observation Prediction Services)** facility at INCOIS represents a major achievement in the realm of integrated ocean services. Officially dedicated to the nation by Shri Kiren Rijiju, Hon'ble Union Minister of Earth Sciences, on 14 February 2024, this state-of-the-art center was developed in an impressive 70 days. Transforming a 10,000 sq. ft. shell area into a fully customized operational facility, SynOPS stands as a testament to rapid and effective project execution (Figure 4.4.8).

The facility is equipped with the Science on Sphere (SoS) system, which allows for advanced visualization of INCOIS ocean data. This innovative feature enhances the ability to present complex oceanographic information in a more intuitive and engaging manner.

Figure 4.4.8. Shri Kiren Rijiju, Hon'ble Union Minister of Earth Sciences inaugurating the SynOPS at INCOIS

In addition to the SoS, the SynOPS facility boasts two video conference rooms designed to facilitate seamless communication for INCOIS scientists and officials, supporting online and offline meetings.

This ensures that the team can collaborate efficiently, whether within the organization or with external partners.

Furthermore, the existing INCOIS auditorium has been upgraded with Active LED technology, and the Director's conference room now features enhanced audio-visual facilities. These improvements not only elevate the facilitiy's technical capabilities of but also enhance the overall experience for users and visitors.

SynOPS is a significant milestone for INCOIS, underscoring its commitment to advancing monitoring capacities of INCOIS for marine science and providing integrated ocean services for the nation.

4.4.3.2 Establishment of 2.4m X/L band antenna

INCOIS successfully established a 2.4m X/L band antenna to receive data from the NOAA and METOP series of satellites and ARGOS payload data from Oceansat-3, SARAL, HOPS, and ANGELS (Figure 4.4.9). The X-L band data acquisition and processing facility was inaugurated on 03 February 2024, by Dr. V. K. Saraswath, a member of NITI Aayog.

The facility successfully tracked and acquired satellite passes from the NOAA series (NOAA-18, NOAA-19, NOAA-20, NOAA-21) and the METOP series (METOP-B and METOP-C). The data collected from the ground station is utilized by the PFZ team for INCOIS operational services. Additionally, ARGOS data from Oceansat-3, ANGELS, and the HOPS series of satellites is shared with KINEIS as part of the INCOIS Memorandum of Understanding (MoU).

Figure 4.4.9 2.4 m X/L band antenna & Seattleite tracking and processing system

4.4.3.3 INSAT MMS & 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 Raider Buoy Network, Drifters, and other observational platforms deployed by INCOIS and MoES institutions.

The diligent maintenance of the INSAT MSS & DRT Hub Stations (Figure 4.4.10) 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 endeavors.

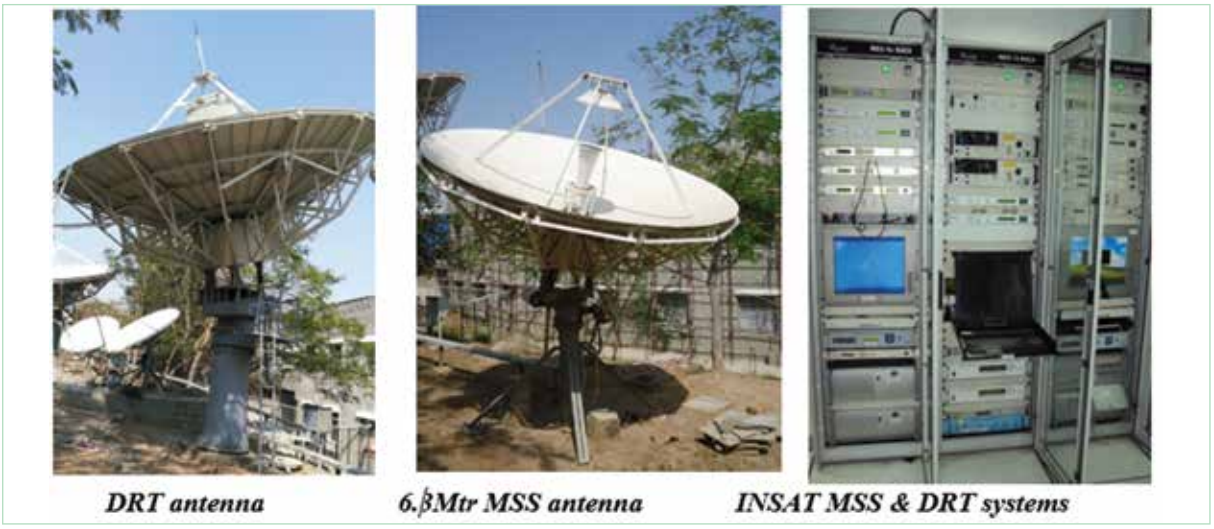


Figure 4.4.10 INSAT DRT & MMS antenna and receiving system

4.4.3.4 Other Significant Works

- Upgradation **of Oceansat Ground Station:** Installed new ACSS software by NRSC, based on inputs from the INCOIS team. Successfully tracked and acquired satellite passes of Oceansat-3, R2A, and RS2 using the new ITS procured by INCOIS. Daily tracking of Oceansat-3 satellites provides data to INCOIS operational services (PFZ).

4.5 Consultancy Services

Operational Oceanographic and meteorological related consultancy projects were continued for M/s. Afcons House and M/S McDERMOTT and carried out for the clients as detailed below. Project on Ocean state in terms of wave and currents for M/S Adani Vizhinjam port Pvt Ltd is being executed. As part of the consultancy MOU signed with DG Hydrocarbon, we conducted a 2-day training for DG-HC, OISD (Oil Industry Safety Directorate) and other related officials from the Oil & Natural gas offshore E&P companies. We conducted a weeklong consultancy training for NPCIL,aiming to scope a proposal to conduct Tsunami and Storm Surge studies for Tarapur site of NPCIL. There are other project proposals and plans under discussion to be carried out.

Table 4.6: Details of the consultancy projects/ECF during reporting period

Sl. No.	Industry/firm	Project type	Amount earned *-last 1 year (Rs)*	Remarks
1	M/S ADANI-VIZHINJAM Port	Project on wave and current off Vizhinjam using observational deployment and studies	46 Lakhs	Successfully executing the project for last 10 months.

2	M/S Mc DERMOTT (for KG-Basin)	Project on forecast and climatological trend analysis for KG basin development and operations	~ 1.3 Lakhs	2 Months operational consultancy issued.
3	DG Hydro Carbon	Consultancy in the form of a training and clarifications	1.33 Lakhs	One-time two-day training and consultancy
4	Nuclear Power Corporation of India Limited (NPCIL)	Consultancy in the form of a 5-day training and clarifications	4.5 Lakhs	One time 5-day training and clarifications
5	M/S Mc DERMOTT (for KG-Basin)	Project on forecast of Wave height, period and winds for marine operations	~2 Lakhs	Daily operational forecasts are being issued April 24 onwards
6	M/S AFCONS	Project on "hindcast analysis of wave, swell, and winds during the period 15 Dec 23 to 29 Jan 2024	~2.5 Lakhs	One time delivery
There were minor projects also done for M/S Kandla port, M/S Proclaim Insurance Surveyors -Chennai, M/S Structural Specialities & Projects (India) Pvt. Ltd. *Discussions and liaisoning with clients such as NPCIL, NODPAC-Indian Navy, M/S CDRI/PWC, DG Shipping, SCI, DG Hydrocarbon, M/S Vishwa Samudra-Hyderabad etc are underway, and waiting for the projects to be awarded, and executed by INCOIS.*				

Table 4.7: List of consultancy projects carried out by INCOIS in collaboration with the National Centre for Coastal Research (NCCR), Chennai

Sl. No.	Project Title	Client	Cost (Tax Included)
1	Blue Carbon Inventory for Mangroves along Tamil Nadu Coast	Tamil Nadu Forest Department Government of Tamil Nadu	23,60,000.00
2	Feasibility of mangrove afforestation and impact of proposed modernization of Chennai fishing harbour on the movement of turtles and other aquatic species	Chennai Fishing Harbour	7,50,480.00

3	Rehabilitation of coastal habitat for climate change adaptation through eco-friendly solutions	Department of Environmental and Climate Change, Government of Tamil Nadu	45,31,200.00
4	Shoreline Changes and Dredge Disposal Studies for Proposed Construction of Pen Monument off the Coast of Marina Beach, Chennai, Tamil Nadu	Public Works Department, Government of Tamil Nadu	28,32,000.00
5	Assessment of Shoreline Changes and Morphology for the Proposed Vadhavan Port, Maharashtra	Jawaharlal Nehru Port Authority, Government of India	19,82,400.00
6	Shoreline Management Plan for Tamil Nadu Coast	Department of Environmental and Climate Change, Government of Tamil Nadu	42,48,000.00
7	Study the Impact of Dredging and Dumping on the Flow Characteristics and Marine Ecology and Draw up a Management Plan	Ministry of Ports, Shipping and Waterways, Chennai Port Trust	50,00,000.00
8	Assessment of Shoreline Change for the Proposed Outer Harbour Development for V.O.C. Port, Tamil Nadu	VOC Port Authority	46,72,800.00
9	Assessment of Shoreline Changes for the Proposed Machilipatnam Port	Andhra Pradesh Maritime Board	84,96,000.00

Efforts were put in for the Expansion of consultancy projects during the following major events

- **Global Maritime Indian Summit 2023 (GMIS),** 17-19 Oct 2023, Mumbai.
- **Human Assisted Disaster Response exercise (HADR),** Indian Navy, 9-11 October 2023, Goa.
- **World Ocean Science Congress (WOSC)-2024,** 27-29 February 2024, Chennai – A paper with every detail and updations of the commercial ocean service products for various categories of users gathered during the Ocean Service session.
- **OSICON-2023,** Hyderabad, 23-25 August 2023. A paper with every detail and updations of the commercial ocean service products for various categories of users gathered during the Operational Ocean Services session.
- **Workshop on offshore exploration synergies and opportunities** (OESO), 15-16 February 2024, Mangalore, Karnataka.

5

RESEARCH HIGHLIGHTS

5.1 Applied Research

5.1.1 Socioeconomic Vulnerability Assessment along the Andhra Pradesh Coast

Climate change is a global phenomenon that has enhanced sea-level rise and aggravated the prevailing coastal hazards that make coasts more vulnerable. Hence, it is imperative to assess the comprehensive coastal vulnerability by considering physical, social, and economic factors. In this regard, INCOIS has developed a Socioeconomic Vulnerability Index (SEVI) framework to assess the coastal vulnerability of villages and buildings along the Andhra Pradesh Coast within the coastal multi-hazard zones (Figure 5.1.1). A total of 16 socioeconomic risk indicators about Adaptive Capacity and Sensitivity for the villages and 10 indicators from the building level are used in the study. The results highlight the vulnerable villages and buildings exposed to oceanic hazards considering social and economic factors. The decision matrix generated at the village and building levels will help decision-makers identify the contributing risk indicators for each village/building for appropriate resilience interventions.

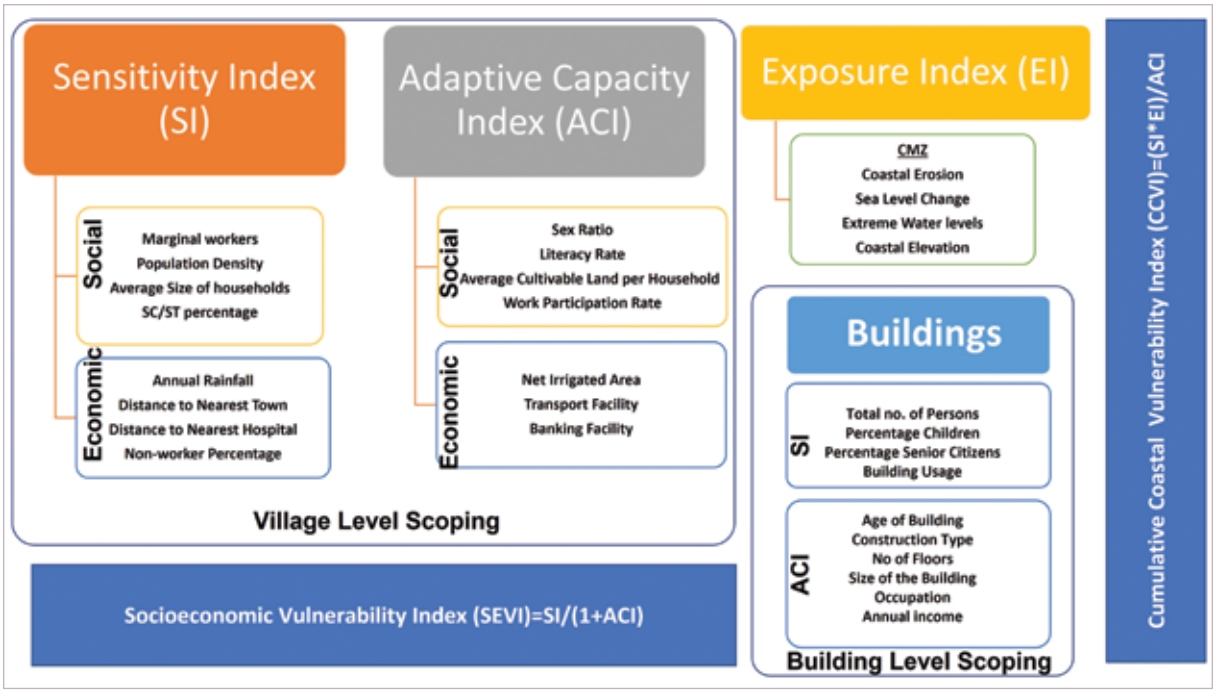


Figure 5.1.1. Framework developed for the assessment of SEVI

5.1.2 Marine Heat Wave Advisory Service (MAHAS)

This MAHAS service was further extended to the Western Pacific Island countries as a new service in May 2023. The MAHAS are routinely generated and served in the WebGIS map service. The sample figure of this domain is shown in Figure 51.2.

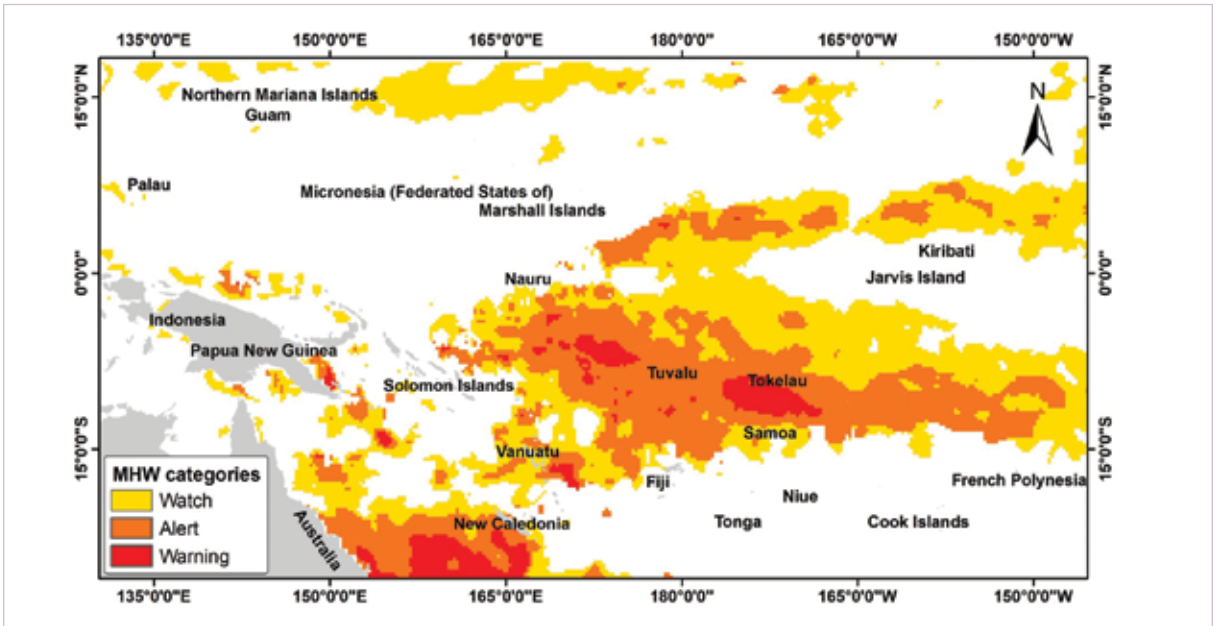


Figure 5.1.2. The spatial distribution of Marine Heat Wave in Western Pacific Region categories dated 30th January 2024

5.1.3 GNSS Data Processing flow for Tsunami Early Warning

INCOIS has deployed an advanced Global Navigation Satellite System (GNSS) coupled with a Strong Motion Accelerometer (SMA) network (Figure 5.1.3) in the Andaman and Nicobar Islands. This network, dedicated to tsunami early warning, was officially commissioned and inaugurated on February 14, 2024, by the Honorable Minister of the Ministry of Earth Sciences, Government of India. Comprising 35 targeted locations for installing GNSS and SMA stations, real-time data from 32 stations is now being successfully received at INCOIS. The primary objective of this network is to monitor the co-seismic perturbations from tsunamigenic seismic events occurring near the Andaman and Nicobar Islands.

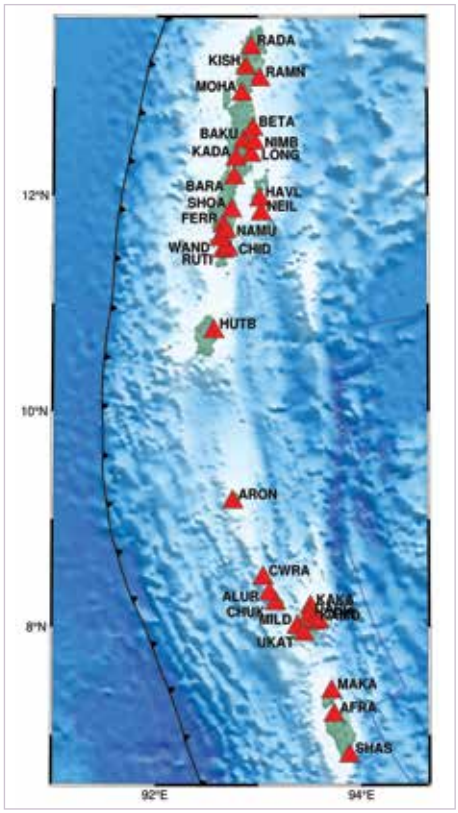


Figure 5.1.3. GNSS-SMA stations represented by a red triangle spread across the Andaman and Nicobar archipelago of the Indian subcontinent.

The real-time data from this network plays a crucial role in enhancing the operational tsunami advisories issued by the Indian Tsunami Early Warning Center (ITEWC), which operates 24/7 at INCOIS in Hyderabad. The GNSS data processing flow includes two main stages: (1) Real-time processing for co-seismic displacements and (2) post processing of observed displacement for earthquake source parameters. A comprehensive methodology for the real-time processing of GNSS data has been developed in collaboration with M/s Trimble (Figure 5.1.4).

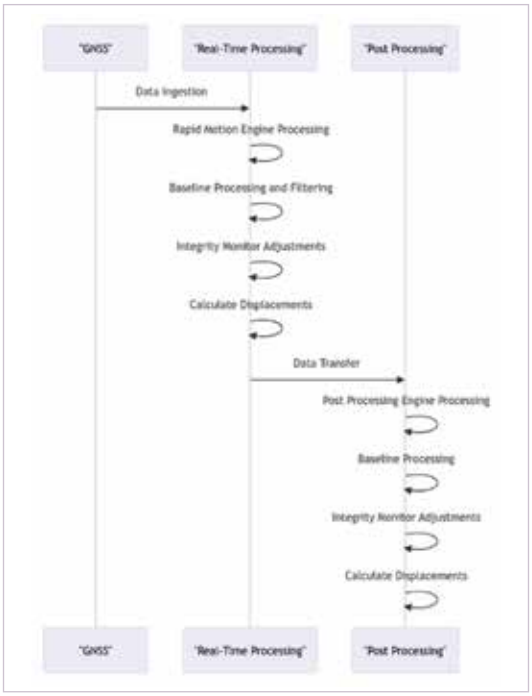


Figure 5.1.4. Real-time data processing flow of GPS/GNSS data for co-seismic displacements using the Rapid Motion and Network Motion Engine Modules.

These procedures ensure that the data processed is accurate and timely to estimate the real-time co-seismic displacements due to a tsunamigenic earthquake, which forms the backbone of effective tsunami early warnings. An example of displacement data obtained from real-time processing of GNSS data for a station named BAKU is shown in figure 5.1.5.

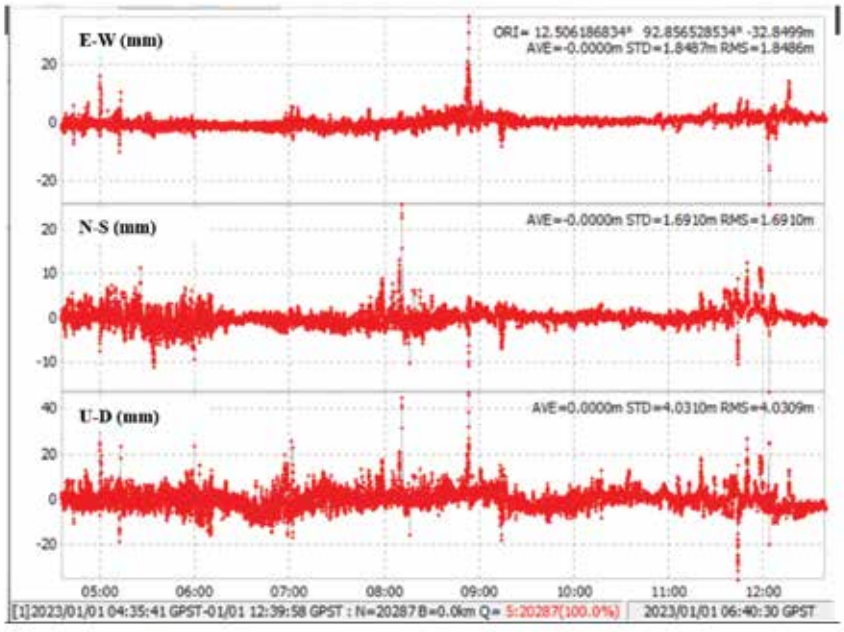


Figure 5.1.5. GPS/GNSS data from BAKU Station processed in real-time for co-seismic displacements – E-W, N-S & U-D components

5.1.4 Estimation of Seismic Source parameters using 'real-time' co-seismic displacements derived from GNSS Data & Realtime Inundation Modelling for Tsunami Early Warning

The study on the estimation of seismic source parameters using 'real-time' co-seismic displacements derived from GNSS Data and Real-time Inundation Modeling in a hypothetical situation, but using resources that would be available in real-time. Focusing on the Andaman and Nicobar Archipelago, the research utilized synthetic GNSS data from 35 stations based on the Andaman and Nicobar GNSS-SMA network geometry. The real-time processing was achieved using the Trimble RTK-Net Integrity Manager Pivot Platform, equipped with Rapid Motion and Network Motion Engine Modules. This setup allowed for the estimation of seismic source parameters through a probabilistic approach within 60 seconds and launched the ADCIRC Model to compute real-time tsunami inundation, achieving results within 2 to 4 minutes. The flowchart in Figure 5.1.6 depicts the entire process of estimating earthquake source parameters to generate tsunami inundation maps.

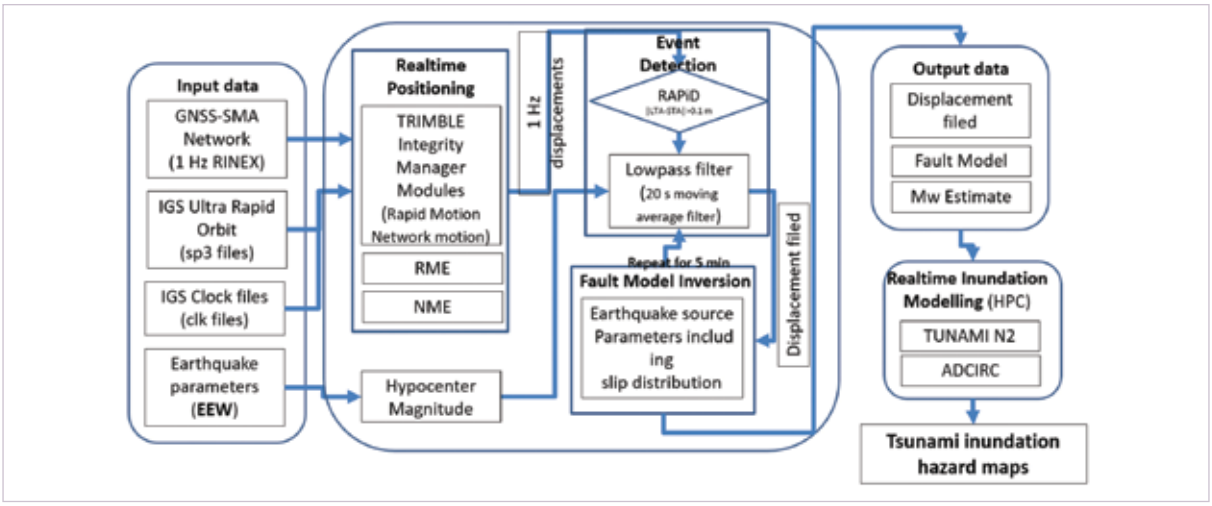


Figure 5.1.6. A block diagram depicting End-to-End work flow of Data acquisition from 35 GNSS stations, processing, fault model inversion, and real-time inundation estimation using ADCIRC model

5.1.5 Tsunami detection based on Ionospheric Total Electron Content

Ionospheric Total Electron Content (TEC) measures the total number of free electrons in an ionized gas (plasma) column in the Earth's ionosphere. It has been observed that surface deformation related to major earthquakes and tsunami propagation produces ionospheric changes in the total electron content. Studying TEC variations generated by an earthquake involves analyzing the changes in the ionosphere's electron density caused by an earthquake event. At 1:17 UTC on 06 February 2023, an Mw 7.8 earthquake struck southern and central Turkey and northern and western Syria. The earthquake had a maximum Mercalli intensity of XII (Extreme) around the epicenter. It was followed by an Mw 7.5 earthquake at 10:24 UTC. Studies on co-seismic ionospheric disturbances associated with these events have shown some promising results of ionospheric TEC variations. GNSS data from 11 GPS stations surrounding the earthquake epicenter were analyzed using GPS-TEC Software for Ionospheric TEC Extraction (Figure 5.1.7). TEC variations are observed for a few hours before and after the event. A sudden drop in TEC was noticed a few minutes after the earthquake.

Interestingly M7.5 quake at 10:24 UTC exhibits more substantial ionospheric effects than the M7.8 quake at 1:17 UTC, likely due to the higher background TEC of the daytime ionosphere. Ionospheric perturbations were observed 11 to 13 minutes after the earthquake generation. This study will help in continuous TEC monitoring that will be used to detect earthquakes and Tsunamis in seismically active regions and support conventional systems. This technique will be beneficial for existing Tsunami early warning Systems. By continuously monitoring TEC variations, it is possible to detect anomalous changes in TEC that indicate impending seismic or tsunami activity.

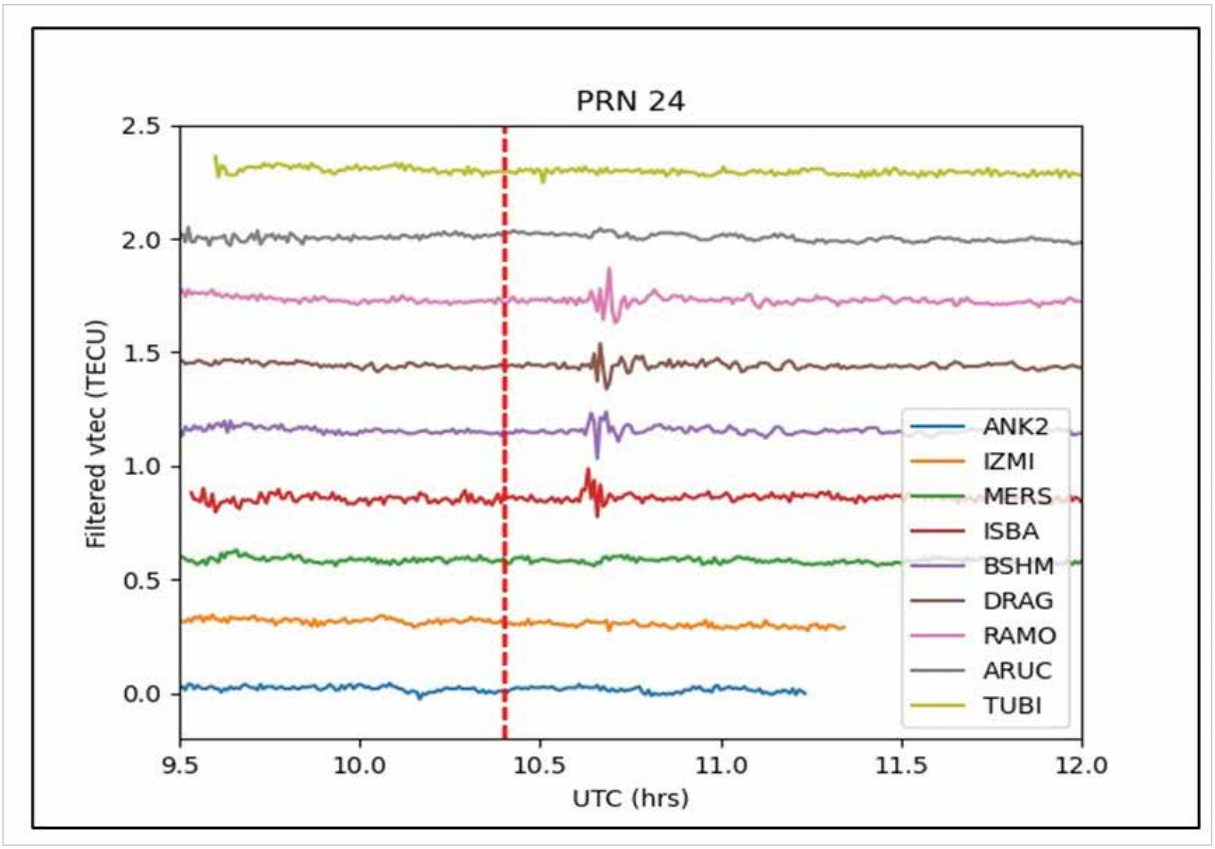


Figure 5.1.7. Detection and analysis of ionospheric signature of Turkey earthquake February 5th 2023

5.1.6 Role of Improved Ocean Initial State in the Seasonal Prediction of Indian Summer Monsoon: A Case Study

Seasonal forecasting of Indian summer monsoon rainfall (ISMR) has been attempted for almost a century due to its immense usefulness for the Indian economy and livelihood of the inhabitants. Numerous efforts have been made to enhance the skill of ISMR using the atmosphere-ocean general circulation coupled model but with limited success. Among them, ocean initialization is one of the critical aspects. In this regard, a case study has been carried out to show the impact of improved ocean initial conditions (ICs) in a coupled forecast system (CFSv2) simulation for ISMR. CFSv2 is used as an operational dynamical model for the seasonal prediction of ISMR by the India Meteorological Department (IMD). This exercise resulted in an improved ISMR skill by initializing the ocean component of CFSv2 using new improved ocean ICs based on Global Ocean Data Assimilation System (GODAS) analysis. This new analysis is better than the NCEP GODAS, which uses the earlier-generation ocean

model MOM4p0d and assimilates observed temperature and synthetic salinity using the 3DVar assimilation scheme. However, the new, improved GODAS analysis uses the MOM4p1 ocean model and assimilates observed salinity instead of synthetic salinity. A twin sets of nearly identical model experiments have been performed differing only in their ICs, with one set using NCEP ICs and the other using the new ICs (NIC). The NIC experiment shows better ISMR prediction skills (Figure 5.1.8). The improved ocean ICs have led to substantial improvements in both oceanic and atmospheric variables in a coupled feedback system contributing to the improved ISMR skill.

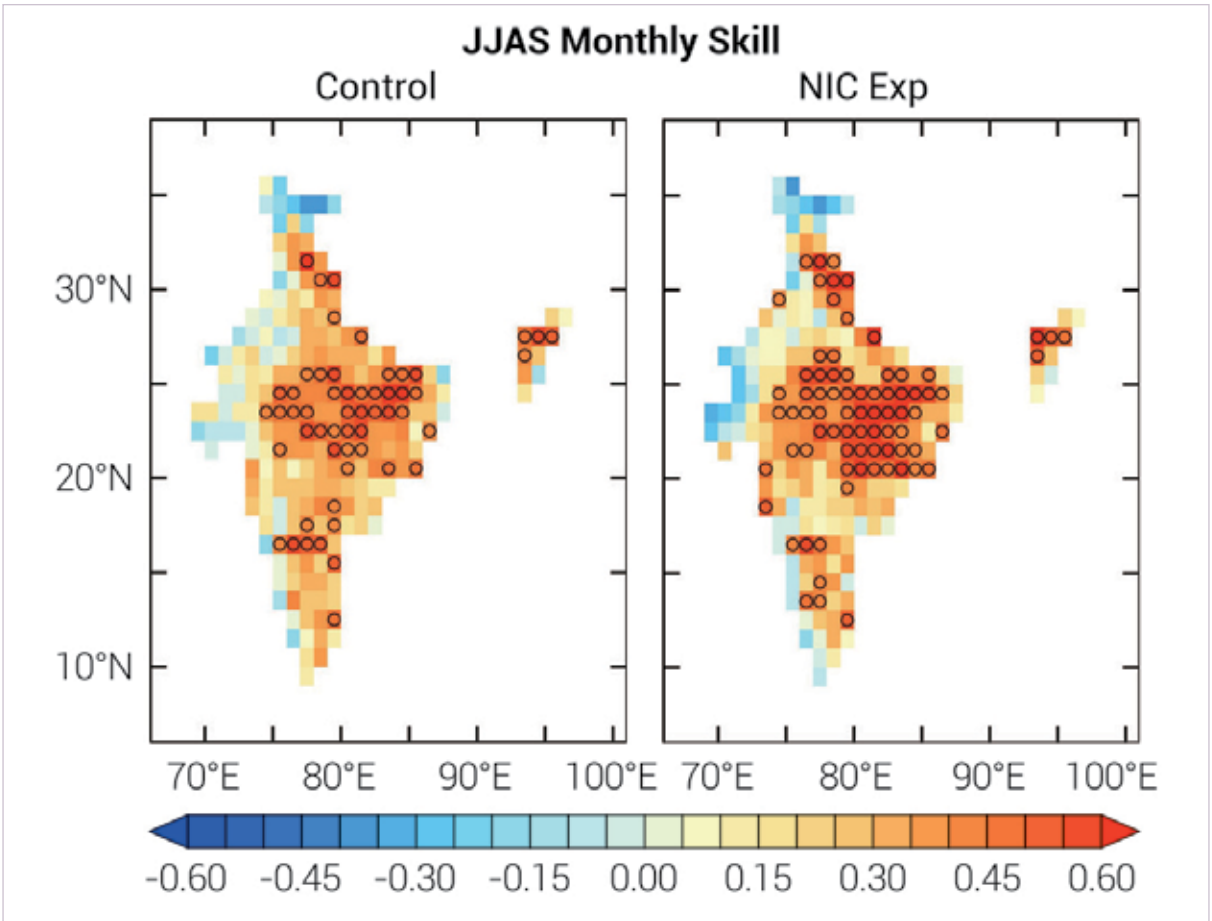


Figure 5.1.8. Monthly spatial skill of the JJAS season with respect to the IMD data for the (a) CTL and (b) NIC experiments. The grid with a circle represents a 99% significant correlation

5.1.7 Development of Search And Rescue Tool (SARAT) version 2

The Search and Rescue Aid Tool (SARAT) was developed and operationalized at INCOIS in 2016 to aid the Search and Rescue operations of the Indian agencies. The SARAT application can simulate the probable search area of a range of objects lost at sea when provided with information on the last known time and location of the lost object. A significant drawback concerning the probability was discovered in a review of the application's performance, as well as several other shortcomings. Many identified issues were resolved, and several improvements were made to the existing SARAT application, paving the way for SARAT version 2.0. Most importantly, the position from which the search area expands has now been corrected to be the last known position of the object (Figure 5.1.9).

The improved probable search area now corresponds well with the density of the simulated particle tracks (Figure 5.1.9). Other improvements in SARAT version 2.0 include the provision of simulated particle tracks, their mean trajectory in addition to the probable search area, better visualization in terms of distinct fine color-coded search regions, and a marker for an easier identification of the last known position of the object, among others. With all these enhancements, SARAT version 2.0 is expected to significantly improve the accuracy of search and rescue operations in the Indian Ocean.

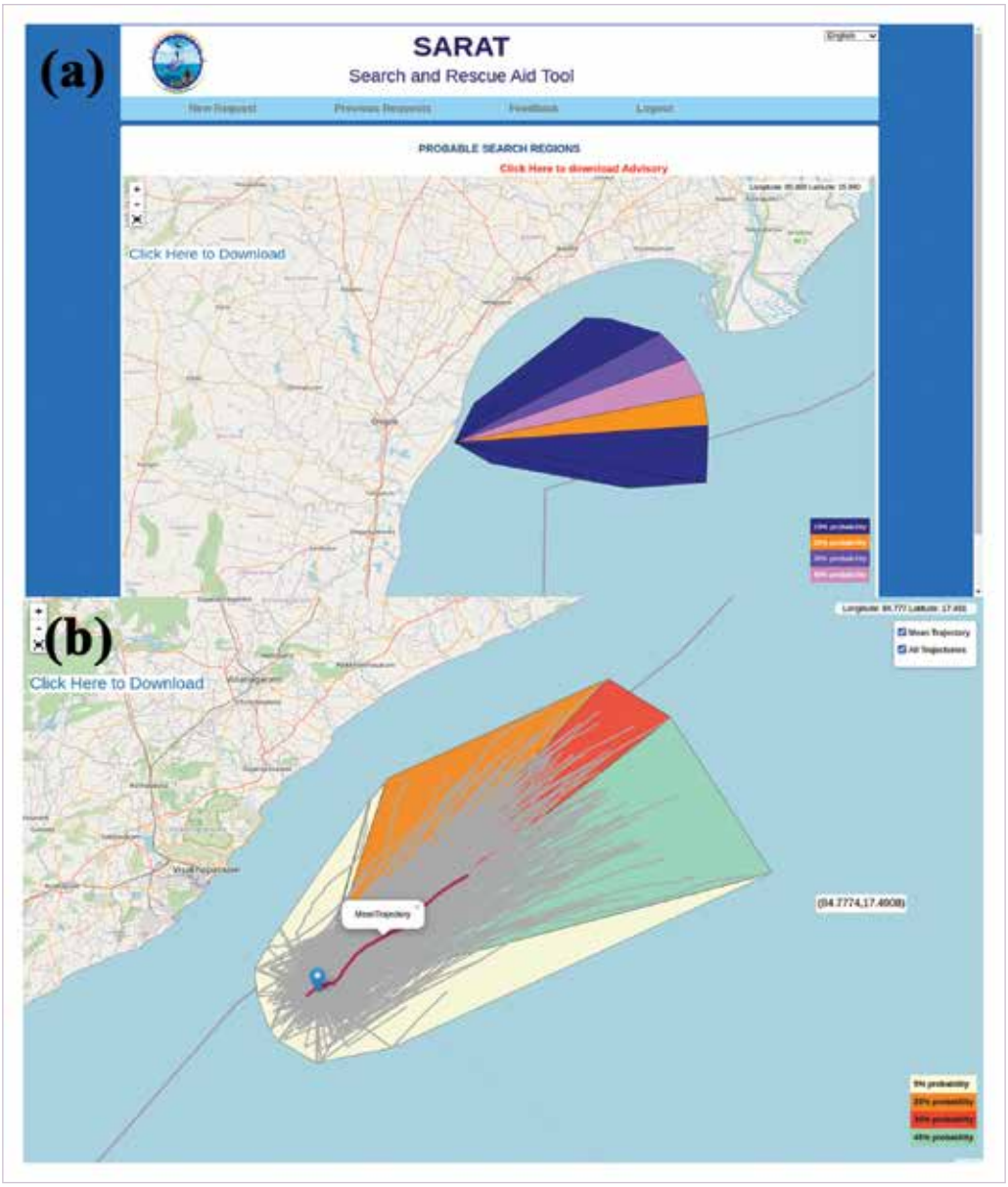
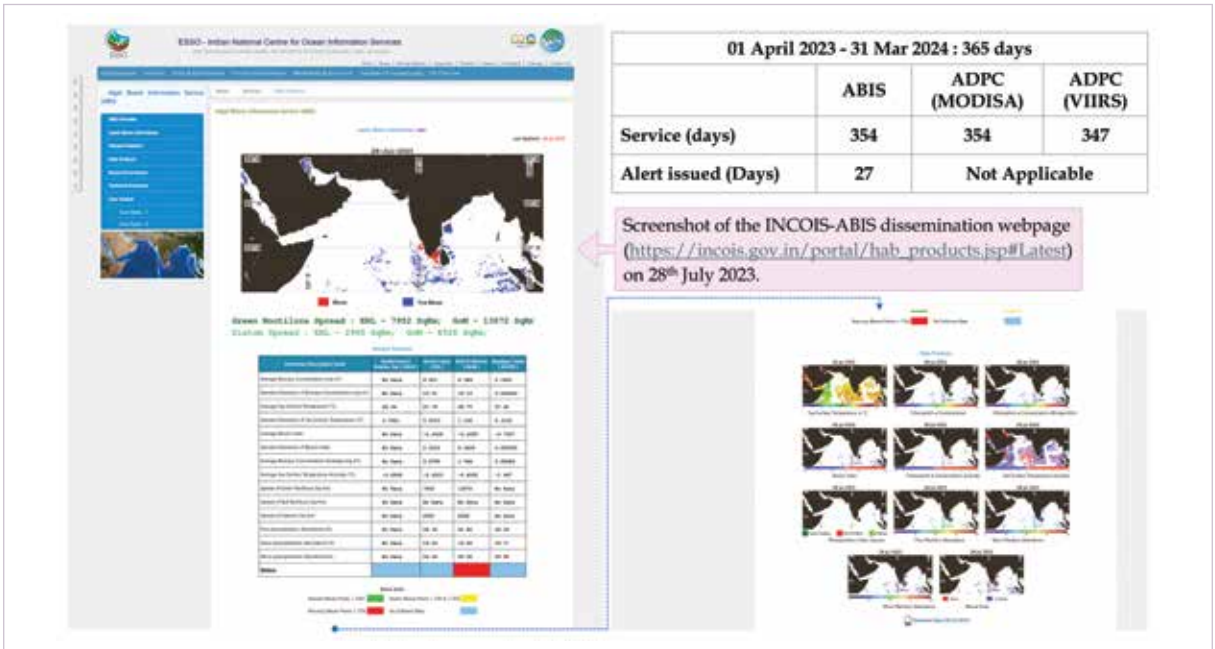


Figure 5.1.9. SARAT web interface

5.1.8 Algal Bloom Information Service (ABIS)

The increasing frequency of algal bloom is a major concern due to its harmful effects on fishery, marine life, and water quality. In this regard, INCOIS has developed and operationalized "Algal Bloom Information Service (ABIS)". The targeted users are fishermen, fishery resource managers,

researchers, ecologists, and environmentalists. The service is based on the products derived from ocean colour remote sensing data and also complements marine fisheries advisories. INCOIS-ABIS provides near real-time information on the presence of bloom in the north Indian Ocean, specifically four algal bloom hotspots such as the northeastern Arabian Sea, the coastal waters of Kerala, the Gulf of Mannar, and the coastal waters of Gopalpur. The ABIS has been sustained during the reporting period (Figure 5.1.10). As an effort to improve ABIS, an improved algal species detection algorithm(s) for Noctiluca ecotypes for the MODISA-Aqua sensor has been tested and finetuned. Additionally, the spatial variation in the intensity of species-specific algal blooms (Green *Noctiluca scintillans*) algorithm was finetuned and tested with published works. Integrated-ABIS for the Water Quality Nowcasting System has also been sustained for the coastal waters off Visakhapatnam and Kochi.



01 April 2023 - 31 Mar 2024 : 365 days			
	ABIS	ADPC (MODISA)	ADPC (VIIRS)
Service (days)	354	354	347
Alert issued (Days)	27	Not Applicable	

Screenshot of the INCOIS-ABIS dissemination webpage (https://incois.gov.in/portal/hab_products.jsp#Latest) on 28th July 2023.

Figure 5.1.10. INCOIS-ABIS web page disseminating algal bloom information

5.1.9 Water Quality Nowcasting System (WQNS)

The Indian coastal waters are stressed due to a multitude of factors, such as the discharge of industrial effluents, urbanization (municipal sewage), agricultural runoff, and river discharge. The coastal waters along the eastern and western seaboard of India exhibit contrasting characteristics in terms of seasonality, the magnitude of river influx, circulation pattern, and degree of anthropogenic activity. Therefore, understanding these processes and forecasting their occurrence is highly necessary to secure the health of coastal waters, habitats, marine resources, etc. Therefore, INCOIS has operationalized a Water Quality Nowcasting System (WQNS) to provide real-time data on several important physical-biogeochemical parameters. The WQNS system consists of a real-time data monitoring mechanism through autonomous water quality observatories, ocean remote sensing data, a wireless medium for transmitting data, a data processing system, and a web-based data visualization application (Figure 5.1.11). The WQNS system receives real-time data from two autonomous water quality observatories positioned at two important locations along the east (Visakhapatnam) and west (Kochi) coast of India. The web-based dissemination system of WQNS provides real-time information

through web-based infographics to the public, researchers, policymakers, and other stakeholders interested in the water quality data for specific locations.

WQNS has been sustained during the reporting period. The performance assessment test was carried out for both the water quality observatories using sensor performance assessment statistics. Preliminary results from the WQNS show promising outcomes, including the short-term changes in the water column oxic and hypoxic regimes within a day in coastal waters off Kochi during the monsoon period, whereas effluxing of high levels of CO_2 into the atmosphere associated with the mixing of water driven by local depression in the coastal waters off Visakhapatnam. The system has demonstrated its ability to detect changes in the water column properties due to episodic events and mesoscale processes. Additionally, it offers valuable data for research, management, and policy development related to coastal water quality.

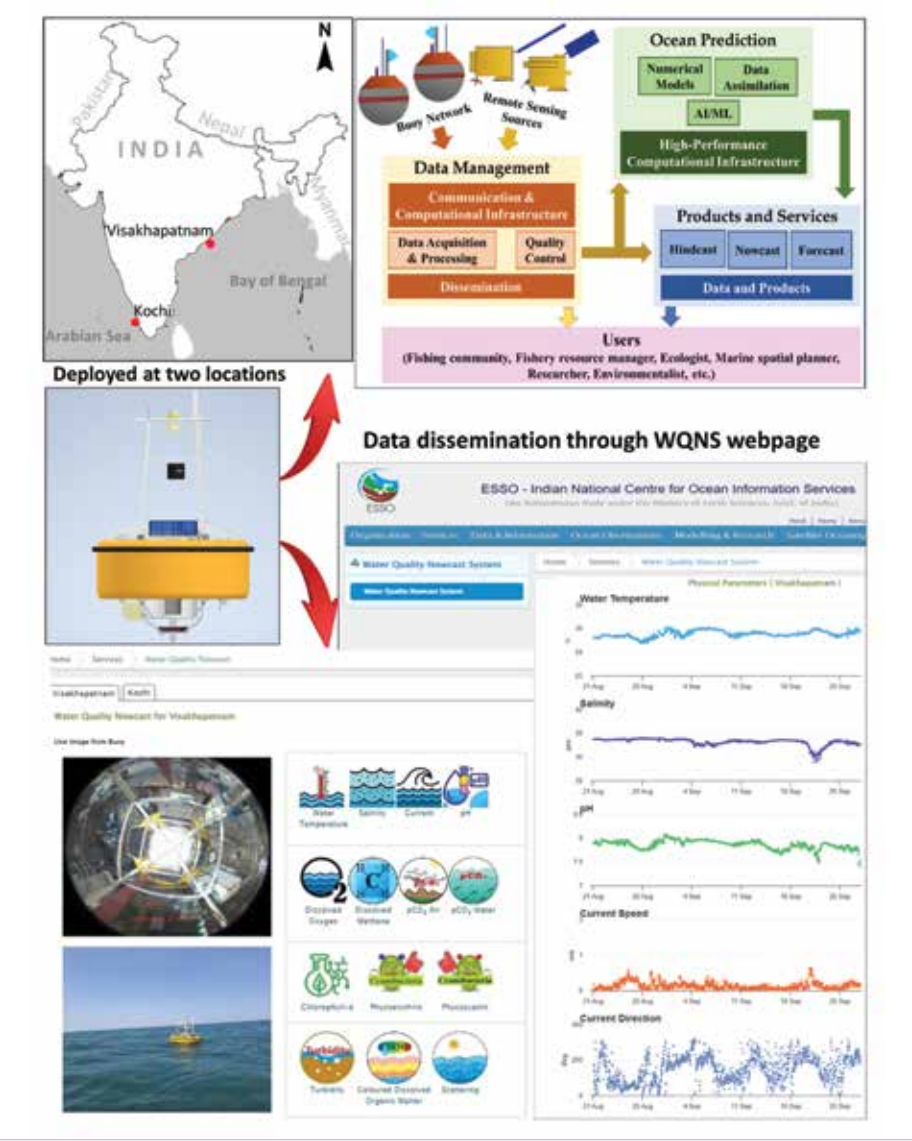


Figure 5.1.11. Overview of INCOIS' Water Quality Nowcasting System (WQNS)

5.1.10 Species-specific marine fishery advisories

5.1.10.1 Development of experimental Hilsa fishery advisory

Hilsa fishery in the northern Bay of Bengal is of high commercial, cultural, and ecological importance. INCOIS has made remarkable progress in research and development endeavors to understand the conducive conditions for the Hilsa habitat, with the ultimate goal of establishing a Hilsa-specific advisory service. A machine learning-based technique has been devised for the spatial prediction of Hilsa catch in the northwestern Bay of Bengal and adjoining Hugli estuary (Figure 5.1.12). The model's prediction uncertainty has been estimated using an ensemble approach, incorporating elements from bootstrapping and Monte Carlo techniques in statistics. Key input parameters such as salinity, sea surface temperature, and current (both speed and direction) have been considered in this predictive framework. The study employed Random Forest and Extreme Gradient Boosting

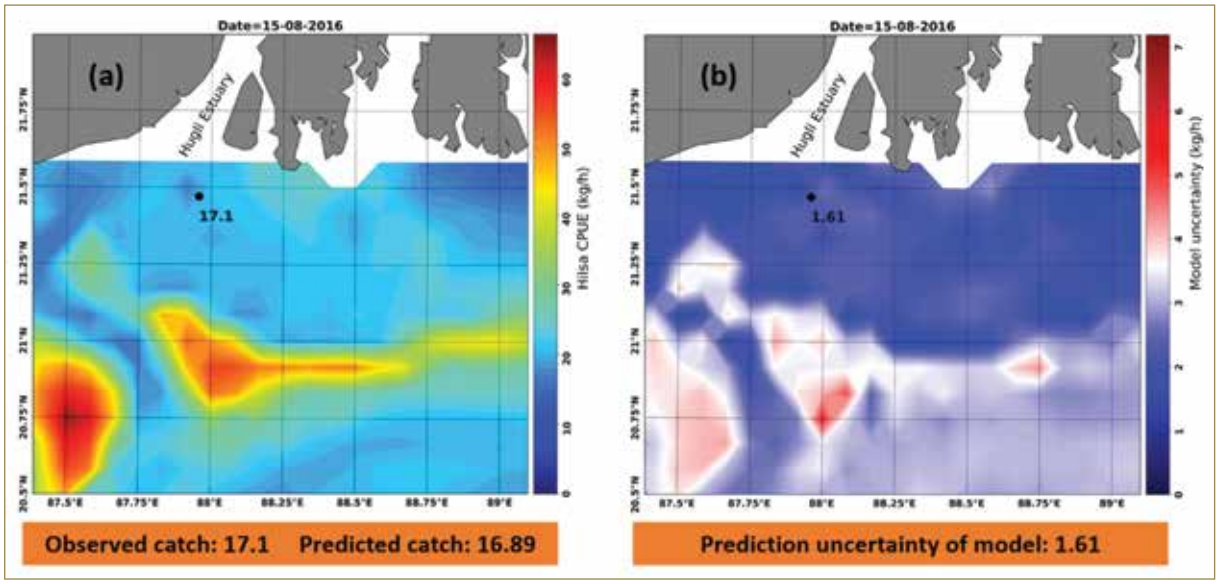


Figure 5.1.12. (a) Spatial prediction of Hilsa CPUE and (b) prediction uncertainty of the model for a particular day (15.08.2016). The spatial resolution of the maps is 1/12 degree.

(XGBoost) models, with XGBoost identified as the superior performer. This effort marks the first-ever endeavor to develop a model for the spatial prediction of Hilsa catch utilizing machine learning approaches. Furthermore, the outcomes of this study hold promise for the establishment of an experimental Hilsa fishery advisory service at INCOIS, facilitating informed decision-making in Hilsa fishery management.

5.1.10.2 Development of experimental Indian Oil Sardine fishery advisory

INCOIS has initiated the development of a species-specific advisory for oil sardines in Kerala on an experimental basis. Initial endeavors have involved the utilization of geo-tagged fish catch data and satellite/model-derived oceanographic parameters within a multi-model framework to identify the most appropriate model. The research involves the study of interrelationships between oceanographic variables and sardine catch, employing a combination of regression techniques (GAM, GLM) and AI/ML algorithms (BRT, RF) to train habitat suitability models and determine the optimal

approach. Additionally, the investigation encompassed a comprehensive analysis of sardine-run events spanning an entire year (2022-2023, comprising fourteen events) through satellite data analysis, marking a pioneering endeavor in this domain. Through the analysis, precipitation and sea surface temperature (SST) emerged as pivotal factors influencing the aggregation of sardine schools in the coastal waters of Kerala (Figure 5.1.13). This research represents a significant step towards enhancing our understanding of sardine ecology and informing management strategies for sustainable fisheries practices.

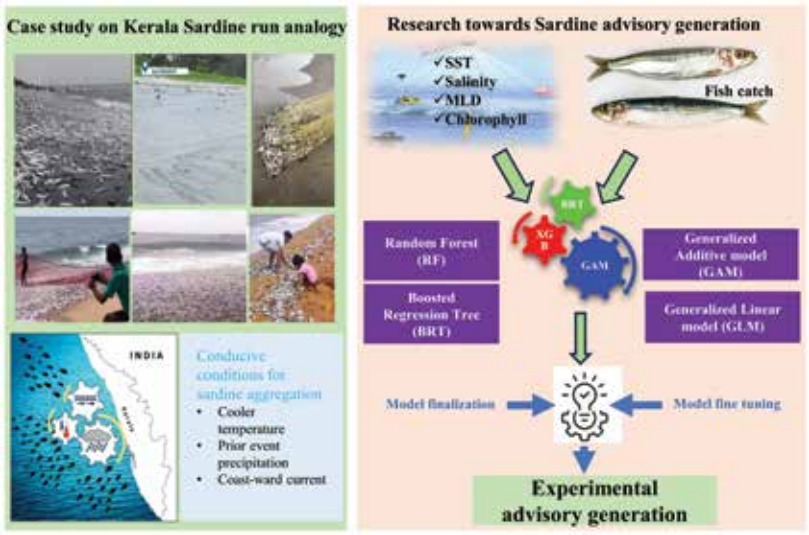


Figure 5.1.13. Investigation on the sardine run events in the coastal waters of Kerala

5.1.10.3 Development of experimental Indian mackerel fishery advisory

INCOIS has initiated R&D towards a species-specific advisory for Indian Mackerel. In the endeavour to create habitat suitability models for mackerel, an investigation into multidecadal historical mackerel catch data sourced from the INCOIS database has been initiated to understand the potential factors impacting the abundance of the species in the upwelling regions of Kerala and Karnataka. The primary results indicated the greater influence of net primary productivity, temperature at 50 m depth, and MLD in Mackerel catches in the region (Figure 5.1.14). Additionally, ongoing research involves

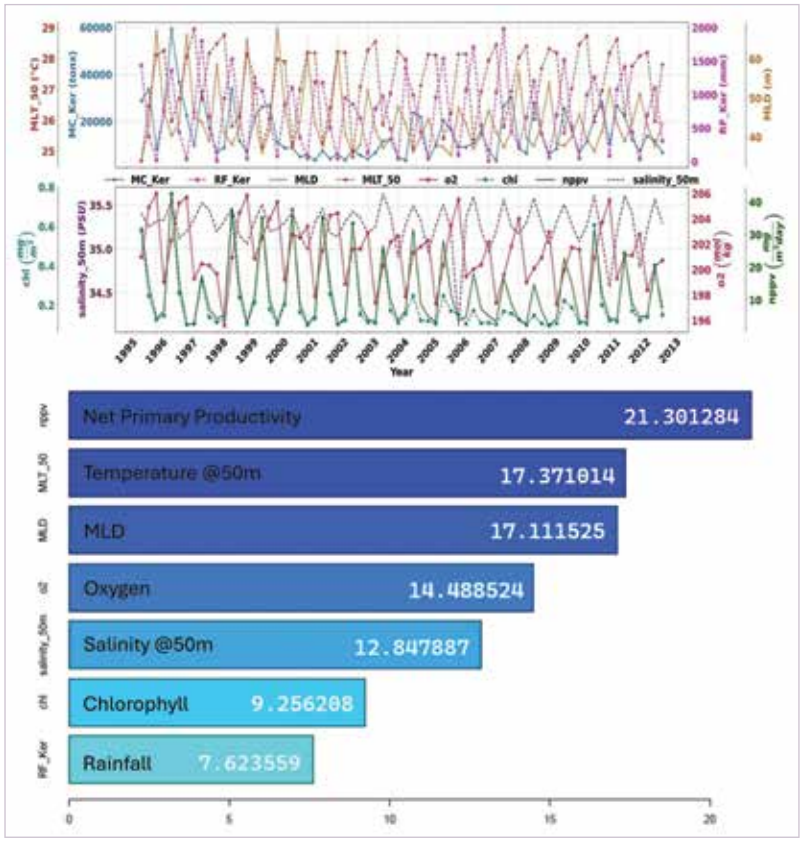


Figure 5.1.14. Upper Panel: Trend of mackerel landings and environmental variables in the Malabar upwelling region, Lower Panel: Relative influence of environmental variables on Mackerel landing

the analysis of existing geotagged fish catch data, focusing on environmental variables, and employing both statistical methods and machine learning models. These multifaceted analyses aim to uncover intricate relationships between environmental factors and mackerel abundance, ultimately contributing to the development of effective and targeted advisories for the sustainable management of mackerel fisheries.

5.1.10.4 Development of Jellyfish Aggregation Advisory

Jellyfish swarming have significant impacts on various sectors such as tourism, atomic power plants, fisheries, the navy, etc. However, they also present opportunities, such as harvesting edible jellyfish for export and foreign exchange earnings. Therefore, there is a crucial need to develop jellyfish advisories to provide advanced information to tourists, power plant operators, fishermen, scientists, policymakers, and other relevant stakeholders. These advisories can help these groups to react promptly and effectively to potential jellyfish-related issues, ensuring the protection of both economic interests and environmental sustainability. The overview of research towards development of Jellyfish Aggregation Advisory Service is shown in Figure 5.1.15.

Figure 5.1.15. Overview of research towards development of Jellyfish Aggregation Advisory Service

In order to understand the conducive habitat conditions, a compressive literature survey was carried out, and a suite of key parameters influencing jellyfish aggregation was identified. Additionally, a database has been compiled on 180 jellyfish aggregation events along the Indian coast, encompassing diverse species belonging to hydrozoa, scyphozoa, cubozoan, etc (Figure 6.15). Additionally, prominent jellyfish swarming events have been backtracked using available operational data to identify important parameters and data sources. After realizing the occurrence of frequent

jellyfish aggregations along the coastal waters of the western Bay of Bengal with major hotspots off Machilipatnam, Nellore, and Hamsaladeevi, a two-leg scientific expedition was planned. In November 2023, the first leg of the scientific expedition was conducted in the coastal waters of the central Bay of Bengal, strategically timed just after the dissipation of jellyfish aggregations. During this cruise, in-situ measurements were carried out to understand the physical-biogeochemical regimes that form conducive conditions for jellyfish aggregation. The follow-up expedition is scheduled during the onset of the southwest monsoon, targeting the swarming season.

In an exercise to decipher the impact of cyclones resulting in jellyfish aggregations in coastal waters, a case study has been carried out examining the jellyfish swarming prior to landfall of cyclone Yass on the northern Odisha coast with a peak intensity on 26 May 2021 (Figure 5.1.16). The daily climatology and anomaly of Sea Surface Temperature (SST) and the daily average of phytoplankton biomass (proxy: *chlorophyll-a*) from satellite data were analyzed. The current speed and direction were calculated using the Hybrid Coordinate Ocean Model (HYCOM) inputs. The jellyfish swarms observed from the event were mainly of two types, i.e., Crambionella and unidentified jellyfish, and the fish species was rainbow sardine. The fish mass mortality was observed one day before the jellyfish swarming, which could be due to the rise in water temperature (Figure 5.1.16). In the context of jellyfish, increases in temperature support the abundance by triggering their reproduction rate. This case study also revealed that the plausible reason behind the swarming of jellyfish could also be related to the occurrence of rainbow sardines, as jellyfish feed on sardine larvae. The resultant jellyfish swarms were washed away towards the beach by shoreward currents and ended up with beach stranding.

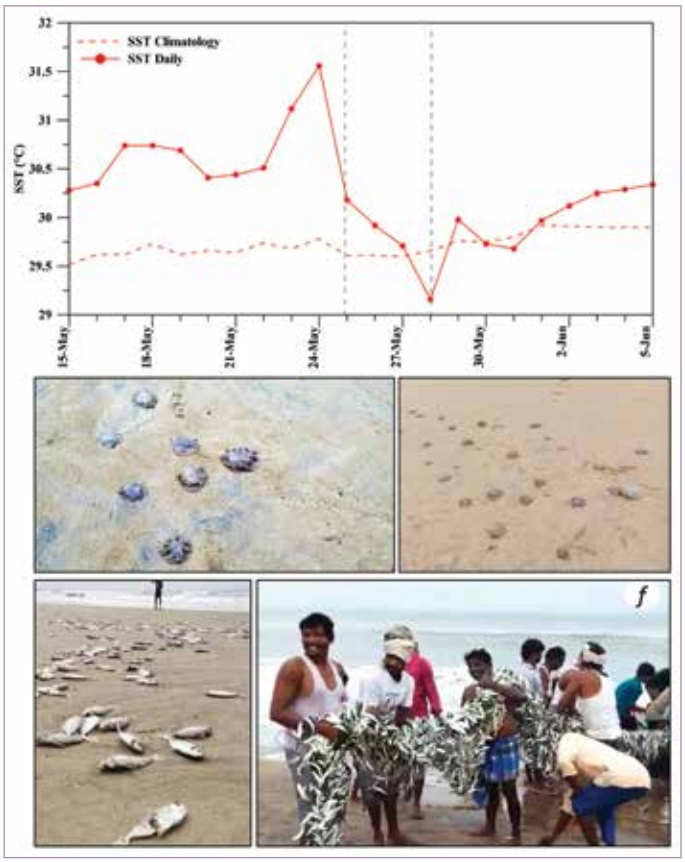


Figure 5.1.16. The upper panel shows the variability of Sea Surface Temperature (SST) in the coastal waters of Puri, the middle panel shows dead jellyfish washed away on the sea beach, and the lower panel shows dead rainbow sardines washed away on the sea beach.

5.1.11 INCOIS Online Oil Spill Advisory (OOSA)

INCOIS OOSA (V4.0) is an integrated setup of oil spill trajectory model, General ocean circulation models, atmospheric models, and Geographical Information System (GIS). OOSA v4.0 has a better representation of oil drift patterns in web map services.

5.1.11.1 Introduction of OOSA (VER 4.0) at NATPOLREX-IX

OOSA VER 4.0 has been introduced to Indian Coast Guard officials and marine environment stakeholders during the National Pollution Response Exercise (NATPOLREX – IX) conducted in Gujarat on 24 Nov 2023. OOSA v4.0 has a better representation of oil drift patterns in web map services (Figure 5.1.17a). The user can generate the oil drift patterns of the domain 40°E to 120°E, 30°S to 30°N. The users can interpret the trajectory patterns using the video/play options provided. A better representation of the oil drift pattern in web map services and the quantitative status of the spilled oil pollutant, which was not in the previous version, is now made available for the users in the form of graphs.

Figure 5.1.17. (a) Demonstration of OOSA V4.0, involved in Tabletop exercise during NATPOLREX -IX (24 Nov 2023)

5.1.11.2 Oil drift pattern with fate and budget using PYGNOME+ADIOSDB (R&D mode)

PyGNOME (a very flexible and customizable particle tracking and oil weathering model) has been set (in R & D mode) along with weathering of oil from Automated Data Inquiry for Oil Database (ADIOS_DB) for certain regions Off Mumbai to generate the oil drift pattern. The fate and budget of the spilled oil pollutant were obtained with an oil drift pattern. While compared with the conventional model, this PyGNOME setup pulls oil from ADIOS_DB which is designed to support oil spill response and oil spill preparedness operations through a compilation of publicly available oil assays (combinations of physical and chemical data that uniquely describe or characterize an oil pollutant).

The model was set for the Mumbai high region and forced using ECMWF winds and ROMS currents (Figure 5.1.17b). Oil drift patterns of Arabian heavy oil were generated from the hypothetical spill

location (72.8233 °E, 18.7436 °N) for 96hrs from 16 Nov 2023, 2000hrs. The fate and budget of spilled oil pollutants are obtained after weathering which describes the evaporation, dispersion, floating, and beaching of the oil pollutant.

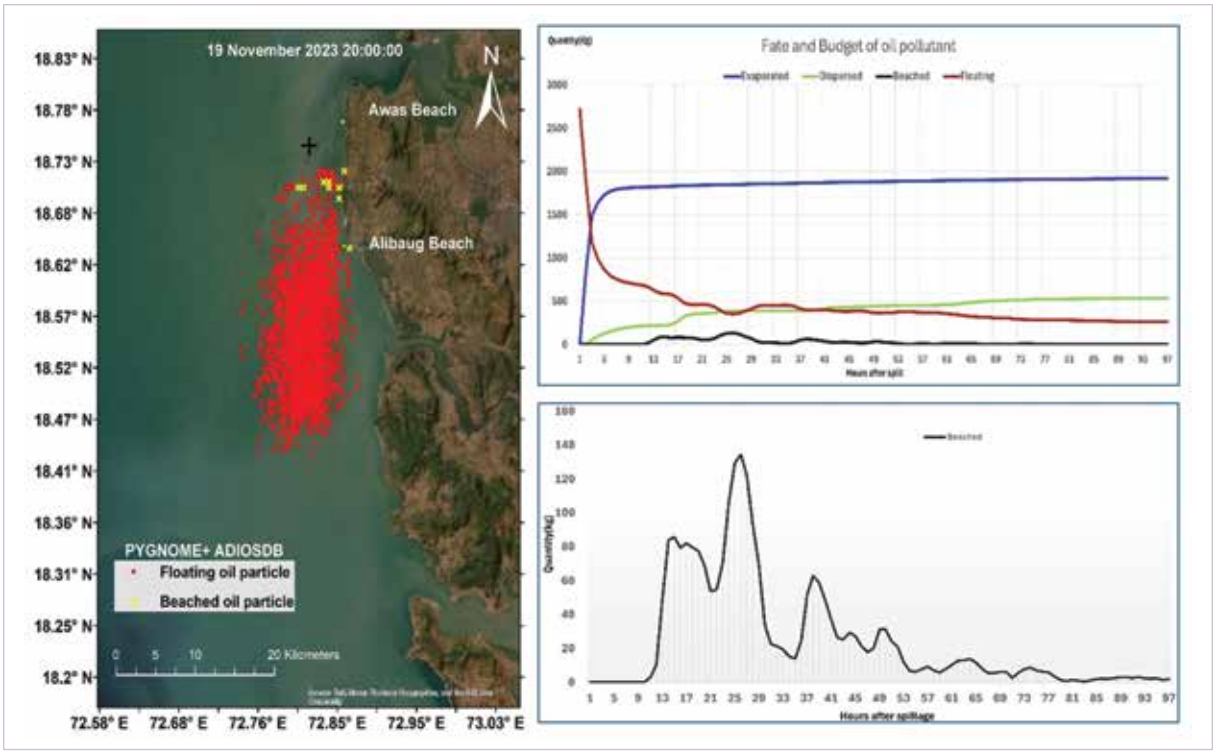


Figure 5.1.17. (b) Hypothetical oil drift pattern from PyGNOME+ADIOS_DB (left) and Fate & Budget of oil pollutant (right). The lower right panel shows only the beached quantity

5.1.12 Bridging the gap between the evolution of fronts to fisheries

The Front-to-Fish program, a research initiative towards improving INCOIS's potential fishing zone (PFZ) advisories by investigating dynamics for ocean fronts has been executed. The program primarily aims to study the probable reasons for high fisheries potential anticipated at the ocean fronts by investigating the background conditions and food web succession at the ocean fronts. An Initial study in this direction was carried out by investigating the patterns of SST frontal formation and dynamics at the Goa-Mangalore region from 2014 to 2019 using the Automatic Front Detection Algorithm.

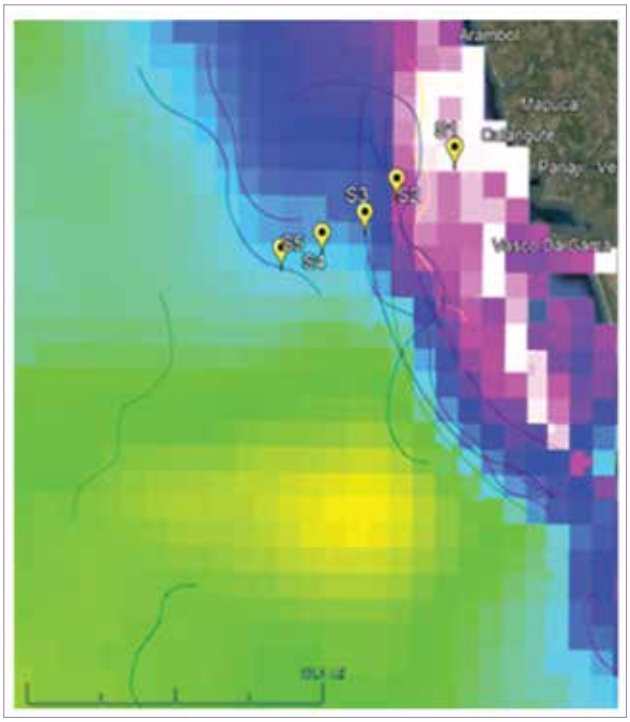


Figure 5.1.18. Persistent SST frontal features observed along the Goa coast during 14-22 December 2023.

The study revealed that the most prominent and persistent thermal fronts occur during the North-East monsoon to Winter seasons in November to March in the Arabian Sea, lasting up to 2-5 days. Furthermore, studies to reveal the in-situ environmental conditions and the biological activity including the ecological succession at the ocean fronts were initiated in the Goa/Mangalore region. The fundamental aspect of this study is to monitor the occurrence and persistence of frontal features using remote sensing data on SST and chlorophyll, which is being carried out continuously and the information being disseminated to the Principal Investigators of the INCOIS outsourced projects on PFZ. Three field trips were conducted during 2023-24, with two near Calangute (Goa) and one along the Udupi region, confirming higher fish abundance and catch along the frontal features (Figure 5.1.18). Ongoing efforts are directed towards further understanding the relation between multiple aspects including frontal persistence, precursors for productivity, and patterns of species succession at the oceanic fronts to model the dynamics of food web development in oceanic ecosystems, which are anticipated to increase the scope of PFZ.

5.1.13 Marine Energy Atlas

Contributing to the Indian blue economic growth, INCOIS has prepared comprehensive estimates of various ocean energy resources within the Indian Exclusive Economic Zone (EEZ). The potential energy available from solar, wind, waves, tides, and ocean currents has been estimated. Additionally, the energy potential from salinity and thermal gradients has been assessed. The estimates show that solar energy dominates 99+% of the total energy available from various resources, followed by thermal gradient and wind energy. The percentage contribution of all energy resources except solar energy is presented in Figure 5.1.19. These estimates are expected to provide broader guidelines to policymakers and public/ private sector enterprises in the energy sector that contribute to India's targeted carbon footprint reduction.

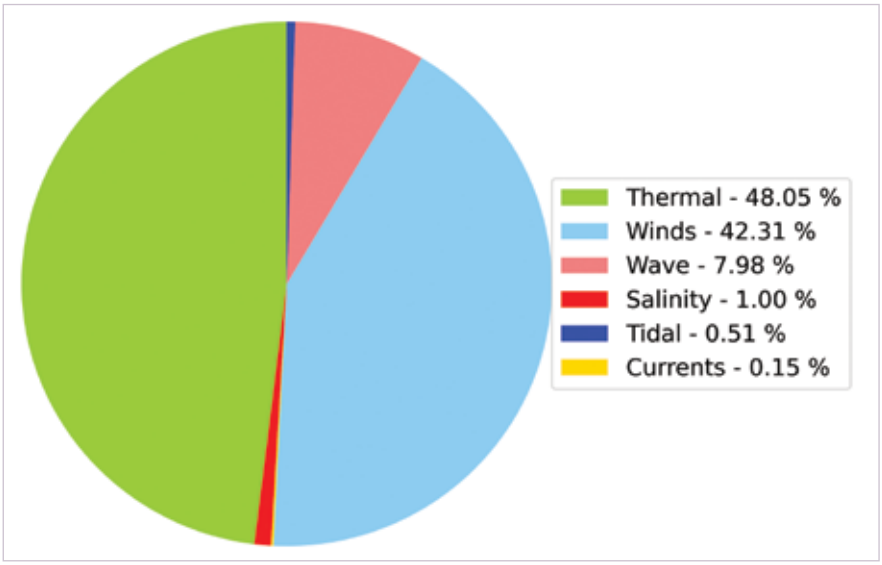


Figure 5.1.19. Percentage of the contribution of energy resources except for solar energy

5.2 Basic Research

5.2.1 Recent global increase in multiple rapid intensification of tropical cyclones

Rapid Intensification (RI) of tropical cyclones (TCs) is defined as a wind speed increase of at least 30 knots within 24 hours. Forecasting a rapid intensification phase in a cyclone's life cycle has proven to be a challenging task for recasters. Cyclone prediction can get even worse if cyclones have experienced rapid intensification phases more than once in their lifetime. On a global scale, from 1981–2020, the frequency of cyclones having multiple-rapid intensification phases has significantly increased at a rate of 1.2 cyclones/decade (Figure 5.2.1). Generally, rapid intensification occurs predominantly in the early stages of a cyclone's life cycle, with mature stages typically characterized by high surface friction inhibiting such rapid intensification. However, due to global warming, mature cyclone stages are now becoming increasingly favorable for rapid intensification events. This shift allows cyclones to intensify multiple times throughout their lifetime, posing additional challenges for forecasters (Figure 5.2.2).

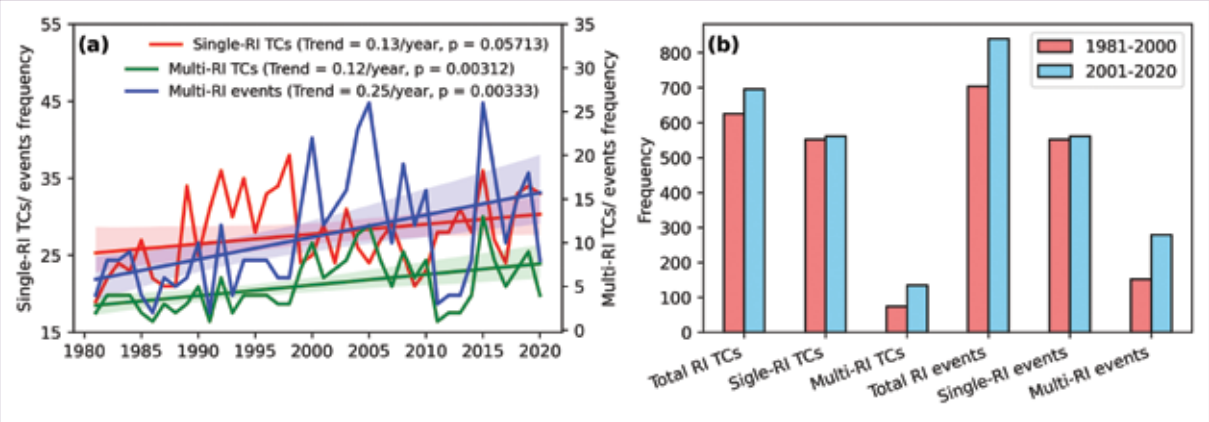


Figure 5.2.1. (a) Time series and trend of annual single-RI TCs frequency (red), multiple-RI TCs frequency (green), and multiple-RI events frequency (blue) during the period 1981–2020. (b) Frequency changes of total RI-TCs and total RI events, single-RI TCs and events, multiple-RI TCs and events between the periods 1981-2000 and 2001-2020

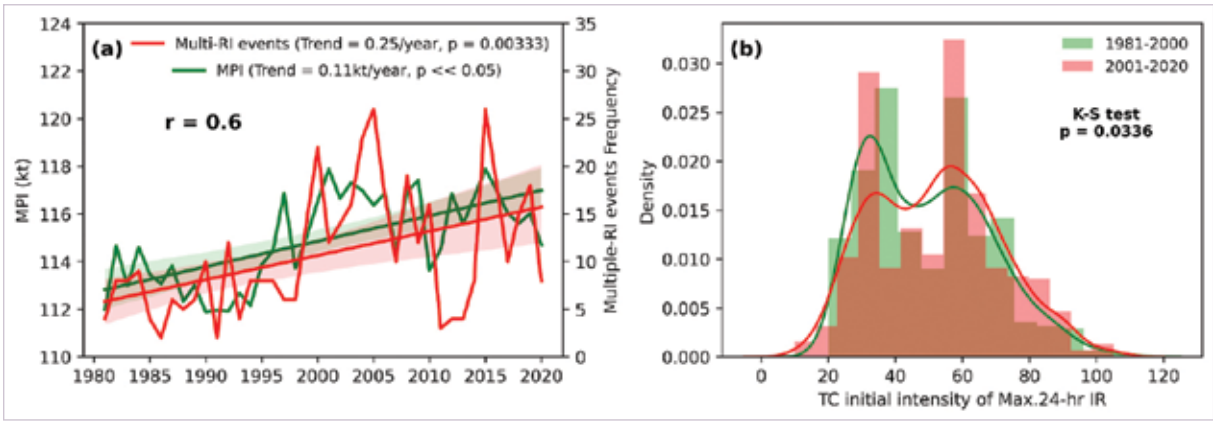


Figure 5.2.2. (a) Time series of Maximum Potential Intensity (MPI) (shown in green colour) calculated for global tropical oceans (30N—30S) for the period 1981–2020 using ERA5 data along with time series of multiple-RI events (red) (b) Distribution plots of initial TC intensity of maximum intensification rate for RI TCs for the periods 1981-2000 (green) and 2001-2020 (red).

Ref: *Manikanta, N. D., Joseph, S., & Naidu, C. V. (2023). Recent global increase in multiple rapid intensification of tropical cyclones. Scientific Reports, 13(1), 15949*

5.2.2 Estimation of seismic source parameters from seismogeodetic observations and its application for tsunami early warning

This study introduces a novel approach in the Indian Ocean region, marking a first of its kind in using real-time GNSS data to enhance the Indian tsunami early warning system and operational procedures of the Indian Tsunami Early Warning Center (ITEWC). By leveraging data from 35 stations in the Andaman and Nicobar Islands, GNSS-SMA network established by INCOIS-MoES, the research focuses on characterizing tsunamigenic earthquakes using co-seismic displacements derived from GNSS data and implementing real-time tsunami inundation modeling (Figure 5.2.3). This pioneering work sets a new standard in disaster management technology, providing crucial tsunami inundation forecasts for the Indian coastline in real time. In the absence of significant seismic events in the Andaman and Nicobar Archipelago since the GNSS-SMA network's establishment, the research employs synthetic data to simulate co-seismic fault displacements for hypothetical earthquakes. These simulation datasets of hypothetical earthquakes in the locations in and around the Andaman and Nicobar archipelago aid in better understanding and characterizing earthquake sources and enhance the development of more effective tsunami early warning procedures.

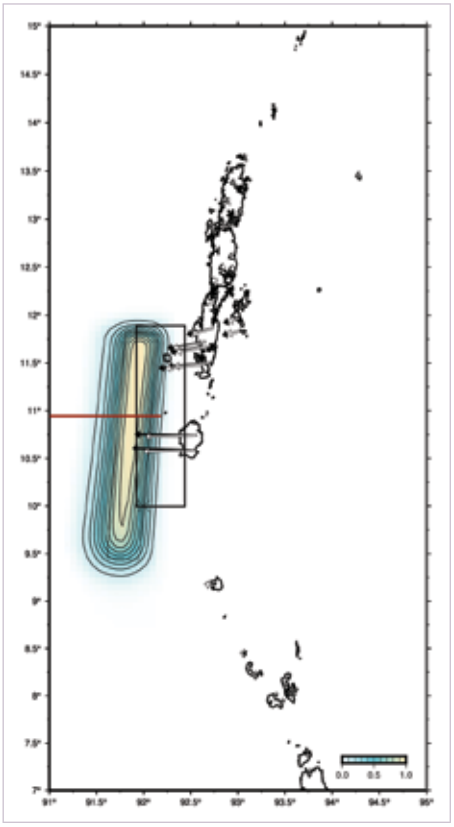


Figure 5.2.3. Estimated co-seismic fault models with varying colour gradients from light blue to yellow (0.1 to 1.0) indicate the range of solutions, with yellow representing the most probable fault model for a hypothetical earthquake

The ITEWC uses robust state-of-the-art software tools like the TRIMBLE Integrity Manager Pivot Platform Software Modules, which include the Rapid Motion Engine and Network Motion Engine, to calculate real-time co-seismic displacements from 35 stations of GNSS-SMA network established in the Andaman and Nicobar Archipelago. These state-of-the-art software modules, along with the LTA-STA algorithm that detects significant movements and applies a lowpass filter, ensure data integrity within a critical five-minute confirmation window. The study also adopts a probabilistic approach to fault model inversion, which accurately determines earthquake source parameters and incorporates uncertainties as probability distribution functions (PDFs). This method provides deeper insights into earthquake dynamics, considering the uncertainties inherent in earthquake source parameters. The estimated source parameters are used to initiate the ADCIRC tsunami inundation model with Finite Element Mesh (FEM) in real-time (Figure 5.2.4). This model generates essential inundation estimates and tsunami inundation hazard maps for the Andaman and Nicobar Archipelago within just 2 to 3 minutes on high-performance computing (HPC) platforms. Furthermore, the research highlights the importance of station density and spatial configuration in accurately determining seismic parameters. While the strike angle and fault lengths are well-recovered for nearby earthquakes, the dip angle, fault widths, and depths are less accurately

determined, with fault widths often overestimated. However, in hypothetical earthquake scenarios where the fault rupture area is well covered by the network, the slip amount is accurately recovered for those hypothetical earthquakes. The probabilistic method enhances the representation of uncertainties and estimation of source parameters of the fault model. This groundbreaking research, recognized with the 'Best Research Award' at the Disaster Management Policy Program 2022-2023, represents a collaborative effort with Tohoku University, the International Institute of Seismology and Earthquake Engineering (IISEE), BRI, Japan, under the Knowledge Co-Creation Program 2022-2023 by Japan, exemplifying effective international cooperation in advancing disaster preparedness and response technologies.

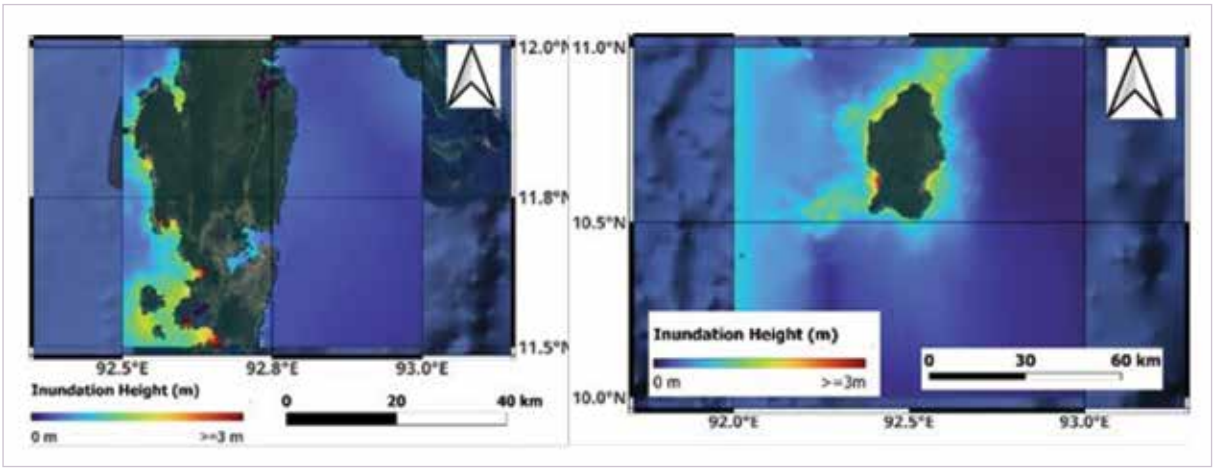


Figure 5.2.4. Maximum wave amplitudes and tsunami inundation were computed using ADCIRC Model as a real-time hypothetical earthquake case for the study areas Port Blair and Car Nicobar areas

Ref: *Chodavarapu, P., Ohta, Y., & Shibazaki, B. (2023), Rapid determination of tsunamigenic source parameters and real time inundation modelling for TEWS, Synopsis of IISEE-GRIPS Master's Thesis.*

5.2.3 Impact of bathymetry on Indian Ocean circulation in a nested regional ocean model

The oceans regulate the global weather and climate. Understanding the ocean is crucial for accurate weather and climate forecasts. The main transport mode for global trade is the ocean by shipping. Due to the vast economic benefits of planning maritime activities, it is essential to accurately forecast specific oceanographic parameters such as currents, temperature, and salinity of surface and subsurface on different time scales. For better prediction, the essential requirements are enhanced observations and improved models. In recent times, through the IndOOS program, Indian Ocean observing systems have now been reasonably well represented on a space-time scale. However, models are still unable to simulate its mean and variability accurately. Ocean model simulation errors are mainly caused by errors in forcing fields, model physics, numeric, and the representation of bathymetry. With the aim of improving the models, this study focuses on the importance of realistic representation of bathymetry in circulation models and explores the intricate dynamics of Indian Ocean circulation using advanced computer models. This study examined how the shape of the ocean floor (bathymetry) affects the state of the ocean, both at the surface and in the deep regions. Incorporating more realistic ocean floor shapes into the models allowed for more accurate

simulations of real-world ocean behaviour. This enhanced understanding allowed to make better predictions of salinity and temperature, particularly near coastal regions (Figure 5.2.5). The ocean currents are improved as well with more realistic bathymetry. The influence of islands, such as the Maldives and Andaman and Nicobar Islands, on ocean currents was also explored, revealing that these islands significantly altered the current direction and speed to a greater extent. Additionally, evidence of deep swirling patterns in the ocean depths, which were opposite to surface currents, is also noted. The most recent and widely used state-of-the-art modeling centres ocean reanalysis products i,e ORAS5 and SODA, underestimate the observed coastal currents around India. This study presents the first evidence of a basin-wide cyclonic gyre over the Bay of Bengal at 1000 m depth during spring, which is just opposite to that of a basin-wide anti-cyclonic gyre at the surface. The presence of poleward EICC during spring at 1000 m and 2000 m depth, opposite to the surface, was observed. The presence of this deeper EICC structure is completely absent during fall. During peak summer months, June–July, a strong eastward zonal jet is present at 1000 m depth, similar to Wyrtki Jet (WJ), which serves as the first report. Inter-monsoon Jets, i.e., spring and fall jets, are also seen but are in the opposite direction, i.e., westward, unlike eastward in WJ. Overall, this study highlights the importance of bathymetry on ocean general circulation models in advancing the understanding of ocean dynamics, and they will improve the ocean state forecast, weather forecast, and climate forecast over the Indian rim countries and subcontinent.

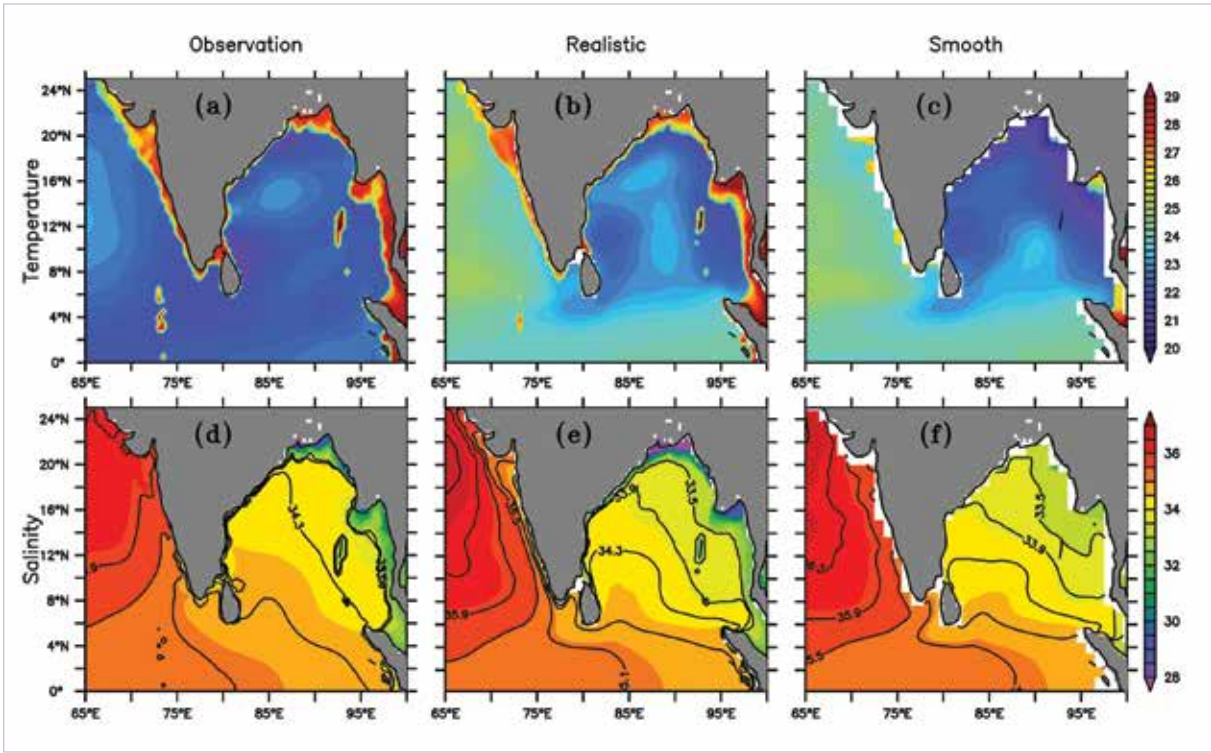


Figure 5.2.5. The upper ocean (0-200 m) temperature and salinity for observation, realistic modified bathymetry, and smoothened bathymetry. (a),(b),(c) temperature and (d),(e),(f) salinity

Ref: *Rahman, R., & Rahaman, H. Impact of bathymetry on Indian Ocean circulation in a nested regional ocean model. Sci Rep 14, 8008 (2024). https://doi.org/10.1038/s41598-024-58464-2*

5.2.4 Volcanic Eruption Triggers a Rare Meteotsunami in the Indian Ocean

Meteotsunamis is a lesser-known category of tsunamis. While a meteotsunami is like a tsunami, the way the two events are created differs. Unlike the more well-known tsunamis—such as the catastrophic 2004 Indian Ocean tsunami, which was caused by an earthquake on the seafloor, meteotsunamis are caused by weather, in particular, some combination of changing air pressure, strong winds, and thunderstorm activity or volcanic activity. Meteotusnami events are reported in various parts of the world and have the potential to be disastrous in some cases. However, such a study or event is not reported in the Indian Ocean basin. This study presents the observation and evaluation of a meteotsunami in the Indian Ocean triggered by the Hunga-Tonga volcanic eruption. The event was detected through tide gauges and bottom-pressure recordings across the Indian Ocean, with an amplitude of 10–15 cm, lasting for a few days. A numerical model was used to understand the ocean's response to meteotsunami and evaluate the dynamics behind it. The model results show that the sea-level oscillations result from the ocean waves generated by a propagating Lamb wave. In addition to interaction with bathymetry, refracted and reflected waves also determine the sea-level variability. Our analysis shows that bathymetric slope plays a vital role in near-shore processes. The spectral and spatial characteristics of the meteotsunami were reminiscent of seismic tsunamis. This research on this rare event elucidates the unresolved issues and eventually leads to designing a blueprint for future observation and modeling of meteotsunamis and seismic tsunamis (Figure 5.2.6).

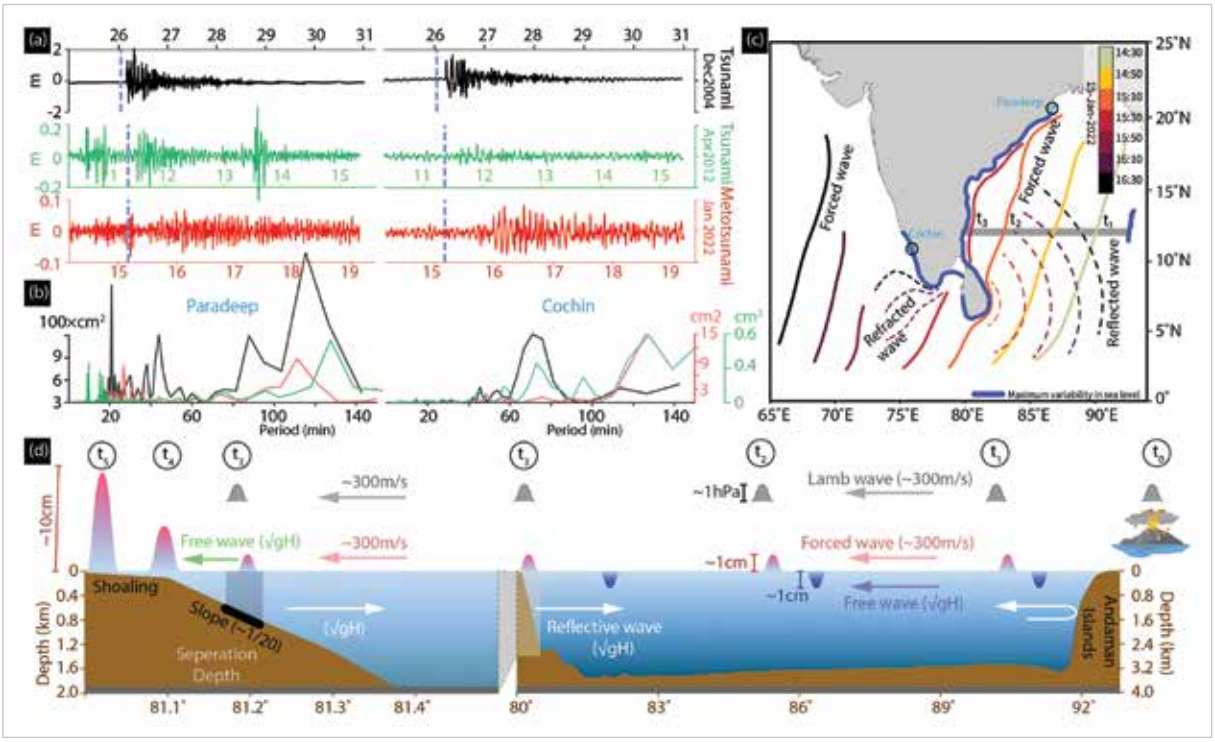


Figure 5.2.6. Conceptual view of meteotsunami due to Tonga eruption (t0) in the Bay of Bengal at five instances in time (t1-t5).

Ref: *Anup, N., Rohith, B., Vijith, V., Rose, L., Sreeraj, P., Sabu, A., Krishnamohan, K.S., Sudeepkumar, B.L., Sunil, A.S., & Sunil, P.S. (2024). Volcanic eruption triggers a rare meteotsunami in the Indian Ocean. Geophysical Research Letters, 51(2), e2023GL108036.*

5.2.5 Extraction of persistent Lagrangian coherent structures for the pollutant transport prediction in the Bay of Bengal

Accurate surface ocean currents are crucial for effectively predicting the trajectories of oil spills at sea; thus, improving the precision of trajectory forecasts necessitates realistic current simulations. However, spatial and temporal gridded in situ measurements are limited and only accessible for specific locations. Therefore, it becomes vital to rely on simulated models or satellite-derived currents for thorough basin-scale studies. The uncertainties and inaccuracies present in these simulated currents could potentially affect the prediction of pollutant trajectories.

In this study, an attempt has been made to yield the improvised Lagrangian transport patterns using a Lagrangian Coherent Structures (LCS) method. We computed the monthly climatological LCSs (cLCS) maps utilizing 24 years (1994–2017) of HYbrid Coordinate Ocean Model (HYCOM) currents and ECMWF re-analysis winds in the Bay of Bengal (BoB) for the first time. LCS are the hidden fluid flow skeletons that provide meaningful information about the Lagrangian circulation. This study identifies the Coherent Lagrangian Coherent Structures (cLCSs) linked with seasonal monsoon currents and mesoscale processes (eddies) in the BoB. The simulated cLCS were augmented with the complex empirical orthogonal functions to confirm the dominant Lagrangian transport pattern features better (Figure 5.2.7). The constructed cLCS patterns demonstrated a seasonal accumulation zone and the transport pattern of freshwater plumes along the coastal region of the BoB. Furthermore, the findings were validated by comparing them with satellite imagery of real-time oil spill dispersion and modeled oil spill trajectories, which align closely with

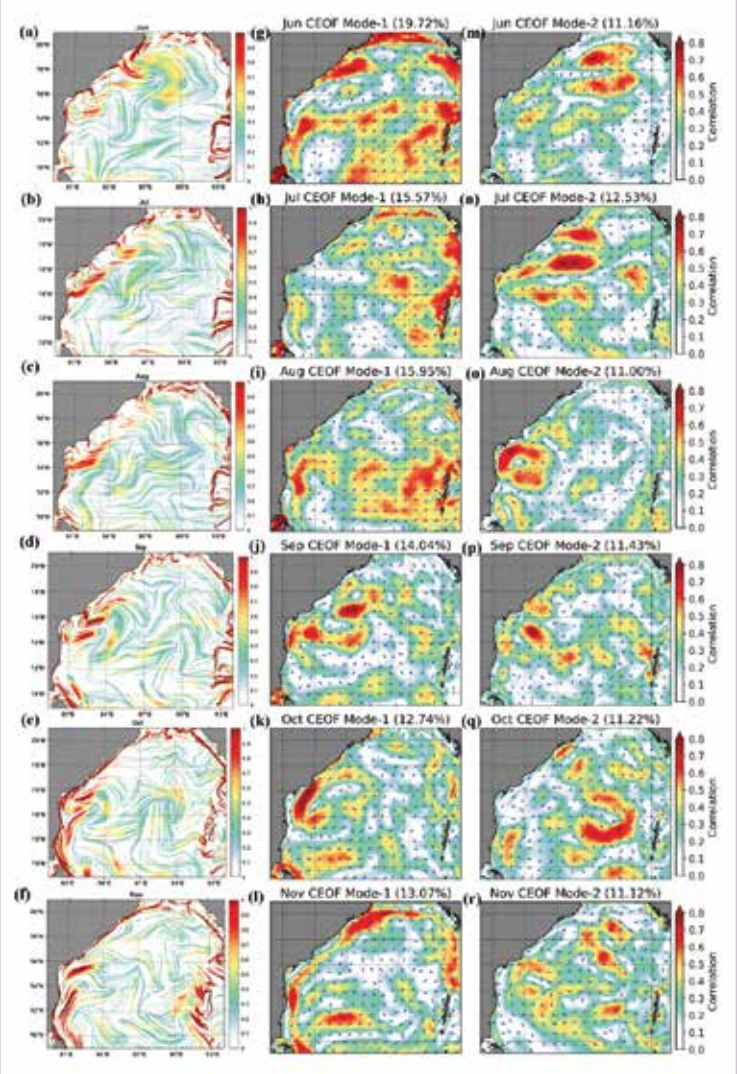


Figure 5.2.7. Climatological Lagrangian coherent structures and Complex empirical orthogonal function analysis mode-1 and 2 over the Bay of Bengal during 1994–2017 for the months of June, July, August, September, October, and November.

Ref: *Trinadha Rao, V., Suneel, V., Gulakaram, V. S., & Sravani, C. L. (2024). Extraction of persistent lagrangian coherent structures for the pollutant transport prediction in the Bay of Bengal. Scientific Reports, 14(1), 8761. https://doi.org/10.1038/s41598-024-58783-4*

the LCS patterns. Additionally, the cLCSs were applied to examine the transport of hypothetical oil spills originating from one of the active oil exploration sites (Krishna-Godavari basin). This illustrated the accumulation zones in the BoB and verified that the persistent monthly cLCS maps effectively predict the trajectory of pollutants, such as oil spills. These maps will help to initiate mitigation measures in case of any occurrence of oil spills in the future. This approach is the first used in the BoB to reveal surface transport patterns by augmenting the cLCS and EOFs.

5.2.6 Role of oceanic internal variability in the interannual-to-longer timescale in the Indian Ocean

The Indian Ocean (IO), with densely populated continents of Africa, Asia, and Australia, is prone to a plethora of climatic hazards. IO rim includes one-third of the world's population, mostly living in developing countries that are highly vulnerable to climate variability. The interannual-to-longer timescale (also referred to as low-frequency) variability in sea surface temperature (SST) of the Indian Ocean plays a crucial role in affecting the regional climate. These low-frequency variability can be caused by surface forcings and oceanic internal variability.

Internal variability refers to the intrinsic variability arising from the nonlinearity of the oceanic system. Considering that the internal variability is not tied to the external forcing, the occurrence of internal variability limits the predictability of the oceanic system. The role of oceanic internal variability in generating low-frequency variability in the Indian Ocean was identified using high–resolution global Modular Ocean Model (MOM5) simulations. The model is first forced by climatological surface atmospheric fluxes from CORE-II climatological forcing, and the simulation is carried out for 175 years from a state of rest. This climatological simulation is referred to as CLIM. The model is further integrated forward using an interannual forcing from JRA55do for 1958–2017 and is referred to as Control run (CTRL). The previous studies have explored the impact of internal variability in the Indian Ocean; they have primarily focused on the tropical basin due to limitations imposed by the

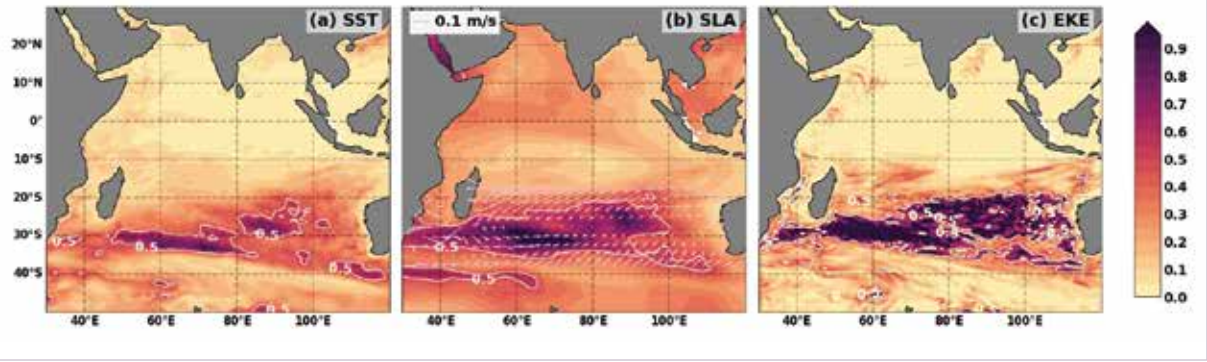


Figure 5.2.8. The ratio of the standard deviations of (a) SST, (b) SSH, and (c) eddy kinetic energy derived from CLIM and CTRL simulation overlaid by a contour of 0.5. Standard deviation is calculated after removing the annual cycle and then low-passed with a 15-month lowpass filter. The vectors overlayed in Panel (b) represent mean surface currents highlighting SEC and SICC in the SIO.

regional setup of the models used. However, this study reveals a notable southward shift in the latitude band of active internal variability for the low frequencies (Figure 5.2.8) compared to earlier estimations based on coarser regional models. An energy budget analysis reveals that baroclinic

instability (Figure 5.2.9), associated with the vertical shear between the surface eastward flow of the South Indian Counter Current and the subsurface westward flow of the Southern Ocean supergyre, is the primary driver of internal variability. The slowly growing baroclinic instabilities, characterised by longer time and length scales, facilitate the generation of Rossby waves, which propagate the signals westward, carrying the energy to the western part of the basin.

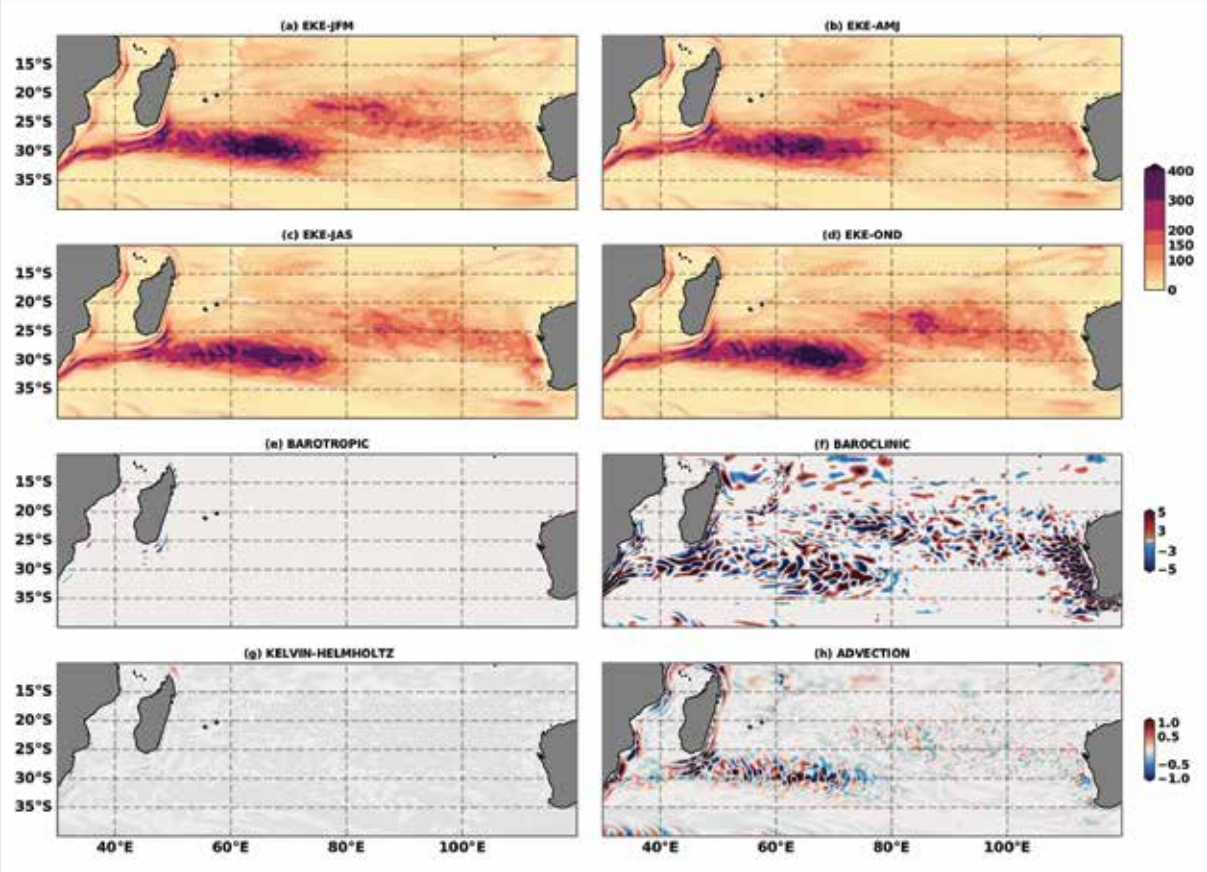


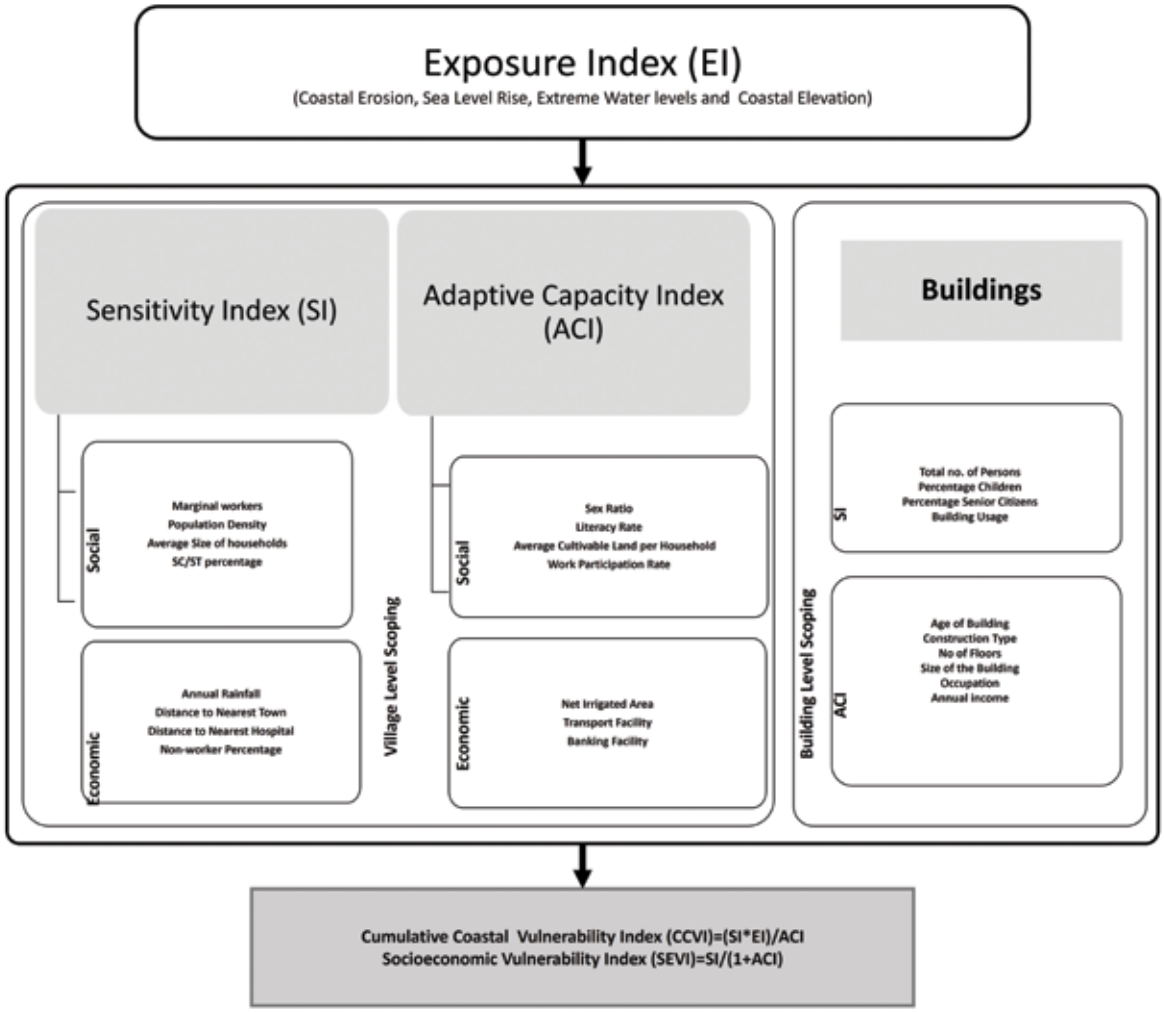
Figure 5.2.9. Eddy kinetic energy (EKE; kg s^{-3}) for the four seasons: (a) summer (January-March)), (b) fall (April-June)), (c) winter (July-September), (d) spring (October-December). (e)are the barotropic energy conversion (10^4 kg s^{-3}), (f) baroclinic energy conversion (S_{bc}, 10^4 kg s^{-3}), (g) Kelvin-Helmholtz and (h) advection averaged for the entire period and are integrated over the top 200m water column. Note that the scale for Kelvin-Helmholtz conversion and advection is smaller than the baroclinic and barotropic terms as they contribution from these terms are considerably weaker.

Ref: *Anjana, S., Chatterjee, A., Han, W., Prerna, S., & Sajidh, C. K. (2023). Role of oceanic internal instability in the generation of low-frequency variability in the Indian Ocean. Geophysical Research Letters, 50, e2022GL102489. https://doi.org/10.1029/2022GL102489.*

5.2.7 Socioeconomic Vulnerability Assessment of Coastal Villages and Buildings along Andhra Pradesh East Coast of India

Climate change is a global phenomenon that has enhanced sea-level rise and aggravated the prevailing coastal hazards that make coasts more vulnerable. The socio-economic vulnerability of villages for the entire Andhra Pradesh state and buildings at the selected locations along the Andhra Pradesh coast is estimated to understand the level of risk due to exposure. This study attempts to understand the reality of grassroots communities/households and derive vulnerability indicators that affect coastal communities. In this regard, (i) the exposure index (EI), (ii) Coastal cumulative

Vulnerability Index (CCVI), and (iii) Socio-economic Vulnerability Indexes are calculated. EI is calculated based on oceanogenic multi-hazard zones (MHZ) estimated using the long-term extreme water levels, shoreline change rate, sea-level change rate, and high-resolution topographic data (Figure 5.2.10). The cumulative coastal vulnerability index (CCVI) and socioeconomic vulnerability index (SEVI) are calculated for all villages and buildings in the selected villages. A total of 16 socioeconomic risk indicators from the village census of 2001 and 10 indicators from the survey at the building level are used in the study. The current study suggests 23 villages comprising 6000 households, which is associated with 0.022 million people under the very high SEVI category. Four villages comprising 1000 households associated with 3000 people are in the very high cumulative vulnerability index category. Nineteen hundred eighty-five buildings in the selected parts of the study area had a very high SEVI. One hundred and forty-five buildings in the village chosen had very high SEVI. The decision matrix generated at the village and building levels will help decision-makers identify the contributing risk indicators for each village/building for appropriate resilience interventions.



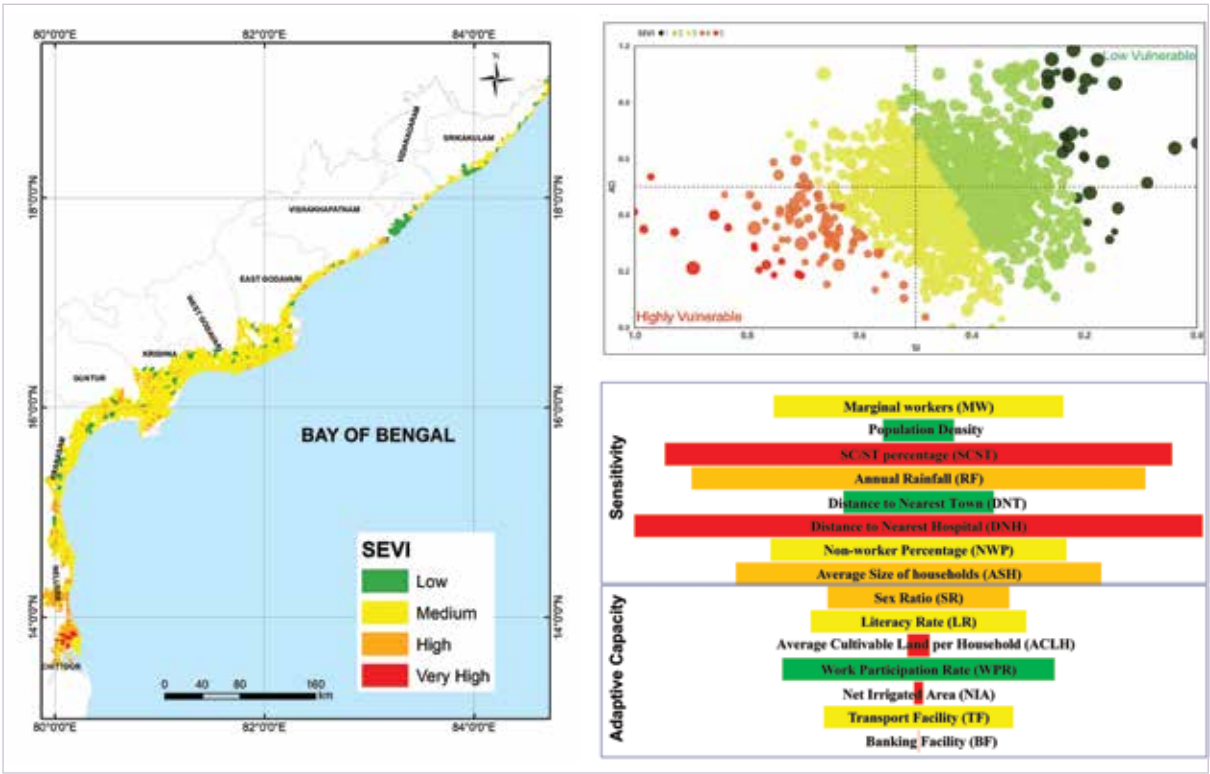


Figure 5.2.10. The Socioeconomic Vulnerability Index (SEVI) Framework (top) resultant SEVI map depicting the vulnerable coastal villages (a) and the decision matrix (b) highlights the vulnerability drivers (c) in each village.

Ref: *Mahendra, R.S., Mohanty, P.C., Francis, P.A., Sudheer Joseph, Balakrishnan Nair T. M. and Srinivasa Kumar T. (2023). Socioeconomic Vulnerability Assessment of Coastal Villages and Buildings along Andhra Pradesh East Coast of India. Environment, Development and Sustainability, https://doi.org/10.1007/s10668-023-03955-x*

5.2.8 Assessment of satellite-based Net Primary Productivity models in different biogeochemical provinces over the northern Indian Ocean

The study investigates the accuracy and variability of satellite-based Net Primary Productivity (NPP) models in different biogeochemical provinces of the northern Indian Ocean. Proper monitoring of phytoplankton primary production is crucial for understanding aquatic ecosystems' responses to global climate change and managing sustainable ecosystems. The study utilized MODIS-Aqua satellite data from 2003 to 2021 to assess five NPP models: VGPM, Eppley-VGPM, CbPM, CAFE, and SABPM. The results indicated that all models show significant seasonal variability in the ARAB and INDW regions, with two prominent peaks during the southwest and winter monsoons. The peak productivity was attributed to summer upwelling and winter mixing. The CbPM model performed the best, with a high coefficient of determination (R^2 = 0.77) and the lowest Mean Absolute Percentage Difference (MAPD = 38%) compared to in-situ measurements. The spatial variability analysis revealed that regions influenced by river discharge, particularly above 15°N in the Arabian Sea and east of 90°E in the Bay of Bengal, showed poor model performance. The Simpson's Diversity Index (SDI) analysis within NPP models revealed that the INDW province exhibited the highest variability (74.6–77.1%), followed by INDE (77.2–78.0%), ARAB (77.2–78.4%), and MONS (78.6–78.9%). The regions above 15°N and west of 60°E in the Arabian Sea and east of 90°E in the Bay of Bengal

exhibited the highest diversity, indicating significant influence from river discharge and physical processes affecting model performance (Figure 5.2.11). The study provides insights into the selection and utilization of appropriate NPP models for climate change studies and sustainable ecosystem management. Understanding the variability and accuracy of these models can enhance predictions and assessments of oceanic primary productivity, which is crucial for global carbon cycling and fisheries management.

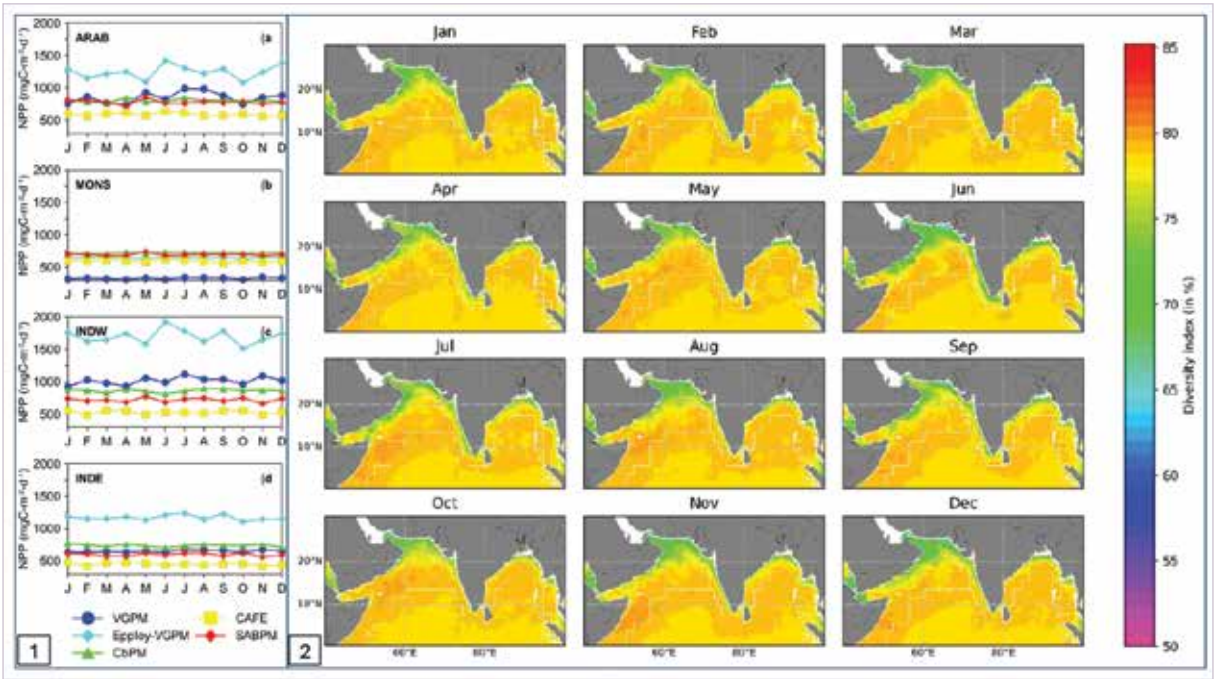


Figure 5.2.11. Temporal variability of Net Primary Productivity (NPP) derived using VGPM, Eppley-VGPM, CbPM, CAFE and SABPM models in (a) ARAB, (b) MONS, (c) INDW and (d) INDE ecological provinces. 2)Spatial distribution of Simpson's Diversity Index within NPP models at monthly climate scale

Ref: *Kalita, R., & Lotliker, A. A. (2023). Assessment of satellite-based Net Primary Productivity models in different biogeochemical provinces over the northern Indian Ocean. International Journal of Remote Sensing, 1–20. https://doi.org/10.1080/01431161.2023.2247533.*

5.2.9 The Anomalous 2012–13 Boreal Winter Oceanic Excitation of Earth's Polar Motion

It has been shown in an earlier study that Madden–Julian Oscillation (MJO) winds around the maritime continent drive a see-saw in oceanic mass between the Indian and Pacific oceans on intraseasonal time scales (30-80 days). During the boreal winter (December-April) of 2012–13, this see-saw facilitated about two-thirds of an unusually large (~ 30 mas, milliarcseconds) fluctuation in the oceanic excitation of Earth's polar motion about the 90°E meridian. Interestingly, the magnitude of the oceanic influence was nearly at par but out-of-phase with that of the atmosphere and a factor of ~ 10 larger than the effects associated with the hydrological cycle. This is unusual, given that the atmospheric influence is about an order of magnitude larger than the oceanic influence at these timescales. The oceanic influence arises from changes in the spatial distribution of oceanic mass and anomalies in the transport pattern. This study demonstrates, using a high-resolution global circulation model that oceanic mass changes and transport anomalies during the 2012–13 boreal winter were most pronounced in the Indo-Pacific basin (Figure 5.2.12). These changes exhibited a

favorable geometry to excite polar motion variations about the 90°E meridian. The 2012-13 boreal winter event was unique because there were phase alignments in the mass and motion excitation signal from different regions unlike events from other years. The Indian Ocean, followed by the Pacific Ocean acted as a dominant contributor to the 2012–13 polar motion excitation at MJO periods. Overall, ocean dynamics in the 10°–65°S latitudinal belt over the Indo-Pacific basin accounted for ~ 93% of the global intraseasonal oceanic excitation function during the 2012–13 winter. The processes figuring most prominently in modulating intraseasonal polar motion were mass rearrangements in the southern Indian Ocean and the south-east Pacific Ocean, the east Australian current, and the Antarctic circumpolar current around the Antarctic landmass. Wind-driven dynamics in the Southern Ocean thus appear to be the main cause for the 2012–13 oceanic excitation signal not attributable to the see-saw.

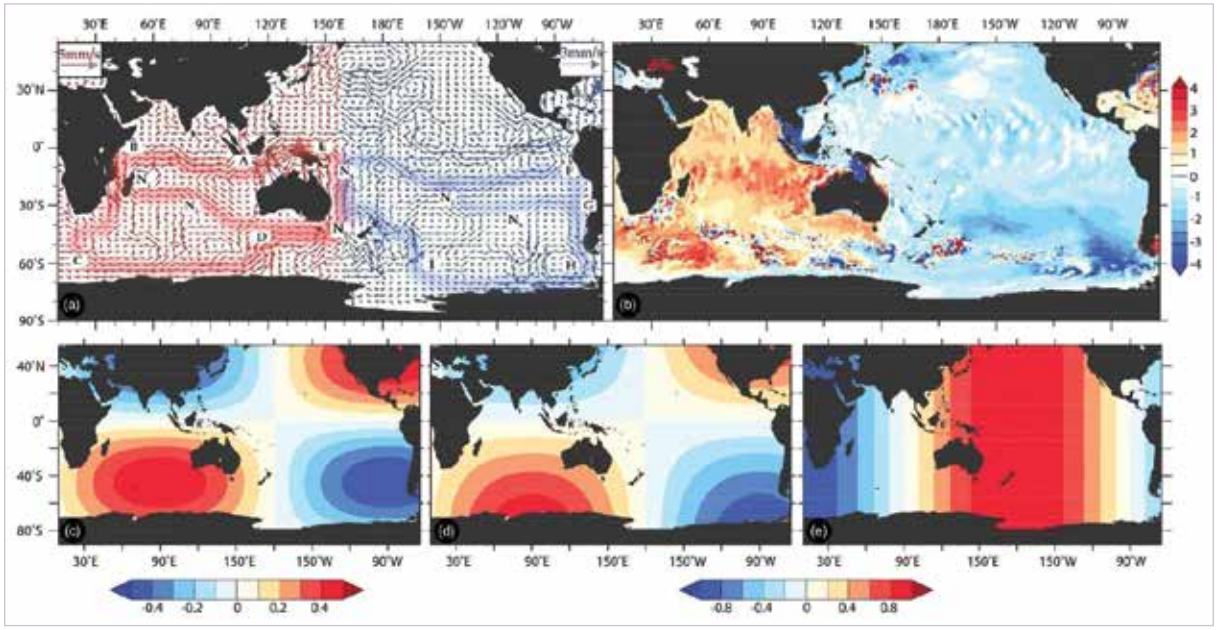


Figure 5.2.12. a) Intraseasonal barotropic circulation (unit = mm/s) in CTRL-EXP during the positive phase of the 2012 – 13 see-saw in the Indo-Pacific basin. The two different arrow colors (red and blue) correspond to different scales represented in the corresponding top corners. The basin-scale pathways in the Indian and Pacific basin are shaded. b) Intraseasonal Equivalent Water Height (unit = cm) in the Indo-Pacific basin from CTRL-EXP at the largest positive peak of the see-saw index. Weights associated with the polar motion excitation about the 90°E meridian are shown for signals due to c) ocean mass redistribution, d) zonal velocity and e) meridional velocity in the Indo-Pacific basin

Ref: *Paul, A., Afroosa, M., Rohith, B., Schindelegger, M., Durand, F., Bourdallé-Badie, R., & Shenoi, S. S. C. (2024). The Anomalous 2012–13 Boreal Winter Oceanic Excitation of Earth's Polar Motion. Pure and Applied Geophysics, 1-17. https://doi.org/10.1007/s00024-024-03429-9*

5.2.10 Diapycnal mixing induced by salt finger and internal tides on the northwest coast of India

The Arabian Sea is an important oceanic area as far as biogeochemistry and fisheries are concerned. A better understanding of the relative importance of different small-scale diapycnal mixing processes in these environments helps to accurately simulate physical and biogeochemical states by better representing these processes in the ocean general circulation models used for potential fishing zone advisories and water quality forecasting. The general notion is that internal wave-induced diapycnal

mixing might be the dominant process on the west coast of India throughout the water column. Microstructure measurements of velocity shear from the continental slope of the west coast of India (WCI) in the eastern Arabian Sea are used to quantify the relative importance of double diffusion and internal waves induced diapycnal mixing in the different depth regimes. This study demonstrates the first microstructure-based evidence of salt finger existence, particularly in the upper 200 m of the water column on the continental slope of the west coast of India (Figure 5.2.13). A moderately strong salt finger regime with a well-defined staircase structure is apparent in the upper 200 m of the water column, whereas internal wave-induced shear-driven mixing dominates the deeper portion. The present study highlights that diapycnal mixing associated with double diffusion and internal waves should be appropriately represented in the ocean general circulation model to accurately simulate the physical and biogeochemical state on the west coast of India.

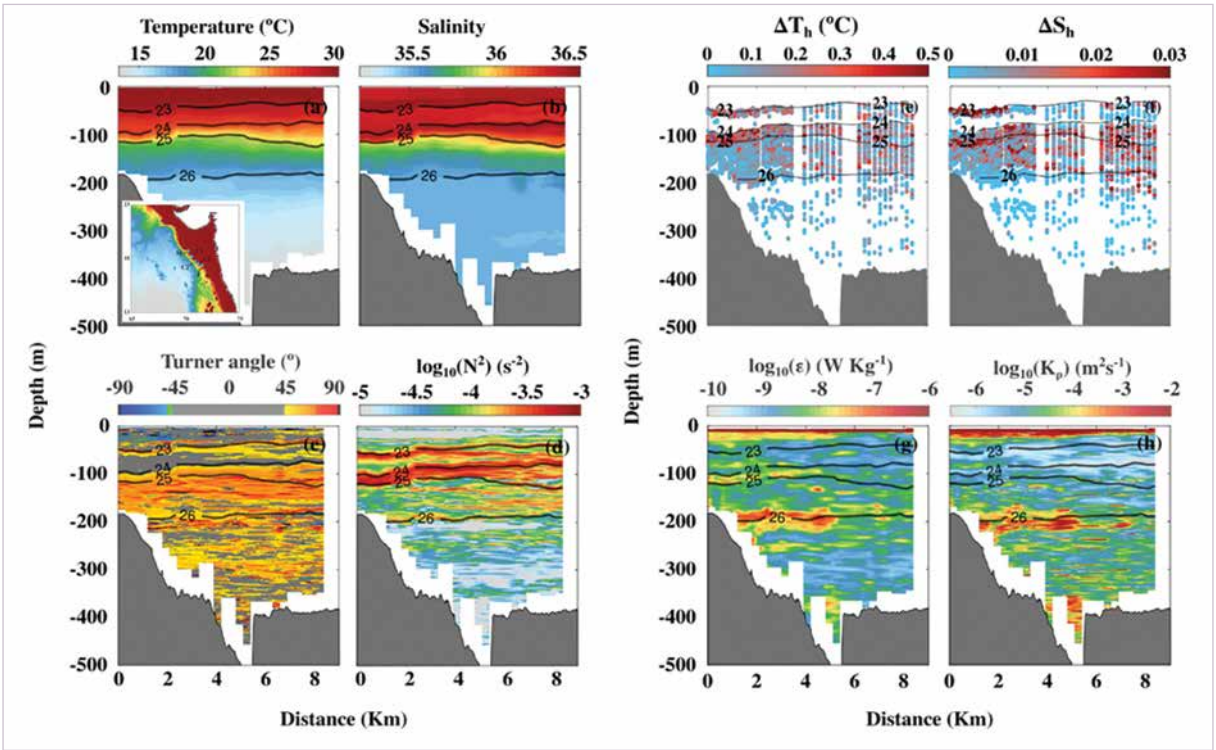


Figure 5.2.13. The vertical distribution of (a) temperature (°C), (b) salinity, (c) Turner angle (°) and (d) $\log_{10}$ (N^{-2}; s^{-2}), (e) the magnitude of temperature (ΔT_h), (f) salinity (ΔS_h;) difference across the staircase interface (g) $\log_{10}(\varepsilon)$ (W kg^{-1}), and (h) $\log_{10}(K_\rho)$ (m^2s^{-1}) from transect 2 in the continental slope of Jaigarh (~17.38°N, 71.56°E) between 24 May 2019 and 25 May 2019. The inset map in panel (a) is the SRTM15+V2.0 [Tozer et al., 2019] bathymetry (m) in the eastern Arabian Sea. In panel (a), the locations of transects at Mumbai (M; 18.73°N, 70.27°) and Jaigarh (J; 17.38°N, 71.56°E) and spot measurements at C1 (18.20°N, 70.60°E), C2 (17.76°N, 70.90°E), and C3 (17.55°N, 71.18°E) are marked in cyan filled circles. The grey contour represents the 400 m isobath.

Ref: *Girishkumar, M.S., Ashin, K., & Rama Rao, E.P. Diapycnal mixing induced by salt finger and internal tides on the northwest coast of India (2024) Continental Shelf Research, 273, art. no. 105172ISSN 0278-4343, https://doi.org/10.1016/j.csr.2024.105172.*

5.2.11 Impact of southern annular mode on Indian Ocean waves

SAM, a crucial interannual climate mode, modulates wave dynamics, influencing both distant swell and local wind-sea waves in the Indian Ocean. The research highlights how positive and negative SAM phases affect wave generation and propagation, aiding long-term wave prediction accuracy

in the region. The research utilized ERA5 reanalysis data spanning 40 years (1979-2018) to examine the seasonal and interannual variability of key wave parameters, including significant wave height (SWH), significant height of wind wave (SHWW), significant height of total swells (SHTS), and mean wave period (MWP) (Figure 5.2.14). During a positive SAM phase, two primary regions of swell generation in the IO are identified: the extratropical southern Indian Ocean (ETSI) and the tropical southern Indian Ocean (TSIO). Positive SAM phases cause a poleward shift of westerlies in the ETSI, reducing wave generation in the northern ETSI and diminishing swell propagation into the North Indian Ocean (NIO). Conversely, the western TSIO experiences positive wind anomalies, generating new swells that elevate wave heights in the Arabian Sea during monsoon seasons. Negative SAM phases enhance easterly winds in the TSIO, increasing swell activity in the Bay of Bengal, especially during pre-monsoon and monsoon seasons. The study also reveals the influence of SAM on the NIO wave climate through wind-sea interactions, mediated by shifts in the Hadley cell (HC) circulation. Positive SAM phases are linked to anomalous warming in the NIO and mid-latitudes, intensifying the HC and surface winds in subsequent seasons. This interaction termed the "SAM

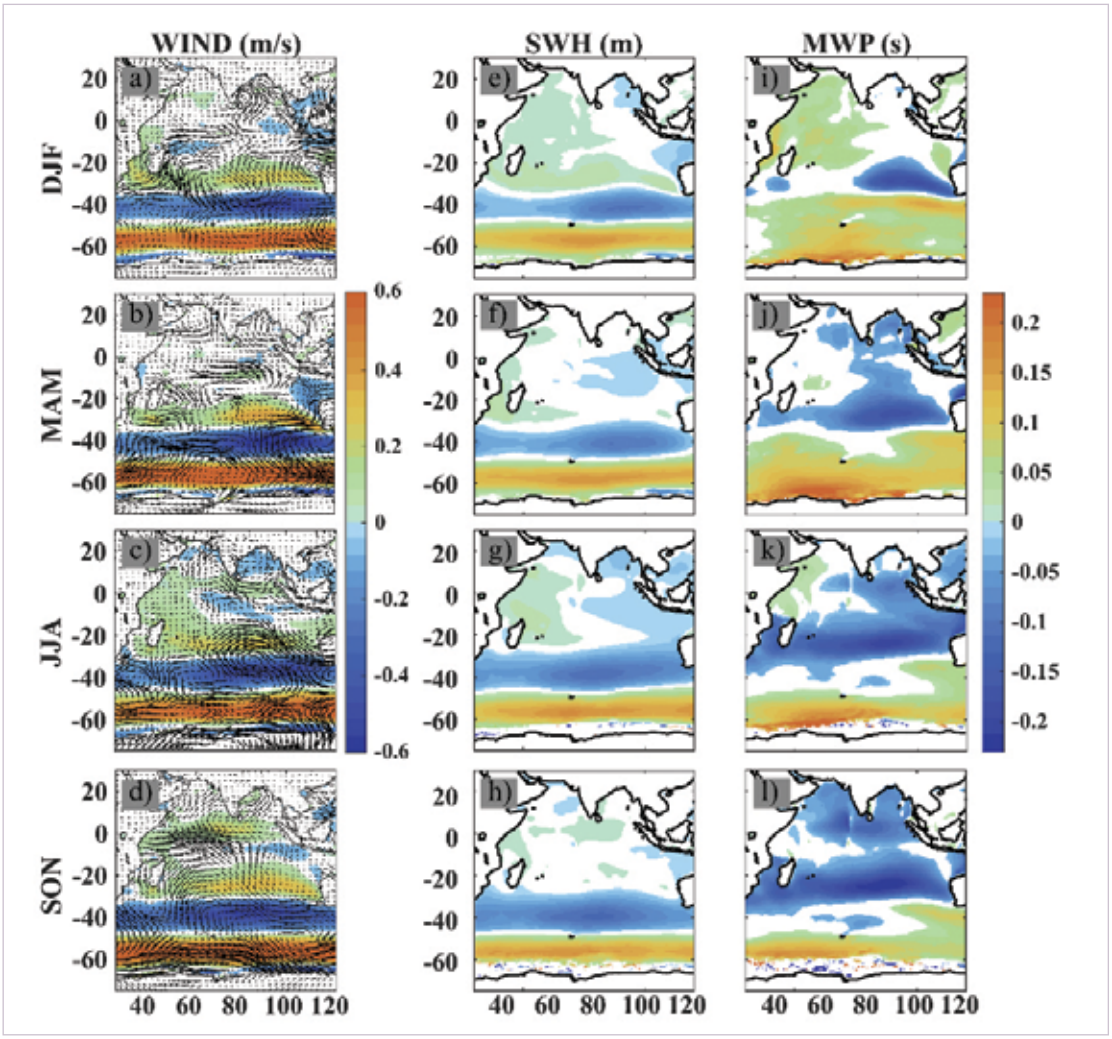


Figure 5.2.14. Regression pattern of wind(a-d), Significant wave height(e-h) and Mean Wave period(i-l)

Ref: *Sreejith, M., Remya, P.G., Praveen Kumar, B., Srinivas, G., & Balakrishnan Nair, T.M. (2023). Impact of southern annular mode on the Indian Ocean surface waves. International Journal of Climatology, 43(16): 7606–7617. https://doi.org/10.1002/joc.8282*

Positive Anomaly Wind-SST Oscillations (SPAWSO)," acts as a delayed, season-dependent positive air-sea interaction cycle, significantly impacting wind-sea dynamics. These findings enhance long-term wave prediction accuracy in the IO by integrating both direct swell influences and SPAWSO-driven wind-sea changes, providing insights for coastal planning and disaster preparedness amid evolving climate conditions.

5.2.12 A study of forecast sensitivity to observations in the Bay of Bengal using LETKF

Observing System Experiment (OSE) is an integral part of the operational forecasting system that identifies the bad (detrimental) observations from the good (beneficial) observations in order to improve forecast skills. In an OSE, a continuous assimilation-forecast cycle is run, assimilating as well as denying a particular set of real observations, and the results from these simulations are compared to assess the impacts of that set of observations on NWP forecasts. Being a data denial experiment, OSE is a resource-consuming experiment. Ensemble Forecast Sensitivity to Observations (EFSO) can evaluate the impact of each and every assimilated observation simultaneously. It is a faster and less resource-consuming alternative to traditional OSE. EFSO was not implemented for ocean models earlier because of the unavailability of a proper weight matrix that helps in evaluating the impact of observations. A novel weight matrix formed from the norm of the baroclinic vector has recently been developed, proving efficient for the Bay of Bengal (Figure 5.2.15). This method segregates the impact of each observation (temperature, salinity, and surface temperature) at every model grid point for every vertical layer at each assimilation step as beneficial or detrimental observation. On average, only 50% of observations of each type are found to be beneficial. The model that assimilates only beneficial observations is more efficient in simulating surface currents near the coast, subsurface currents in deep water, and thermocline depth. The improvement is prominent in higher stratified regions like the head of the Bay of Bengal.

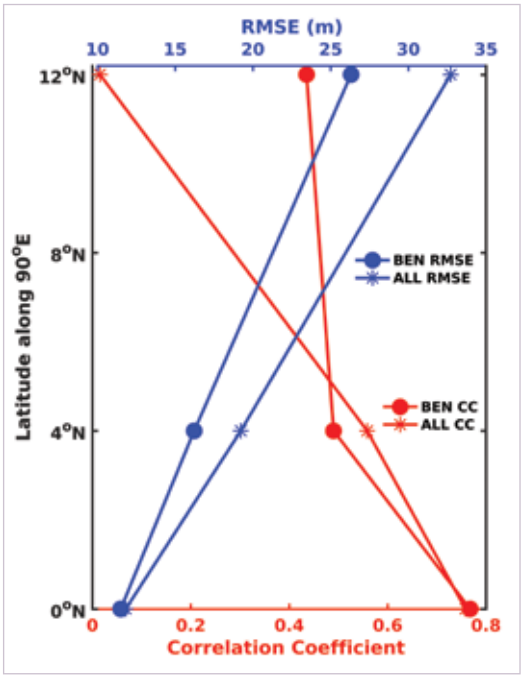


Figure 5.2.15. Model simulations with only beneficial (BEN) and all (ALL) observations: BEN continues to increase (decrease) Correlation (RMSE) compared to ALL as we approach northwards on the Bay of Bengal. BEN is more efficient than ALL in simulating subsurface characteristics (thermocline depth) in higher stratified regions.

Ref: *Paul, B., Baduru, B., & Paul, A. (2024). A study of forecast sensitivity to observations in the Bay of Bengal using LETKF. Frontiers in Marine Science, 11, 1340129.*

5.2.13 Mechanisms and drivers controlling spatio-temporal evolution of pCO_2 and air-sea CO_2 fluxes in the southern Java coastal upwelling system

This study investigates the complex dynamics of surface pCO_2 in the upwelling system off the southern coast of Java during the southeast monsoon (SM), utilizing a sophisticated coupled, high-resolution regional model (Figure 5.2.16). Through a detailed decomposition analysis, the study

assesses the contributions of various factors such as surface temperature (T), surface salinity (S), dissolved inorganic carbon (DIC), and total alkalinity (ALK) to changes in pCO_2 over different time scales. This study reveals that during the SM, the upwelling of deeper, cooler waters leads to a reduction in surface pCO_2, while the presence of DIC-rich waters at shallower depths tends to elevate it. Additionally, biological processes exert an influence, contributing to an increase in surface pCO_2. Despite the influence of biological factors, the study emphasizes the predominant role of physical mechanisms, particularly those related to upwelling, in driving the reduction of surface pCO_2 during the SM. This study highlights the significance of understanding and accounting for these physical processes in assessing carbon dynamics in upwelling systems. Moreover, the study suggests that the southern coast of Java acts as a seasonal sink for CO_2 during the SM, although the region is observed to be a net source of CO_2 over a longer period from 2006 to 2017. Notably, following a negative Indian Ocean Dipole (IOD) year, the region acts as a sink of atmospheric CO_2 during the SM.

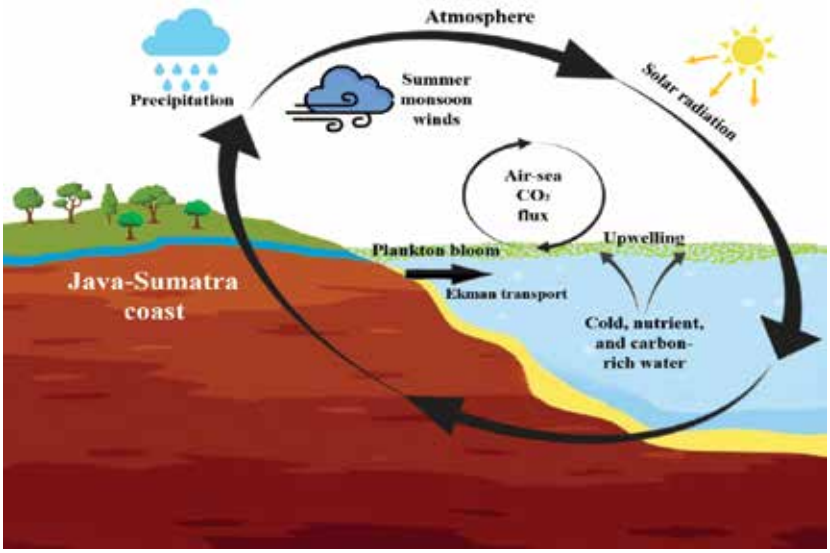


Figure 5.2.16. A schematic representation of the processes controlling air-sea CO_2 flux in a coastal upwelling region.

Ref: *Chakraborty, K., Joshi, A. P., Ghoshal, P. K., Ghosh, J., Akhand, A., Bhattacharya, T., ... & Valsala, V. (2023). Mechanisms and drivers controlling spatio-temporal evolution of pCO_2 and air-sea CO_2 fluxes in the southern Java coastal upwelling system. Estuarine, Coastal and Shelf Science, 293, 108509.*

5.2.14 An assessment of air-sea CO_2 flux parameterizations during tropical cyclones in the Bay of Bengal

The interactions between the ocean and the atmosphere lead to exchanges of gases, particles, momentum, and energy across the interface. Of particular interest to researchers is the exchange of CO_2 because of its possible long-term impacts on the global climate. In this context, extreme transient events like tropical cyclones (TCs), which can effectuate enhanced effluxes of CO_2 from the ocean to the atmosphere, play an important role in controlling the global carbon cycle. The transfer of momentum, moisture, and heat across the sea-air boundary can be calculated by tracer diffusion methods, eddy covariance, inertial dissipation, co-spectral peak methods, gradient-flux method (budget methods), and bulk parameterizations. Bulk parameterization is known to hold well in moderate wind regimes (3–15 m/s). However, at the lowest (<3 m/s) and highest (>15 m/s) wind speed ranges, the bulk formulation over- and underestimates the drag, respectively. Characterizing turbulent fluxes across the air-sea boundary is an important step in parameterization of gas transfer. The computation of CO_2 flux is dependent on the solubility of CO_2 in water, the partial pressure

difference of CO_2 between air and sea, and a transfer velocity parameter that denotes the efficiency of transfer across the interface.

This study assesses the performance of different types of parameterizations to estimate turbulent transfers of momentum and the resultant CO_2 fluxes during eight TCs passing over the Bay of Bengal (Figure 5.2.17). The comparison of the estimated CO_2 transfer velocity in this study with those from wind-wave tank experiments reveals that among wind parameterizations, the hybrid parameterization proposed by Nightingale et al. (2000) comes out to be closest (magnitude) to experimental values in the high wind speed regime while all other linear and quadratic parameterizations underestimate transfer velocities at high winds. Both the wave-dependent parameterizations of CO_2 transfer velocity considered in this study perform better than all wind-only parameterizations when compared with available experimental measurements.

Globally, the quadratic formulation is widely accepted and applied for gas transfer and CO_2 flux computations. The OCMIP and its participating models, the GLODAP, the global database of surface SOCAT, and even global carbon emission budgets estimate CO_2 fluxes using quadratic parameterization. Coupled ocean-atmosphere-ecosystem models like the NEMO, CMIP phases, HWRF-COAWST, WRF-ROMS, HYCOM, and a suite of other models dedicated to climate research implement the bulk parameterization of momentum and gas transfer. The present study reveals that the uncertainties arising out of the choice of wind products, data-filling techniques in regions of low spatial coverage of satellite measurements, and other factors are far less important compared to the uncertainties in flux estimates due to the choice of parameterization, especially in very high wind speed regimes. Therefore, the segregation of estimation techniques of fluxes and carbon budgets under extreme conditions is paramount in helping the convergence of the community efforts of model-data inter-comparisons.

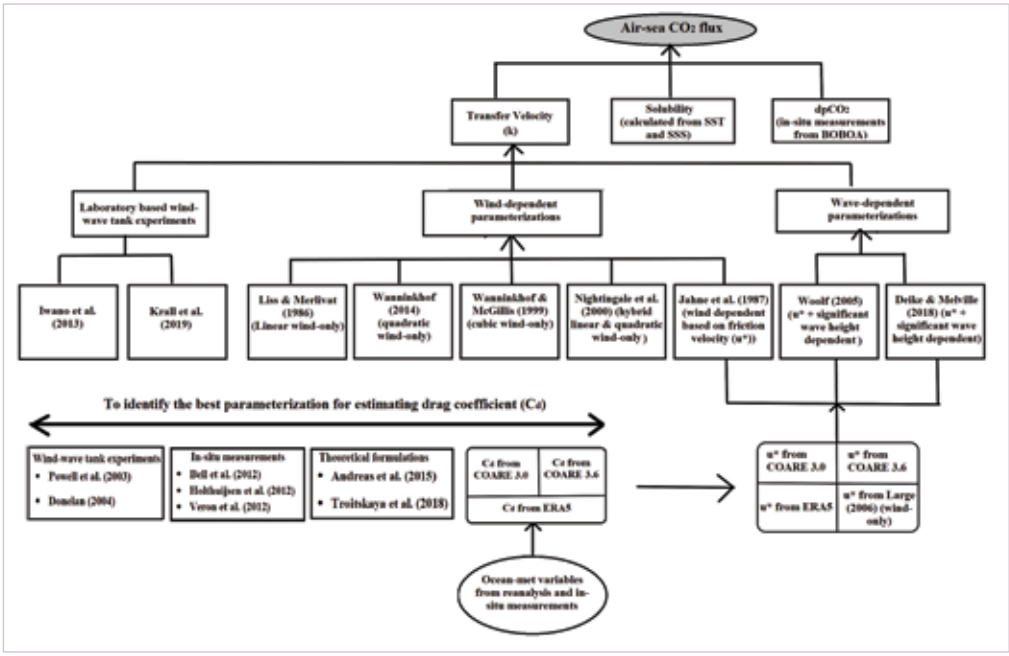


Figure 5.2.17. A schematic representation of the workflow of the methodology adopted for analysis in our study.

Ref: *Bhattacharya, T., Chakraborty, K., Anthoor, S., & Ghoshal, P. K. (2023). An assessment of air-sea CO_2 flux parameterizations during tropical cyclones in the Bay of Bengal. Dynamics of Atmospheres and Oceans, 103, 101390.*

5.2.15 Sea-surface pCO_2 maps for the Bay of Bengal based on advanced machine learning algorithms

The increasing anthropogenic activities have led to the rise of carbon dioxide (CO_2) in the atmosphere. The constant rise in this atmospheric CO_2 in the ever-changing climate may lead to hazardous effects on human health. Ocean has played a key role in modulating this atmospheric CO_2. The ocean surface, through gas exchange, absorbs or emits CO_2. The amount of CO_2 in a liquid or gas environment is often referred to by its partial pressure. This partial pressure of CO_2 is abbreviated as pCO_2. The mathematical sign (positive/ negative) of the difference between the atmospheric and ocean surface pCO_2 shows whether the ocean is absorbing (positive difference) or emitting (negative difference) CO_2. The amount of CO_2 absorbed or emitted by the ocean is quantified as air-sea CO_2 flux. The Bay of Bengal (BoB) has unique physical characteristics compared to other world ocean basins. BoB receives high freshwater influx from rivers and precipitation. The reversing coastal currents due to the seasonal reversing winds play a vital role in changing the physical and biogeochemical characteristics of this basin. Understanding the spatial and temporal variations of the sea-surface pCO_2 for the BoB has been limited due to the unavailability of sufficient observations. The limited number of observations results in high prediction errors in the machine learning (ML) based available products for the BoB. Using a significant number of open and coastal ocean pCO_2 measurements and collocated variables controlling pCO_2 variability in the BoB, an ML-based high-resolution (1/12°) climatological data product (known as INCOIS-ReML) has been developed, which provides sea-surface climatological (mean state) pCO_2 maps and associated air-sea CO_2 fluxes for the BoB (Figure 5.2.18). The capability

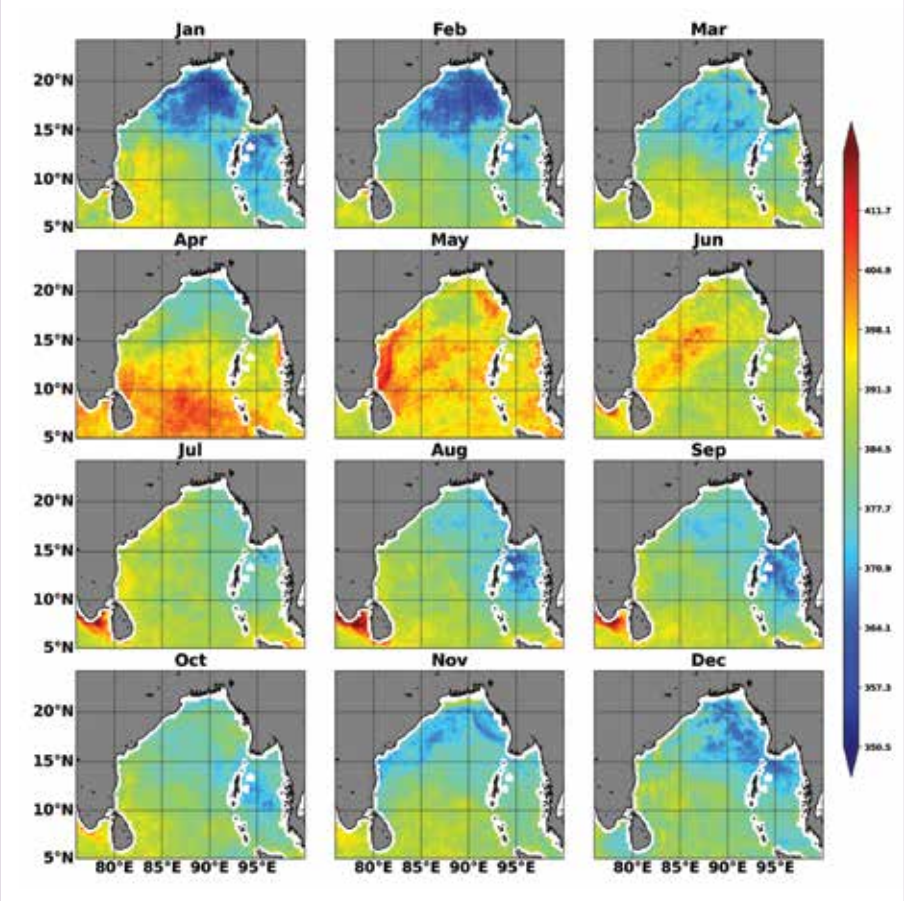


Figure 5.2.18. Climatological monthly variability of the sea-surface pCO_2 produced by INCOIS-ReML. The climatological reference year for this dataset is 2015.

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

of INCOIS-ReML has been demonstrated by comparing it with sea-surface pCO_2 data from the BoB Ocean Acidification mooring-based observations and gridded Surface Ocean CO_2 Atlas (SOCAT) data. INCOIS-ReML has been found to be performing better than six widely used ML-based pCO_2 data products. The high-resolution INCOIS-ReML captures the spatial variability of pCO_2, and associated air-sea CO_2 flux compared to other ML products in the coastal BoB and the northern BoB. This data product is expected to help the researchers distinguish the source/sink behavior of the BoB, which essentially improves the Indian Ocean carbon budget in a changing environment.

5.3 List of Research Publications during April 2023 March 2024

1 Adhikari, A., Menon, H.B., Lotliker, A. Coupling of hydrography and bio-optical constituents in a shallow optically complex region using ten years of in-situ data (2023) ISPRS Journal of Photogrammetry and Remote Sensing, 202, pp. 499-511. DOI: 10.1016/j.isprsjprs.2023.07.014

2 Acharyya, T., Das, D.B., Raulo, S., Srichandan, S., Baliarsingh, S.K., Singh, S., Sudatta, B.P., Sahoo, C.K. Surviving in a warming and crowded world: a review of Irrawaddy dolphin in Asia's largest brackish water lagoon (2023) Journal of Coastal Conservation, 27 (5), art. no. 50, . DOI: 10.1007/s11852-023-00982-8

3 Acharyya, T., Raulo, S., Singh, S., Sudatta, B.P., Srichandan, S., Baliarsingh, S.K., Samal, R.N., Sahoo, C.K. Status and conservation challenges of the second-largest seagrass bed in India: Chilika lagoon (2023) Environmental Science and Pollution Research, 30 (45), pp. 100265-100281. DOI: 10.1007/s11356-023-29369-w

4 Acharyya, T., Sudatta, B.P., Das, D.B., Srichandan, S., Baliarsingh, S.K., Raulo, S., Singh, S., Samal, R.N., Mishra, M., Bhat, I. Irrawaddy dolphin in Asia's largest brackish water lagoon: A perspective from SWOT and sentiment analysis for sustainable ecotourism (2023) Environmental Development, 46, art. no. 100863, . DOI: 10.1016/j.envdev.2023.100863

5 Afroosa, M., Rohith, B., Paul, A., Durand, F., Bourdallé-Badie, R., Shenoi, S.S.C. The MJO-driven Indo-Pacific barotropic see-saw (2023) Deep-Sea Research Part I: Oceanographic Research Papers, 199, art. no. 104104, . DOI: 10.1016/j.dsr.2023.104104

6 Anjana, S., Chatterjee, A., Han, W., Prerna, S., Sajidh, C.K. Role of Oceanic Internal Instability in the Generation of Low-Frequency Variability in the Indian Ocean (2023) Geophysical Research Letters, 50 (9), art. no. e2022GL102489, . DOI: 10.1029/2022GL102489

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8 Arya, K.S., Gireeshkumar, T.R., Vignesh, E.R., Muraleedharan, K.R., Abdul Jaleel, K.U., Abdul Razaque, M.A., Furtado, C.M., Sudheesh, V., Balakrishnan Nair, T.M., Krishnamohan, K.S. Dynamics of nitrous oxide and methane in the southeastern Arabian Sea (2024) Marine Chemistry, 258, art. no. 104333, .DOI: 10.1016/j.marchem.2023.104333

9 Aswathy, V.S., Girishkumar, M.S., Athulya, K. Seasonal and intraseasonal modulation of near-inertial wind power associated with fluctuations in unidirectional wind speed in the Bay of Bengal (2024) Ocean Dynamics, 74 (2), pp. 81-95. DOI: 10.1007/s10236-023-01589

10 Balakrishnan Nair, T.M., Sarma, V.V.S.S., Lotliker, A.A., Muraleedharan, K.R., Samanta, A., Baliarsingh, S.K., Shivaprasad, S., Gireeshkumar, T.R., Raulo, S., Vighneshwar, S.P., Shesu, R.V., Krishna, M.,

Kumar, N.K., Naik, R.C., Joseph, S., Annapurnaiah, K., Rao, E.P.R., Srinivasa Kumar, T. An integrated buoy-satellite based coastal water quality nowcasting system: India's pioneering efforts towards addressing UN ocean decade challenges (2024) Journal of Environmental Management, 354, art. no. 120477. DOI: 10.1016/j.jenvman.2024.120477

11 Baliarsingh, S.K., Dash, B., Jena, A.K., Raulo, S., Samanta, A., Joseph, S., Balakrishnan Nair, T.M., Srichandan, S., & Sureshkumar, S. (2024). Investigating Indian Oil Sardine aggregation events in coastal waters of the southeastern Arabian Sea. Environmental Science and Pollution Research, 31(23), pp. 34271-34281. DOI: 10.1007/s11356-024-33519-z

12 Baliarsingh, S.K., Jena, A.K., Srichandan, S., Raulo, S., Joseph, S., Balakrishnan Nair, T.M., Barik, K.K. A scientific basis for fish mass mortality and jellyfish beach stranding in relation to cyclone yaas (2023) Journal of Coastal Conservation, 27 (2), art. no. 15, . DOI: 10.1007/s11852-023-00944-0

13 Bhattacharya, T., Chakraborty, K., Anthoor, S., Ghoshal, P.K. An assessment of air-sea CO2 flux parameterizations during tropical cyclones in the Bay of Bengal (2023) Dynamics of Atmospheres and Oceans, 103, art. no. 101390, . DOI: 10.1016/j.dynatmoce.2023.101390IF

14 Biswamoy Paul, Balaji B, Arya Paul, A study of forecast sensitivity to observations in the Bay of Bengal using LETKF, Frontiers in Marine Science, DOI: 10.3389/fmars.2024.1340129

15 Chakraborty, K., Joshi, A.P., Ghoshal, P.K., Ghosh, J., Akhand, A., Bhattacharya, T., Sreeush, M.G., Valsala, V. Mechanisms and drivers controlling spatio-temporal evolution of pCO_2 and air-sea CO_2 fluxes in the southern Java coastal upwelling system (2023) Estuarine, Coastal and Shelf Science, 293, art. no. 108509, . DOI: 10.1016/j.ecss.2023.108509

16 Chakraborty, T., Pattnaik, S., Joseph, S. Influence of tropical cyclone Jawad on the surface and sub-surface circulation in the Bay of Bengal: ocean–atmosphere feedback (2023) Ocean Dynamics, . DOI: 10.1007/s10236-023-01572-w

17 Dall'Olmo, G., Bhaskar TVS, U., Bittig, H., Boss, E., Brewster, J., Claustre, H., Donnelly, M., Maurer, T., Nicholson, D., Paba, V., Plant, J., Poteau, A., Sauzède, R., Schallenberg, C., Schmechtig, C., Schmid, C., Xing, X. Real-time quality control of optical backscattering data from Biogeochemical-Argo floats (2023) Open Research Europe, 2, art. no. 118, . DOI: 10.12688/openreseurope.15047.2

18 Gadgil, S., Cane, M.A., Francis, P.A. On rogue La Niñas, with below-average monsoon rainfall (2023) Journal of Earth System Science, 132 (3), art. no. 111, . DOI: 10.1007/s12040-023-02121

19 Ghosh, J., Chakraborty, K., Valsala, V., Bhattacharya, T., Kanti Ghoshal, P. A review of the Indian Ocean carbon dynamics, acidity, and productivity in a changing environment (2024) Progress in Oceanography, 221, art. no. 103210, .DOI: 10.1016/j.pocean.2024.103210

20 Girishkumar, M.S., Ashin, K., Rama Rao, E.P. Diapycnal mixing induced by salt finger and internal tides on the northwest coast of India (2024) Continental Shelf Research, 273, art. no. 105172,. DOI: 10.1016/j.csr.2024.105172

21 Janet Sprintall, Motoki Nagura, Juliet Hermes, M. K. Roxy, Michael J. McPhaden, E. Pattabhi Rama Rao, Srinivasa Kumar Tummala, Sidney Thurston, Jing Li, Mathieu Belbeoch, Victor Turpin. COVID Impacts Cause Critical Gaps in the Indian Ocean Observing System. (2024), Bulletin of American Meteorological Society, Volume: 105, Issue: 3, Pg: E725-E741.DOI: https://doi.org/10.1175/BAMS-D-22-0270.1

22 Jha, R.K., Udaya Bhaskar, T.V.S. Generation and Assessment of ARGO Sea Surface Temperature Climatology for the Indian Ocean Region (2023) Oceanologia, 65 (2), pp. 343-357. DOI: 10.1016/j.oceano.2022.08.001IF

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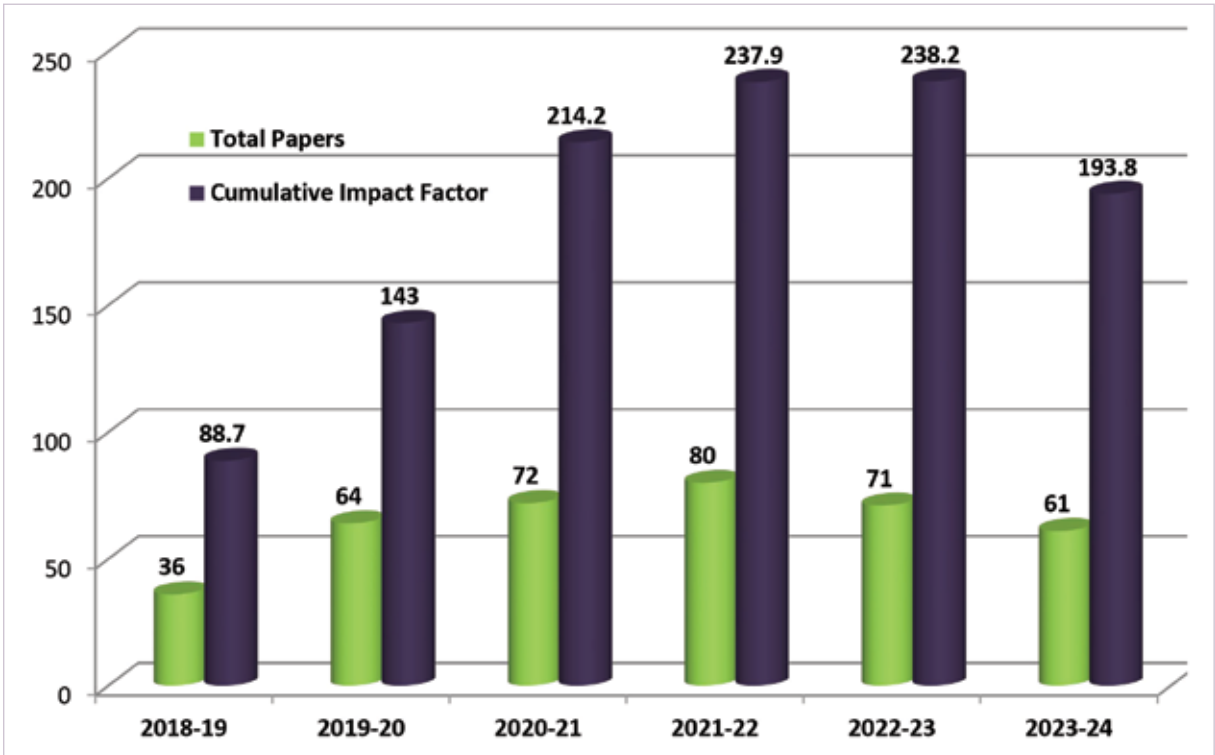


Figure 5.2.19. Growth of publications in peer review journals and their cumulative impact factor

6

OCEAN OBSERVATION NETWORK (OON)

6.1 In-situ Ocean Observation Network (OON)

INCOIS efforts towards sustaining the in-situ ocean observation network as a contribution to a Global Ocean Observing System (GOOS) and to facilitate the development and improvement of various operational ocean forecast services continued during the last year. The COVID-19 pandemic generated significant gaps in the many INCOIS *in-situ* ocean observation networks over the Indian Ocean, and it was primarily due to the non-availability of ship time, scarcity of hardware, spares, and sensors due to a break in the global supply chain. During the reporting period, INCOIS revived full-fledged procurement and deployment activities, and as a result, most platforms reached close to the proposed targets. The progress of the INCOIS in-situ ocean observation network is summarized below. The progress under each observation platform under OON during the period from April 2023 to March 2024 is summarized below.

6.2 Argo programme

Figure 6.1. INCOIS scientists are deploying BGC Argo float from Sagar Nidhi in the Bay of Bengal

During the 2023-24 period, INCOIS deployed 44 Argo floats in the tropical Indian Ocean. These deployments include 40 core Argo floats with temperature and salinity sensors and 04 BioGeoChemical (BGC) Argo floats (Figures 6.1 and 6.2). With these deployments, INCOIS contributed 538 Argo floats to the international Argo programme from inception. Currently, 72 Argo floats, including 59 core Argo and 13 BGC floats, are active and transmitting data to the INCOIS ground station. To further enhance the existing float network, INCOIS placed a purchase order for the procurement of another 50 floats, which are expected to be delivered by the end of 2024.

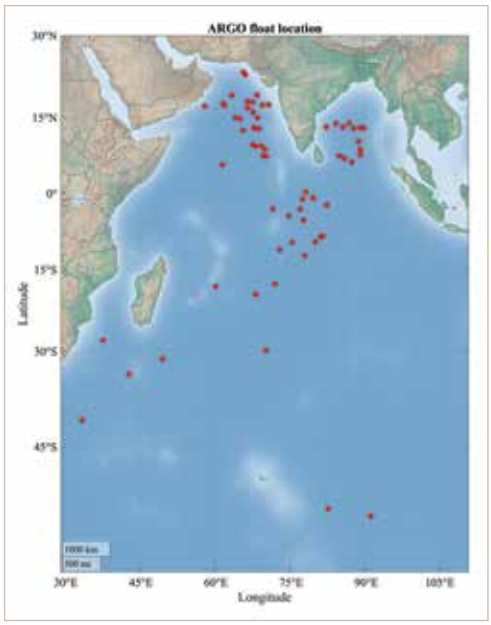


Figure 6.2. The locations of Indian active floats as of 15 May 2024

6.3 SVP-Drifter Buoy programme

INCOIS continued to support the global drifting buoy programme by deploying 5 Marlin Yug drifters equipped with sea surface temperature and barometric pressure

sensors in the Arabian Sea. Nine drifters were active during the reporting period (Figures 6.3 and 6.4). In addition, the deployment of 10 indigenous drifters is scheduled for June-July 2024, and the procurement of 20 indigenous drifters is in progress.

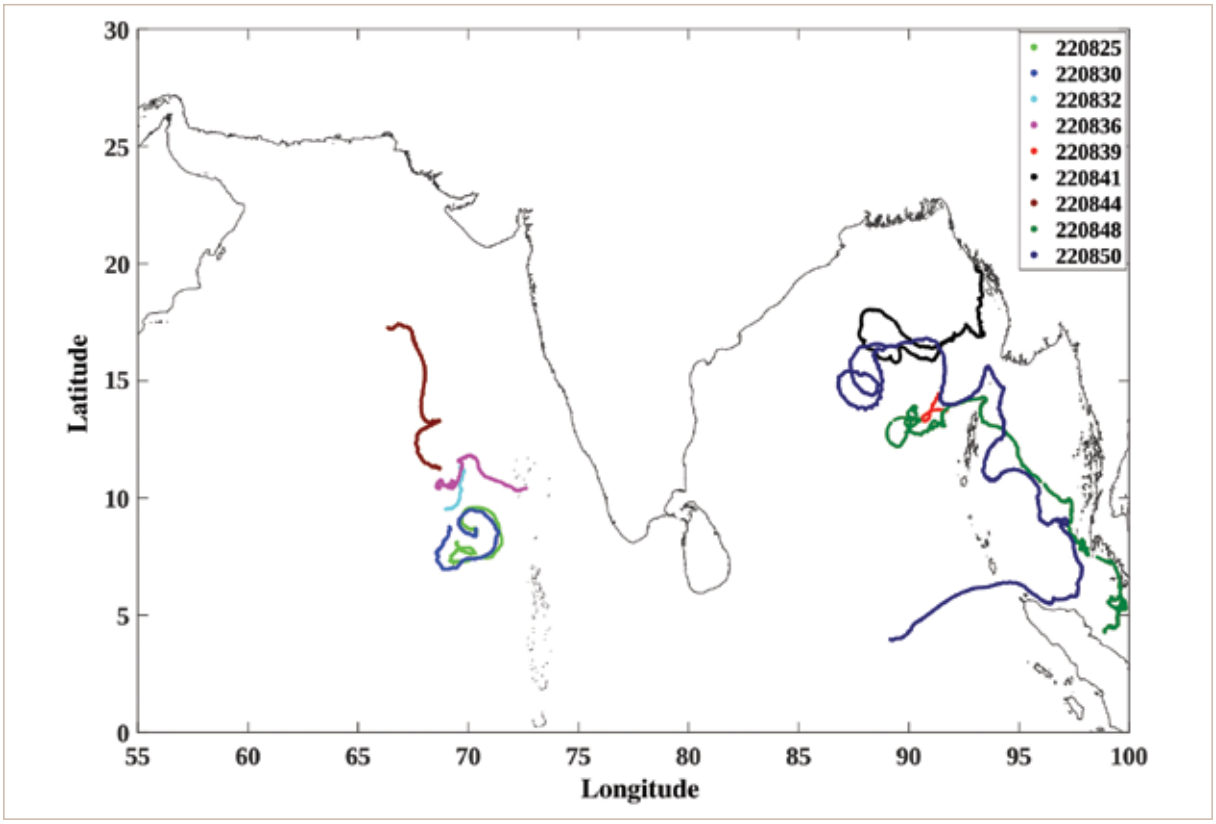


Figure 6.3. INCOIS SVP-drifter track from April 2023 to March 2024

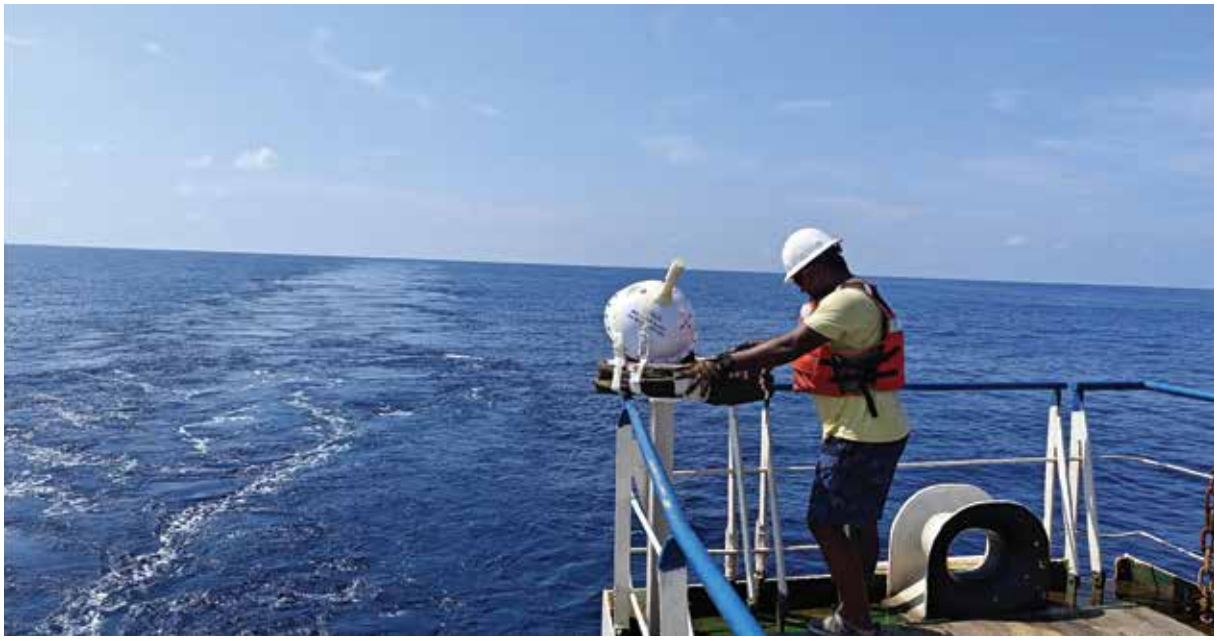


Figure 6.4. INCOIS scientist is deploying an SVP drifter from Sagar Nidhi in the Bay of Bengal

6.4 ADCP mooring array

In collaboration with Council of Scientific & Industrial Research (CSIR) - National Institute of Oceanography (NIO), Goa INCOIS has maintained 17 coastal ocean moorings along India's west and east coasts and three moorings in the equatorial Indian Ocean (Figure 6.5). As part of recovery and re-deployment of these mooring as part of annual maintenance, two cruises were carried out onboard Sindhu Sankalp (SSK163: 06-18 December 2023; SSK168: 26 February - 08 March 2024), and one cruise was carried out onboard Sindhu Sadhana (SSD088:06-23 November 2023) (Figure 6.6). At present, all these buoys are in position.

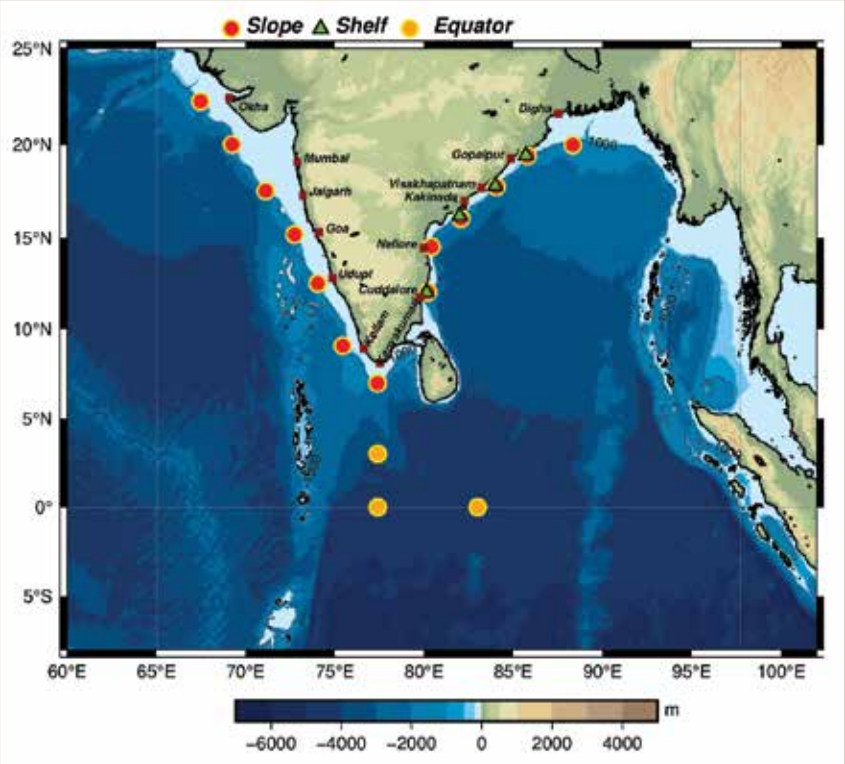


Figure 6.5. The present status of the ADCP mooring array along the east and west coasts of India and the equatorial Indian Ocean

Figure 6.6. Deployment and recovery of equatorial current meter array

6.5 eXpendable Bathy Thermographs (XBT) / XCTD transects

In collaboration with the CSIR-NIO, Goa Council of Scientific & Industrial Research (CSIR) - National Institute of Oceanography (NIO), 12 XBT/XCTD transects were carried out along the Chennai-Port Blair, Port Blair-Visakhapatnam, and Port Blair-Kolkata during the reporting period. 94 XBT profiles and 125 sea surface salinity samples along the Chennai-Port Blair transect, 20 XBT profiles, 11 XCTD profiles, and 76 sea surface salinity samples along the Port Blair-Visakhapatnam transect and 11 XCTD profiles and 44 sea surface salinity samples along Port Blair-Kolkata transects were collected during the reporting period (Figure 6.7). Further, the real-time XBT data transmission through the INSAT satellite was successfully performed at CSIR-NIO. In addition, weekly sampling for sea surface salinity at ten stations along the east coast of India was continued.

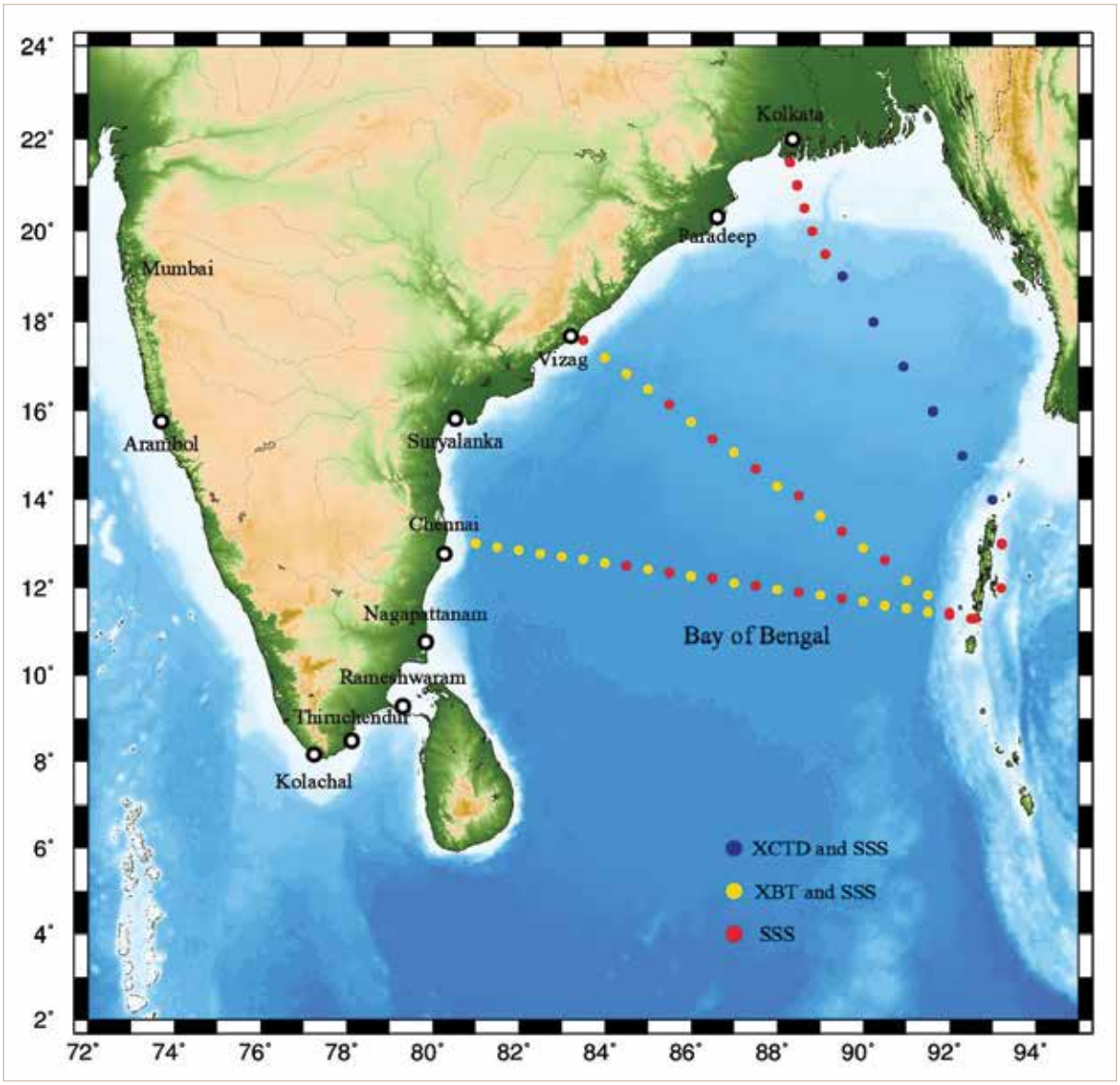


Figure 6.7. Data density map of XCTD (blue circles)/XCTD (yellow circles) profiles and sea surface salinity sample locations (red circle) in the Bay of Bengal from April 2023 to March 2024. The white closed circle along the east coast of India represents the location of the weekly sea surface salinity sampling location

6.6 Tsunami buoy

To support tsunami monitoring and warning services, a network of 7 tsunami buoys is maintained in the northern Indian Ocean (Figure 7.8). During the reporting period, INCOIS meticulously performed maintenance activities on the SAIC tsunami buoy network to ensure the reliability and efficacy of the tsunami monitoring and warning services. For this purpose, a scientific cruise onboard RV Sagar Nidhi was undertaken in the Bay of Bengal and Arabian Sea from 16 September to 17 October 2023. The operations included the successful recovery of the bottom pressure recorder at the STB05 location in the Bay of Bengal and the deployment of a new tsunami buoy system at STB-01 in the Bay of Bengal (Figure 6.9). In addition, the old system at the STB02 site was retrieved, and the new system was deployed as part of the maintenance process. At present, two SAIC buoys and two NIOT tsunami buoys provide data in real time.

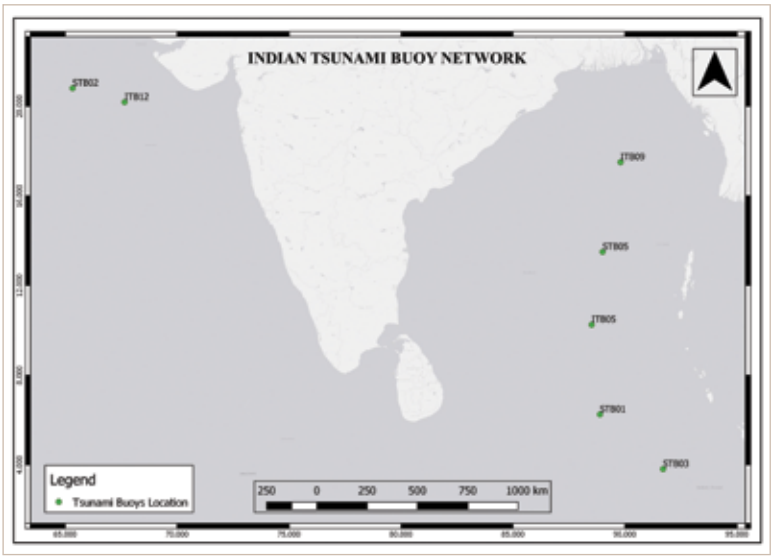


Figure 6.8. The Tsunami buoy network in the north Indian Ocean

Figure 6.9. INCOIS scientists during the deployment and recovery of the bottom pressure recorder and tsunami buoy

6.7 Marine AWS network

To collect near-surface meteorological parameters for a better understanding of the air-sea interaction processes in the north Indian Ocean, INCOIS installed automatic weather station onboard 34 vessels managed by NCPOR, NIOT, GSI, NIO, CMLRE, SCI, FSI, LDCL, and NHO. At present, 10 AWS reports data in real-time. AWS systems onboard INS Nirupak and MV Chowra were decommissioned during this period. A site survey has been conducted to install a new AWS system onboard MFV Lavanika. INCOIS is in the process of upgrading the existing AWS systems with the latest technology.

6.8 Tide gauge network

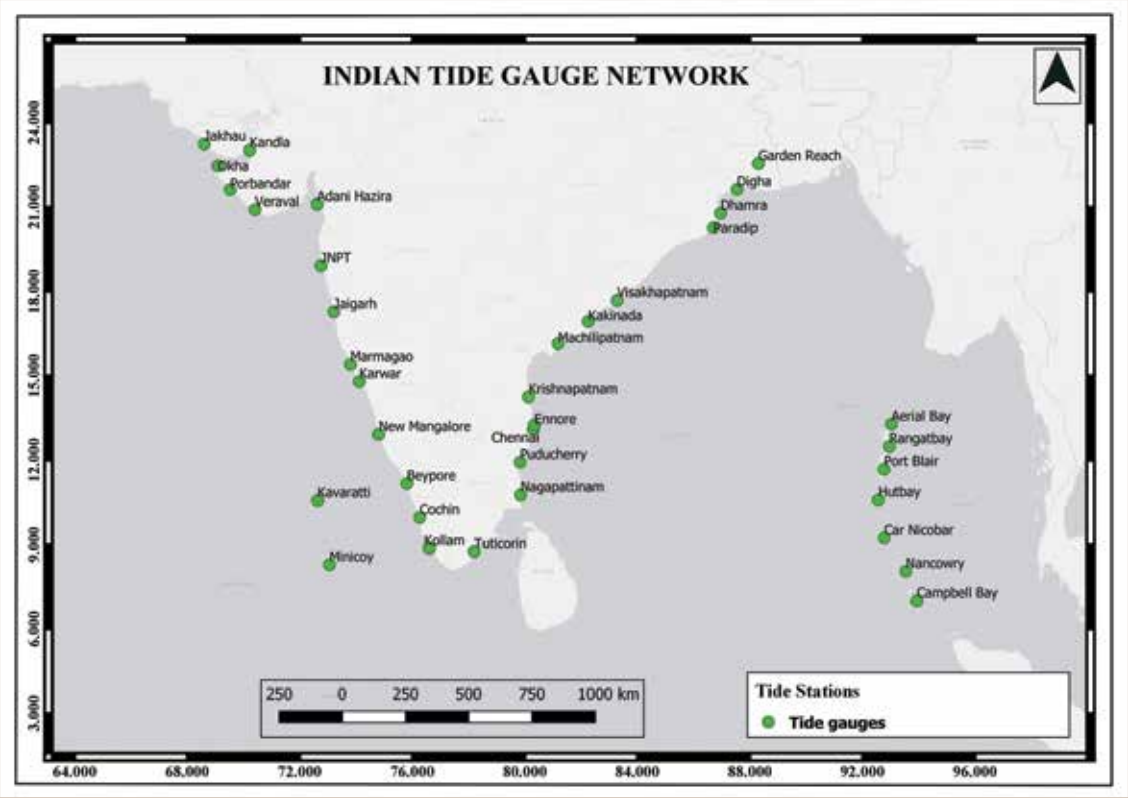


Figure 6.10. The present status of INCOIS Tide gauge stations

INCOIS had installed and maintained 36 tide gauge stations along the Indian coastline and Islands, and real-time data was transmitted through INSAT and GPRS (Figure 6.10). Installation of the radar tide gauge station at Jakhau, Gujarat, and replacement of the radar sensor for the Chennai Tide gauge station were carried out during the reporting period (Figure 6.11). In addition, timely regular and breakdown maintenance was carried out at all the existing tide gauge stations. As of now, tide gauge benchmarks establishment and leveling exercise to define the absolute sea level datum was accomplished at 8 INCOIS radar tide gauge stations along

Figure 6.11. The newly installed radar tide gauge stations in Gujarat and Chennai

Kerala and Tamil Nadu, which includes Kochi, Kollam, Beypore, Tuticorin, Nagapattinam, Pondicherry, Chennai and Ennore.

6.9 Wave rider buoy network

INCOIS maintains a network of 16 wave rider buoys for monitoring the ocean state and conducting real-time and delayed-mode validations of ocean state forecasts with support from various research

Figure 6.12. Present status of wave rider buoy network

and academic institutions (Figure 6.12). During the reporting period, timely maintenance and breakdown activity were carried out, and at present, 11 WRBs are operational and provide real-time data. In addition, As part of a consultancy project with Adani Vizhinjam Port Pvt. Ltd, a wave rider buoy was deployed off Vizhinjam on 22 February 2024 (Figure 6.13).

Figure 6.13. Deployment of wave rider buoy at Vizhinjam as part of the consultancy project

6.10 Coastal Observatory

As part of the development of a water quality nowcasting system in Indian coastal waters, two moored buoy-based autonomous water quality observatories have been established off the Kochi and Visakhapatnam coasts. The buoys are equipped with real-time data telemetry systems and sensors that can measure 22 water quality parameters in real-time, which include surface current speed and direction, salinity, temperature, pH, dissolved oxygen, phycocyanin,

phycoerythrin, coloured dissolved organic matter, chlorophyll-a, and turbidity. These measurements monitor water quality parameters and health of coastal and estuarine waters and facilitate to understand the factors that modulate them in various temporal scales. Monthly in-situ sampling is also carried out at the buoy location to ensure the quality of the sensor data. Since it is a coastal buoy, frequent maintenance is imperative, and four deployments and recovery activities at Visakhapatnam and eight deployments and recovery at Kochi were carried out (Figure 6.14). At present, both buoys are operational and provide real-time data for INCOIS. In addition, a week of training is organized jointly by INCOIS and NIO-RC-Kochi on operations of the coastal observatory in March 2024 at Kochi (Figure 6.15). The participants were trained on the deployment and recovery of mooring, sensor handling, pre- and post-deployment sensor checks, data handling and visualization, in-situ data collection, and sensor data validation.

Figure 6.14. Deployment and recovery of coastal observatory at Kochi coast

Figure 6.15. Participants during training on operations of buoy-based autonomous coastal observatory in March 2024 at Kochi

6.11 Deep Ocean Observation System (DOOS)

To implement the objectives of the observations component of the Deep Ocean Observations system (DOOS) under the Deep Ocean Mission program, eight deployments and five recoveries of the deep sea gliders have been performed to maintain the glider transect along 88.47°E in the Bay of Bengal and 67°E in the Arabian Sea during the period April 2023 to March 2024 (Tabl-1; Figures 6.16 and 6.17). With the deployment of a glider in the Arabian Sea on October 23, 2023, the proposed Arabian Sea transect became operational for the first time. Four gliders are operational and making meridional transects In addition, INCOIS organized a Slocum glider training programme from 6–13 September 2023, and 25 participants from various MoES institutes got training from OEM engineers on Slocum Glider instrumentation, ballasting, piloting, data handling, deployment, and recovery in the field. In addition, 30 Directional Wave Spectra Drifters, capable of measuring sea surface temperature, barometric pressure, and wave parameters such as significant wave height, directional spread, and swell direction, were deployed in the tropical Indian Ocean from July 2023 to January 2024 (Figure 6.18).

Table-1. Summary of INCOIS Glider Mission under DOOS from April 2023 to March 2024

Glider Missions	Locations	Start date	End date
M_BoB_04	Bay of Bengal	08 March 2023	02 July 2023
M_BoB_05	Bay of Bengal	23 September 2023	15 March 2024
M_BoB_06	Bay of Bengal	23 September 2023	10 March 2024
M_AS_01	Arabian Sea	27 October 2023	Ongoing
M_AS_02	Arabian Sea	30 January 2024	Ongoing

Figure 6.16. INCOIS scientist during the recovery of a glider from the Bay of Bengal

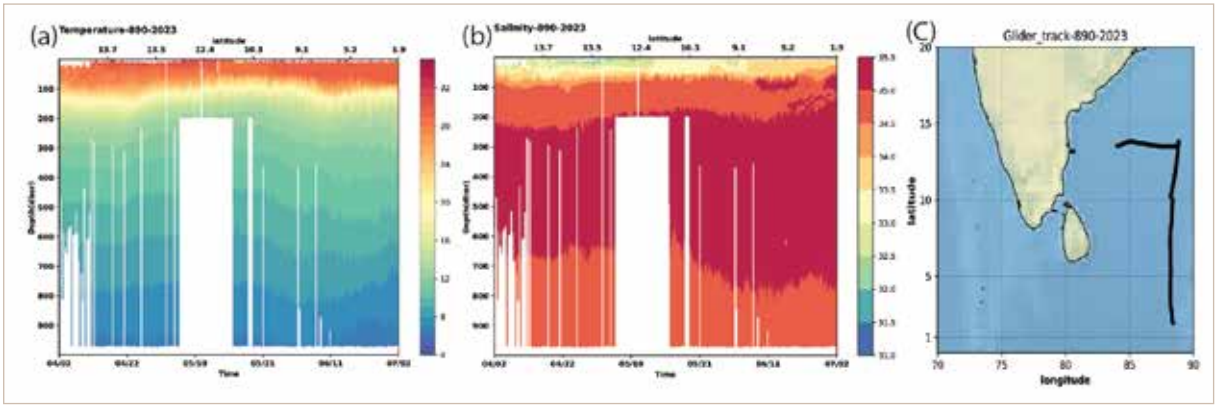


Figure 6.17. The depth time section of (a) temperature (°C), (b) salinity (PSU), and glider track in the Bay of Bengal from April 2023 to July 2024

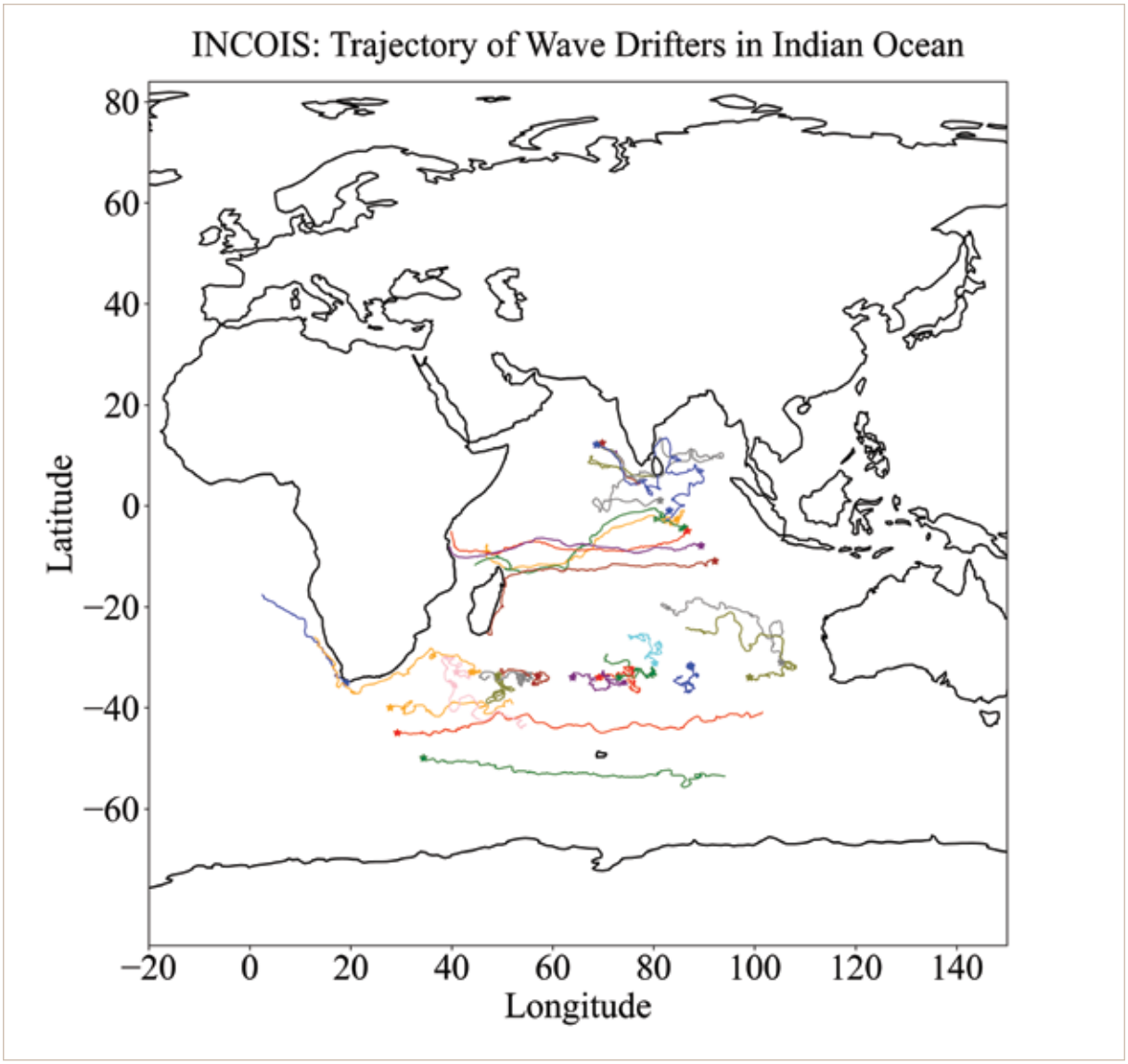


Figure 6.18. Deployment location and track of 30 directional wave spectra drifter in the Indian Ocean

6.12 Global Navigation Satellite System (GNSS) and Strong Motion Accelerometer (SMA)

INCOIS plans to establish GNSS and SMA networks in the Andaman and Nicobar Islands at 35 locations. At present, the recording room's construction has been completed at 32 stations, and the remaining three are in progress (Figure 6.19). During the reporting period, the GNSS receiver and its accessories were successfully commissioned and installed at the Shastri Nagar Site on 31 December 2023, and the GNSS network has now been increased to 32 sites co-located along with the existing 32 SMA sites. Further, the GNSS and SMA network at the Wandoor site was dedicated to the nation by the Honorable Minister of Earth Sciences (MoES) on 14 February 2024.

Figure 6.19. GNSS and SMA network locations map at Andaman and Nicobar Islands. GNSS station at Wandoor

6.13 Processes-specific observation field campaigns

6.13.1 EKAMSAT cruise

The Arabian Sea has a vital role in shaping climatic patterns in the Indian Ocean regions at various spatiotemporal scales. Recognizing the growing scientific importance of the Arabian Sea, a joint research initiative was formulated between India and the United States of America, titled "Enhancing Knowledge of the Arabian Sea Marine Environment through Science and Advanced Training" (EKAMSAT). Under the EKAMSAT programme, it is proposed to conduct several collaborative field campaigns in the Arabian Sea by Indian and US teams to collect fine-scale oceanographic and atmospheric measurements, focusing on examining surface mixed layer/interior ocean processes and marine atmospheric boundary layer processes and their representations in numerical models.

As a pilot phase of this programme, INCOIS conducted a month-long scientific cruise in the Arabian Sea from 29 June to 24 July 2023, onboard the Ministry of Earth Sciences research vessel Sagar Nidhi, immediately following the field campaign by the USA team, along with six Indian scientists, onboard Roger Revelle during 10-25 June 2023, to collect fine-scale oceanographic and atmospheric measurements using vertical microstructure profiler (VMP), ship-based eddy

Figure 6.20. EKAMSAT cruise team before the commencement of the cruise at Chennai

covariance flux system, lowered acoustic Doppler current profiler (L-ADCP) and Radiosonde. The science team includes 18 Indian participants, one scientist from Bangladesh, and one from Mauritius (Figure 6.20). Water samples were also collected as part of these two expeditions to study the factors that modulate bio-geo-chemical parameters. The field campaigns were focused on the southeastern Arabian Sea, a region known for its pivotal role in the onset and progression of the Indian summer monsoon. Following the Rover Revelle voyage, the observation campaign onboard Sagar Nidhi was carried out to comprehend the unique characteristics of air-sea interaction processes in the Arabian Sea during the initial and peak phase of the summer monsoon 2023. Two

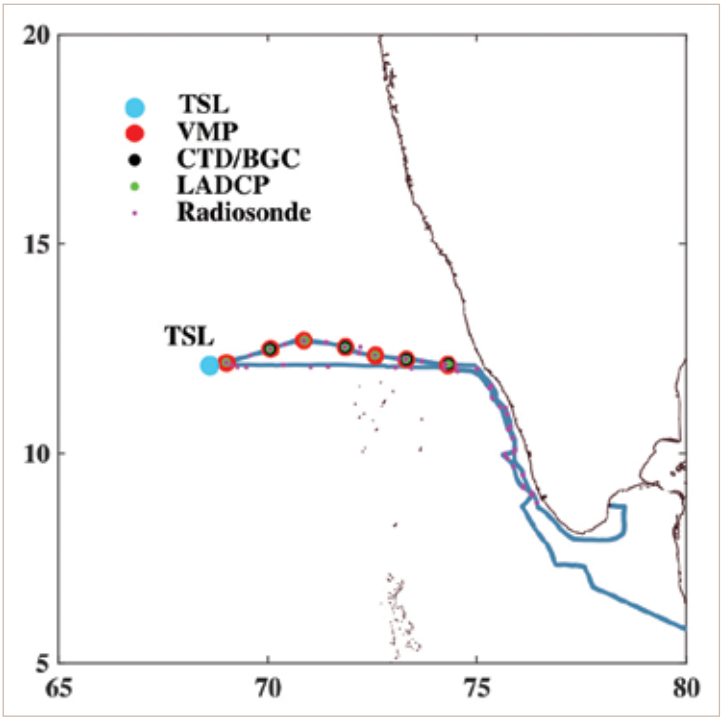


Figure 6.21. EKAMSAT cruise track in July 2024 (blue line). The time series station at AD08 mooring location (~12.05°N and 68.65°E) is marked in a cyan circle. VMP (red circle), CTD/BGC (black circle), LADCP (green), and Radiosonde (pink)

experiments were carried out during this field campaign: a five-day time series observation near the AD08 mooring location and a zonal transect along 12°N between the east coast of the Arabian Sea and 68.5°E (Figures 6.21, 6.22 and 6.23).

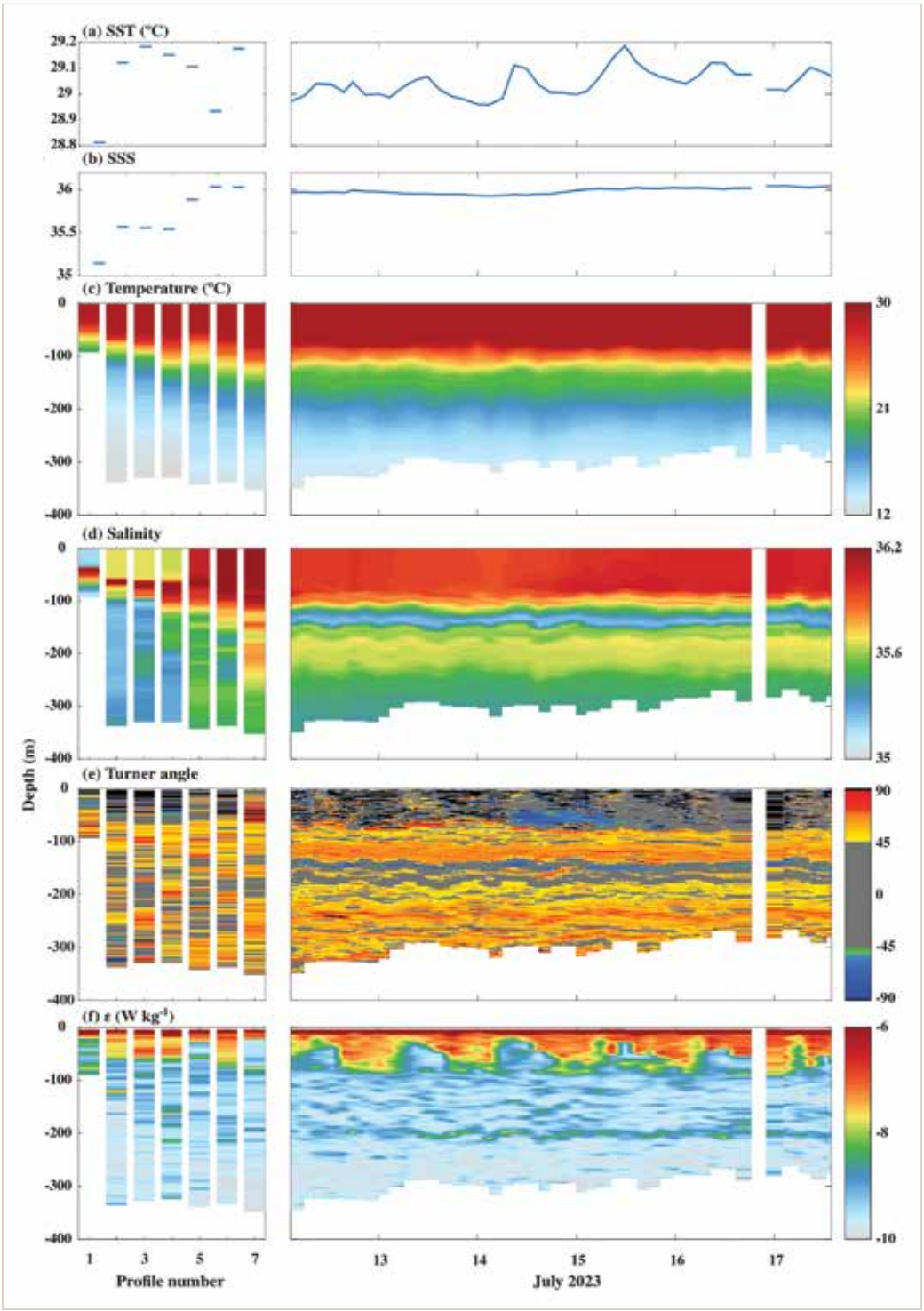


Figure 6.22. (a) sea surface temperature (SST) (°C), (b) sea surface salinity, (c) depth-time section of temperature (°C), (d) depth-time section of salinity and (e) depth-time section of $\log_{10}(\varepsilon)$ (W kg^{-1}) along the zonal transect at 12°N and at time series station at 12.05°N and 68.65°E

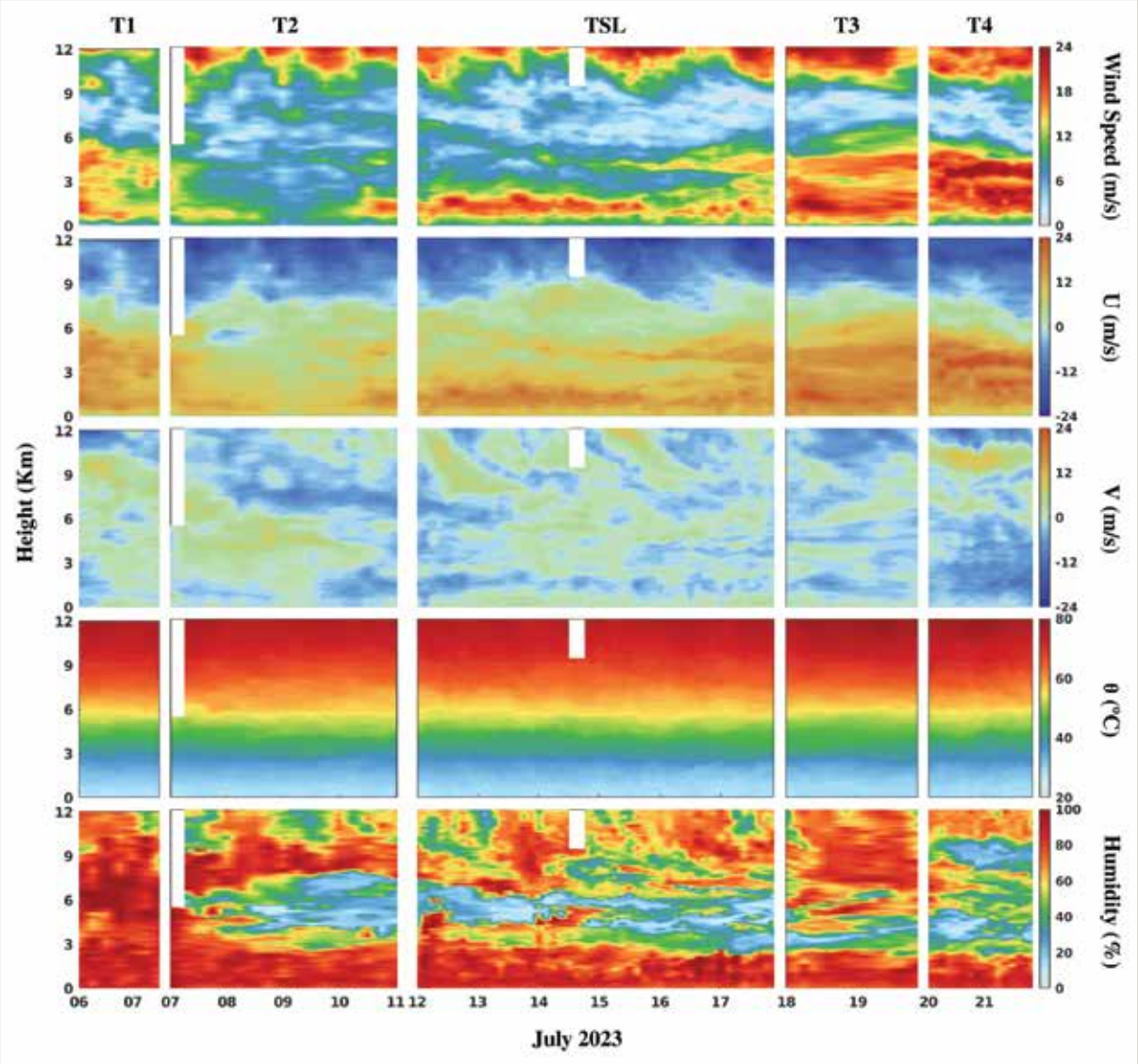


Figure 6.23. Radiosonde observation of vertical profiles of (top to bottom) wind speed (ms^{-1}), zonal wind speed (ms^{-1}), meridional wind speed (ms^{-1}), potential temperature (°C), and relative humidity (%) during the EKAMSAT cruise in July 2024

These unprecedented fine-scale measurements from the Arabian Sea aim to improve our understanding of the small-scale mixing processes in the ocean surface boundary layer, interior ocean, and air-sea interaction processes. These measurements will also aid in investigating how these processes are best represented in existing parameterization schemes in ocean and atmospheric coupled models, thereby improving the accuracy of physical process representations and reducing systematic erroneous monsoon predictions.

6.13.2 Bio-Geochemical process study in the coastal southeastern Arabian Sea

To understand the biogeochemical variability and validate the measurements from the coastal water quality buoy data off Kochi, a scientific cruise was carried out onboard ORV Sagar Manjusha

(SAMA025) from Beypore to Beypore in the continental shelf of southeastern Arabian Sea from 09-22 January 2024. The measurements includes sport measurements at 16 stations between the 5-100 m isobaths and six days time series measurements with four hour temporal resolution at 9.84°N, 76.20°E. As part of this cruise, physical, biogeochemical, and optical measurements were carried out, which included salinity, temperature, dissolved oxygen, nutrients, pH, chlorophyll, phytoplankton, zooplankton, pH, TA, CDOM, and PAR (Figures 6.24 and 6.25). These measurements also facilitate understanding the variability in absorption due to phytoplankton and absorption with pigment composition and concentration. A primary productivity experiment was carried out across euphotic depth along the cruise tracks to develop the primary productivity model from satellite data.

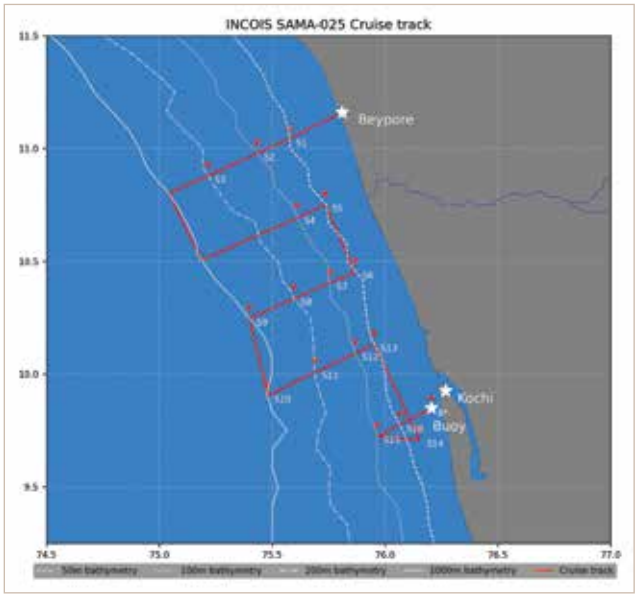
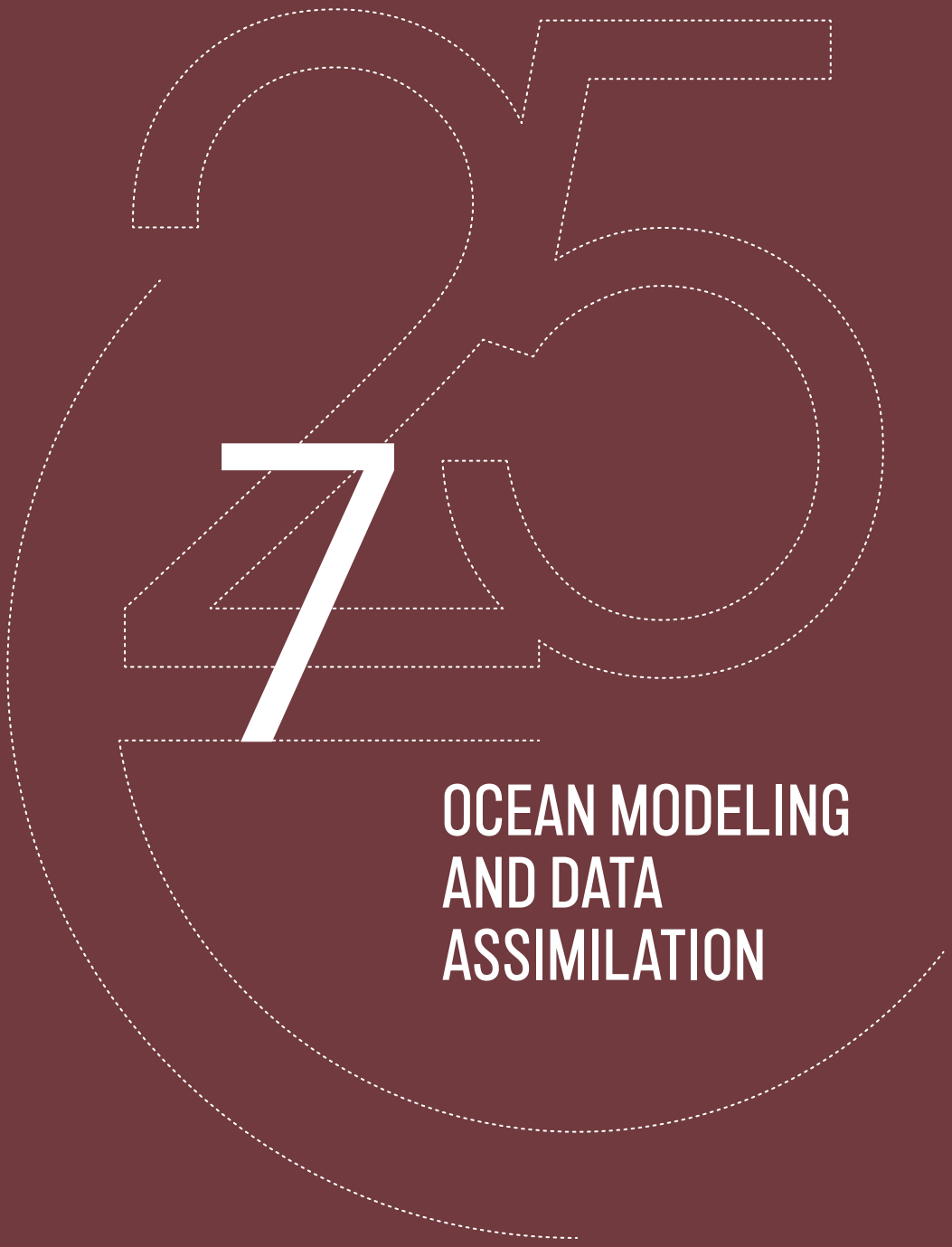


Figure 6.24. The track and measurement locations of the INCOIS bio-geochemical process study cruise onboard Sagar Manjusha (SAMA-025) in the coastal southeastern Arabian Sea from 09-22 January 2024

Figure 6.25. The INCOIS scientist onboard Sagar Manjusha during the INCOIS biogeochemical cruise



7 OCEAN MODELING AND DATA ASSIMILATION

7.1 Numerical Ocean Modeling and Data Assimilation for Operational Services

INCOIS is responsible for providing operational ocean state forecast and analysis to the nation and its rim countries. For the same purpose, INCOIS has already developed a Regional Analysis of Indian Ocean (RAIN) system that uses Regional Ocean Modeling System (ROMS) which is coupled with LETKF (Local Ensemble Transform Kalman Filter) based data assimilation system and a marine ecosystem model under the paradigm of Indian Ocean High Resolution Operational Ocean Forecast System (IO-HOOFS). INCOIS has been persistently striving to improve the ocean analyses and forecasts through targeted research endeavours.

7.1.1 Assimilation of HF-Radar currents into ROMS model

The original RAIN system assimilated temperature, salinity and Sea Surface Temperature (SST) which is now further augmented with the assimilation of satellite swathes of sea level anomaly. Ocean currents play a significant role in energy transfer, marine life, fishing activities and many more. Keeping the importance of currents, we are expanding the scope of our data assimilation to include assimilation of zonal and meridional currents from HF-Radars which are installed along the Indian coast.

Preliminary results from assimilating HF-Radar currents (during October 2017 to May 2018, while excluding other observations) with LETKF demonstrate a significant improvement in surface currents (see Figure 7.1) and currents up to a depth of 70 metres within the HF-Radar coverage area. The RMSE of the surface current has decreased by nearly 50% (the average RMSE over time was 42 cm/s for Free-ROMS (no assimilation), which has been reduced to 21 cm/s for LETKF-ROMS).

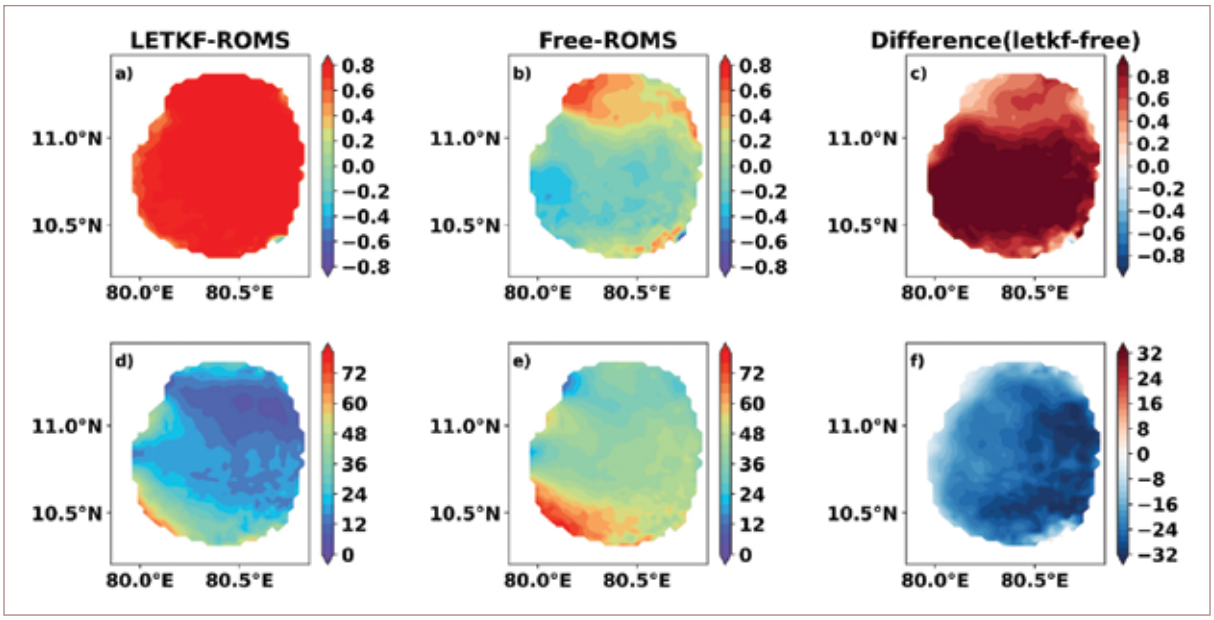


Figure 7.1. (a-b) Correlation, (d-e) root mean square deviation (in cm/s) between HF-Radar surface Zonal currents and model derived surface Zonal current from LETKF-ROMS and Free-ROMS (no assimilation) respectively at Tamil Nadu coast. Difference in (c) correlation and (f) RMSD between LETKF-ROMS and Free-ROMS respectively. Positive (negative) values in (c) and negative (positive) values in (f) indicates improvement (degradation)

7.1.2 INCOIS – Global Ocean Analysis System (GODAS)

INCOIS Global Ocean Data Assimilation System (INCOIS-GODAS) is an operational system that produces three-dimensional ocean analysis fields by employing a Three-Dimensional Variational (3DVAR) data assimilation system to integrate observed temperature (T) and salinity (S) profiles obtained through the Global Telecommunication System (GTS). The ocean model is based on Modular Ocean Model (version 4.0) with a tripolar global grid. Its horizontal resolution is 0.5° (~55 km) in zonal and varying meridional resolution (0.25° within 10°S-10°N) which gradually increases to 1° at the poles. Initial conditions from INCOIS-GODAS analysis are used to force the CFS models of IITM and IMD and for the extended and seasonal prediction of monsoon. INCOIS uses this analysis to provide lateral boundary conditions to the high-resolution Indian Ocean regional analysis IO-HOOFS. Additionally, INCOIS-GODAS provides climatic indicators over the Indo-Pacific basin (Figure 7.2).

During FY23-24, a total of 501,292 Argo profiles and 274,499 buoy profiles containing temperature and salinity data were obtained from the GTS. Of these, 442,454 Argo temperature profiles and 321,872 Argo salinity profiles were assimilated. Additionally, 268,953 buoy temperature profiles and 248,248 buoy salinity profiles were assimilated into GODAS.

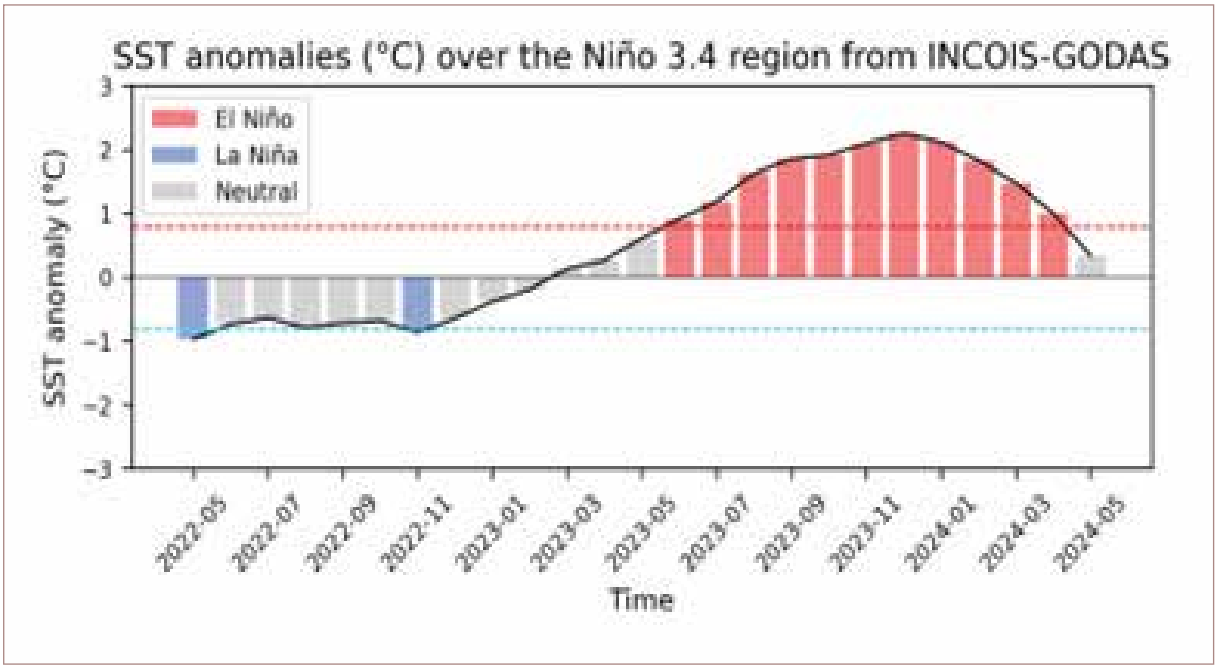


Figure 7.2: Evolution of SST anomalies (°C) simulated by INCOIS-GODAS for the Niño 3.4 (5°S-5°N, 170°W-120°W) region in the period May 2022-May 2024. The RED and CYAN horizontal lines represent 0.8°C SST anomaly. This illustrates the spin-off of the 2023 El-Nino and its decay during early summer of 2024

7.1.3 Biogeochemical State of the Indian Ocean

The oceans play a significant role in regulating the amount of CO_2 in the atmosphere. The increasing oceanic uptake of CO_2 counterbalances the increase in atmospheric CO_2. This uptake has a considerable impact on marine biogeochemistry, leading to pH and alkalinity imbalances in the water column, commonly referred to as ocean acidification. In an acidic ocean, excess CO_2 reacts with seawater to form carbonic acid, which is highly unstable and undergoes further reduction by releasing hydrogen

ions (H^+) and acidifying the seawater (reduces the pH) (Figure 7.3). Several studies have projected a decline of upper ocean pH by 0.3-0.4 by the end of the 21st century, which has the potential to reduce oceanic biological production considerably. The number of available observations to study Indian Ocean acidification is limited. There is a critical need to understand the status of Indian Ocean acidification and identify its key drivers. This study consolidates the current level of understanding about the Indian Ocean acidification based on the available field observations, reconstructed data sets, and model simulations.

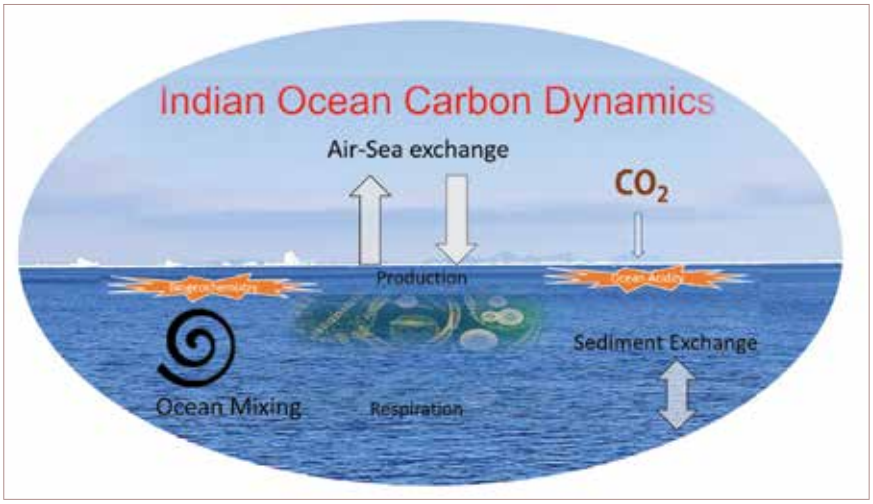


Figure 7.3. Schematic diagram highlighting the primary processes controlling air-sea CO_2 exchange in the ocean.

This changes in the Indian Ocean seawater pH in response to the changes in sea-surface temperature (SST), sea-surface salinity (SSS), dissolved inorganic carbon (DIC), and total alkalinity (ALK) and its driving mechanisms have been studied over the period 1980-2019 using the available field observations, reconstructed data sets, and model simulations. The regional high-resolution (1/12 degree) coupled ocean-ecosystem model (INCOIS-BIO-ROMS) simulated outputs configured for the Indian Ocean to participate in the 'REgional Carbon Cycle Assessment and Processes Phase 2 (RECCAP-2)' were used for analysis. The analysis indicates that the rate of change of declining pH in the Arabian Sea (AS), the Bay of Bengal (BoB), and the Equatorial Indian Ocean (EIO) is -0.014 ± 0.002, -0.014 ± 0.001, and -0.015 ± 0.001 unit dec-1, respectively. Both in AS and BoB (EIO), the highest (lowest) decadal DIC trend is found during 2000-2009. The surface acidification rate has accelerated throughout the IO region during 2010-2019 compared to the previous decades. Further, our analysis indicates that El Nin~o and positive Indian Ocean Dipole events lead to an enhancement of the Indian Ocean acidification. The increasing anthropogenic CO_2 uptake by the ocean dominantly controls 80% (94.5% and 85.7%) of the net pH trend (1980-2019) in AS (BoB and EIO), whereas ocean warming controls 14.4% (13.4% and 7.0%) of pH trends in AS (BoB and EIO). The changes in ALK contribute to enhancing the pH trend of AS by 5.0%. ALK dominates after DIC in the EIO and, similar to the AS, contributes to increasing the negative pH trend by 10.7%. In contrast, it has a buffering effect in the BoB, suppressing the pH trend by -5.4%.

7.1.4 Tsunami Modeling

Tsunamis are massive waves generated by the sudden water displacement on the ocean surface, causing devastation as they sweep across the coastlines, posing a global threat. The aftermath of the 2004 Indian Ocean tsunami led to the establishment of the Indian Tsunami Early Warning System (ITEWS). Predicting real-time tsunami heights and the resulting coastal inundation is crucial in ITEWS for safeguarding the coastal communities. Global tsunamis other than those in the Indian

Ocean might weaken at Indian coasts due to distance yet still cause significant damage due to local coastal morphological amplification. The current study focuses on tsunami simulations over global oceans, focusing on distant tsunamis worldwide, with a specific emphasis on assessing the threat to Indian coasts. A finite-element-based ADvanced CIRCulation (ADCIRC) model is configured to the global domain to model global tsunamis accurately and efficiently. The model mesh has a spatial resolution of 2km in the shallow waters and relaxed to 20km in the deeper waters. Model simulations are performed for the major historical events, assessing their effect on near and far field regions. Computed results are compared with the observations, and it is found that the model's predictions align well with the observations. The simulation results demonstrate that ADCIRC can be applied to real-time tsunami predictions due to its computational efficiency and accuracy.

Current research highlights ADCIRC's ability and accuracy in real-time predictions, leveraging its parallel finite element approach. Through simulations of major historical tsunamis, including the 2011 Japan and 2010 Chile events, the 2004 Indian Ocean tsunami, the 1964 Alaska tsunami, and the Valdivia 1960 tsunami, the study establishes that ADCIRC provides reliable predictions of tsunami wave heights and arrival times. The comparison with tide gauge observations from various global locations reveals a close alignment between model predictions and actual observed data (Figure 7.4). The current setup could be advantageous for operational purposes, facilitating timely evacuation measures. The global unstructured mesh with varying spatial resolutions, ranging from 2 km in shallow waters to 20 km in deeper waters, effectively balances optimized computations without compromising the simulation accuracy. The study opens avenues for enhanced global tsunami hazard modelling and risk mapping. The real-time simulation capabilities of ADCIRC offer valuable insights for tsunami warning centers, enabling prompt identification of coastal hot spots and issuance of timely warnings to mitigate potential damages and save lives.

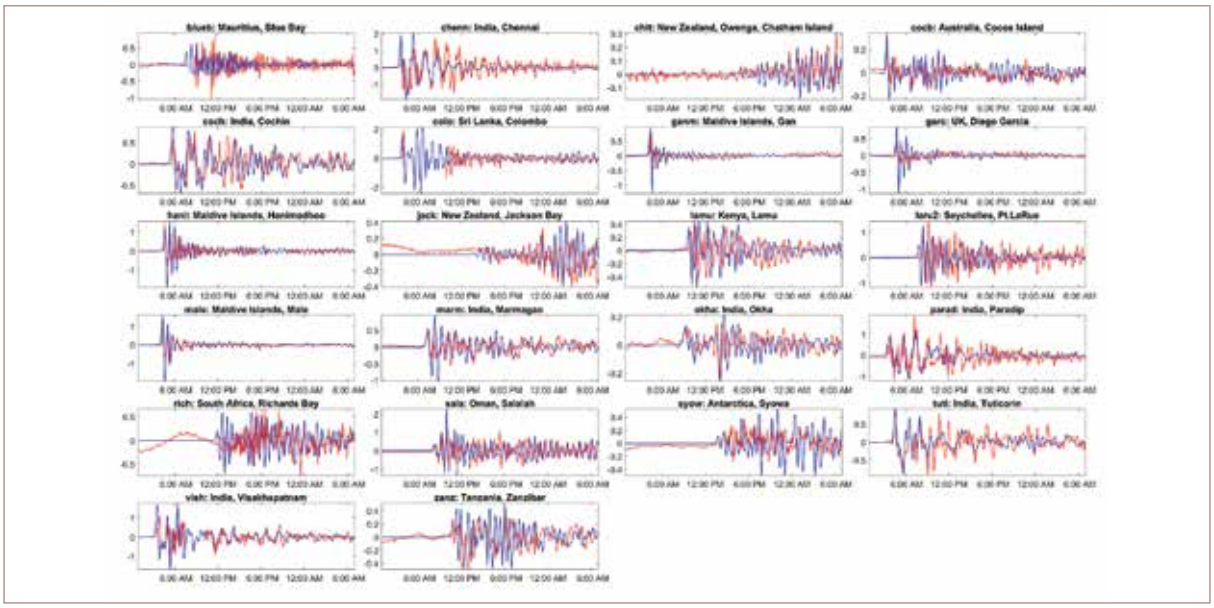


Figure 7.4. Comparison of the computed tsunami wave heights against the tide gauge observations at various global locations for the Indian Ocean 2004 event. The red color corresponds to tide gauge observations, and the blue color represents a numerical simulation. The locations of the tide gauge stations are shown as titles on each subplot. The x-axis represents the time stamp, and the y-axis represents the wave height amplitude in meters. The starting time in the abscissa in each sub-plot is 26 December 2004 00:58:50 UTC

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

INCOIS is responsible for providing operational ocean forecasts and analyses. To enhance its services, INCOIS planned a comprehensive overhaul of its modeling system, opting to use a smaller number of models. Consequently, it developed a unified ocean modeling system framework under its Modelling Mission to eventually replace the existing operational models. The Global Ocean model will be based on Modular Ocean Model version 6 (MOM6) and 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, as well as short-term ocean state forecasts and datasets for preparing climate indices. It will also provide boundary conditions for a finer resolution regional Indian Ocean model based on MOM6. The Carbon, Ocean, Biogeochemistry and Lower Trophic (COBALT) ecosystem model will model the biogeochemical and planktonic food web response. The regional ocean model, also based on MOM6 and coupled with data assimilation, will provide improved ocean state forecasts and analyses of the Indian Ocean at a finer scale compared to the global model.

INCOIS also has the responsibility to support the coastal population of India. For instance, tsunami and storm surge predictions significantly impact the lives and livelihoods of millions living along the coastal regions, while forecasts on coastal currents, waves, tides, etc., have a daily impact on the coastal populace. Tsunami and storm surge predictions will be carried out using the ADCIRC model coupled with SWAN, and wave forecasts will be handled by WAVEWATCH III. The near-coastal oceanic state, including water quality, will be predicted and analyzed using the Finite Volume Community Ocean Model (FVCOM) coupled with an ecosystem model. The development of all these models is currently 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 existing operational models with a very high resolution regional/global 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.

7.2.1.1 Global MOM6

The global configuration of MOM6 has a uniform 1/12° horizontal resolution and 41 hybrid vertical layers. The sea ice is simulated with SIS2 module integrated with the MOM6. The model is initialized with ocean states derived from global HYCOM simulation. Forced by the JRA55-do atmospheric forcing, a hindcast of 10 years is completed. The mean sea level anomaly from MOM6 aligns reasonably well with the altimeter SLA (Figure 7.5).

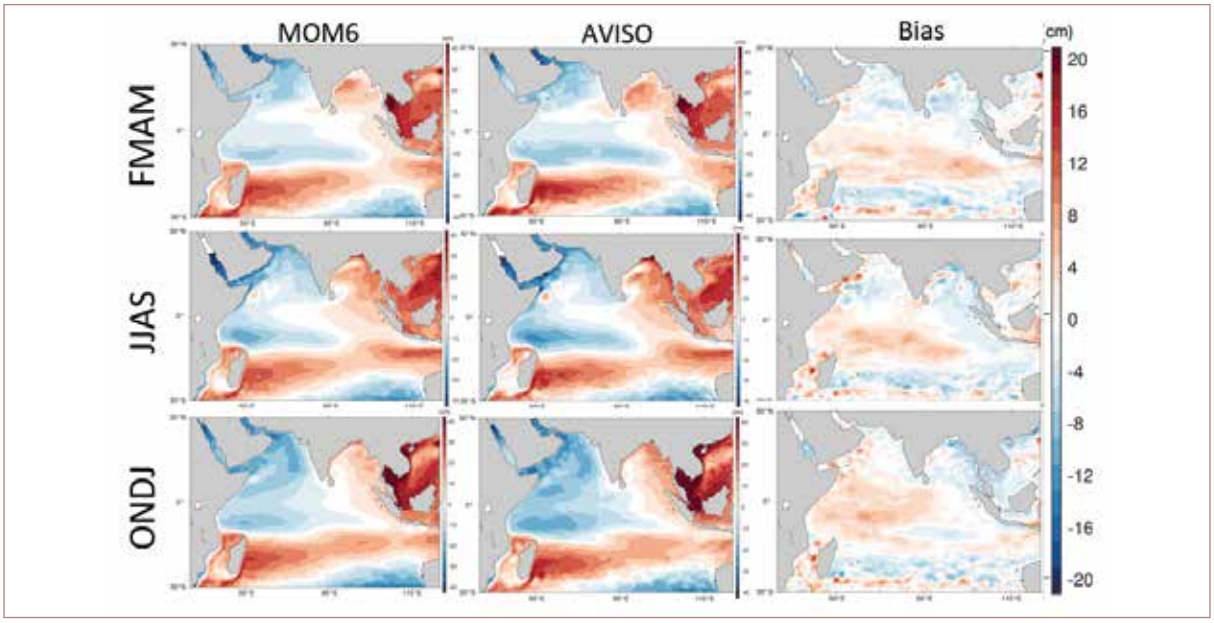


Figure 7.5. Comparison of model simulated seasonal mean sea level anomaly and their biases with respect to altimeter for the year 2016-2021

7.2.1.2 Indian Ocean Regional MOM6

The regional Indian Ocean model is intended to be of much finer resolution to better simulate the mesoscale/sub-mesoscale features of the north Indian Ocean, a perquisite for better forecast skill. The model will also have to be nested with the global configuration for lateral boundary exchange. To develop and test the open boundary exchange in MOM6, initially the regional configuration is also set with the same resolution as that of the global model. The model is spun up using the initial condition from the global model and run for a year to test the open boundary conditions. The simulations show reasonable agreement between the regional and global simulation, except at the top of the mixed layer likely driven by the vertical interpolation at the open boundary (Figure 7.6).

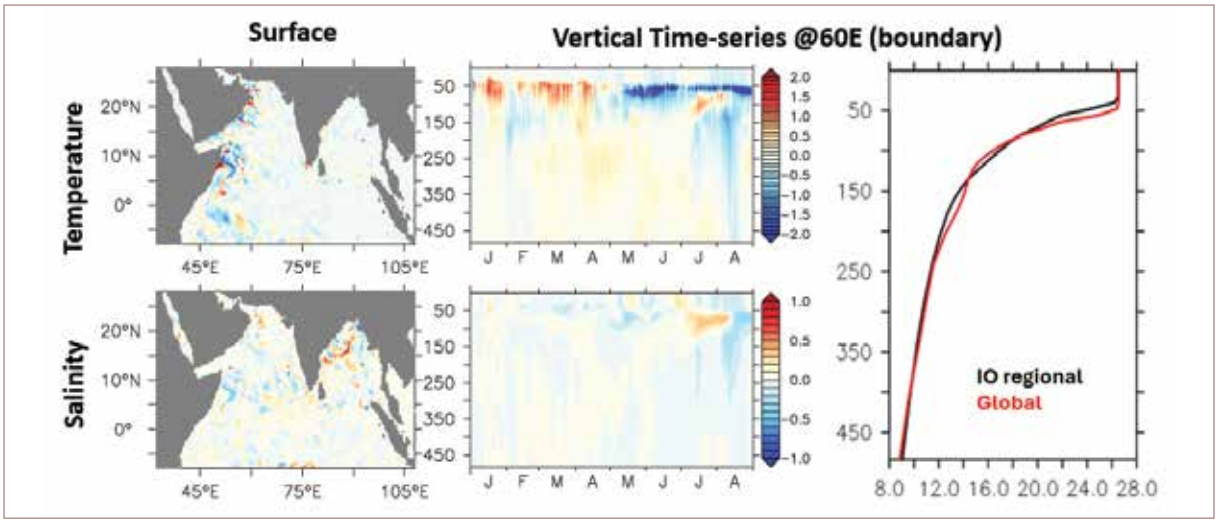


Figure 7.6. Comparison of regional model simulation with the global model (Regional-global) at surface (left) for 15 July 2013 and close to the open boundary of the regional model (60°E/7.9°S) (middle and right)

7.2.2 Development of a global wave model

The global ocean surface wave conditions during 2018 were simulated using a high-resolution WAVEWATCH III 6.07 model (spatial resolution of 1/8 degree, and temporal resolution of 3 hours). The performance of the model was evaluated separately for the Indian Ocean, Pacific Ocean, and the Atlantic Ocean using the observational data from OMNI buoys, waverider buoys, NOAA NDBC buoys, and satellite data using statistical error estimates such as correlation coefficient (CC), root mean square error (RMSE), scatter index (SI), and bias. In the Indian ocean, CC for significant wave height (Hs) and swell height (Hsw) at all OMNI buoy locations were above 0.95. The CC for Tm02 was nearly 0.8 or above in most locations. The model data was compared with JASON-2 data for all the available colocation points, and the match was found to be quite good with a CC of 0.97 and a SI of 0.13 for Hs (Figure 7.7). The spatial pattern of significant wave heights was also verified with the JASON-2 data for representative days and the patterns were found to have good agreement. Similar studies were conducted for the Pacific and Atlantic oceans using the available buoy, and satellite data. More experiments with different parameterization schemes are to be conducted to arrive at a conclusion regarding the best scheme to be selected.

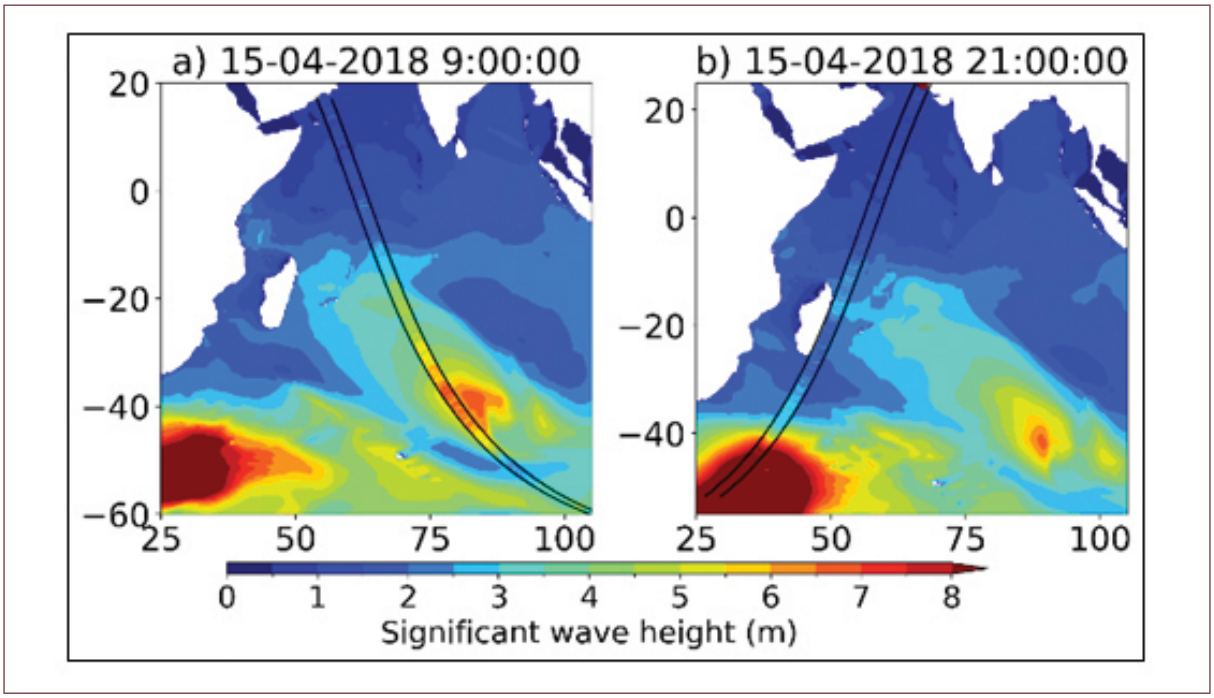


Figure 7.7. Validation of wave heights for the Indian ocean using JASON-2 satellite data for April 2018

Table 7.1: Comparison of model Hs performance in Atlantic & Pacific using satellite data

Statistical Error Estimate	Atlantic Ocean	Pacific Ocean
CC	0.95	0.91
SI	0.08	0.04
Bias (m)	0.08	0.02
RMSE (m)	0.21	0.12

7.2.3 Development of coastal general circulation model

Improving the representation of coastal and shelf seas in global models is a great challenge to the ocean modelling community. Accurate forecast of near shore ocean state requires a high-resolution finite element modelling approach, that can delineate the coastlines and shallow regions better and improve the representation of physical and biological processes. In this context, a high and flexible resolution, coupled and nested framework of the FVCOM-FABM-ERSEM model has been adopted. The hydrodynamic model Finite Volume Community Ocean Model (FVCOM) has been configured for the Cochin estuarine system with realistic bathymetry, initial condition, boundary condition and atmospheric and river forcing. The framework utilises the European Regional Seas Ecosystem Model (ERSEM), a generic and well established lower-trophic level marine food web and biogeochemical cycling model, while enabling their coupling via a universal generic coupler, Framework for Aquatic Biogeochemical Models (FABM). Compatible versions of the coupled system were installed in Mihir-HPC and tested the configuration with an ideal estuary scenario. Currently, the focus is on developing an FVCOM-based physical setup to simulate the hydrodynamics of the coastal waters off Kochi. In this regard, a finite element mesh (varying resolution between 8 km and 200 m) was created for Cochin region based on a blended bathymetry using SRTM 1arcsecond topography, SRTM 15arc second bathymetry and detailed Vembanad lake bathymetry data from different central and state government departments. Open-source mesh generation tool OceanMesh2D ***v5.0*** was used to generate the current mesh, dropping the dependency on commercial software Aquaveo-SMS. The model domain is an unstructured semi-circular grid extending from 74-77°E and 8-12°N with varying horizontal resolution (200 m to 8 km). Several model experiments were conducted to identify the best vertical grid distribution, atmospheric forcings, boundary prescriptions, mixing and heating schemes to develop a physical model configuration with acceptable accuracy.

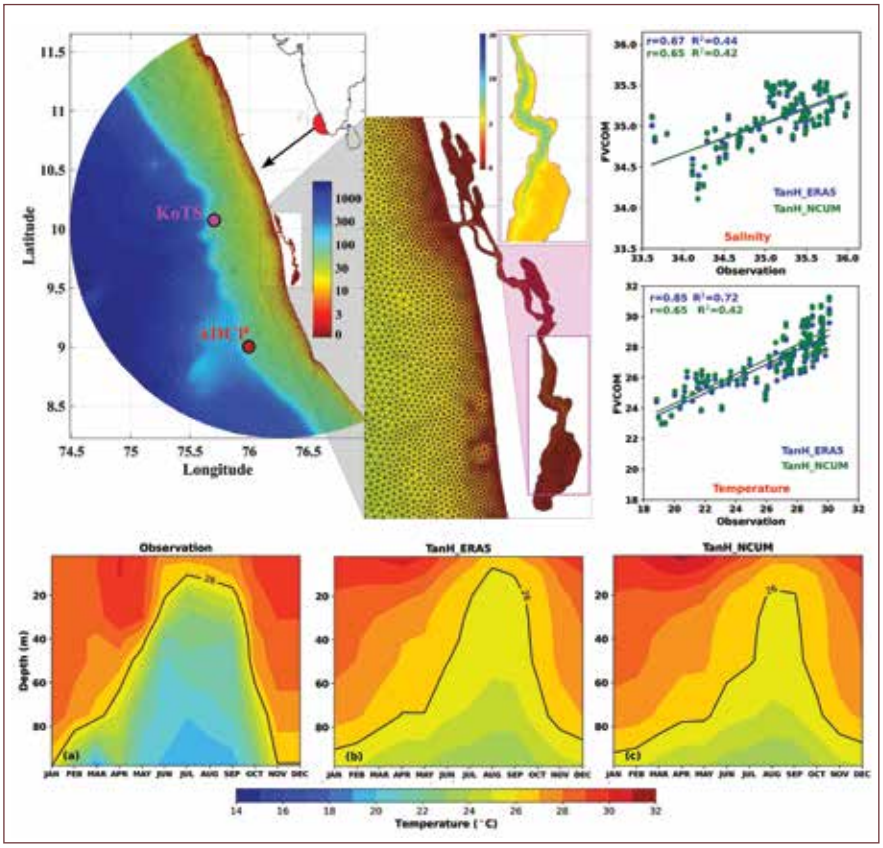


Figure 7.8. Flexible mesh grid of the physical model configured using FVCOM for the coastal waters off Kochi. Comparison of time-depth section of temperature and scatter plots for temperature and salinity at Kochi time series observation (KoTS) at 75.6° E and 10° N

ROMS type terrain-following sigma vertical coordinates (depth dependent vertical grid distribution) scheme has been implemented in the FVCOM model source code. 5 years of simulation were carried out using the climatological forcing and 1 year of interannual simulation was carried out using interannual atmospheric fields from ERA5. Validation of the model simulated output was carried out with available observations.

The FVCOM simulations were carried out using two different atmospheric forcing fields, viz., NCMRWF's Unified model (NCUM) and ECMWF's Reanalysis v5 (ERA5). The model simulated time-depth section of temperature at the KoTS location (75.6°E and 10°N) shows a good agreement with observation (Figure 7.8). The model captures the upwelling of cooler waters from the subsurface layers during the summer monsoon season well. The strong semi-annual surface temperature signals for this region and the variation of 26 °C isotherm depth are well reproduced by the model (Fig. 7.8). Additionally, model simulated zonal and meridional currents at the ADCP location showed that FVCOM-ERA5 outperforms ROMS and FVCOM-NCUM simulated currents (Fig. 7.9). Overall, the model reproduced the observed oceanographic characteristics of the region well.

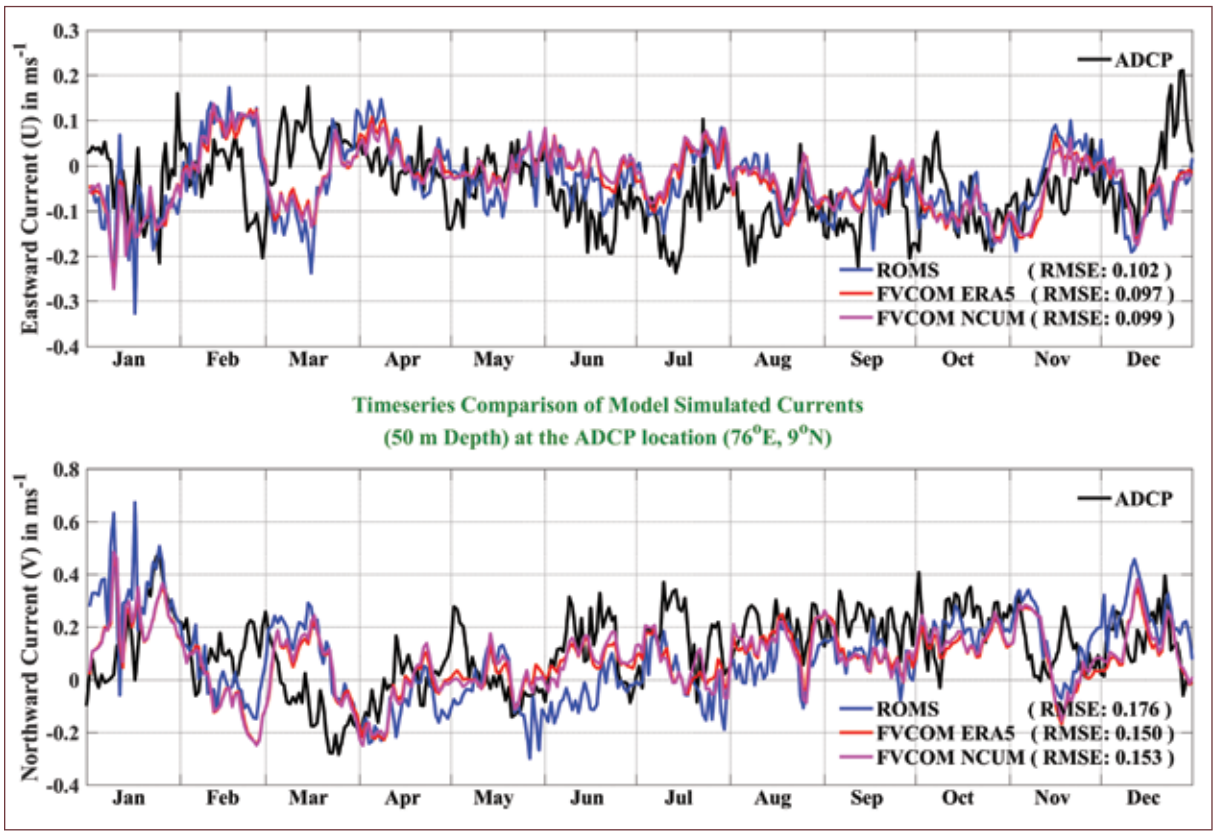


Figure 7.9. Time series comparison of FVCOM and ROMS simulated currents (50 m water depth) at an ADCP location (76° E and 9° N)

7.2.4 Development of marine ecosystem models for regional and coastal applications

The European Regional Seas Ecosystem Model (ERSEM) is a generic and well established lower-trophic level marine food web and biogeochemical cycling model. It is one of the few marine

ecosystem models that uses variable stoichiometry and resolves the ecosystem dynamics with major biogeochemical cycles of carbon, nitrogen, phosphorus, iron and silicate. It divides the phytoplankton, zooplankton and benthos into functional groups, and calculates the biomass for each group individually. The model includes various state variables, including pelagic and benthic living organisms, dissolved and particulate nutrients, dissolved oxygen and carbonates. ERSEM follows the lower trophic food-web chain from primary producers of phytoplankton, consumers like zooplankton, to decomposers of bacteria. ERSEM includes four types of phytoplankton, namely, pico-, nano-, and microphytoplankton, and diatoms. ERSEM includes three types of zooplanktons, meso-, and microzooplankton and heterotrophic nanoflagellates. Decomposers include one type of heterotrophic bacteria. Chlorophyll-a is determined separately in the model based on the quantification formulation. ERSEM is also equipped with a comprehensive three-layer benthic model and a fully resolved carbonate system. It provides active nutrients and mass exchanges in the water-sediment interface.

The coupling between FVCOM and ERSEM has been successfully implemented through FABM (Framework for Aquatic Biogeochemical Models; http://fabm.net) during the reporting period.

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 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 by the reversing monsoon currents, seasonal upwelling, river influx and terrigenous discharge. Specially, in the context to algal biomass (proxy: concentration of chlorophyll-a), the Indian coastal water has been experiencing frequent upsurges due to algal bloom events. Most of the time the high biomass algal bloom events significantly influence the ambient water quality and make the situation very important to be considered in the biogeochemical models. On the other hand, it's very important to predict algal bloom events for a wide variety of applications. The algal bloom reports from both east and west coast of India are very sporadic in nature. Therefore, a comprehensive compilation of the reported algal bloom events with quantitative information on chlorophyll-a concentration and abundance of phytoplankton has been prepared by mining the available literature on algal blooms in the coastal waters of India for 114 years. Additionally, the reported bloom events are also categorized according to the coast and season. The analysis depicted a dynamic range of chlorophyll-a varying within 0.02 to 238 (average 31.5) $mg.m^{-3}$ during the bloom conditions in the coastal waters of the western Bay of Bengal whereas within 0.03 to 721 (average 28.66) $mg.m^{-3}$ in the coastal waters of the eastern Arabian Sea (Figure 7.10). In the context to phytoplankton abundance, the variability in the coastal waters of the western Bay of Bengal was from 655 to 9.32 x 10^7 (average 10.71 x 10^6) cells l^{-1} and the variability in the coastal waters of the eastern Arabian Sea was from 16 to 41 x 10^9 (average 4.57 x 10^8) cells l^{-1}. The quartile analysis of the chlorophyll-a values (Figure 7.10) represented the 25^{th} percentile of chlorophyll-a value as 6.32 $mg.m^{-3}$, 50th percentile as 17.55 $mg.m^{-3}$ and 75^{th} percentile as 29.97 $mg.m^{-3}$ along the coastal waters of the western Bay of Bengal whereas, the 25^{th}, 50^{th}, and

75th percentile values in the coastal waters of the eastern Arabian Sea are 1.96, 8.3, and 20 $mg.m^{-3}$, respectively. Similarly, the 25th, 50th, and 75th percentile values for the phytoplankton cell abundance are 2.38 x 10^4, 2.95 x 10^5, and 4.95 x 10^6 $cells.l^{-1}$, respectively along the coastal waters of the western Bay of Bengal and 1.4 x 10^5, 1.4 x 10^6, and 1.59 x 10^7 $cells.l^{-1}$, respectively in the coastal waters of the eastern Arabian Sea (Figure 7.10).

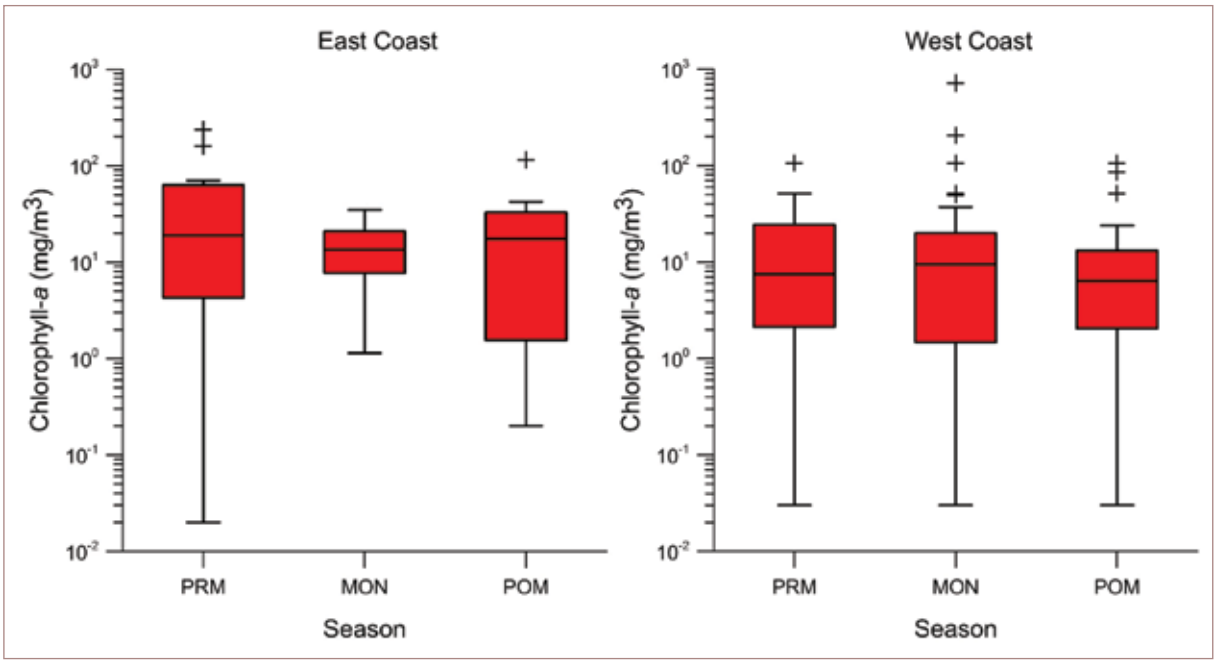


Figure 7.10. Seasonal variability of chlorophyll-a concentration in the coastal waters of the western Bay of Bengal and eastern Arabian Sea during algal bloom conditions

7.3 Development of Ocean Climate Change Projections

INCOIS is leading the 'Development of Ocean Climate Change Advisory Services (OCCAS)' as part of the "Deep Ocean Mission" initiated by the Ministry of Earth Science (MoES). This project aims to understand the impacts of climate change on the ocean state and enhance the sustainable use of marine resources.

The OCCAS program is designed to predict long-term changes in sea levels, the intensity of cyclones, storm surges, and waves, and their impacts on coastal communities, including coastal erosion and inundation. The project aims to inform better policy decisions to mitigate coastal damage due to climate change. Another key focus is to assess the impact of climate change on the coastal marine ecosystem and provide advisories on the likelihood and spread of Harmful Algal Blooms, which could affect future fishing zones and the marine-driven economy along India's coastline.

The project is divided into five modules, each implemented with the help of well-designed observing and monitoring networks and a suite of modeling frameworks. The outcomes of these modules, in terms of climate assessments, will be provided through interactive GIS-based mapping applications to be effectively utilized for coastal zone management and policy decisions.

7.3.1 Sea Level Projections

The increasing flood risks along the coastlines are driven by extreme sea levels (ESL). The ESL results from combined effect of mean sea level (MSL), astronomical tides, and variations due to wave and storm surges. The sea level is driven by global thermal expansion, glacier, Greenland and Antarctic Ice sheets, and land water storage components along with circulation and density-driven variation ('zos' variable), gravitational-rotational-deformational (GRD) effects, and vertical land movement (VLM) due to natural as well as anthropogenic processes including glacial isostatic adjustment (GIA).

Existing available global datasets for the above components are used to generate probabilistic 100-year return ESLs along the coasts of Indian subcontinents (65°-95°E, 0°-25°N) based on high emission business as usual scenario projections of mean sea level (MSL), high tide water level, and water level variations due to extreme events which may occur as a result of climate change which is a function of storm surge and significant wave height at the end of 21st century. The aim is to assess the change in ESLs and in the constituent components with uncertainty of change which would assist in coastal vulnerability mapping as the considered parameters are the risk factors for coastal vulnerability assessment.

Since ESL events occur as an integrated effect of mean sea level rise, astronomical tide, wave, and storm surge events. The probability distribution of each of these components are adopted from different publicly available datasets. The mean sea level and its uncertainty is taken from IPCC AR6 sea level projections. For high-tide estimation, we have used FES2014 (latest version of Finite Element solution for tidal model) for baseline period (1994-2014) and DFLOW FM model simulation forced with CMIP5 RCP8.5 sea level boundary condition for projections. The other climate extreme processes such as storm surge and wave setup were estimated using DFLOW FM and

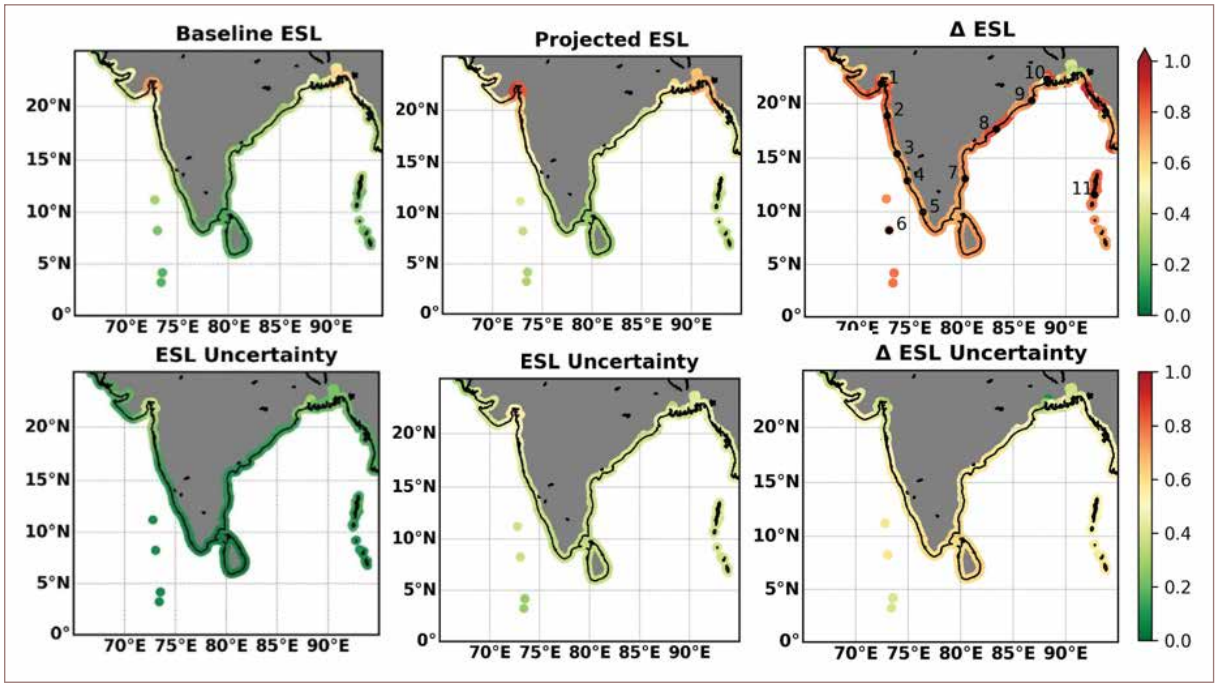


Figure 7.11. (Top) The baseline (present day; 1994-2014), projected (for 2100) and the change in ESL (m) along the coast of India. (Bottom) Corresponding 1 standard deviation uncertainty associated with ESL estimates

WaveWatch III model, respectively forced by ERA-interim for the baseline period and CMIP5 RCP8.5 fields for projecions. These baseline and projected tidal datasets pertaining to 5th, 50th and 95th percentiles are available at LISCoAsT (Large scale Integrated Sea-level and Coastal Assessment Tool), developed by JRC (Joint Research Commission) of the European Commission. To estimate complete probability distribution for climate extremes, the available percentiles from the datasets at each location were fitted using a generalized extreme value (GEV) distribution using Nelder-Mead algorithm. The individual probability density function was added by sampling values from each distribution and repeat the same 10,00,000 times to create the distribution for ESL (Figure 7.11).

As part of the Deep Ocean Mission, INCOIS plans to use in-house high-resolution models to dynamically downscale CMIP6 sea level projections for the coastal waters of India.

Mean regional Sea Level projections

For downscaling regional sea level projections, we plan to use high-resolution ocean models forced by bias-corrected atmospheric forcings from CMIP6 simulations.

As a first step, the systematic bias of the CMIP6 atmospheric forcing fields were removed using 3-hourly European Centre for Medium-Range Weather Forecasts Reanalysis 5 (ERA5) dataset for the historical (1980–2014) and projected (2015–2100) period. At this stage only RCP8.5 scenario is considered. In order to incorporate the high-frequency variability in the projected field, 30-day highpass variability after removing the annual mean from ERA5 is added back to each of the atmospheric reconstructed fields. The mean fields and high-frequency components are repeated every year and 4-cycle, respectively, to cover the whole period from 1980 to 2100 (Figure 7.12).

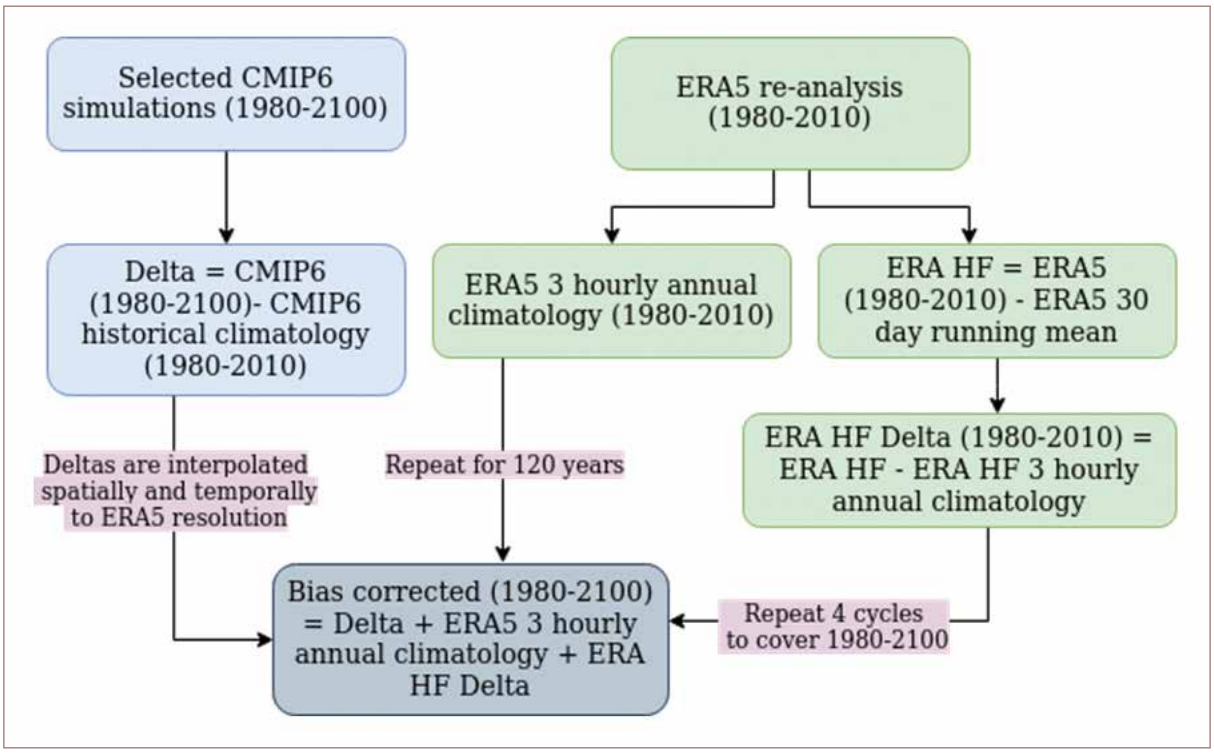


Figure 7.12. Flow chart of the method adopted for bias correction of the forcing fields

To test these bias-corrected CMIP6 forcing fields, we use the existing operational Regional Ocean Modeling System (ROMS) with an eddy-permitting resolution (1/12°). To capture the spread of projections, the model used forcing fields from four different CMIP6 GCMs, selected based on a performance evaluation in the Indian Ocean domain by Sajid et al. (2023). Their study evaluated the performance of ESMs in simulating dynamic sea levels (DSLs) and related surface wind fields over the Indian Ocean, identifying a subset of approximately ten top-performing models. CMCC_CM2_SR5, EC-EARTH3, HadGEM3-GC31-LL and CNRM-CM6-1-HR were selected to provide climate change signals from ROMS. Downscaled ocean features from the ROMS historical experiment (1995-2015) show more spatial detail than the GCM, with the means and variances of parameters such as SST, SSS, and RSL more consistent with the observations in ROMS than GCMs (Figure not attached). In all downscaling, the projected RSL rises in the northern Indian Ocean during 2081–2100 relative to 1995-2015 is generally half or less than RSL rises in the GCMs (Figure 7.13). The discrepancies of the RSL rise in the Indian Ocean between the GCMs and ROMs are less than 10cm.

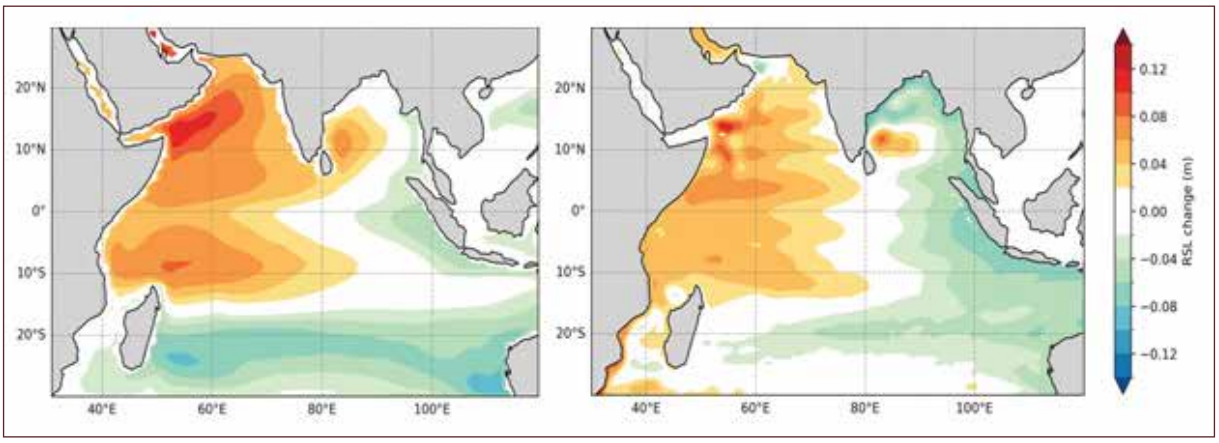


Figure 7.13. Multi-model mean of projected changes in mean DSL for 2081-2100 relative to 1995-2014 from CMIP6 climate models (left) and ROMS downscaled models (right)

Finally, the downscaling will be made using high-resolution global model configuration based on MOM6 (Uniform horizontal resolution of 1/12° and 41 hybrid vertical layers).

7.3.2 Projections of Biogeochemical State of the Indian Ocean

Working towards the future projections of the biogeochemical state variables for the Indian Ocean, we have selected three CMIP6 models which cover almost 80% of all the CMIP6 future projections in two ecosystem basins (the Arabian Sea and Bay of Bengal). The three models are a) GFDL, b) CNRM, and c) UKESM.

After the model selection is completed, we explore several downscaling and bias-correction approaches. For the ocean state variables, we found that the Time-Varying Delta (TVD) method could only be applied for downscaling and bias-correction as the variables are 4D in nature (i.e., Lon, Lat, Depth, and Time). We apply four (TVD, Quantile mapping, Variance Scaling, and Linear Scaling) downscaling and bias correction approaches for the atmospheric variables (3D i.e., Lan, Lot, and Time) and find TVD as the best approach to bias correct atmospheric variables too. Following this we bias correct and downscale all the state variables (8 atmospheric variables, 5 physical state

variables, and 8 biogeochemical state variables) required for model runs. Figure 7.14 shows the steps for developing the biogeochemical projections of the Indian Ocean and Figure 7.15 shows the future changes in air temperature after applying TVD downscaling and bias-correction method.

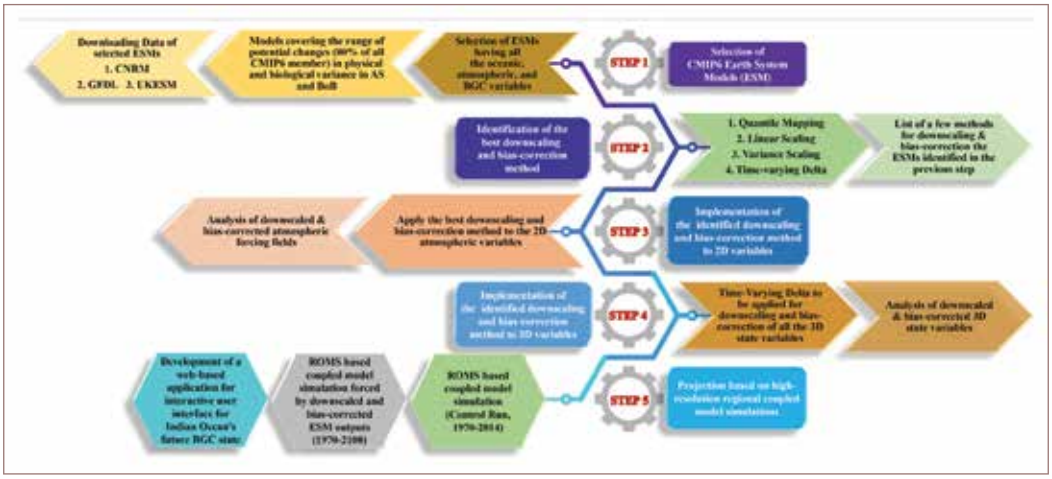


Figure 7.14. Schematic diagram shows the steps to be followed for developing the projections of biogeochemical state of the Indian Ocean

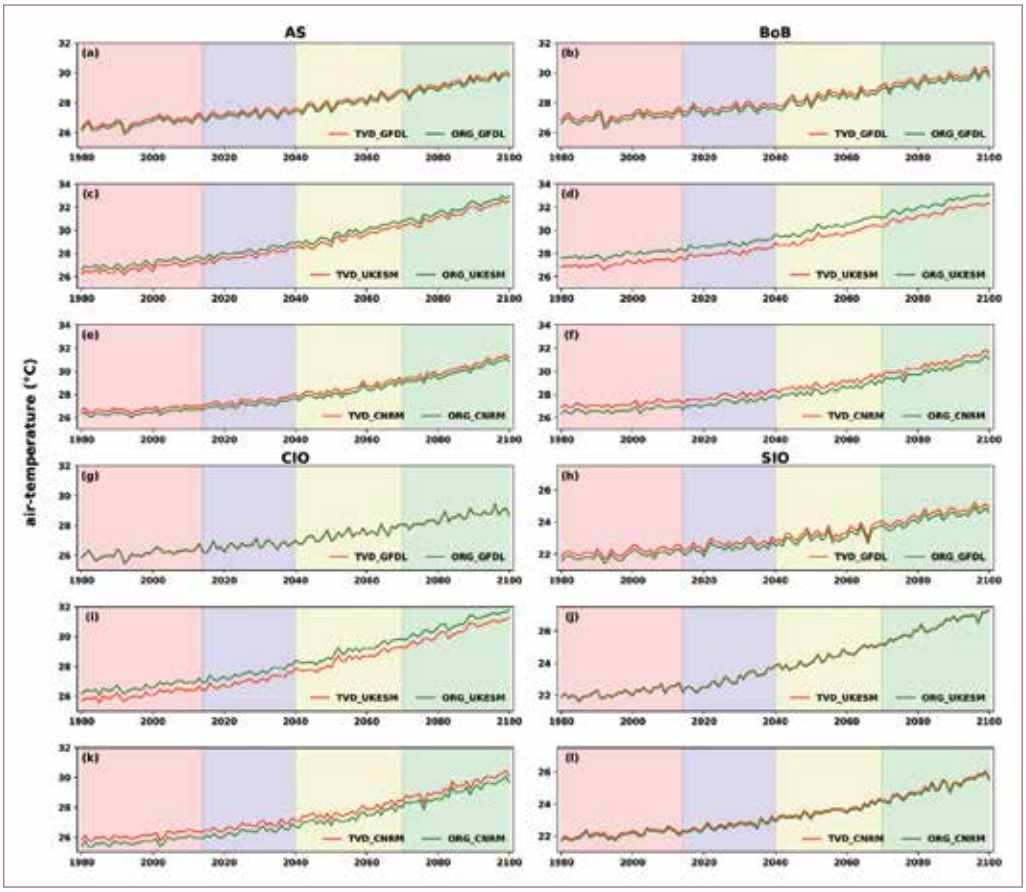


Figure 7.15. Region averaged annual mean air-temperature (°C) of CMIP6 Earth system Models (GFDL, UKESM, and CNRM) from 1980 to 2100 for the Arabian Sea (AS), Bay of Bengal (BoB), Central India Ocean (CIO), and Southern Indian Ocean (SIO). The red-shaded region indicates the historical period, the blue-shaded region for the near-future period, the yellow-shaded region for the mid-future period, and the green-shaded region for the far-future period

7.3.3 Wave Climate Projections

Under the Deep Ocean Mission, the Indian National Centre for Ocean Information Services (INCOIS) is tasked with providing robust wave climate projections for the Indian Ocean (IO) region. The Coupled Model Intercomparison Project Phase 6 (CMIP6) does not offer ocean surface wave projections, necessitating the development of a WAVEWATCH III (WW3) model setup specifically for the IO region. This setup involves evaluating various source term packages within the WWIII model to identify the optimal scheme for the IO under diverse conditions, ultimately selecting the ST4 scheme for wave climate projection.

The model setup for projection has three mosaic grids in a nested configuration: Global (0°-360°, 80°S-70°N), Indian Ocean (30°E-120°E, 60°S-30°N), and North Indian Ocean (32°E-100°E, 5°S-29°N). This nesting facilitates a two-way exchange of information between overlapping grids. Spatial resolution varies from a coarse 1° global grid to a finer 0.1° North Indian Ocean grid, generated using an automated grid generation package (V2.2) with ETOPO1 bathymetry data.

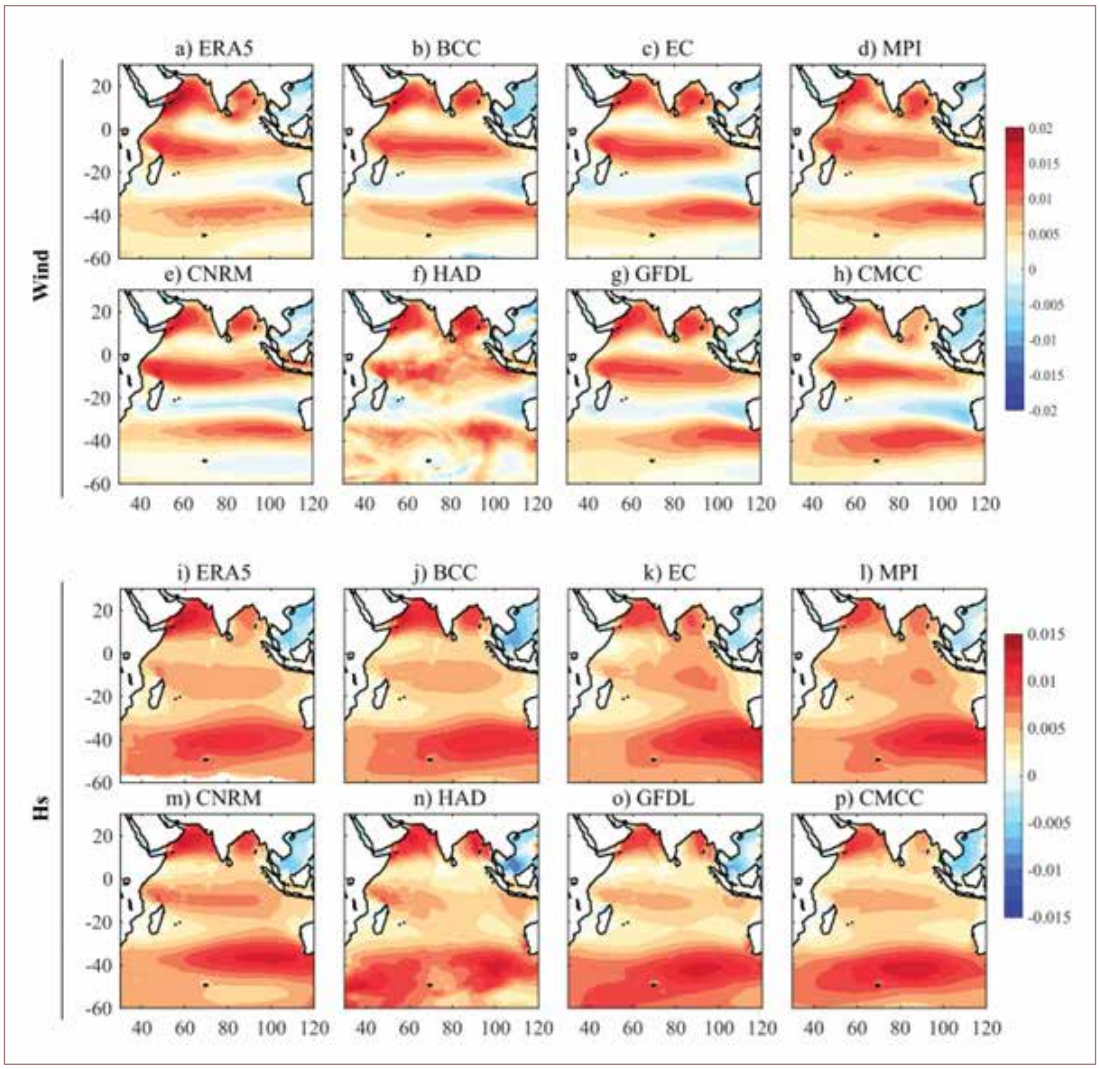
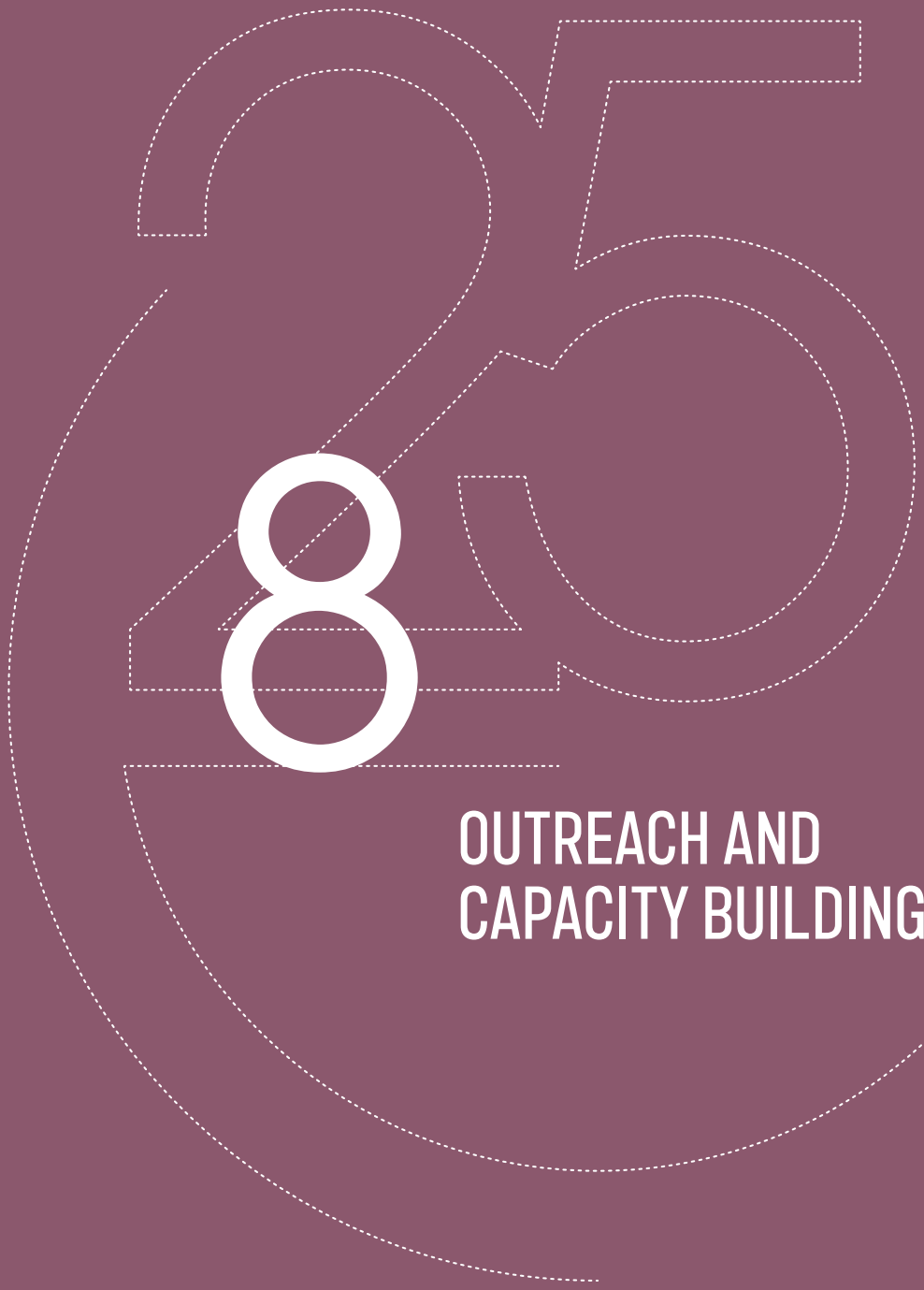


Figure 7.16. Comparison of the first mode of Empirical Orthogonal Function (EOF) for wind speed and significant wave height in the Indian Ocean between ERA5 reanalysis data and CMIP6 models

To identify the optimal CMIP6 model wind fields for IO wave climate projections, a 35-year (1980-2014) wind-wave climate simulation was conducted using WW3, forced with seven CMIP6 Global Climate Models (GCMs): BCC-CSM2-HR, EC-Earth3, CMCC-CM2-SR, GFDL-ESM4, CNRM-CM6-1-HR, HadGEM3-GC31-MM, and MPI-ESM1-2-HR. These simulations were validated against in-situ buoy observations and ERA5 reanalysis data. Statistical analyses demonstrated that the MPI, BCC, and EC models most accurately represent wave characteristics in the IO, showing strong correlations with observations and effectively capturing inter-annual variability (Figure 7.16).

Extreme wave analysis revealed that simulations forced by the MPI, BCC, and EC models align well with ERA-5 data, showing more than 220 rough days south of the equator and fewer than 150 rough days north of it. Consequently, these three models were selected for composite analysis to evaluate their ability to reproduce the impacts of climate modes on IO wave climate. Among them, the EC model performed best in capturing wave fields influenced by the El Niño-Southern Oscillation, Southern Annular Mode, and Indian Ocean Dipole, followed by BCC and MPI.

Thus, this study identifies the EC, BCC, and MPI models as the optimal CMIP6 models for projecting wave climate in the Indian Ocean.



8 OUTREACH AND CAPACITY BUILDING

Starting on its 25th Foundation Day on 03 February 2023, INCOIS embarked on a year-long celebration of its significant contributions to ocean science and society. Recognized as a national leader, INCOIS has played a pivotal role in advancing oceanic knowledge and providing essential services to India and neighboring countries. To enhance the outreach of its services and mark its silver jubilee year, INCOIS organized competitions and events to foster ocean awareness and engagement. These activities showcased the institution's endeavors over its 25-year journey, reinforcing its commitment to sustainable ocean management and societal well-being. Through these efforts, INCOIS sought to strengthen its outreach and impact, ensuring that its services continue to benefit communities and industries reliant on the ocean.

8.1 Mega Awareness Campaigns

INCOIS celebrated its 25th year with five Mega Awareness Campaigns across five coastal states, engaging 2,300 fishermen. The campaigns included events in Andhra Pradesh, Gujarat, West Bengal, Maharashtra, and Tamil Nadu, involving collaborations with various organizations and institutions. Notable inaugurations were by Union Minister shri Kiren Rijiju, Minister Biplab Roy Chowdhury, and Governor Dr. Tamilsai Soundararajan (Figure 8.1). These events brought together fisherfolk, women entrepreneurs, students, marine scientists, and organizational representatives, fostering knowledge sharing on research and operational services for the fishing community.

Figure 8.1. Images taken during the Mega Awareness Campaigns held across the coastal states as part of INCOIS silver jubilee celebrations

8.2 User Interaction Workshops

INCOIS hosted User Interaction Workshops at 237 coastal villages in partnership with various organizations, engaging over 9,000 fishermen from 10 coastal states. These workshops provided fishermen with valuable insights into oceanic conditions, weather forecasts, and safety measures.

Through interactive sessions and demonstrations, INCOIS facilitated meaningful dialogue and knowledge exchange, empowering fishermen to make informed decisions while navigating the seas. By fostering collaboration and community engagement, these workshops contributed to enhancing the resilience and well-being of coastal communities reliant on marine resources.

Additionally, INCOIS facilitated unique interaction workshops with 70 fishermen leaders from Andhra Pradesh, further strengthening the dissemination of crucial oceanographic knowledge and safety practices among key community representatives.

8.3 Swachch Sagar Surakshit Sagar

INCOIS, in partnership with Matsyakara Samkshema Samiti, led the 'Swachch Sagar Surakshit Sagar/Clean Coast Safe Sea Campaign' across 37 sites in 12 coastal districts of Andhra Pradesh on September 16 and 17, 2023, coinciding with International Coastal Cleanup Day (Figure 8.2). This initiative is geared towards fostering coastal cleanliness, environmental awareness, and responsible beach management. Apart from organizing beach clean-up efforts involving 6470 participants, the campaign featured awareness programs led by INCOIS scientists. These sessions aim to educate attendees about INCOIS' crucial role in delivering ocean information services, encompassing vital aspects such as Potential Fishing Zone advisories, Tsunami Early Warning, High wave, Storm Surge, coral bleaching, and harmful algal bloom alerts. Through this initiative, INCOIS sought to enhance public understanding of ocean conservation and its own contributions to safeguarding coastal ecosystems.

Figure 8.2. Collage image of the Swachh Sagar, Surakshit Sagar/Clean Coast Safe Sea Campaign across the 12 coastal districts of Andhra Pradesh during 16-17 September 2023

8.4 World Environment Day

On the occasion of the World Environment Day, on 05 June 2023, students from nearby schools visited INCOIS and gained insights on various Ocean services (Figure 8.3). The young minds were captivated by learning how INCOIS's services are benefiting coastal communities, especially through early warnings.

Figure 8.3. Image taken during the world Environment Day celebrations and open day at INCOIS on 05 June 2023

8.5 World Oceans Day

On the eve of World Oceans Day on 08 June 2023, INCOIS organized an open house programme. The event attracted over seven-hundred (700) visitors, ranging from school and university students to retired officers and the general public (Figure 8.4). Attendees gained valuable insights into the critical role oceans play in their daily lives. Visitors had the opportunity to witness state-of-the-art laboratories (National Tsunami Early Warning Centre, Operational Ocean Services Laboratory, underwater gliders and satellite ground stations) and engage in interactive sessions with the scientists about ocean science and technologies.

Figure 8.4. Collage image of the world Ocean Day celebrations and open day at INCOIS on 08 June 2023

8.6 Orientation program on iGOT by Mission Karma Yogi

As part of capacity building initiative, an orientation program on Mission Karmayogi and the usage of the iGOT platform was conducted by ITCOOcean On 24 July 2023. The Mission Karma Yogi (MKY) team provided an online training to all INCOIS staff to work in harmonisation for effective and efficient delivery of public service.

8.7 Ocean Society of India Conference

The Eighth National Conference of Ocean Society of India (OSICON 23) was held at INCOIS during 23-25 August 2023. The conference brought together scientists, engineers, and technologists from academic institutions, research laboratories, scientific organizations, industries, and anyone engaged in any ocean-related activity or profession to discuss the latest advancements in ocean science and technology (Figure 8.5). A total of three hundred and fourteen (314) papers were presented and around six hundred (600) participants attended the conference. The Focal Theme of OSICON 23 was "Operational Oceanography - Science to Services." The conference also hosted two special sessions of the Indian Meteorological Society and Federation of Indian Geosciences Associations. In addition to the academic and technical sessions, the event featured an exhibition showcasing cutting-edge marine technologies, new instruments, etc.

Three new products of INCOIS (1. Coastal Water Quality Buoy at Visakhapatnam, 2. Ocean Information Portal for the South Pacific Region and 3.WMO-RSMC for Numerical Ocean Wave Prediction & Global Numerical Ocean Prediction) were inaugurated by Dr. M. Ravichandran, Secretary, Ministry of Earth Sciences during the conference.

Figure 8.5. Collage image of the events conducted as part of OSICON-2023

8.8 Communication Test

26th Communications (COMMs) tests of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) was conducted on 07 June 2023 to validate the TSPs (Tsunami Service Providers) dissemination process 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 scenario of magnitude 9.0 at the Nicobar Islands, India, was evaluated, and ITEWC disseminated notifi cation messages through email, fax, GTS, SMS, the website to 26 NTWCs and including two TSPs (Australia & Indonesia) in the Indian Ocean Region. TSP-India success rate is shown in Figure 8.6.

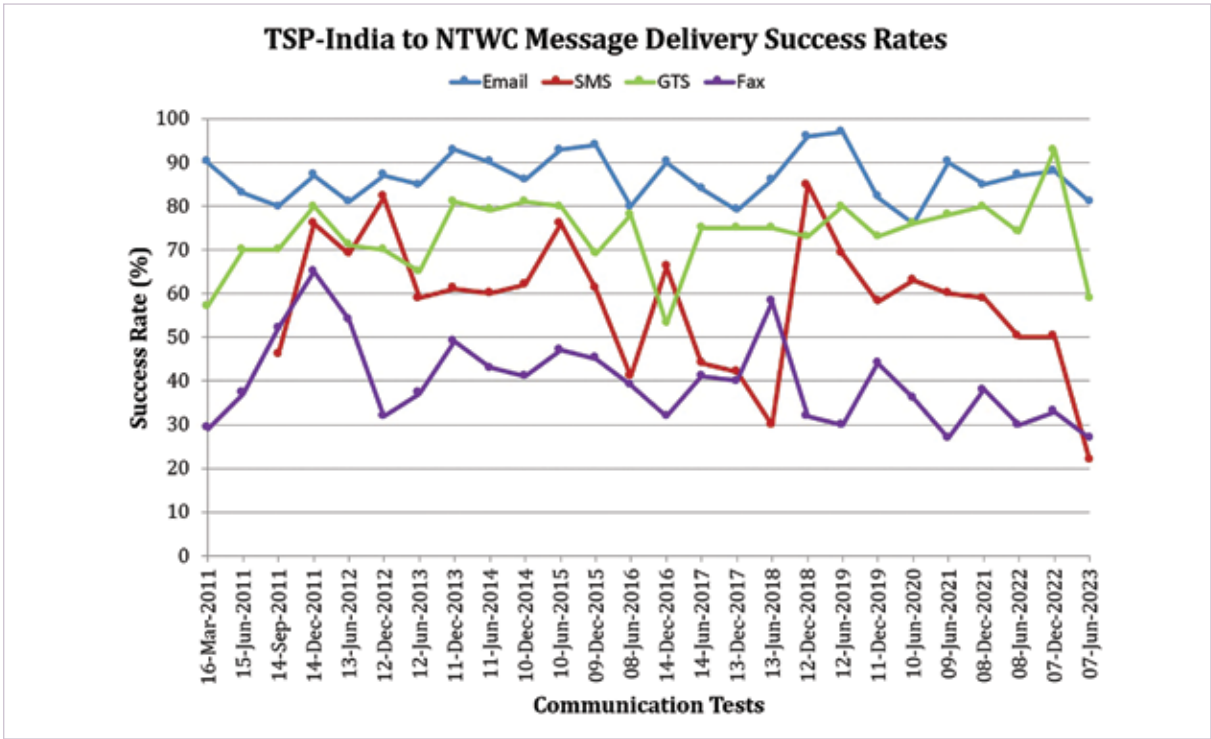


Figure 8.6. Success rates of TSP-India message delivery during COMMs Tests

8.9 Pre-IOWave23 Workshop on Tsunami Standard Operating Procedure (SOP)

In preparation for the IOWave23 tsunami exercise scheduled for October 2023, INCOIS, in collaboration with the National Disaster Management Authority (NDMA), organized a Pre-IOWave23 Workshop on 'Tsunami Standard Operating Procedure' on 13 and 14 September 2023 (Figure 8.7). The purpose of this workshop was to familiarise the Disaster Management Organisations (DMO) of Coastal States/ UTs with the tsunami bulletins issued by INCOIS, facilitate improvement of their SOPs at DMOs and Broadcasting media and to provide briefing on mock tsunami exercise A total of fifty-five(55) participants attended the workshop from various organizations such as NDMA, CWC, Ministry of Jal Sakthi; DRDO; Disaster Management Officials from coastal states; officials from the Indian Navy, Coast Guard, Airforce, Airport Authority of India, Maritime board, fisheries departments, and media.

Figure 8.7. Images taken during the Pre-IOWave23 Workshop on Tsunami Standard Operating Procedure

8.10 Outreach activities as part of World Tsunami Awareness Day

On the occasion of World Tsunami Awareness Day (WTAD) on 05 November 2023, INCOIS hosted an Open Day that drew a diverse crowd of over 1000 visitors. The theme of 2023 WTAD was "Fighting Inequality for a Resilient Future". As part of the WTAD the following events were also organized by INCOIS.

(1) On 15 October, the Indian Tsunami Early Warning Centre at INCOIS marked 16 years of dedicated service to the nation. ITEWC monitors two (2) tsunamigenic source regions (Andaman-Sumatra and Makran subduction zones in the Indian Ocean) and provides tsunami services to 25 Indian Ocean rim countries.

(2) Tsunami Mock Exercise: On 05 November 2023, World Tsunami Awareness Day, the Odisha State Disaster Management Authority conducted a Tsunami Mock Exercise based on test bulletins issued by INCOIS to Odisha. Around twenty thousand (20,000) people from thirty (30) villages, under eighteen (18) blocks of six (6) coastal districts participated and were evacuated to higher ground. Thirty (30) IOC-UNESCO Tsunami Ready programme implementing communities participated in the exercise to evaluate Tsunami Ready Indicators.

(3) As part of WTAD, various competitions such as drawing/painting, extempore, and science exhibition/model making were held to raise tsunami awareness among students from various schools across Hyderabad. The events featured participation of 33 students in drawing/ painting, 34 students in extempore, and 24 students in science exhibition/model making. Winners were felicitated with awards during the closing ceremony of the event (Figure 8.8).

(4) INCOIS participated in the World Tsunami Awareness Day Webinar on 07 November organized by the UNESCO-IOC Intergovernmental Coordination Group for Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) and Indian Ocean Tsunami Information Center (IOTIC on the theme 'Fighting Inequality for a Resilient Future.' During the event, Dr. T. Srinivasa Kumar, Director of INCOIS & IOC Vice Chairperson, delivered a talk on 'Research, Development, and Implementation Plan for the Ocean Decade Tsunami Programme'.

(5) A social media contest was held to raise awareness about tsunami. INCOIS set up an informative

photo booth where visitors could capture moments and learn about tsunami response plans. Participants were encouraged to take selfi es and post them on social media with messages about "Tsunami Awareness & Preparedness."

Figure 8.8. Collage images of the World Tsunami Awareness Day Celebrations at INCOIS

(6) To encourage dialogue and address queries, INCOIS organized Q&A sessions where attendees could interact directly with scientists and researchers. This helped break the barrier between the scientific community and the public.

(7) INCOIS conducted Week-long Events in Kerala in collaboration with Amrita University as part of tsunami awareness campaigns in Alappad, Kollam, Kerala including Tsunami awareness sessions, Drawing competitions, Scavenger hunt (game for awarness on preparing an emergency kit for tsunamis) etc. About 365 students from various schools in the locality participated in the events (Figure 8.9).

Figure 8.9. Collage of images taken during Week-long Events in collaboration with Amrita University as part of tsunami awareness campaigns in Alappad, Kollam, Kerala

(8) Dr. Patanjali Kumar, Scientist, INCOIS and

the team met with local Panchayat leaders and ward members to raise tsunami awareness and gather information on evacuation plans, sheltering, and signage. He also delivered hybrid awareness sessions to Faculty and students at the Amrita University, Amritapuri campus, effectively educating them about tsunami awareness and preparedness.

(9) The team of 16 participants, including women, men, and students, organized a vulnerability assessment in Azheekal village, Kollam, Kerala. They conducted a comparative analysis with government offi cials and introduced the concepts of the "Problem Tree" and "Solution Flower" to engage with the community.

(10) The faculty of Amrita University and the team conducted an online program to raise tsunami awareness, especially for Amrita-adopted villages. As part of this program, they conducted a drawing competition in other parts of the Amrita-adopted villages, including content in the local language Malayalam.

8.11 Tsunami Ready Recognition Programme

UNESCO-IOC Tsunami Ready Recognition Programme (TRRP) is a community performance-based programme that facilitates tsunami preparedness as an active collaboration of the public, community leaders, and local and national emergency management agencies. Tsunami Ready communities are better prepared to save lives through better planning, education, and awareness. The TRRP is essential for enhancing preparedness, and INCOIS continued its support of the programme.

- In Odisha, after the Venkatraipur and Noliasahi were recognised as Tsunami Ready communities by UNESCO-IOC, the Odisha State Disaster Management Authority (OSDMA) is implementing the tsunami ready programme in another 24 coastal villages (each Coastal district 4 villages). INCOIS provided all related maps (tsunami hazards, Inundation, etc.) to OSDMA to implement the related TRRP indicators.

Figure 8.10. TRRP meeting held at Bhubaneshwar on 19 March 2024

- In Andaman & Nicobar Islands, the process of implementing tsunami ready is initiated for the Car Nicobar area.
- In Kerala, the implementation of the tsunami-ready programme in nine coastal villages of nine districts is in progress. Kerala State Disaster Management Authority (KSDMA) conducted training and awareness programmes.
- INCOIS conducted the National Tsunami Ready Board (NTRB) meeting on 07 February 2024. The meeting was conducted along with the ICG/IOTWMS Steering Group meeting. IOTWMS experts also participated in the NTRB meeting and highlighted 12 TRRP indicators.
- INCOIS Scientists provided training to OSDMA officials on TRRP indicators and related documentation to proceed with 24 villages for TRRP held at Bhubaneshwar, Odisha on 19 March 2024 (Figure 8.10).

8.12 Outreach activities as part of Swachhata Pakhwada

INCOIS organized several activities such as plantation drive, awareness and campus sanitization as part of swachhata pakhwada celebrations. On 01 October, 2023 a mass cleanliness drive was organized by INCOIS outside the campus premises where more than 100 students along with parents from Pragnya Montessori School, Pragathi Nagar were also participated with the INCOIS staff (Figure 8.11). Following the event, students and parents had the opportunity to visit the INCOIS facilities and interact with scientists. This enabled them to learn about the advanced technologies employed by INCOIS for ocean research and its societal applications.

A special swachhata campaign 3.0 was also held on 20 September 2023 during which, Nodal Officers of INCOIS visited/inspected the Record Rooms and identified the physical files under the preparatory phase of Special Campaign 3.0. There are a total of 3150 files in the Record Rooms and 200 are for review.

Figure 8.11. Collage images of various activities held as part of Swachhata Pakhwada

8.13 Outreach Program of 9th India International Science Festival (IISF)-2023

In connection with an Outreach Program of 9th IISF-2023 and on the occasion of the 19th year of Indian Ocean Tsunami on 26 December, 2023, INCOIS opened its doors to the public, hosting an Open Day that drew a diverse crowd of over 600 visitors. During the Open Day, visitors had a chance to engage with the scientists and researchers at INCOIS through Q&A sessions. The Open Day helped the visitors to understand in detail about the advanced tools used by INCOIS in generating Tsunami Early Warning and other ocean services.

A scientific talk was also organized on the 'Utilization of GNSS (Global Navigation Satellite System) data for earthquakes and Tsunamis'. Dr. Vineet K. Gahalaut, Chief Scientist, National Geophysical Research Institute (CSIR-NGRI), Hyderabad & former Director of National Centre for Seismology (NCS), delivered an enlightening talk during the event. Dr. Gahalaut's explained about the earthquake cycle, based on inter seismic, co-seismic and post seismic deformation. The talk delved into the critical role of GNSS data in understanding and monitoring seismic activities and tsunamis.

To spread awareness about IISF, Dr. S.S.C. Shenoi, Former Director, INCOIS and National Vice-President of Vijnana Bharati (VIBHA) delivered a brief overview of the upcoming IISF 2023 event and encouraged the active participation of MoES and related institutions in the program (Figure 8.12). Director, INCOIS congratulated and appreciated the INCOIS team and Vijnana Bharati (VIBHA) for successful conduct of this outreach programme.

Figure 8.12. Collage images of various events held at INCOIS as part of Outreach Program of 9th IISF-2023 & 19th Year of Indian Ocean Tsunami (2004)

8.14 Awards of Doctor of Philosophy

Table 8.1. List of staff awarded the degree of PhD during 2023-24

Sl No	Name & Designation	Guides Name	Subject	University/ Department	Thesis Title
1	Dr. Ajay Kumar B., Scientist-D, INCOIS	Prof. B. Veeraiah. Professor & Head, Dept. of Geophysics, Osmania University, Hyderabad	Geophysics	Dept. of Geophysics, Osmania University, Hyderabad	Earthquake source characteristics of Indian region with special emphasis on tsunami early warnings
2	Dr. Teesha Mathew., Senior Research Fellow, INCOIS	Dr. Abhisek Chatterjee, Scientist-E, OMARS, INCOIS	Oceanography	INCOIS-KUFOS joint centre, Kerala University of Fisheries and Ocean Studies, Kochi	Biogeochemical Variability of North Indian Ocean and its Coastal Waters
3	Dr. Afroosa Balkies Bai M., Senior Research Fellow, INCOIS	Dr. Arya Paul, Scientist-E, OMARS, INCOIS	Oceanography	INCOIS-KUFOS joint centre, Kerala University of Fisheries and Ocean Studies, Kochi	"Madden Julian Oscillation driven see-saw in the Indo-Pacific barotropic sea level
4	Dr. Patanjali Kumar CH., Scientist-E, INCOIS	Prof. B. Veeraiah. Professor & Head, Dept. of Geophysics, Osmania University, Hyderabad	Geophysics	Dept. of Geophysics, Osmania University, Hyderabad	Tsunamigenic Source Characterization for Indian Ocean: Numerical Modelling, Database Generation and Decision Support

5	Dr. Jofia Joseph., Project Scientist-I, INCOIS	Dr. Girish Kumar M.S., Scientist-E, ODICT, INCOIS	Oceanography	INCOIS-KUFOS joint centre, Kerala University of Fisheries and Ocean Studies, Kochi	Sub-daily scale variability of air-sea interaction processes in the north Indian Ocean
6	Dr. Mahendra R.S., Scientist-E, INCOIS	Dr. Francis P.A., Scientist F & Division Head, OMDA, INCOIS	Geoinformatics	Dept. of Marine Geology, Mangalore University, Mangalore	Coastal Multi-Hazard Vulnerability and Risk Assessment along the Andhra Pradesh Coast using Geospatial Techniques

8.15 Academic Project/Internship carried out by students at INCOIS

INCOIS continued to support the student research in ocean science and related fields and thereby facilitated their completion of academic courses as well as future progress in their career. As part of this programme, 69 students from various Universities and Institutes across India completed their academic Projects/Internship under the guidance of INCOIS scientists during 2023-24. The details of the student projects are provided at Table 8.2.

Table 8.2 List of Students Completed their Academic Project Dissertation/Internship during 2023-24

SL No	Name	Institute Name	Project Guide
1	Mr. Kommu Charan Kumar	Central University of Kerala	Ajay Kumar B
2	Mr. Sudheer Y	Malla Reddy College of Engineering, Hyderabad	Venkat Shesu R
3	Mr. Vaishak GS	Mangalore University	Kiran Kumar N
4	Mr. Subrahmanya N	Mangalore University	Mahendra RS
5	Mr. Sainath Reddy C	Mangalore University	Prakash Mohanty
6	Mr. Shreyas K	Mangalore University	Prakash Mohanty

7	Mr. Ameen TP	Kerala University of Fisheries and Ocean Studies (KUFOS)	Remya P.G.
8	Ms. Martina Sandra	Kerala University of Fisheries and Ocean Studies (KUFOS)	Praveen Kumar B
9	Ms. Aiswarya TG	Kerala University of Fisheries and Ocean Studies (KUFOS)	Sanjiba Baliarsingh
10	Ms. Gayathri D	Cochin University of Science and Technology	Balakrishnan Nair T.M.
11	Mr. Dhanasekar SZ	IIT Kharagpur	SJ Prasad
12	Ms. Jeevika T	Nalla Malla Reddy Engineering College, Hyderabad	Vighneshwar S.P.
13	Ms. Keerthi P	Osmania University, Hyderabad	Ajay Kumar B
14	Ms. Haritha T	Osmania University, Hyderabad	Ajay Kumar B
15	Mr. Roni Johns Abraham	Cochin University of Science and Technology (CUSAT), Kochi	Thangaprakash VP
16	Mr. Sherif	IISc Bangalore	Sudheer Joseph
17	Mr. Pranay Kumar D	Telangana University	Mahendra RS
18	Mr. Anil T	Telangana University	Mahendra RS
19	Ms. Nadana Uni	Pondicherry University	Kunal Chakraborty
21	Ms. Malavika S	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Balakrishnan Nair T.M.
22	Ms. Aparna M	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Sandhya KG
23	Ms. Akshara S	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Sandhya KG
24	Ms. Treesa D	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Remya P.G.
25	Mr. R Sai Teja Reddy	MLR Institute of Technology (MLRIT), Hyderabad	Venugopala Rao V
26	Ms. Shaik Subani	MLR Institute of Technology (MLRIT), Hyderabad	Venugopala Rao V
27	Mr. S Bharath	MLR Institute of Technology (MLRIT), Hyderabad	Venugopala Rao V

28	Mr. P Uday Kiran	MLR Institute of Technology (MLRIT), Hyderabad	Venugopala Rao V
29	Ms. Naineni Shiny	Malla Reddy College of Engineering, Hyderabad	Udaya Bhaskar TVS
30	Mr. M Mani Ratan	MLR Institute of Technology (MLRIT), Hyderabad	Padmanabham J
31	Mr. K Bharath Kumar	MLR Institute of Technology (MLRIT), Hyderabad	Padmanabham J
32	Mr. P Shyam Koushik	MLR Institute of Technology (MLRIT), Hyderabad	Padmanabham J
33	Mr. Nagapuri Himesh	B V Raju Institute of Technology, Hyderabad	Udaya Bhaskar TVS
34	Ms. Poulami Chakraborty	Centurion University of Technology and Management (CUTM)	Prakash Mohanty
35	Mr. Mohammed Sohel	Centurion University of Technology and Management (CUTM)	Prakash Mohanty
36	Mr. M Surya Teja	Central University Karnataka	Srinivasa Rao N
37	Mr. SSN Achyut P	Central University Karnataka	Srinivasa Rao N
38	Mr. D Kamal	Central University Karnataka	Srinivasa Rao N
39	Ms. Haritha M Anna	Central University Karnataka	Kiran Kumar N
40	Ms. Hana K U	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Abhisek Chatterjee
41	Ms. Anju Maria Sony	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Rohith B
42	Ms. Akshaya H Das	Cochin University of Science and Technology (CUSAT), Kochi	Udaya Bhaskar TVS
43	Mr. Shanif CT	Cochin University of Science and Technology (CUSAT), Kochi	Sudheer Joseph
44	Ms. S Jasmin MB	Cochin University of Science and Technology (CUSAT), Kochi	Abhisek Chatterjee
45	Ms. Midhuna S	Cochin University of Science and Technology (CUSAT), Kochi	Remya P.G.
46	Mr. Sidharth S	Cochin University of Science and Technology (CUSAT), Kochi	Rohith B
47	Mr. Vishnu Prasad CV	Cochin University of Science and Technology (CUSAT), Kochi	Hasibur Rahman

48	Mr. Parthav N	VNR-VJIET, Hyderabad	Siva K Srinivas
49	Mr. Sai Ritish Reddy	VNR-VJIET, Hyderabad	Siva K Srinivas
50	Ms. Grishma B	GRIET, Hyderabad	Balaji B
51	Ms. Meenakshi R	Central University Karnataka	Srinivasa Rao N
52	Mr. Nandhu Mohan	Central University Karnataka	Srinivasa Rao N
53	Ms. Sruthy AS	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Patanjali Kumar CH
54	Ms. Karthika TS	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Patanjali Kumar CH
55	Ms. Sree Priya VB	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Patanjali Kumar CH
56	Mr. Amaljith PJ	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Sudheer Joseph
57	Mr. Aswin K Ajayan	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi	Prasad SJ
58	Mr. Bhawdeep P	Chaitanya Bharathi Institute of Technology, Hyderabad	Siva K Srinivas
59	Mr. M Munevver K	Central University Harayana	Sidhartha Sahoo
60	Mr. Siddharth K	Manipal University Jaipur	Balaji B
61	Ms. Sheeba Khan	University of Madras	Kiran Kumar N
62	Mr. Deepak L	ICFAI Foundation for Higher Education (IFHE), Hyderabad	Vighneshwar SP
63	Ms. Triparna P	Vellore Institute of Technology, Vellore	Vighneshwar SP
64	Mr. Samagra B	Vellore Institute of Technology, Vellore	Vighneshwar SP
65	Mr. YG Naga Sai Bhupathi	Andhra University, Visakhapatnam	Udaya Bhaskar TVS
66	Ms. Poojakshi	Mangalore University	Mahendra R.S.
67	Ms. Vijayashree	Mangalore University	Mahendra R.S.
68	Ms. Jayashree N	Mangalore University	Mahendra R.S.
69	Ms. Meghashree	Mangalore University	Kiran Kumar N

8.16 Outreach Lectures by INCOIS Scientists

As a part of INCOIS's 25th anniversary celebrations scientists at INCOIS, delivered a series of enlightening lectures across seven schools and colleges. This initiative was aimed to inspire and educate students about the significance of oceanic research and its critical role in global

sustainability. The scientists shared their expertise on various aspects of oceanography, marine sciences, and environmental conservation, nurturing the next generation of scientists and environmental stewards. The initiative saw a series of lectures delivered across various educational institutions. At Gitanjali Vedika School, Hyderabad, Dr. Nimit Kumar spoke on the "Ocean of Opportunities during the Ocean Decade." Dr. TVS Udaya Bhaskar delved into "Oceanography - Diving Deep into the Oceans" at Neo Geetanjali School, Hyderabad. Silver Oaks International School, Bachupally, hosted Dr. Sivaiah Borra, who discussed "INCOIS Operational Advisory, Forecast, and Early Warning Services." Dr. Srinivasa N. Rao addressed "Exploring the Role of Oceans and Utilizing Remote Sensing for Observations" at Pragnya Montessori School, Hyderabad. At Oakridge International School, Dr. T. Srinivasa Kumar (Director, INCOIS) and Dr. TVS Udaya Bhaskar shared their insights. Dr. TVS Udaya Bhaskar and Dr. Nimit Kumar spoke at New Era School, Gajularamaram, and Dr. Harikumar presented at Bhashyam Blooms. These lectures covered a wide array of topics, emphasizing the opportunities during the Ocean Decade, deep dives into oceanography, operational advisory services, the role of oceans in environmental systems, and the use of remote sensing technology for ocean observation.

8.17 Popular Science Talks

As part of INCOIS's 25th anniversary celebrations, distinguished experts from various fields addressed critical environmental and scientific issues through a series of talks.

On 07 September, Dr. Elizabeth Holmes, a Research Fish Biologist from NOAA's Northwest Fisheries Science Center, USA, delivered a talk on "Open Science". Dr. Danielle Su, an Oceanographer at DHI Water & Environment in Singapore, addressed "Challenges in Regional Ocean Modelling - The 'Island' Issue" on 04 October. Mr. Md Shamsuddoha, Chief Executive of CPRD in Dhaka, Bangladesh, explored "Climate (In)Justice: How Feeble Global Commitments Cause Localized Injustice" on 12 October.

Further talks included Dr. Imogen Napper, a National Geographic Explorer and Post-Doctoral Researcher at the University of Plymouth, UK, sharing insights on "Plastic Detective: Investigating the Sources and Fate of Plastic Pollution" on 21 November. Finally, on 14 December, Dr. Kasturi Devi Kanniah, Associate Professor at Universiti Teknologi Malaysia (UTM) in Johor Bahru, Malaysia, discussed "Saving the Green Lungs of the Coast: Remote Sensing for Mangrove Conservation."

These events were integral to INCOIS's anniversary celebrations, aimed at disseminating knowledge and highlighting the organization's contributions and future directions in environmental and ocean sciences.

8.18 Ocean Research Vessel Visit

As a part of the celebrations marking 25 years of service by INCOIS, a sequence of events was organized to enhance awareness among various stakeholders. One such event, designed to educate young students about ocean research and the capabilities of Ocean Research Vessels (ORV), was held on 24 June 2023. During this event, 91 students from 12 colleges, universities, and institutes in Chennai were presented with the unique opportunity to visit the ORV Sagar Nidhi (Figure 8.13).

Figure 8.13. Students exploring and gained first-hand experience on board ORV Sagar Nidhi, as part of INCOIS silver jubilee celebrations

8.19 Open Days

As a part of our 25th anniversary celebrations, INCOIS hosted three Open Days on multiple occasions, attracting more than 1,050 visitors from the general public (Figure 8.14). These events provided an opportunity for visitors to explore our facilities, learn about our research and services, and engage with our scientists. The Open Days were a great success, fostering greater public understanding and appreciation of our work in ocean science.

Figure 8.14. Students visit during INCOIS open day

8.20 Campus Visit of Students

INCOIS continue to create awareness of its services and activities by conducting several outreach programes throughout the year. During the reporting period, a total of 6690 students and trainee

officers visited the campus and gained insights on various oceanic services. They also learned how INCOIS aids the coastal communities through providing oceanographic services and early warnings during extreme events. The list of campus visitors from various Institutions are in table 8.3.

Table 8.3 Campus Visitors List

Sl No.	Institute Name/Dept. Name
1	Academic Heights Public School, Hyderabad
2	Agarwal Junior College for Girls, Pattarghatti, Hyderabad
3	Air Force Academy, Dundigal, Hyderabad
4	Avinash College, Hyderabad
5	Bachupally Zilla Parishad High School, Hyderabad
6	Bajaj Institute of Technology, Wardha, Maharashtra
7	Bapuji High School, Hyderabad
8	Canary The School, Hyderabad
9	CGR International School, Hyderabad
10	College of Defence Management (CDM), Hyderabad
11	Daksha School, Hyderabad
12	Dhruva Degree College, Hyderabad
13	DMR International School, Hyderabad
14	DPS, Miyapur, Hyderabad
15	Dr. S.C. Gulhane Prerna College of Commerce, Science & Arts, Nagpur
16	Environment Protection Training & Research Institute (EPTRI), Hyderabad
17	Extension Education Institute, Hyderabad
18	Farook Training College, Calicut, Kerala
19	G.Pulla Reddy degree and PG college, Hyderabad
20	Geetanjali High School, Hyderabad
21	Geethanjali College of Engineering and Technology, Hyderabad
22	Gitanjali International School, Hyderabad
23	Gitanjali Vedika school, Hyderabad
24	Gokaraju Rangaraju Institute of Engineering and Technology (GRIET), Hyderabad
25	Government Polytechnic, Hyderabad
26	Govt Degree College, Chevella
27	IIT Hyderabad
28	Insight International School

29	K.K.R's Gowtham School, Hyderabad
30	Kakatiya Institute of Technology & Science (KITS), Warangal
31	Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi
32	M.S. Bidve Engineering College, Latur, Maharashtra
33	MANAGE Hyderabad
34	Mangalore University, Karnataka
35	Meru International School, Hyderabad
36	MLR institute of Technology, Hyderabad
37	MS Mission High School, Hyderabad
38	Nawab Shah Alam Khan College of Engineering & Technology,Hyderabad
39	New Era School, Hyderabad
40	NIRD&PR, Hyderabad
41	Oakridge International School, Bachupally, Hyderabad
42	Ocean The ABM School, Hyderabad
43	Osmania University, Hyderabad
44	Pallavi International School, Hyderabad
45	Pondichery University
46	Pragathi Central School, Hyderabad
47	Quantum Leap School, Hyderabad
48	Quest International School, Hyderabad
49	Reyan High School, Hyderabad
50	Shantiniketan Degree College for Women, Hyderabad
51	Shantiniketan International School, Bowrampet, Hyderabad
52	Shikra International School, Hyderabad
53	Siddhis School, Hyderabad
54	Sreenidhi Institute of Science and Technology, Hyderabad
55	Sreyas Institute of Engineering and Technology, Hyderabad
56	Sri Vidyanjali School, Hyderabad
57	Srinidhi Global School, Hyderabad
58	St Joseph Junior College for Girls, Hyderabad
59	St. Francis college for Women, Hyderabad
60	St. Martin's Engineering College, Hyderabad

61	St. Vincent Pallotti College of Engineering & Technology, Nagpur
62	Stanley College of Engineering and Technology for Women, Hyderabad
63	The Global Edge School, Hyderabad
64	The Hyderabad Millennium School, Hyderabad
65	The Progress Junior College, Hyderabad
66	TRR College of Technology, Hyderabad
67	Unicent School, Hyderabad
68	Vardhman College of Engineering, Shamshabad, Hyderabad
69	Vignan Institute of Technology and Science, Hyderabad
70	VNR Vignana Jyothi Institute of Engineering & Technology, Hyderabad

8.21 Student competitions

As part of the silver jubilee celebrations, INCOIS held competitions for school children on 24-25 January 2024. The competitions included a Science exhibition, Quiz, and Drawing/Painting competition, inviting enthusiastic students from various schools across Telangana. These contests aim to cultivate and encourage students' interest and passion in knowledge, science, and art. Further, these events were focused on raising awareness among school students. Drawing/Painting competition was conducted for the students of 3-5 standards, Quiz for 6-8 standards and science exhibition for 9-12 standard. 245 students from 28 different schools located across 9 districts of Telangana participated in these competitions. Winners were awarded cash prizes, certificates, and medals by Dr. Paruchuri Subbarao from Gandhi Naturopathic Medical College, Hyderabad, during the Republic Day celebrations (Figure 8.15).

Figure 8.15. Students competitions conducted as a part of silver jubilee celebrations

8.22 List of Important meetings and Talks by INCOIS Scientists

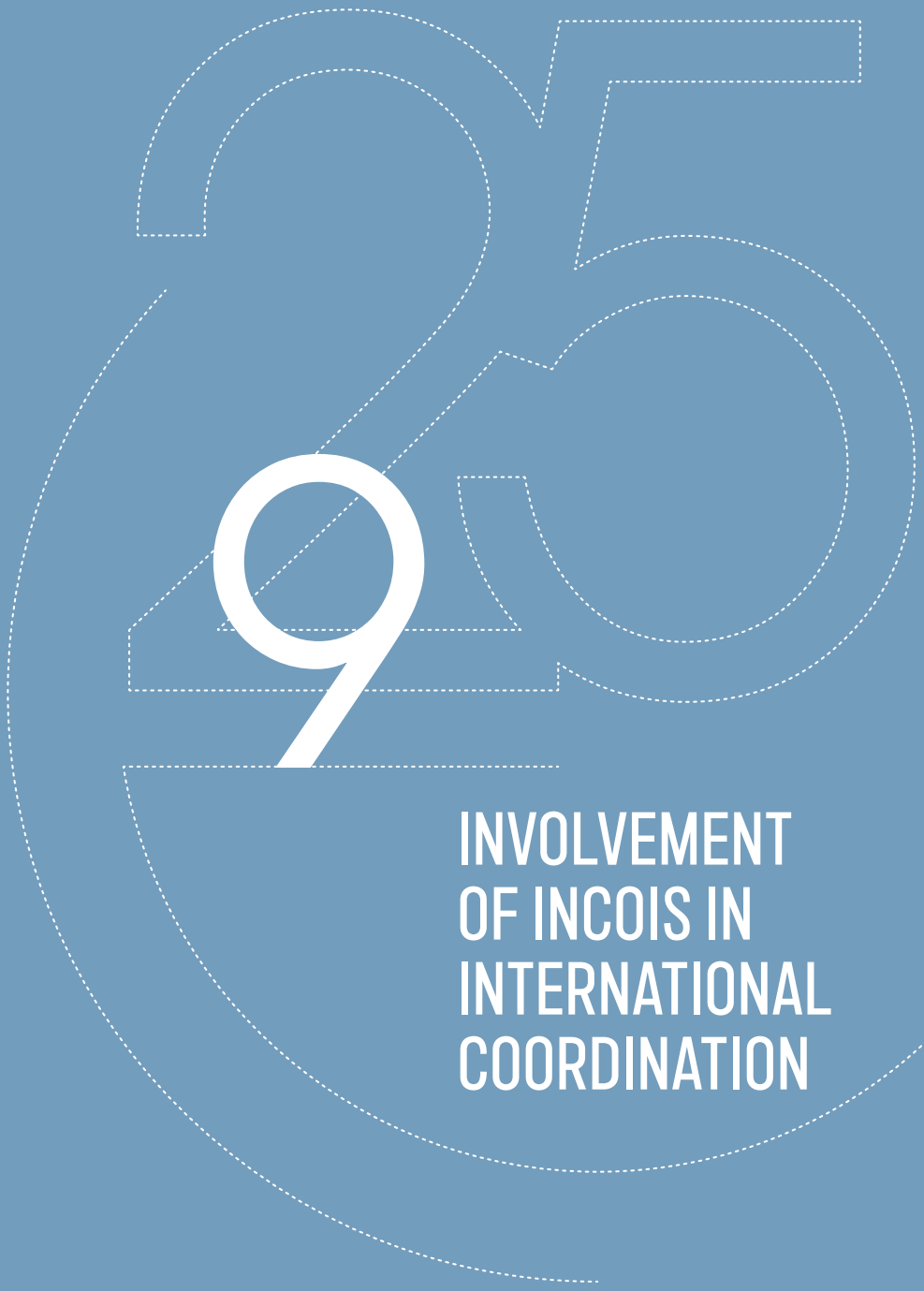
- On 10 April 2023 Dr. T. Srinivasa Kumar, Director, INCOIS attended the CSIR-National Environmental Engineering Research Institute (Hyderabad Zonal Centre) Foundation Day as the chief guest and delivered a lecture on "Ocean Value Chain: Observations to Services."
- On 25 April 2023 Dr. T. Srinivasa Kumar, Director, INCOIS participated in the Earth Day celebrations at the CSIR-National Geophysical Research Institute (NGRI) as the chief guest and delivered a lecture on "Ocean Observations and Services".
- Dr. T. Srinivasa Kumar, Director, INCOIS attended SaGAA-7 (South African Geophysical Association')- Panel Discussion 1 (The Future of Arctic Ice: An Indo-Pacific Connect) at New Delhi on 27 April 2023.
- INCOIS scientists (Dr. Aneesh Lotliker, Dr. Mahendra R S, Dr. Siva Srinivas K, and Dr. Nimit Kumar) participated in an online meeting of Quad Space Working Group kick-off Workshop on "India Concept Note - Extreme Weather Events: Space Based Monitoring and Climate Impact" on 28 Apr 2023 and showcased INCOIS strengths reg. storm surge and coastal vulnerability as well as capacity development under ITCOOcean (a UNESCO C2C training center) that it hosts.
- Shri Nagaraja Kumar M and Dr. Nimit Kumar participated in the online event 'Interactive dialogue on Ocean Accounting: Synthesizing Lessons and Understanding Challenges' organized by Australia-India Indo-Pacific Oceans Initiative Partnership (AIIPOIP) on 16 May 2023.
- Dr. Nimit Kumar (Scientist, INCOIS) participated in online event 'Access to Space for All Expert Meeting' organized by United Nations Office for Outer Space Affairs (UNOOSA) during 15-17 May 2023.
- INCOIS participated in the exhibition on the sidelines of the G20 Research and Innovation Initiative Gathering (RIIG) meeting at Diu on 18-19 May. On 18 May, Dr. T. Srinivasa Kumar, Director, INCOIS gave a presentation on data management and prediction systems using innovative technologies, developed by MoES.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended G20 (Ocean 20 Dialogue) event at Diu, India on 21 May 2023.
- Dr. T. Srinivasa Kumar, the Director INCOIS, joined the mega G20 Beach Cleanup drive at Juhu Beach, Mumbai, on 21 May 2023. He also participated in the 3rd ECSWG meeting on Ocean20 Dialogue and delivered a "context setting" talk in the inaugural session. He also moderated a Policy, Governance, and Participation for Blue Economy session.
- On 24 May 2023, INCOIS (IOR-DCC) team including Director, Dr. T. Srinivas Kumar, Dr. Uday Bhaskar TVS, and Dr. Nimit Kumar participated in a bilateral online meeting with Coastal Resilience DCC (DCC-CR. University of Bologna)'s Working Group – 6 'Increase community resilience to ocean hazards'.
- INCOIS scientists (Dr. Uday Bhaskar, Shri Nagaraja Kumar, Dr. PVN Rao & Dr. Nimit Kumar) participated and contributed to UN Ocean Decade online meetings, including DCC, NDC, and NDC working group meetings hosted by DCU, IOC-UNESCO.

- On 26 May, INCOIS Director chaired a session on Ocean Sciences at the International Climate Research Conclave (ICRC-2023) organized by DST & MoES at the DST's Centre of Excellence in Climate Studies at IIT Bombay.
- Dr. T. Srinivasa Kumar, Director, INCOIS, participated in the 32nd Session of the Intergovernmental Oceanographic Commission (IO, Paris, France, from 21 to June 30. He participated in the Fourth meeting of the Governing Board of the ITCOOcean as a Category 2 center under the auspices of UNESCO.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended G-20 RIIG Summit and Research Minister's meeting on July 4th & 5th, 2023 at Mumbai.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended "Mega Awareness Campaigns under Azadi Ka Amrit Mahotsav"(AKAM) Workshop on 07 July 2023 at Machilipatnam, Andhra Pradesh.
- Dr. TVS Udaya Bhaskar, Scientist – F, participated in a workshop on "International Quality Control Ocean Database" online held during 10-11 July 2023. At this meeting standardization of quality control methods for performing QC od temperature profiles was discussed along with the future prospects of the IQuOD program.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended 2nd Meeting of Deep Ocean Council (DOC) under Deep Ocean Mission at MoES, New Delhi on 17 July 2023.
- On 21 and 22 July, INCOIS Director Dr. T. Srinivasa Kumar participated in the International Workshop "Advances in Coastal Research with special reference to Indi-Pacific (AdCoReIP-2023). He was one of the panelist on the session on Coastal Ecosystem Services.
- On 28 July, INCOIS Director Dr. T. Srinivasa Kumar participated in the 4th Meet of the Environment Climate Sustainability Working Group (ECSWG) G-20 Ministerial Meeting held in Chennai. The members adopted the 'High-Level Principles on Sustainable and Resilient Blue Ocean-based Economy'.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended "Mega Awareness Campaigns under Azadi Ka Amrit Mahotsav" (AKAM) at Mumbai on 03 August 2023.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended "Mega Awareness Campaigns under Azadi Ka Amrit Mahotsav" (AKAM) at Chennai on 11 August 2023.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended"Machine Learning based Species Distribution Modelling" meeting held at INCOIS during 11-22 September 2023.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended "CSIR-NIO, GOA-2nd meeting to discuss the impact on sea level on the islands and frame policy & measures to protect these islands" through VC held on 22 September 2023.
- On 06 October, Dr. T. Srinivasa Kumar, Director, INCOIS participated in the Reliance Foundation Roundtable - Innovative Approaches to Disaster Risk Reduction at Kolkata. He discussed innovative solutions for coastal disaster preparation, particularly tsunami readiness & scaling up of IOC-UNCESCO Tsunami Ready programme.
- On 09 October, Dr. T. Srinivasa Kumar, Director, INCOIS participated in the INDIAN SPACE CONCLAVE 2023 and shared his valuable insights in a panel discussion on 'leveraging space technology for effective disaster management & rescue response' held at Manekshaw Centre, New Delhi.

- On 11 October, Dr. T. Srinivasa Kumar, Director, INCOIS delivered the 25th Prof. S. N. Singh Memorial Lecture at the Palaeontological Society of India event at the Centre of Advanced Study in Geology, University of Lucknow. He also presented the Sharda Chandra Gold Medal & S. K. Singh Memorial Gold Medal.
- Dr. T. Srinivasa Kumar, Director, INCOIS delivered a Keynote talk on 'Ocean Value Chain for Coastal Communities' in the session on 'New space economy' held at the GeoSmart India event during 17 to 19 October 2023 at Hyderabad. He also chaired the Session 'User Case Studies on Agriculture, Mining, Space for Community, Rural Development under the Program New Space Economy.'
- Shri Pattabhi Rama Rao, Scientist 'G' & Group Director, ODICT, INCOIS participated in the 39th Session of the WMO-IOC Data Buoy Cooperation Panel (DBCP-39) at Bali, Indonesia from 24-27 October & presented the National Report of India.
- On 09 October, Dr R Harikumar, Scientist, INCOIS delivered a talk on "Ocean Forecast, Warning, Advisory & Information Services for the Safety of Lives & Livelihoods" at the Joint Annual Humanitarian Assistance and Disaster Relief (HADR) ('Chakravat') seminar organised by the Indian Navy at Goa.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended Survey of India's Inauguration of Nationwide CORS Network and Stakeholder Conference held at New Delhi on 12 October 2023.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended 4th Scientific Review and Monitoring Committee (SRMC) Meeting of Monsoon Mission III held at IITM, Pune on 13 October 2023.
- From October 16 to 20, INCOIS scientists participated in the International Sea Surface Temperature Users' Symposium & GHRSST science team meeting hosted by ISRO and Space Application Center in Ahmedabad. Dr. T. Srinivasa Kumar, Director, INCOIS delivered a talk on Ocean Decade Activity: India's Initiative. He also chaired a session on 'Science applications for operational users of SST in India.'
- On 17 October, Dr. Nimit Kumar, Scientist, INCOIS took part in a panel discussion on 'Development & Application of Technologies for Climate Resilience' and gave a presentation on the 'Ocean Information Services from INCOIS' at Chennai. On 18 October, INCOIS participated in the Brainstorming Session on India's Preparedness for Adapting to Climate Change in Marine Fisheries. Dr. Nimit Kumar, Scientist, INCOIS delivered the lead talk on 'Driving Capacity Development in the Bay of Bengal Region for the UN Ocean Decade.
- Dr. T. Srinivasa Kumar, Director, INCOIS delivered lecture in NIAS-DST training programme on "Science & Technology: Global Developments and Perspectives" on 27 November 2023.
- Dr. T. Srinivasa Kumar, Director, INCOIS Hyderabad, participated in 'the 6th International Conference on Global Warming: The Critical Role of Oceans' organized by the Environmental Protection and Development agency Ras Al Khaimah government, UAE on 06 December 2023, and delivered a talk on ocean value chain during session III: Blue Economy.
- Dr. T. Srinivasa Kumar, Director INCOIS, participated in a Panel Discussion at the India pavilion COP28 UAE side event organized by the Ministry of Environment, Forests & Climate Change, Government of India & elaborated on the role of Science Technology Innovation for Sustainable

Blue Economy, G20 Chennai HLPs, Ocean Observations, Forecasting, Digital Ocean and Advisories on 08 December 2023.

- Dr. T. Srinivasa Kumar, Directorof INCOIS Hyderabad, participated in the Space Panel Discussion on 22 December 2023 and delivered the talk 'Leveraging Observational/ Remote Sensing Technology into Wide Area Application in Maritime Domain' at the College of Defence Management.
- Dr. Balakrishnan Nair TM, Sc-G & Group Dir, INCOIS chaired a session on 'Coastal Hazard Early Warning Systems' at the World Meteorological Organization RA II Meeting held at Japan Meteorological Agency, Tokyo from 04-08 December 2023.
- Shri. Pattabhi Rama Rao E Sc-G & Group Dir, INCOIS co-chaired the session 'Climate Change & Meteorological Disasters' and gave a talk 'Tsunami & Storm Surge Early Warning Services' in National Workshop 'Space Technology in Disaster Risk Management' jointly organized by National Disaster Management Authority (NDMA) and National Remote Sensing Centre, ISRO during 5-7 December 2023 at National Institute of Disaster Management.
- Dr. T. Srinivasa Kumar, Director INCOIS attended the 85th Meeting of the Research Council at CSIR-CSMCRI at Bhavnagar, Gujarat during 07-08 January 2024.
- Dr. T. Srinivasa Kumar, Director INCOISattended IOC Officer's meet (22-24 January 2024) & Scientific Committee for the UN Ocean Decade Tsunami Programme, ODTP-SC (25-26 January 2024) at Paris.
- Dr. T. Srinivasa Kumar, Director, INCOIS attended the Inter-ICG Task Teams on Disaster Management Preparedness (TT-DMP) and Tsunami Watch Operations (TT-TWO) of Intergovernmental Oceanographic Commission (IOC)-UNESCO & 17th meeting of the Working Group on Tsunamis and Other Hazards Related to Sea-Level Warni at Sendai, Japan during 19-24 February 2024.
- Dr. T.V.S. Udaya Bhaskar, Scientist- G, Division Head, ODM, participated in IOC/UNESCO Project Office for IODE (International Oceanographic Data and Information Exchange) Management Group meeting at Oostende, Belgium during 05-07 February 2024.
- Dr. B Ajay Kumar, Scientist-D, OOS, participated in the Fourth South Asia Hydromet Forum (SAHF-IV) held in Colombo, Sri Lanka during 06-09 February 2024.
- Mr. Padmanabham J, Scientist-E, ICT, participated in the Inter-ICG Task Team on Tsunami Watch Operations (TT-TWO) and the 17th meeting of the Working Group on Tsunamis and other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG) scheduled held during 19 - 23 February 2024 at the International Research Institute of Disaster Science (IRIDes), Tohoku University, Sendai, Japan.
- Dr. T. Srinivasa Kumar, Director, INCOIS delivered a keynote speech on 'UN Decade of Ocean Science for Sustainable Development' at 3rd IORA Working Group on Science Technology & Innovation (WGSTI) Meeting in New Delhi.



9 INVOLVEMENT OF INCOIS IN INTERNATIONAL COORDINATION

9.1 International Training Centre for Operational Oceanography (ITCOOcean)

The International Training Centre for Operational Oceanography (ITCOOcean) is aimed at promoting the development and optimization of scientific base, technology and information system for operational oceanography at national, regional and global scales.

During the reporting period, ITCOOcean conducted 17 training programs (9 International and 8 National), and 4 seminars. In these courses, 1025 persons were trained, of which 807 (Male: 506, Female: 301) are from India, and 218 (Male: 146, Female: 72) are from 25 other countries. The analytics of the trainings conducted by ITCOOcean during the reporting period are given in Figure 9.1. A short-term courses on "Advanced Operational Oceanography" for Officers from the Indian Navy was continued and conducted successfully for 2nd year in a row during 09 October 2023 to 26 January 2024.

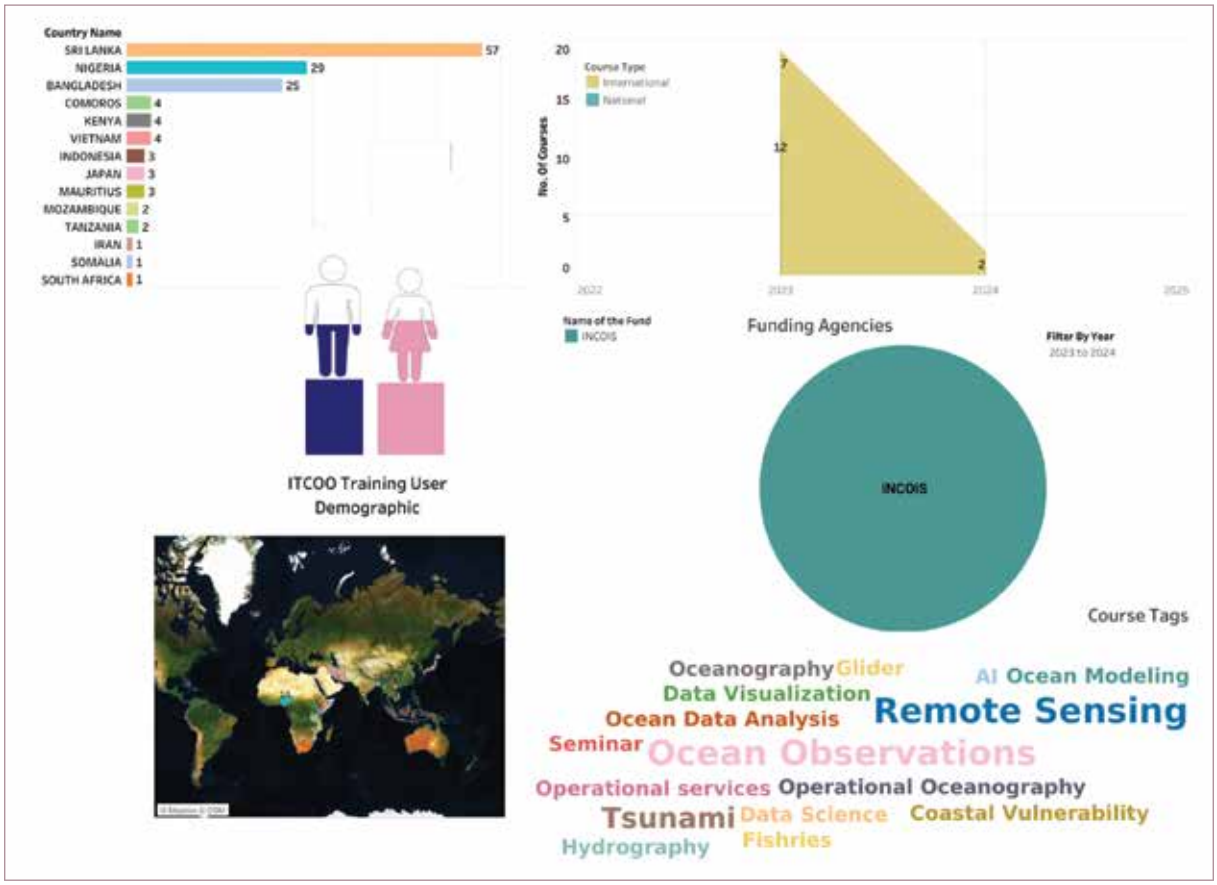


Figure 9.1. Analytics of the training courses conducted, topics covered, Participant countries, and agencies funded during the period April 2023 – March 2024

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

1. **Training on "Fundamentals of Remote Sensing & GIS and Oceanographic Applications", 10-14 April 2023.** This course was conducted to provide knowledge on the basics of remote sensing with practical knowledge to apply learning techniques and how to derive meaningful results. Remote sensing helps to observe and measure Earth's (ocean, atmosphere, and land)

resources. The utilization of remote sensing tools and satellite data is inevitable in studying global seas. Therefore, remote sensing and Geographic Information System (GIS) are integral parts of the marine sciences course curriculum of the different academia.

2. **Training on "Operational Oceanography, Marine Meteorology & Operational Ocean Forecasting, Warning and Advisory Services for offshore E&P industries (DG HC)", 11-12 July 2023.** This course demonstrated the operational services of INCOIS. The focus was on operational activities which are of importance to the personnel working offshore. It was mainly a theoretical training, where the trainees were provided information on how to use the forecast disseminated by INCOIS for their safe operations. In total 10 participants attended this course.
3. **Training on "Operational Services Training for National Institute of Hydrography Officers (NIH - Advance Hydrography Course)", 25 July 2023.** This training was conducted on operational services for the Hydrography officers.
4. **Training on "Visualization of Marine Met data (using FERRET)", 20-24 July 2023.** This course was organized to introduce the use of open-source software FERRET for generation of NetCDF data and visualize various types of plots, save and reuse them at a later stage.
5. **Training on"Oceanographic Remote Sensing: Bridging the Gap between Fundamentals and Applications", 07-11 August 2023.** This course explores oceanographic remote sensing, focusing on the basics and practical uses of ocean color, thermal, and microwave remote sensing. It was designed for university students and early-career researchers who want to enhance their knowledge and skills in oceanographic remote sensing.
6. **Training on "Earth Observation Satellites (EOS-04 & EOS-06) Data for Ocean Applications", 22 August 2023.** This course was conducted to provide exposure to the utilization of Earth Observation (EO) satellites data especially EOS-04 & EOS-06 satellites to address various ocean applications. These two Indian EO missions provide the data in the microwave (EOS-04, C-band SAR) and optical & microwave (EOS-06: Ocean Color Monitor (OCM3) & Ku-band scatter meter) regions of the electromagnetic spectrum.
7. **Training on "Operational Services Training to CSSTEAP members", 30 August 2023.** This course provided exposure to the trainees from "Centre for Space Science And Technology Education In Asia And The Pacific" (CSSTEAP), IIRS, Dehradun attending training program at NRSC, Hyderabad on the products and services developed by INCOIS for various operational requirements. INCOIS has been using various remote sensing products from both Indian and foreign satellites for generating and disseminating operational services.
8. **Training on "Tsunami, storm surge, ocean state and vulnerability mapping to NPCIL Officers", 04-08 September 2023.** The purpose of this course was to introduce the basic concepts of physical and dynamic oceanography and numerical modeling of the ocean general circulation, waves, tides, etc to participants.
9. **Training on "Sea Glider instrumentation, testing, data processing and analysis", 06-13 September 2023.** In this training program, trainees were provided both classroom and hands on training on Dockserver, Glider Terminal, and Software, Ballast tank hardware, Glider control & TWR tools, glider communications & Data Visualizer.
10. **Training on "Machine Learning based Species Distribution Modelling", 11-22 September 2023.** This course demonstrated in-depth understanding of machine learning for species

(macrofauna) distribution modeling (SDM) which was needed by many young ecosystem researchers. SDMs are an important class of models used to understand species association with the environment.

11. **Training on "7th Advanced Oceanographic Course", 09 October 2023 – 26 January 2024.** As per MoU signed with Indian Navy for providing training support in the field of Operational Oceanography, Phase – I of the Advanced Oceanography course for a duration of 16 weeks comprising 3 Officers was conducted between 9 October to 26 January 2024. Phase – I focused on theoretical and operational aspects of oceanography and hands-on with ocean 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 part of all international training conducted under the auspices of ITCOOcean. All three officers were awarded certificates in the month of January 2024.
12. **Training on "AI for Digital Transformation and Data-Driven Decision Making", 06-09 November 2023.** ITCOOcean-INCOIS and the Wadhwani Foundation conducted a 4-days course on AI for Digital Transformation and Data-Driven Decision Making. Twenty-six (26) scientists from various institutes under the Ministry of Earth Sciences attended the course.
13. **Training on "Coastal Vulnerability Mapping and analysis using QGIS", 20-24 November 2023.** In collaboration with Ocean Teacher Global Academy (OTGA), ITCOOcean-INCOIS conducted this international training course. Geospatial science provides vital information on the sustainable use of coastal resources and planning. It an imperative to use such techniques for managing densely populated coastal environs. This course provided an overview of GIS applications pertaining to coastal vulnerability and analysis. It also covered the basic GIS mapping techniques on storm surge vulnerability, and its socio-economic impact using GIS tools. This course included topics like data acquisition, processing, analysis and interpretation of coastal spatial data.
14. **Training on "Ocean Color Remote Sensing - Data, Processing and Analysis", 04-08 December 2023.** Ocean color analysis is a proven tool for determining the health of the ocean using oceanic biological activity through optical means. The dominant phytoplankton pigment, chlorophyll-a, is the index of phytoplankton biomass and indicator of ecosystem trophic status. The oceanic color changes due to chlorophyll providing the level of primary productivity whereas the color change due to CDOM can be attributed to the level of pollution and higher particulate matter. The ability of optical sensors to map the spatial and temporal patterns of ocean color over regional and global scales has provided important insights into the fundamental bio-optical properties and bio-physical processes occurring in the aquatic media.
15. **Training on "Oman operators in early warning systems of Tsunami & Ocean Related Hazards", 11-22 December 2023.** A two-week in-person training course was conducted to Oman National Multi-Hazard Early Warning System operators under ITCOOcean from 11-21 December 2023. A total of five (5) officials from Oman participated in the training at INCOIS. Basic science and ocean hazards services related lectures and hands-on sessions were conducted for the participants.
16. **Training on "Fishery Oceanography for the Ocean Decade (F.O.O.D.)", 18 January – 07 February 2024.** This course was devised to familiarize young professionals with the latest

developments in this field. The UN has proclaimed 2021-30 as decade of ocean science for sustainable development and one of the important challenges identified under it, is to feed global populations sustainably while ensuring health of the marine ecosystems.

17. **Training on"Ocean Observations for Coastal Applications", 29 January – 07 February 2024.** This course was organized to develop capacity of Small Island Developing States (SIDS) from the Indian Ocean and the IO Rim countries incl. GOOS Members, POGO members, etc. to make use of ocean observations for coastal applications. The training is envisaged to contribute to the proposed outcomes of Ocean Decade on "A Predicted Ocean" and "A Safe Ocean".

The glimpses of the trainings on "Fishery Oceanography for the Ocean Decade (F.O.O.D.)" and "Ocean Observations for Coastal Applications" are given at Figure 9.2.

In addition to the above training programs, ITCOOcean also conducted four Seminars during the reporting period. The details of the Seminars are as follows:

1. **Seminar on "An Indian Ocean family of ocean observation-related alliances as an exemplar of what can be achieved collaboratively under a commonspirit", 15 May 2023.** The ocean is rich, has a complex range of dynamical processes, at a cascade of scales. These scales are Ocean-wide and coupled to climate/weather/climate change. From the Ove Hoegh-Guldberg, O. et al. 2015 "Reviving the Ocean Economy: the case for action the overall asset base of the ocean is valued at 24 trillion USD and the Gross Marine Product is valued at 2.5 trillion USD. The western Indian Ocean alone is valued conservatively at 333 billion USD in the year 2015. Physics, Biogeochemistry, Ecosystems, Cross-disciplinary, Terrestrial (catchment to ocean) are essential Ocean Variables for GOOS.
2. **Seminar on "Progress in Weather and Climate Prediction: Advanced Earth System Modeling and Emerging Trends in Data-Driven Models", 21 February 2024.** National Oceanic and Atmospheric Administration's (NOAA's) Environmental Modeling Center (EMC) is a lead developer of operational Numerical Weather Prediction (NWP) systems at the National Weather Service (NWS). These systems are developed through close collaboration with academic, federal and commercial sector partners.
3. **Seminar on "Resilient Oceans: role of mankind", 11 March 2024.** Dr. M. Sudhakar, Visiting Professor, Sai University Chennai & Former Director, CMLRE, MoES, Kochi delivered a talk and enlightened participants with a discourse on "Nurturing Resilient Oceans: Humanity's Vital Contribution"
4. **Seminar on "Satellites helping track climate changes", 21 March 2024.** Continuous observations of atmospheric carbon dioxide concentration and air temperature serve as two key indicators for ongoing climatic changes. The year 2023 marked a significant milestone in recorded history, breaking all records as the warmest. While acknowledging the perturbations in the Earth system, comprehending the spatially and temporally varying responses and feedback remains a formidable task. Satellites, providing a synoptic view of our planet, emerge as ideal tools for the continuous monitoring of our evolving Earth.

Fig 9.2: Glimpses of training programme on "Fishery Oceanography for the Ocean Decade (F.O.O.D.)" during 18 January-07 February 2024 and training on "Ocean Observations for Coastal Applications" during 29 January-07 February 2024

9.2 4th GB Meeting of ITCOOcean

The fourth Governing Board meeting of the UNESCO Category-2 Center, held on 27 June 2023, as a side event during the 32nd Intergovernmental Oceanographic Commission (IOC) Assembly sessions in Paris, France, brought together key representatives from the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO), Iranian National Institute of Oceanography and Atmospheric Sciences (INIOAS) & Regional Education and Research Centre on Oceanography for West Asia (RCOWA), IODE, and regional sub-commissions such as IOC's Sub Commission for Africa and Adjacent Island States (IOC-AFRICA), IOC's Sub-Commission for the Western Pacific (IOC-WESTPAC), UNESCO-IOC Subcommission for the Caribbean and Adjacent Regions (IOC-CARIBE), and IOC Regional Committee for the Central Indian Ocean (IOC-INDIO). The primary focus of the meeting was on leveraging cross-cutting technologies for Capacity Development. A consensus emerged on the importance of fostering international and inter-regional cooperation among IOC Regional Subsidiary Bodies in the areas of Operational Oceanography and Ocean Sciences. This cooperation is crucial to supporting the new IOC Capacity Development Strategy, which is aligned with regional resources, capacities, needs, and priorities. Additionally, the meeting had in-depth discussions on specific Capacity Development needs for the Indian Ocean region, and it was suggested that these needs be addressed by ITCOOcean.

9.3 Renewal of ITCOOcean's C2C Status

The ITCOOcean has been recognized as a UNESCO Category 2 Centre (C2C) since July 2018. ITCOOcean plays a significant role in delivering training programs focused on cutting-edge technologies and topics relevant to the Ocean Decade, Sustainable Development Goals, and Operational Oceanography, particularly for participants from Indian Ocean rim countries. With the initial six-year recognition of ITCOOcean as a C2C set to expire in July 2024, the center initiated the renewal process for its next term. To oversee this process, UNESCO appointed two independent external evaluators to review ITCOOcean's activities from July 2018 to July 2024: Dr. Nick D'Adamo, Adjunct Research Fellow, UWA Oceans Institute, Australia, and Dr. B. Meenakumari, Former Chairperson of the National Biodiversity Authority and Former Deputy Director General (Fisheries Science), Indian Council of Agricultural Research, Kerala, India. The evaluators visited ITCOOcean, participated in several in-person training programs, engaged in discussions with relevant stakeholders, and reviewed the necessary documentation to conduct a comprehensive evaluation. Following their assessment, the evaluators submitted their reports to UNESCO. To ensure adequate time for the completion of the renewal process, the UNESCO Executive Board extended ITCOOcean's C2C status until 31 December 2025.

9.4 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 Thirty-second Session of the IOC Assembly held during 21–30 June 2023 and the Fifty-sixth session of the IOC Executive Council held on 20 June 2023, at UNESCO HQ, Paris. 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, etc. India also provided updates on its progress and support for IOC activities and UN Ocean Decade initiatives.

During the sessions, India's nomination to be part of the Executive Council of IOC from Electoral Group IV has been successful, and Dr. T. Srinivasa Kumar, Director, INC4OIS has been reelected as Vice-Chairperson from Electoral Group IV for another term of two years (2023-25).

9.5 Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS)

- As a part of the ICG/IOTWS of the IOC of UNESCO, INCOIS is acting as a Tsunami Service Provider (TSP) and continues to provide tsunami services to the Indian Ocean Region together with TSPs Australia & Indonesia. TSP-India provides 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 Groups, Working Groups, and Task Teams and participated in related virtual meetings and contributed to associated activities.
- ICG/IOTWMS's 26th communication test was conducted on 07 June 2023, to validate the tsunami information dissemination process. INCOIS participated in the COMMs test and issued test bulletins to 25 Indian Ocean rim countries as TSP. Different dissemination modes were tested.
- ICG/IOTWMS IOWave23 tsunami exercise was conducted during October 2023. As a TSP, ITEWC issued test bulletins to 3 scenarios (4th, 11th & 25th October) for Indian Ocean countries. A total of 19 member states participated in the exercise, and seven member states (India, Indonesia, Iran, Maldives, Mauritius, Sri Lanka, and UAE) were involved up to the community level and evacuated around 50,000 people to safe places.

Figure 9.3. ICG/IOTWMS Steering Group and WG-3 Meeting at INCOIS

- INCOIS scientists participated in ICG/IOTWMS Western and Eastern Indian Ocean Member States Training Workshops on SOPs for NTWCs and DMOs during July 2023 (virtually) and provided related lectures to the member states.

- INCOIS scientists supported the Northwest Indian Ocean (NWIO) group of ICG/IOTWMS activities on "Strengthening Tsunami Early Warning in the NWIO through Regional Cooperation" and participated in related meetings (virtually).
- INCOIS conducted ICG/IOTWMS Steering Group and WG-3 meetings at INCOIS during 05-07 February, 2024. About 20 officials participated, including 11 from Australia, Indonesia, and Iran (Figure 9.3).

9.6 UN Ocean Decade Collaborative Centre for the Indian Ocean Region

The UN Ocean Decade Collaborative Centre for the Indian Ocean Region (DCC-IOR), endorsed by the Intergovernmental Oceanographic Commission (IOC) of UNESCO, has been inaugurated during OSICON-2023 hosted by INCOIS, Hyderabad during 23-25 August 2023 (Figure 9.4). The inaugural event was presided over by Dr. M. Ravichandran, Secretary, Ministry of Earth Sciences, who also chaired the panel discussion in the latter half of the session. Dr. Vladimir Ryabinin (Executive Secretary, IOC-UNESCO) and colleague Dr. Alison Clausen (Programme Specialist) provided their remarks in pre-recorded messages, laying out the expectations from DCC-IOR in achieving the Ocean Decade objectives. Dr. T. Srinivasa Kumar (Head, DCC-IOR and Director, INCOIS) presented a brief on DCC-IOR inception and roadmap. The event also witnessed the release of the DCC-IOR logo and website (https://incois.gov.in/dcc-ior/). The panel that participated was diverse in terms of subjects,

Figure 9.4. Inauguration of the UN Ocean Decade Collaborative Centre for the Indian Ocean Region (DCC-IOR), during OSICON-2023 at INCOIS, during August 23-25, 2023

gender, generation, and geography and included Dr. Enrique Alvarez Fanjul (Technical coordinator, Ocean Prediction-DCC, Mercator Ocean International), Mr. Louis Demargne (Data & Knowledge Management Officer, DCU, IOC-UNESCO), Dr. Fehmi Dilmahamod (IIOE-2 ECSN Chair, GEOMAR), Prof. Heather Koldewey (Senior Marine Technical Advisor & Lead, Bertarelli Foundation's Marine Science Programme), Rear Admiral (Retd) Khurshed Alam (Chair, IOCINDIO), Dr. Kentaro Ando (Chairperson, IOC-WESTPAC), Prof. Nadia Pinardi (Director, DCC-CR, Bologna University), and Dr. Shailesh Nayak (Director, NIAS & Former Sec., MoES). Since its launch, the governing body has been formed, and its meetings have been convened.

The DCC-IOR is actively engaging with other ocean decade actions, viz. it has partnered with DCC-OceanPredict (DCC-OP) to steer the regional team of Indian Seas (www.unoceanprediction.org/en/regional-team-indian-seas), holding co-design dialogues with Ocean Observing Co-Design Tropical Cyclone (TC) Exemplar Steering team and engagements with GOOS's CoastPredict, Ocean Decade Tsunami Programme (ODTP) to name a few. The DCC-IOR also played a pivotal role in contributing to the Vision2030 process and its ocean decade challenge-specific white papers, most notably for working group – 6, co-chaired by Dr. T. Srinivasa Kumar (Head, DCC-IOR).

Figure 9.5. Glimpses of the Indian Ocean Regional Decade Conference (IO-Con 2024) at INCOIS, Hyderabad during 01-03 February 2024

Within months of its formal launch, during 1-3 Feb 2024, the UN Ocean Decade Collaborative Centre for Indian Ocean Region DCC-IOR at INCOIS, Hyderabad, organized the Indian Ocean Regional Decade Conference (IO-Con 2024) as an official prelude to the 2024 Ocean Decade Conference that was scheduled by IOC-UNESCO at Barcelona, Spain later in April 2024 (Figure 9.5). Following the trait of many firsts by India for the UN Ocean Decade, this conference was also the first-ever in-person international (regional) UN Ocean Decade conference in the Indian Ocean. During this policy conference, more than three hundred delegates from India and abroad brainstormed on the ocean decade challenges through the dedicated sessions. These discussions also contributed significantly to the review of Vision2030 draft white papers prepared by Ocean Decade challenge-oriented working groups. Additionally, two special sessions were organized, each focusing on a) the NDCs (National Decade Committees) and b) various regional frameworks in the IOR. Further, a side-event for young researchers was organized collaboratively by IIOE2-ECSN and ECOPs programme. More information including photographs, is made available at the conference portal: ttps://incois.gov.in/dcc-ior/IORDC2024.jsp.

9.7 Ocean Prediction DCC: Indian–Seas Node

INCOIS organized the first Indian-seas regional team meeting of OceanPredict DCC (Mercator Ocean) virtually on 03 May 2023 (Figure 9.6). Users from the scientific community, NGOs, fishermen community, etc., and from member institutes/countries have participated and provided feedback. The Terms of reference for Indian Seas were accepted during the meeting, and a steering team was formed identifying experts from the region for ocean observations, ocean forecasting-physics, ocean forecasting-biogeochemistry, ocean forecasting- climate, new digital ocean developments- and digital twins, ocean health and ocean literacy.

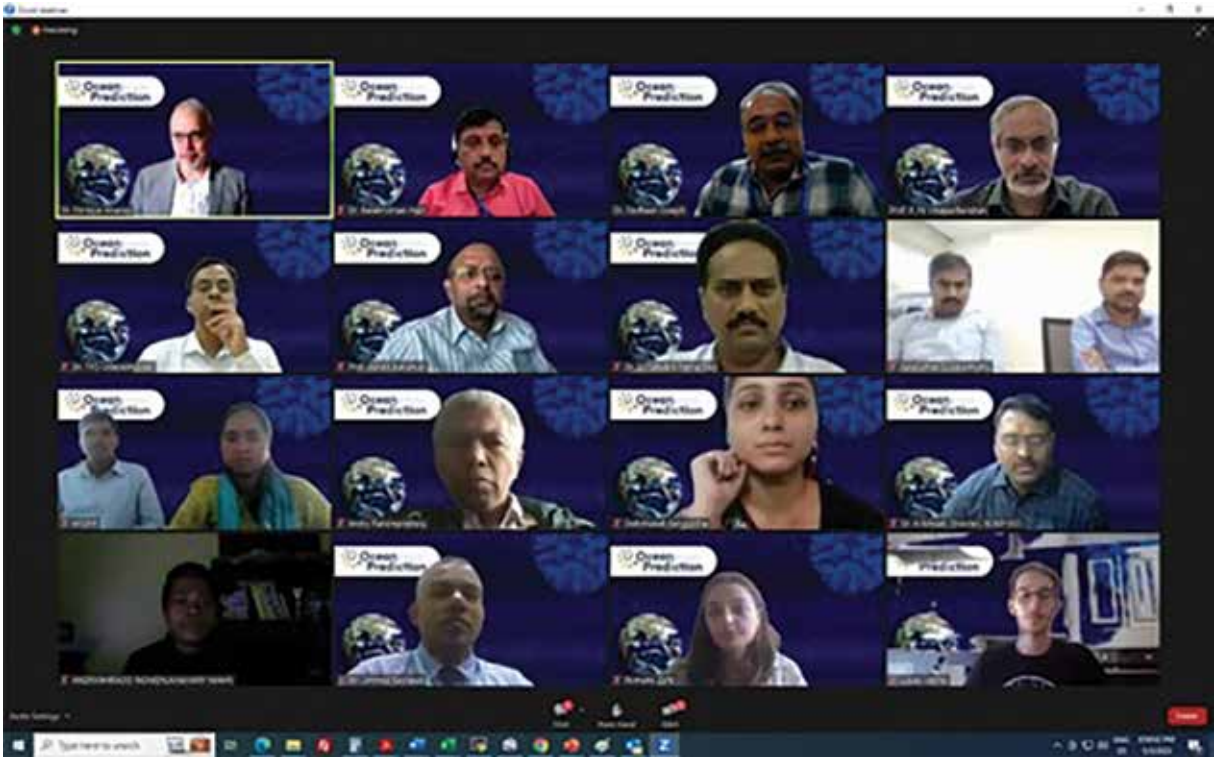


Figure 9.6. Glimpse of the Ocean Prediction DCC meeting held on 3 - May 2023

INCOIS scientist participated in the first Ocean Prediction DCC-Ocean Forecasting Co-design Team meeting held in Toulouse, France, during 27-28 September 2023 for reviewing the co-design of architecture for the operational ocean prediction system and contributed to the formulation of operational readiness level (ORL) index.

9.8 Indian Ocean Rim Association (IORA)

Director, INCOIS delivered a keynote talk on "UN Decade of Ocean Science for Sustainable Development" at the 3rd meeting of the IORA Working Group on Academic, Science, Technology & Innovation (WGSTI) on November 17, 2023.

9.9 Indian Ocean Global Ocean Observing System (IOGOOS)

The integrated annual meetings of IOGOOS-XIX and its allied programs, including the 7th meeting of the International Indian Ocean the Expedition-2 (IIOE-2) Steering Committee, the 20th meeting of the Indian Ocean Region Panel of the CLIVAR/IOC-GOOS (IORP), 15th meeting of Sustained Indian Ocean Biogeochemistry and Ecosystem Research of IMBeR and the IOGOOS (SIBER) (Figure 9.7), 16th meeting of Indian Ocean Observing System Resources Forum of IOGOOS (IRF), IOC Sub-commission for the Central Indian Ocean (IOCINDIO) and Scientific Workshop of the Korea-US Indian Ocean Scientific Research Program (KUDOS) were successfully organised on March 04-08, 2024 under the central theme of "International Indian Ocean Science Conference (IIOSC)-2024". The meetings were hosted by Kawasan Sains Kurnaen Sumadiharga, Badan Riset dan Inovasi Nasional (BRIN), Lombok, Indonesia. These integrated meetings reviewed the progress and scientific knowledge gained due to the concerted efforts of these regional bodies and discussed the action plans to address the issues leading to the UN Decade of Ocean Science for Sustainable Development (2021-2030). Participation comprised about 45 delegates from 10 countries. The weeklong event was a successful gathering of complementary alliances covering equally complementary topics and fostering the strengthening of existing and building of new scientific relationships across individuals and institutions. One of the highlights of the conference was a session led and moderated exclusively by early-career scientists where a series of interesting "flash talks" were given by the youngsters. During the IRF meeting, Dr. Aneesh Lotliker was elected as the Convener of IRF.

Fig. 9.7 IOGOOS 19th Annual Meeting at Lombok, Indonesia

IOGOOS and its allied programs have been taken as the successful case studies under various themes (as listed below) in the report on "Societal Benefits of GOOS Regional Alliances, Challenges, and Opportunities" brought out by GOOS of IOC.

- IIOE-2 as one of the success stories under Ocean Observing and Monitoring
- IndOOS under Data Management and Services
- SIBER under Analysis, Modeling, and Forecasting Systems
- ChloroGIN Data Products under Products and Applications
- IndOOS Resource Forum under Institutional and Governance

9.10 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 the Indian Ocean Global Ocean Observing System (IOGOOS) that is focused 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 an International Program Office to coordinate the activities of SIBER.

Prof. Raleigh Hood, University of Maryland, Cambridge, USA, and Dr Gregory Cowie, University of Edinburgh, UK continue to be co-chairs of the SIBER Scientific Steering Committee (SSC), and Dr Aneesh Lotliker, Scientist-F and Head of Ocean Observation Network Division of INCOIS as an Executive Director, SIBER-International Program Office at INCOIS.

The 14th meeting of the SIBER Scientific Steering Committee Meeting was convened on 24 July 2023 in virtual mode, and the 15th meeting was conducted at the Kawasan Sains Kurnaen Sumadiharga, Badan Riset dan Inovasi Nasional (BRIN), Lombok, Indonesia on 06 March 2024 (Figure 9.8).

Figure 9.8. Participants for the SIBER -15 meeting

During these meetings, the members presented the activities related to SIBER at respective national levels. Dr Gregory Cowie gave an update from the IMBeR steering committee meeting from Paris, which happened in April 2023. He also mentioned that there had been a request from IMBeR to generate ideas for possible synthetic activities. Prof. Reyleigh Hood provided an update on the IIOE-2, indicating a potential extension beyond 2025, in line with the UN Decade's objectives. Subsequently, plans for SIBER post–2025 were also discussed.

9.11 Second International Indian Ocean Expedition (IIOE-2) Project Office

The Second International Indian Ocean Expedition (IIOE-2) is a major global scientific program executed with the engagement of the international scientific community in collaborative oceanographic and atmospheric research in 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, take responsibility for facilitating funding and resources. With participation from numerous countries and scientific institutions, IIOE-2 strives to advance knowledge on climate change, marine ecosystems, ocean circulation, and biodiversity in the Indian Ocean, ultimately contributing to the sustainable management of this critical region and its resources. The program was first formulated for five years (2015-2020) and was extended for another five years till 2025.

INCOIS hosts the IIOE-2 Project Office (PO), which is the nodal point for the network and has day-to-day responsibility for the coordination and implementation of IIOE-2, particularly the science and associated infrastructure as well as capacity building, operational coordination, outreach/communication, data/information management, etc. The IIOE-2 PO India also maintains the IIOE-2 Website, facilitates endorsement of projects, outreach activities in the form of Ocean Bubble and Monthly Newsletter, management of the data generated from IIOE-2 cruises, facilitates Early Career Scientist Network (ECSN) and social media.

Dr T. Srinviasa Kumar continued to be the co-chair of the IIOE-2 Steering Committee (SC) as a representative of SCOR and IOGOOS. Dr Aneesh Lotliker continues as a coordinator of IIOE-2 PO India. Further, IIOE-PO continued to maintain the website (https://iioe-2.incois.gov.in), including timely updates on IIOE-2 expeditions and the metadata portal. In addition, 12 newsletters (https://iioe-2.incois.gov.in/IIOE-2/Publications.jsp?mode_pub_id=NL) and two issues of The Indian Ocean Bubble (Issue No 17 and 18) (https://iioe-2.incois.gov.in/IIOE-2/Bubble.jsp) were published during 2023-24.

The IIOE-2 Steering Committee (SC), during its sixth meeting, noted that the tenure of the IIOE-2 is till 2025. For the last seven years, the IIOE-2 community has contributed significantly to the understanding of the Indian Ocean in terms of observation, research, and capacity development. Also, there have been many international collaborations exchanging scientific ideas. In addition, the ECSN has gained momentum, and discontinuing the pregame may have an impact on ECSN. In order to extend the tenure of IIOE-2 by developing a new program aligned with the UN Decade of Ocean Science for Sustainable Development, the IIOE-2 PO hosted a brainstorming meeting, from 28 to 30 November 2023 of distinguished researchers and policymakers across the globe. Engaged in various forums in Indian Ocean such as Indian Ocean Global Ocean Observing System (IOGOOS),

Indian Ocean Region Panel of CLIVAR/IOC-GOOS (IORP), Indian Ocean Observing System Resources Forum of IOGOOS (IRF), Sustained Indian Ocean Biogeochemistry and Ecosystem Research of IMBeR/IOGOOS (SIBER), IOC Regional Committee for the Central Indian Ocean (IOCINDIO) and Scientific Committee on Oceanic Research (SCOR) (Figure 9.9). The leads of these forums, after a comprehensive discussion, concluded to prepare an addendum to the IIOE-2 science plan and revised implementation strategy for the extension of IIOE-2 tenure till 2030. The addendum will focus primarily on Science Theme-1 (Human Benefits and impacts) along with the coastal observations and aligning it to the challenges and outcomes of the UN Decade of Ocean Science for Sustainable Development.

Figure 9.9. Participants of the brainstorming meeting at IIOE PO at INCOIS, Hyderabad

The PO convened the seventh meeting of the IIOE-2 at the Kawasan Sains Kurnaen Sumadiharga, Badan Riset dan Inovasi Nasional (BRIN), Lombok, Indonesia from 04 to 05 March 2024 (Figure 9.10). As customary since 2015, the IIOE-2 meeting was held under the over-arching banner of the International Indian Ocean Science Conference (IIOSC 2024) as part of an integrated set of meetings (spanning 04 to 08 March at the same venue), including - Sustained Indian Ocean Biogeochemistry and Ecosystem Research of IMBeR and IOGOOS (SIBER: 15th major meeting), Indian Ocean Region Panel of CLIVAR/IOC-GOOS (IORP: 20th major meeting), Indian Ocean Observing System Resources Forum of IOGOOS (IRF: 18th major meeting) and Indian Ocean Global Ocean Observing System (IOGOOS: 19th major meeting) along with the Korea-US Indian Ocean Science (KUDOS) Workshop as art of International Indian Ocean Science Conference (IIOSC 2024). The Kawasan Sains Kurnaen Sumadiharga, Badan Riset dan Inovasi Nasional (BRIN) provided the venue and logistical support. More details of the IIOSC 2024 Conference are available at https://iioe-2.incois.gov.in/IIOE-2/SC7.jsp.

IIOE-2 SC7 endorsed two projects entitled "will nitrog**E**n fi**X**ation offset nitrogen de**P**letion in exp**A**nding ocea**N** **D**eserts (EXPAND)?" by Mar Benavides, Institut de Recherche pour le Développement, France and "**E**nhancing **K**nowledge of the **A**rabian sea **M**arine environment through **S**cience and **A**dvanced

Training [Indian Component] (EKAMSAT)" by Dr. M.S. Girish Kumar, INCOIS, India. More details of the IIOE-2 endorsed project are available at https://iioe-2.incois.gov.in/IIOE-2/Endorsed_Projects.jsp.

Dr. Nick D'Adamo presented the addendum to IIOE-2 science plan (behalf of Prof Raleigh hood) and revised the implementation strategy. In the proposed extended IIOE-2 tenure (2025 – 2023) the emphasis will be on the ST-1 (Human benefits and impacts) along with the coastal observations. The SC-7 also discussed that the IIOE-2 is completing its 10 years in 2025, and hence it is time to bring the Indian Ocean Research community together for a major science conference. The Director, Indian National Centre for Ocean Information Services (INCOIS), India, kindly agreed to host the conference at Hyderabad, India. IIOE-2 PO India will soon be circulating a poll to find an appropriate date for the major Indian Ocean Science Conference.

Figure 9.10. IIOE-2 SC-7 meeting participants

9.12 Indian Ocean Observing System (IndOOS) Resources Forum (IRF)

The Indian Ocean Observing System (IndOOS) Resources Forum (IRF) was developed and approved at the 5th and 6th annual meetings of IOGOOS with objectives to provide a multi-institutional forum for the coordination of resources for implementation of IndOOS, facilitate the identification and alignment of resources (e.g. ocean observing infrastructure, scientific capacity, vessel support) and to carry out the Indian Ocean Panel (IOP) and Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER) implementation plans. The IRF facilitates and coordinates the provision of the resources required for the implementation of IndOOS, promoting contributions from international aid and development agencies as well as from institutions in participating countries. The IRF also monitors and critiques the rationale for the implementation of IndOOS as articulated by the Panel and other relevant expert bodies.

In the recent past, IRF was chaired by Dr. Sidney Thurston, and Dr Nick D'Adamo was acting as a convener. Dr Thurston was relieved as a chair of IRF, from January 2023 in view of his appointment for Global Science and Technology at EarthX. Subsequently, Dr Nick D'Adamo was appointed as an interim Chair and acted as an IRF convener.

The 16th meeting of the IRF was held at the Kawasan Sains Kurnaen Sumadiharga, Badan Riset dan Inovasi Nasional (BRIN), Lombok, Indonesia, on 07 March 2024 (Figure 9.11). During the meeting, Dr. Mike McPhadden presented the status of RAMA moorings followed by the updates on IndOOS progress from IORP and SIBER perspectives. The forum also discussed the process to select a new Chair and Convener. The forum decided that Dr. Nick D'Adamo continued to be an interim chair, and Dr. Aneesh Lotliker is appointed as a convener.

Figure 9.11. Participants of the IRF -16 meeting

9.13 World Meteorological Organization (WMO)

INCOIS has been recognized as the WMO Regional Specialized Meteorological Centre (RSMC) for Numerical Ocean Wave Prediction as well as for Global Numerical Ocean Prediction. INCOIS is the first institute in the world to get recognized for these services. As part of this, INCOIS developed a dedicated web portal for providing essential ocean information services to WMO Member States in the Indian Ocean Region (Figure 9.12). The web portal was inaugurated by Dr. M. Ravichandran, Secretary, Ministry of Earth Sciences during the Ocean Society of India (OSI) Conference (OSICON)-2023 on 23 August 2023 (Figure 9.13).

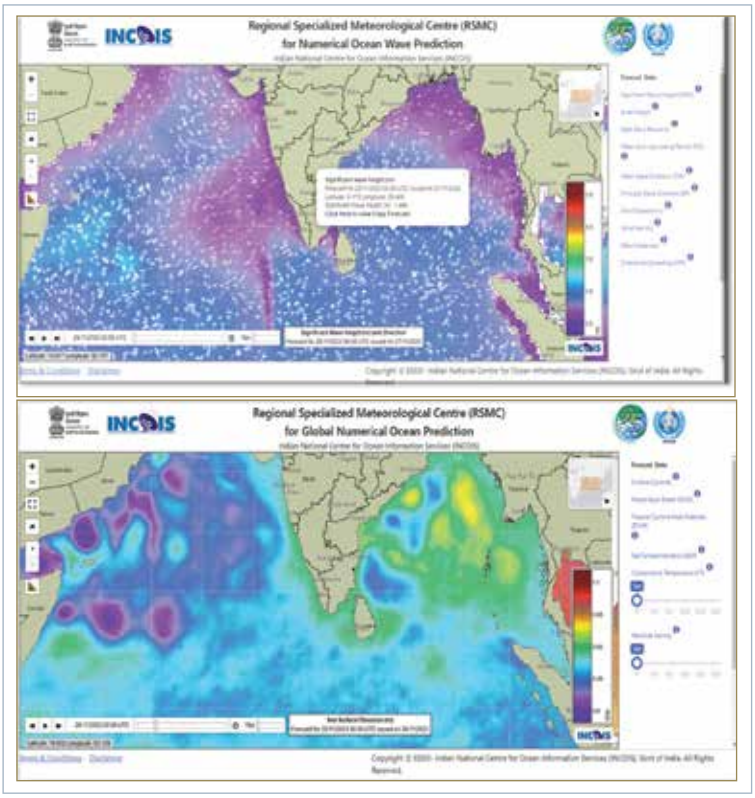


Fig. 9.12. WebGIS Portal for Regional Specialized Meteorological Centre (RSMC) for Numerical Ocean Wave Prediction and Global Numerical Ocean Prediction

Fig. 9.13. Dr. M. Ravichandran, Secretary, Ministry of Earth Sciences inaugurated the Regional Specialized Meteorological Centre (RSMC) website during the OSICON-23 conference on 23 August 2023

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

- As a part of the MoU between MoES, Govt. of India, and RIMES, INCOIS has continued to provide the ocean state forecasts for Comoros, Madagascar, Maldives, Mozambique, Seychelles, and Sri Lanka. INCOIS has also continued to receive seismic/GNSS data from Myanmar, Bhutan, and Nepal, which were established by RIMES and INCOIS.
- INCOIS actively supported the South Asia Hydromet Forum (SAHF) member countries in the region by providing weekly briefings on the ocean conditions (waves, winds, surface currents, sea surface temperature, and the tropical cyclone heat potential) along with online mode training on the usability of these parameters for their operational requirements. The countries in the region *viz.* Bangladesh, Myanmar, Pakistan, Sri Lanka, and Maldives have benefitted from these interactions. RIMES administrates the SAHF and conducts the SAHF forecasters forum every Thursday.
- INCOIS scientist participated in the fourth Session of the South Asia Hydromet Forum (SAHF-IV) in Colombo, Sri Lanka during 06-09 February, 2024. Emphasized the importance of INCOIS services to increase the regional synergies of Indian Ocean/South Asian countries stakeholders. SAHF is a collaborative forum administered by RIMES.

9.15 Partnership for Observation of the Global Ocean (POGO)

- The ITCOOcean (a UNESCO Category-II Centre) at INCOIS, Hyderabad, India, hosted a POGO-funded international training programme 'Ocean Observations for Coastal Applications' from 29 January to 07 February 2024, in collaboration with CEMACS (Malaysia), SUST (Bangladesh), SQU (Oman) and Andhra University (Figure 9.14). A gender-balanced pool of 30 participants from 11 countries participated in the training that included onboard training on operations of ocean instruments. With the support extended by INCOIS, the trainees participated in the first-ever in-person regional ocean decade conference IO-Con 2024, organized by DCC-IOR during 01-03 February 2024. Followed by the first part of the training (which mostly covered the theory)

and conference, the trainees were taken to the eastern port city of Visakhapatnam (Vizag), along with another batch of international trainees which provided not only a hands-on field campaign experience but also wider international networking opportunities beyond the pool of this training. Full details of the training incl. agenda and photos, are made available at: https://incois.gov.in/ITCOocean/pogo1023.jsp.

Figure 9.14. Glimpses of ITCOOcean-POGO international training program 'Ocean Observations for Coastal Applications' conducted during 29 Jan-07 February 2024

9.16 Science discussion meeting under EKAMSAT

- INCOIS hosted a one-day science discussion meeting on 16 January 2024, at Hyderabad, India,

Figure 9.15. One-day science discussion meeting of the EKAMSAT programme held on 16 January 2024, at INCOIS

under the Indo-US collaborative project entitled "Enhancing Knowledge of the Arabian Sea Marine environment through Science and Advanced Training (EKAMSAT)" programme (9.15). The meeting finalized the experimental design of the Arabian Sea field campaign during the summer of 2024 to meet the scientific objectives proposed under EKAMSAT. The researchers from the institutions under the MoES, NOAA, ONR, and the other institutions from India and the USA attended the meeting and contributed to the discussions on the science objectives, requirement of observations to meet the scientific objectives, planning, and implementation of a scientific field campaign, etc.

9.17 Other International and Bilateral Collaborations

- **Ocean Services for Pacific Islands**

The Government of India took the initiative of setting up the Sustainable Coastal Ocean Research Institute (SCORI) at Suva, Fiji, in partnership with the University of South Pacific, Fiji, to extend cooperation with the Pacific Island Countries (PICs) in the area of Coastal and Ocean Sciences. As a part of SCORI activities, INCOIS provided ocean data products and services to the PICs through its customized dashboard made available on the INCOIS Website (Figure 9.16). These products and services fall under three broad categories i) Ocean State Forecast, ii) Ocean Advisory Services, and iii) Ocean Data Products, and are issued for the area enclosed between 26°S to 18°N and 130°E to 145°W covering all the PICs. Dr. M. Ravichandran, Secretary, Ministry of Earth Sciences inaugurated the Ocean Services for Pacific Islands during the OSICON-23 Conference on 23 August 2023 (Figure 9.17).

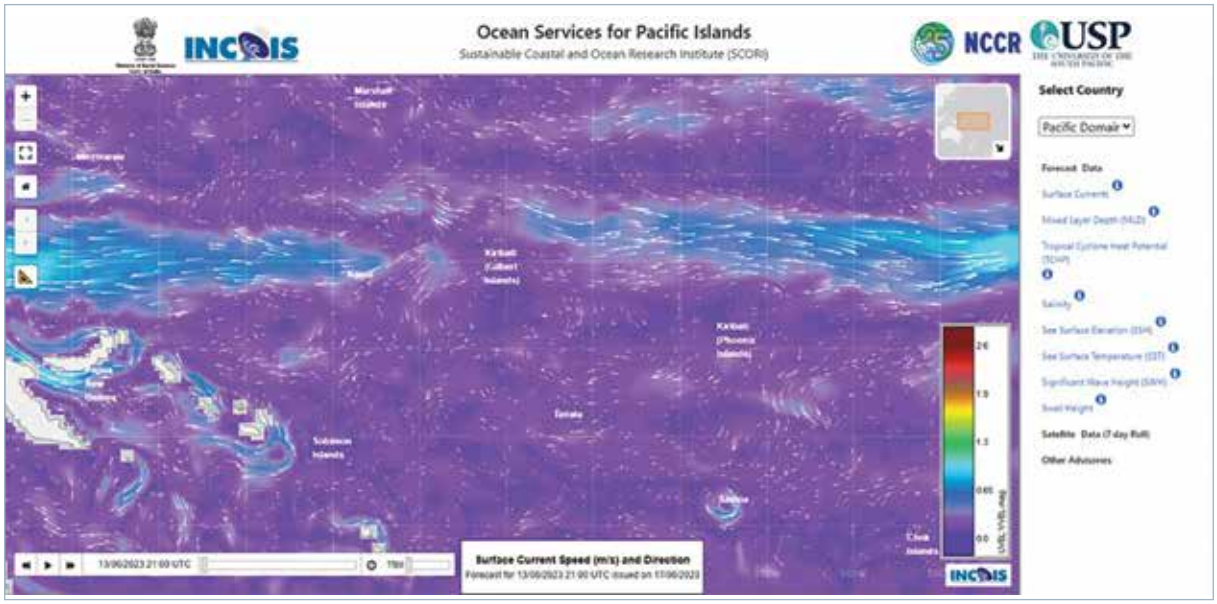


Figure 9.16. WebGIS Application for Ocean Services for Pacific Islands

Figure 9.17. Dr. M. Ravichandran, Secretary, Ministry of Earth Sciences, inaugurated the Ocean Services for Pacific Islands during the OSICON-23 Conference on 23 August 2023

- **Colombo Security Conclave (CSC)**

  India, under the Colombo Security Conclave (CSC), agreed to provide Ocean Information services for the countries within the CSC. INCOIS designed and developed the Ocean Information Portal for these countries integrated with advanced WebGIS capabilities (Figure 9.18). The portal features login-based access, built with open-source GIS technologies including Thredds Data Server, Leaflet for interactive mapping, Plotly for time series visualization, and Bootstrap for responsiveness. Key functionalities include spatial and temporal data selection, interactive map tools, and dynamic data visualization features. The portal was launched during the second edition of the Oceanographers and Hydrographers Conference under the umbrella of the Colombo Security Conclave (CSC) held at the National Institute of Ocean Technology (NIOT), Chennai, and at INCOIS, Hyderabad during 29 – 31 January 2024.

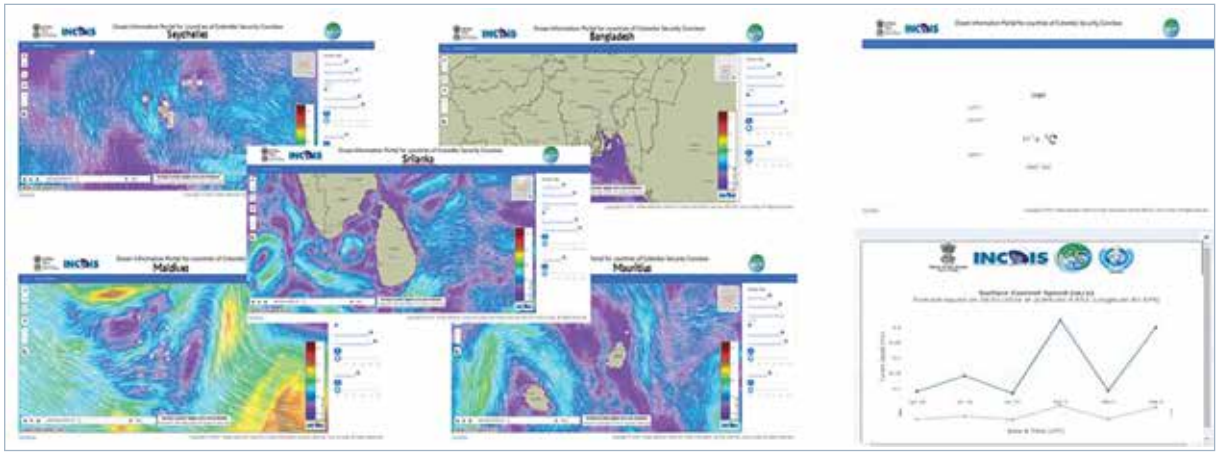


Figure 9.18: Ocean Information Portal for countries of Colombo Security Conclave (CSC)

INCOIS Scientists visited Bangladesh and provided specialized training to scientists from the Space Research and Remote Sensing Organization (SPARRSO) and Bangladesh Oceanographic Research Institute (BORI), Dhaka Bangladesh, on Remote Sensing Applications in Oceanography.

- **The Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC)**

  INCOIS- MoES participated in the 28th Conference of Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) held in Dubai, UAE, during 30 November until 12 December 2023 and participated in the Ocean Pavilion organized by the Woods Hole Oceanographic Institution and UC San Diego's Scripps Institution of Oceanography and showcased INCOIS and MoES Services and setup a side event along with Ministry of Environment, Forest, Climate Change (MoEFCC).

- INCOIS is an active contributor to the G20 Environment and Climate Minister's meeting held at Chennai during July 2023 under India's G20's Presidency. Director, INCOIS contributed towards the finalization of the presidency document on "Accelerating the transition to a sustainable and resilient blue economy" and adopted the G20 High-Level Principles for a sustainable and climate resilient blue economy.
- INCOIS participated and supported the participation of Ocean Experts in the "The Ocean 20 Dialogue: Driving Innovation and Collaboration for a Climate Resilient Blue Economy" workshop held in Mumbai on 21 May 2023.

- **Contributions of INCOIS to G20 Meetings**

  Director, INCOIS participated and delivered a talk in the session on "Understanding Blue Economy – Science & Services" held during the G20 Research and Innovation for an Equitable Society (RIIG) Conference on "Scientific challenges and opportunities towards achieving a sustainable blue economy" at Diu on May 18-19, 2023. Recognizing the unparalleled economic potential of the ocean and its resources on the one hand and the daunting contemporary challenges facing ocean health and marine life on the other, India's G20 Presidency has identified *"Promoting a Sustainable and Climate Resilient Blue Economy"* as a critical priority area for the Environment and Climate Sustainability Working Group (ECSWG) under the Sherpa Track. Within this priority area, India hosted the Ocean 20 Dialogue in Mumbai on 21 May 2023 (on the side-lines of the 3rd ECSWG meeting held during 21-23 May 2023) to bring together international experts, innovators, community representatives, policymakers, and industry leaders to facilitate the discussions that aim to further progress the conversations on the key challenges and opportunities initiated during the Ocean 20 launch event in Bali, Indonesia in 2022 and establish the ocean and Blue Economy as recurring agenda items in the G20 forum. Dr. Srinivasa Kumar, on behalf of Dr Vladimir Ryabinin, Executive Secretary, IOC of UNESCO & Assistant Director General, UNESCO, gave a brief talk on "The Ocean 20 Dialogue: Driving Innovation and Collaboration for a Climate Resilient Blue Economy". INCOIS is an active contributor to the G20 Environment and Climate Minister's meeting held at Chennai during July 2023 under India's G20 Presidency. Director, INCOIS contributed towards the finalization of the presidency document on "Accelerating the transition to a sustainable

and resilient blue economy" and adopting the G20 High-Level Principles for a sustainable and climate resilient blue economy. The G20's Environment and Climate Sustainability Working Group (ECSWG) identified the challenges and priorities for the Blue Economy, including the critical environmental issues that the ocean faces. The priorities of the Indian G20 Presidency for the Blue Economy are (i) addressing marine litter for a sustainable Blue Economy, (ii) conservation and restoration of coastal and marine ecosystems, and (iii) Marine Spatial Planning for a sustainable and resilient Blue Economy.

10

GENERAL INFORMATION

10.1 Awards and Honours

10.1.1 Vice-Chairperson of IOC-UNESCO

Dr. T. Srinivasa Kumar, Director, INCOIS, elected as the Vice-Chairperson of the Intergovernmental Oceanographic Commission (IOC) of UNESCO for the period of 2023-2025. The IOC-UNESCO promotes international cooperation in marine sciences to improve management of the ocean, coasts and marine resources. The Commission enables its 150 Member States to work together by coordinating programmes in capacity development, ocean observations and services, ocean science, tsunami warning and ocean literacy.

10.1.2 Member of the WMO-IOC Data Buoy Cooperation Panel

Shri. Pattabhi Rama Rao, Scientist 'G' & Group Director, ODICT, elected as a Member of the WMO-IOC Data Buoy Cooperation Panel (DBCP) for International Cooperation and Partnership at the 39th Session of DBCP held during 23-24 October 2023 at Bali, Indonesia.

10.1.3 JISRS Best Publication Award-2022

Mr. Sivaiah Borra, Project Scientist, won the "JISRS Best Publication Award-2022" by Indian Society of Remote Sensing (ISRS) for his paper titled "Identifying Rip Channels Along RK Beach, Visakhapatnam using Video and Satellite Imagery Analysis" in the category "Remote Sensing". The award was conferred during the ISG-ISRS Annual Convention event held on 28 November 2023, at the Symposium International (Deemed University), Lavale Campus, Pune (Figure 10.1).

Figure10.1. Mr. Sivaiah Borra receiving the JISRS Best Publication Award-2022

10.1.4 Best Research Award

Dr. Patanjali Kumar CH. Scientist-E, INCOIS awarded with "The Best Research Award" in the Disaster Management Policy Program, Tsunami Disaster Mitigation Course, 2022-2023 from National Graduate Institute for Policy Studies (GRIPS) and Building Research Institute (BRI), institutes of Japan. The award for his Thesis entitled "Rapid Determination of Tsunamigenic Source Parameters and Real time Inundation modelling for TEWS" was conferred during 12-13 September 2023 (Figure10.2).

Figure 10.2. Dr. Patanjali Kumar receiving the Best Research Award, Disaster Management Policy Program, Tsunami Disaster Mitigation Course, 2022-2023

10.1.5 ICTP/IAEA Sandwich Training Educational Programme (STEP)

Ms. Trishneeta Bhattacharya, Senior Research Fellow, at INCOIS under the guidance of Dr. Kunal Chakraborty, selected to participate in the ICTP/IAEA Sandwich Training Educational Programme (STEP). The Abdus Salam International Centre for Theoretical Physics (ICTP) and its UN partner, the International Atomic Energy Agency (IAEA), offer fellowships to Ph.D. students from developing countries in the fields of physics, mathematics and related fields through its Sandwich Training Educational Programme (STEP).

10.1.6 World Ocean Science Congress-2024: Best Paper Award

Dr. Sanjiba Kumar Baliarsingh & Dr. Dhanya M Lal won the "Best Paper Award" under the theme 'Ocean services: what is existing and what is required' at the World Ocean Science Congress-2024 held during 27-29 February 2024. Dr. Sanjiba Kumar Baliarsingh presented his paper on the topic "Advancing Marine Ecological Services for the Indian Seas: INCOIS's Contribution," and Dr. Dhanya M Lal, presented the paper titled "Navigating the Future: Advancing Fisheries Predictions with a Front-to-Fish Approach."

10.2 Memorandum of Understanding

Table 10.1 List of Memorandum of Understanding (MoUs) signed during 2023-24

Particulars	Purpose
MoU between Kineis IoT and INCOIS At INCOIS on 10 October 2023 (Figure10.3)	To leverage the satellite ground station infrastructure at INCOIS for real-time reception and processing of data from ocean observing platforms in the Indian Ocean region that use ARGOS communication.

Figure10.3. Photos Taken During Signing of the MoU Between Kineis IoT and INCOIS

10.3 Official Language Implementation

10.3.1 Hindi Workshop/Seminars

- Dr. R Venkat Shesu, Scientist-E, INCOIS delivered a lecture on the topic "Ocean Data Management - A Challenge" during the Official language workshop held on 30 June 2024.
- Dr. Anuradha Pandey Rajbhasa Adhikari, DRDO, Hyderabad delivered a lecture on the topic “AI in Official Language” on 29 September 2023.
- Mr. Ravi Ranjan, Assistant Manager (Rajbhasha), IRDA, presented a lecture on the topic "Official Language Policy and Compliance" during a workshop held on 27 December 2023. The workshop was highly informative, culminating in a "Rajbhasha Quiz" for the attendees following the lecture.
- Dr. S R. Yadav, Deputy Director, Rajbhasha, Central Research Institute for Dryland Agriculture (ICAR-CRIDA), Hyderabad, delivered a lecture on “Official Language Policy Rules & responsibility of central government employees towards implementation of Official Language”, during the workshop held on 19 March 2024 (Figure 10.4).

Figure 10.4. Images taken during One day Rajbhasha workshop held on 19.03.2024

10.3.2 Hindi Pakhwada (Fortnight) Celebrations

Hindi Fortnight Programme was organized during 14-29 September 2023 by the Official Language Implementation Committee at INCOIS, Hyderabad (Figure 10.5). During this program various Hindi Competitions were conducted, including Hindi Noting & Drafting, Hindi Essay Writing, PPT Presentation, and Hindi Poem recitation for INCOIS employee and their children. The winners of the competitions were felicitated during the concluding ceremony held on 29 September 2023 by the Chief Guest Prof. D Seshu Babu, Maulana Azad National Urdu University (MANU) and Ms. Anuradha Pandey, Rajbhasha Adhikari, DRDO, Hyderabad.

Figure10.5. Collage of images taken during during Hindi pakhwada celebrations held between 14 - 29 September 2023

10.3.3 Official language Implementation Committee (OLIC) Meetings

During the reporting period, OLIC conducted four quarterly meetings at INCOIS, (27 June 2023, 20 September 2023, 20 December 2023 & 10 January 2024) to plan and execute the annual programme targets and assess their progress. Dr. R Venkat Shesu, Mr. H. Nagoji Rao and Ms. Laxmi Kumari, members of OLIC also attended the half-yearly meeting of Town Official Language Implementation Committee (TOLIC) on 26 February 2024 organized by NGRI, Hyderabad.

10.3.4 Release of Hindi book "Bharat Ki Pragati Mein INCOIS ke Rajat Varsh"

A Hindi book "Bharat Ki Pragati Mein INCOIS's ke Rajat Varsh" by Dr. D.D. Ozha & Dr. R. Venkat Shesu were inaugurated on the occasion of the Silver Jubilee of INCOIS on 03 February 2024. The book highlights the progress of INCOIS activities and services over the past years and its contribution towards the growth of Ocean Science in India.

10.4 International yoga day

On the occasion of 9th International Yoga Day (21 June 2023), Dr. R. Prabhakar Reddy, Physical Director, Delhi Public School, Hyderabad, a revered traditional Yoga teacher, lead a revitalizing yoga session for the INCOIS staff (Figure 10.6). He guided everyone on the profound benefits of Yoga for a healthy body, mind and soul.

Figure 10.6. Collage image of the Yoga session conducted as part of International Yoga Day

10.5 Rashtriya Ekta Diwas

INCOIS celebrated Rashtriya Ekta Diwas – National Unity Day on 31 October 2023 by organising Quiz and Drawing competitions for school students. About 250 students from Geetanjali High School and from Zilla Parishad High School, Hyderabad visited INCOIS labs and interacted with the

scientists(Figure 10.7). All INCOIS staff and school students also took the pledge "To preserve the unity, integrity and security of the Nation", lead by the Director INCOIS.

Figure 10.7. Collage image of the Rashtriya Ekta Diwas Celebrations at INCOIS

10.6 Samvidhan Divas

Director INCOIS, and all staff of INCOIS took the preamble on 26 November 2023 as part of the national Constitution Day (Samvidhan Divas) Celebrations.

10.7 Foundation Day (Silver Jubilee) Celebrations

INCOIS celebrated its Silver Jubilee on 03 February 2024, marking 25 years of service to science, the community, and the nation. Dr. Vijay Kumar Saraswat, Member of NITI Aayog, graced the occasion

Figure 10.8. Celebrating INCOIS foundation day on 03 February 2024

as Chief Guest. The event was also attended by Dr. M. Ravichandran, Secretary to the Government of India for MoES; Dr. T. Srinivasa Kumar, Director of INCOIS; Prof. B. L. Deekshatulu, Former Director of NRSA; Dr. A.E. Muthunayagam, Former Secretary of DOD; Dr. Harsh K Gupta, Former Secretary of DOD; Dr. P.S. Goel, Former Secretary of MoES; Dr. Shailesh Nayak, Former Secretary of MoES; and Dr. S. S. C. Shenoi, Former Director of INCOIS. They shared their reflections on INCOIS's journey and provided ideas for the future vision of the organization (Figure 10.8).

10.8 Book Release / Stamp inauguration

As part of its foundation day celebrations, INCOIS released Hindi and English versions of the book on "INCOIS 25-Year Journey" and inaugurated the newly established 'Satellite Data Acquisition and Processing Facility. As a mark of commemorating Silver Jubilee, a customized "My Stamp" has been released. Chief Postmaster General for TS Circle, Hyderabad Dr. P V S Reddy handed over 'INCOIS My Stamp' which was unveiled in the hands of Chief Guest Dr. Vijay Kumar Saraswat (Figure 10.9).

Figure 10.9. Inauguration of book on "INCOIS 25-Year Journey" and My Stamp of INCOIS

10.9 MoES Inter-Institutional Sports Meet

INCOIS organized a mega sports tournament for MoES inter-institutional teams from 11-23 December 2023, as part of its Silver Jubilee Celebrations. Sports tournaments play a vital role in the holistic development of employees, promoting physical activity, stress relief, mental health, social skills, leadership, and time management. They also enhance institutional reputation, promote inclusivity, spot and nurture talent, encourage lifelong fitness, and foster relationships between organizations.

To facilitate this event, the Director of INCOIS invited all MoES institutions, including MoES itself, to participate. An INCOIS sports committee was formed to organize the event, holding several online meetings with all the institutes to encourage active participation and explain eligibility criteria, local logistics, and sports arrangements at INCOIS. INCOIS is the first organization in the ministry to initiate a large-scale sports tournament for MoES institutions.

A total of 180 players participated in the tournament, including 48 women and 132 men from various institutes under the Ministry, making the event a significant milestone in promoting sports and camaraderie within the MoES community (Figure 10.10).

Figure 10.10. MoES inter-institutions mega sports tournament

Prizes were distributed on 03 February 2024, during the Foundation Day celebration. The event was graced by the Honorable Chief Guest Dr. Vijay Kumar Saraswat, Member of NITI Aayog, and Secretary to the MoES, Dr. M. Ravichandran. Other distinguished guests included former secretaries of MoES, former Directors of INCOIS, and the current Director of INCOIS, Dr. T. Srinivasa Kumar. The chief guests presented prizes to all the winning players from various organizations, adding a special touch to the ceremony and honoring their achievements (Figure 10.11).

Figure 10.11. In Prize distribution ceremony for MoES inter-institutions mega sports tournament

10.10 International Women's Day

INCOIS celebrated International Women's Day on 08 March 2024. Mrs. P. Padmavathi, a Distinguished Sociologist, delivered an enlightening talk on 'Leadership and Work-Home Balance,' delving into the dynamics of Leadership and the intricate balance of Work-Home harmony. Our women scientists and staff participated and showed their creativity in Rangoli and e- poster competitions at INCOIS, adding vibrant hues to the celebration (Figure 10.12). The winners of the competitions were felicitated with prizes by the chief guest during final gathering.

Figure 10.12. Collage image of the International Womens Day celebrations at INCOIS

10.11 Policy decisions and the activities undertaken for the benefits of persons with disabilities

The Rights of Persons with Disabilities (RPwD) Act, 2016 committed to fulfill the obligations under the United Nations Convention on the Rights of Persons with Disabilities, ratified by India in 2007. The Act replaces the Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995.

Under the RPwD Act, there are two beneficiaries at INCOIS (one each under group A and B Categories)

comprising approximately 3% of the total beneficiary count. Throughout the Financial Year 2023-24, INCOIS actively pursued various initiatives for the implementation of the RPwD Act, 2016. INCOIS ensured compliance with the Act, focusing on equal opportunities, protection of rights, and full participation of beneficiaries. This was facilitated through a conducive work environment featuring barrier-free building infrastructure equipped with lifts and ramps. Additionally, INCOIS adheres to Government of India rules by providing age relaxation in recruitment for persons with disabilities (PWD) and granting double the normal rates for Transport Allowance. INCOIS also ensures provisions such as escort for unmarried PWD officials during LTC.

In the financial year 2023-24, the total travel allowance utilized for beneficiaries under the Act accounted to Rs. 1,24,992. Beneficiaries also benefit from Income Tax Exemption up to Rs. 100,000/- under Section 80(u), amounting to a cumulative exemption of Rs. 2,00,000 for the reporting period.

10.12 Grievance, Vigilance and RTI Activities

Dr. Balakrishnan Nair T.M., Scientist 'G' and Group Director, OMARS served as the Public Grievance Officer at INCOIS for 2023-24. INCOIS has both external and internal administrative mechanism for redressing the grievances from general public and employs, managed through the Centralized Public Grievance Redress And Monitoring System (CPGRAMS). During the reporting period, a total of seven (7) grievances were received (5 in 2023-24 and 2 pending from 2022-23). Six grievances were disposed of, and one (1) was pending till 31 March 2024. At present, no grievances are pending.

Shri. E. Pattabhi Rama Rao, Scientist 'G' and Group Director, ODICT as the Vigilance Officer of INCOIS. No new complaints were received during the period 01 April 2023 to 31 March 2024.

In respect of Right to Information (RTI) Act 2005, INCOIS is committed to provide the information available to the public through its website and accessible to every citizen of India. Shri. M. Nagaraja Kumar, Scientist 'F' and Division Head, Operational Ocean Services (OOS) functioned as the Central Public Information Officer (CPIO) and Dr. T. Srinivasa Kumar, Director INCOIS as the first Appellate Authority. During the reporting period, 21 RTI Requests (13 through RTI MIS Portal and 08 by Postal) and 02 appeals were received under RTI Act and were disposed off within the time limit prescribed under the RTI Act, 2005. The details are provided at table 10.2.

Table 10.2 Details of RTI requests and responses during 2023-24

Year 2023-24	Opening Balance as on beginning of April 2023	No. of Requests received as transfer from other PAs u/s 6(3)	No. of Requests Received during the current year (including cases transferred to other PAs)	No. of Cases transferred to other PAs u/s 6(3)	Decisions Where requests/ appeals rejected	Decisions Where requests/ appeals replied
Requests	11	12	19	3	2	37
First Appeals	0	0	2	0	0	2

Total no. Of CAPIOs designated	Total no. Of CPIOs designated	Total no. Of AAs designated	
0	1	0	
Registration Fee Collected (in Rs.) u/s 7(1)	Addl. Fee Collected (in Rs.) u/s 7(3)	Penalty Amount Recovered (in Rs.) as directed by CIC u/s 20(1)	No. Of Cases where disciplinary action taken against any Officer u/s 20(2)
130	38	0	0

No. of times various provisions were invoked while rejecting requests Relevant Sections of RTI Act 2005													
Section 8(i)										Section			
a	b	c	d	e	f	g	h	i	j	9	11	24	Others
1	0	0	0	0	0	0	0	0	0	0	0	0	1

Section 4(2) of the RTI Act, 2005 mandated suo-motu disclosure of information to the public so that the public have to resort minimally to the use of this Act to obtain information. INCOIS has successfully completed the Third-Party Transparency Audit to this proactive disclosure of information.

As a pre-cursor to Vigilance awareness week, 2023, prevention vigilance measures cum housekeeping activities were taken up during the three months campaign (16 Aug 2023 to 15 Nov 2023) 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 are also prepared and submitted.

INCOIS observed "Vigilance Awareness Week 2023" from 30 October to 05 November 2023 with the theme “Say no to corruption, commit to the 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 integrity pledge taking ceremony.

A lecture was organised by Shri K.R. Sharma, Former Senior Controller of Administration / Former Senior Deputy Secretary-CSIR on the topic of “Preventive Vigilance” on 21 September, 2023 at INCOIS campus. Banner of Vigilance Awareness Week, PIDPI posters were displayed in the office campus (Figure 10.13).

Fig 10.13. Collage images of various activities held as part of Vigilance Awareness Week

10.13 Health Camp

A health camp for INCOIS staff was conducted at INCOIS on 30 May 2023. The event, led by a team of doctors and medical staff from Sri Sri Holistic Hospitals, Nizampet, was successful with active participation from the staff. Employees benefited from the health check-ups conducted during the camp at INCOIS (Figure 10.14).

Figure 10.14. Collage of image taken during the Hearth camp conducted at INCOIS

10.14 Campus Visit of Dignitaries

During the reporting period several distinguished personalities visited INCOIS and witnessed the cutting-edge technologies and research facilities to deliver various oceanographic services by INCOIS for societal benefits. The details of few of such visits are listed below:

- A twenty (20) member delegation from Bangladesh, and Sri Lanka visited INCOIS on 03 May 2023 as part of Hydromet and Early Warning Joint Learning Exercise II, facilitated by the World Bank and discussed on various collaborative aspects (Figure 10.15).
- On 06 May 2023, INCOIS hosted the official visit of Shri. Jatindra Nath Swain IAS, Secretary (Fisheries), Ministry of Fisheries, Animal

Figure10.15. Collage of images taken during the visit of Bangladesh, and Sri Lanka delegates on 3 May 2023

Husbandry & Dairying, Government of India & Dr. Suvarna, CE NFDB. Discussions were held with the Director & Scientists of INCOIS on further possibilities of extending ocean-related services in the fisheries Sector (Figure 10.16).

Figure 10.16. Image taken during the Visit of Shri. Jatindra Nath Swain IAS, Secretary (Fisheries) Ministry of Fisheries, Animal Husbandry & Dairying, Government of India & Dr. Suvarna, CE, NFDB

- Dr. Cherdsak Virapat, Director General of Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP), Dhaka, Bangladesh visited INCOIS on 10 May 2023, and engaged in valuable knowledge exchange with INCOIS scientists (Figure 10.17).

Figure 10.17. Image taken during the Visit of Dr.Cherdsak Virapat, DG, CIRDAP

- On 01 August, Officials from the Capacity Building Commission visited INCOIS to discuss training initiatives on Data Analysis and AI that can be taken at ITCOOcean for MoES scientists.
- On 08 August, Dr. A.R. Subbiah, Director-of the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) along with his team, visited INCOIS and discussed on International collaborations. They also discussed capacity development activities to RIMES member states on Ocean services to further strengthen RIMES collaboration.
- On 11 August, the Lt Gen Syed Ata Hasnain (Retd), Member, NDMA, Govt of India, along with other officials, visited INCOIS to participate in the Tsunami SOP workshops and Indian Ocean Wave Exercise (IOWave23), and further collaboration activities on multi-hazard capacity building to State/UT disaster management authorities.
- A delegation of six (6) officials from the Department of Disaster Prevention and Mitigation (DDPM), Thailand (NDWC), along with RIMES officials, visited INCOIS on 20 December 2023 (Figure 10.18).

Figure 10.18. Collage of images taken during the visit of deligates from DDPM, NDWC along with RIMES officials

- Shri Suman Bery Hon'ble Vice Chairperson, NITI Aayog, visited INCOIS laboratories & interacted with the scientists on 02 January 2024. He engaged in enriching discussions and provided extremely valuable perspectives on INCOIS's future roadmap (Figure 10.19).

Figure 10.19. Collage of images taken during visit of Shri Suman Bery Hon'ble Vice Chairperson, NITI Aayog

- INCOIS hosted officials from the US Consulate, Hyderabad on 29 February 2024. They witnessed the state-of-art facilities dedicated to ocean observations, modeling, and data management & INCOIS's role in delivering scientific services for societal benefits (Figure 10.20).
- Prof. N.V. Chalapathi Rao, Director, NCESS visited INCOIS on 14 March 2024 and witnessed various research facilities at INCOIS.

Figure 10.20. Collage of images taken during visit of the officials from the US Consulate, Hyderabad

10.15 Deputations Abroad

Table 10.3 Details of staff on official Deputation Abroad

Sl no.	Name of the Officer/Scientist	Country Visited	Period of visit	Purpose of visit
1	Dr. T. Srinivasa Kumar, Director, INCOIS	UNESCO HQ, Paris, France	20-30 June 2023	IFAG and IOC Officers meeting, 56th Session of the IOC Executive Council and the 32nd Session of the IOC Assembly
		Dubai, United Arab Emirates	04-09 December, 2023	"6th International Conference on Global Warming: The Critical Role of the Oceans" and 28th Conference of the Parties (COP28) to the UN Framework Convention on Climate Change (UNFCCC)
		Paris, France	25-26 January 2024	IOC Officer's meeting and meeting of the Scientific Committee for the UN Ocean Decade Tsunami Programme at UNESCO Headquarter

		Sendai, Japan	19-23 February 2024	Inter-ICG Task Team on Tsunami Watch Operations (TT-TWO) and the 17th meeting of the Working Group on Tsunamis and other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG)
2.	Dr.T M Balakrishnan Nair Scientist –G & Group Director of Ocean Modeling, Applied Research & Services	Halifax, Canada	24-28 April 2023	25th session of the GOOS steering committee (GOOS SC-12)
		Tokyo, Japan	04-07 December 2023	WMO Regional Association II (RA II) Expert Team-Marine Services (ET-MS) meeting & Technical Workshop on Marine and Coastal Services
3.	Mr. E Pattabhi Rama Rao Scientist-G & Group Director ODICT	Bali, Indonesia	24-27 October 2023	39th Session of the joint WMO-IOC Data Buoy Cooperation Panel (DBCP)
4.	Dr. Sudheer Joseph, Scientist-G & Division Head, ARO	Toulouse, France	27-28 September 2023	First Ocean Prediction DCC-Ocean Forecasting Co-design Team meeting
		United States of America (USA)	28 October - 08 November 2023	India Interstate Clean Energy Procurement Program Orientation Visit, under the Global Procurement Initiative: Understanding Best Value (GPI)
5.	Dr Francis P A, Scientist-F & Division Head, MDA	Busan, Republic of Korea	6-10 November 2023	8th Ocean Predict Science Team Meeting (OPST- 8)

6.	Dr. CHODAVARAPU Patanjali Kumar, Scientist - E, ARO, OMARS	Tokyo, Japan	28 September 2022 - 16 September 2023	Training in Japan International Cooperation Agency (JICA) In-person Training Programme of Knowledge Co-Creation Program (KCCP) on "Seismology, Earthquake Engineering and Tsunami Disaster Mitigation" under the Technical Cooperation Program of the Government of Japan as "The First Participant" from India
7.	Dr TVS Udaya Bhaskar, Scientist – F & Division Head, ODM	UNESCO HQ Paris, France	21-20 June 2023	32nd session of the IOC assembly
	Dr. T.V.S. Udaya Bhaskar Scientist-G & Division Head, ODM	Ras A1 Khaimah, United Arab Emirates (UAE).	04-07 December 2023	"6th International Conference on Global Warming: The Critical Role of the Oceans"
		Oostende, Belgium	05-07 February 2024	IOC/UNESCO Project Office for IODE (International Oceanographic Data and information Exchange) Management Group meeting
8.	Mr. M. Nagaraja Kumar, Scientist-F, OOS, INCOIS & Secretary, IOGOOS	Lombok, Indonesia	04-08 March 2024	International Indian Ocean Science Conference (IIOSC)-2024
9.	Dr. Aneesh A Lotliker, Scientist-F& Division Head, OON	Dhaka Bangladesh	12-19 November 2023	Visit Space Research and Remote Sensing Organization (SPARRSO) and Bangladesh Oceanographic Research Institute (BORI), providing training on Remote Sensing Applications in Oceanography
		Ras Al Khaimah, United Arab Emirates (UAE)	04-07 December 2023	"6th International Conference on Global Warming: The Critical Role of the Oceans"
		Lombok, Indonesia	04-08 March 2024	International Indian Ocean Science Conference (IIOSC)-2024

10.	Dr Abhisek Chatterjee, Scientist-E	Hamburg, Germany	05-07 June 2023	International conference on Regional Sea level change and societal impacts
		Dubai, United Arab Emirates (UAE)	30 November - 09 December 2023	28th Conference of the Parties (COP28) to the UN Framework Convention on Climate Change (UNFCCC) and Ocean Pavilion organized by the Woods Hole Oceanographic Institution partnered with INCOIS, MoES
11.	Dr. N Srinivasa Rao, Scientist-E ODM	Dhaka Bangladesh	12-19 November 2023	Visit to Space Research and Remote Sensing Organization (SPARRSO) and Bangladesh Oceanographic Research Institute (BORI), for providing training on Remote Sensing Applications in Oceanography
12.	Mr R S Mahendra, Scientist- E (ARO), OMARS	Cape Town, South Africa	15-16 November 2023	5th meeting of the BRICS working group on "ocean and polar science and technology"
13.	Ms. Vijaya Sunanda M Scientist- E	Bologna, Italy	12-13 December 2023	UN Decade Collaborative Centre for Coastal Resilience (DCC-CR) workshop and meeting between DCC-CR and Decade Collaborative Centre for the Indian Ocean Region (DCC-IOR)
14.	Mr. Padmanabham Jijjavarapu, Scientist- E, ICT.	Sendai, Japan	19-23 February 2024	Inter-ICG Task Team on Tsunami Watch Operations (TT-TWO) and the 17th meeting of the Working Group on Tsunamis and other Hazards Related to Sea-Level Warning and Mitigation Systems (TOWS-WG)
15.	Mr. N Kiran Kumar, Scientist-E, ICT, INCOIS & IIOE-2 WG Member	Lombok, Indonesia	04-08 March 2024	International Indian Ocean Science Conference (IIOSC)-2024

16.	Dr. B Ajay Kumar, Scientist- D, OOS	Colombo, Sri Lanka	06-09 February 2024	Fourth South Asia Hydromet Forum (SAHF-IV)
17.	Mr. Shivaprasad S, Scientist-D, OON	Haarlem, Netherlands	12-18 December 2023	Training session on Directional Wave rider buoys being purchased from M/s. Datawell BV, Haarlem, Netherlands
18.	Dr. P. Vijay, Scientist-D, ARO	Suava, Fiji	8–12 May 2023	Launch of the Sustainable Coastal Ocean Research Institute (SCORI) at the University of South Pacific (USP) in Suava, Fiji by the Hon'ble Prime Minister of India
19.	Mr. Jeyakumar Chellaiah, Scientific Assistant-B	Haarlem, Netherlands	12-18 December 2023	Training session on Directional Wave rider buoys being purchased from M/s. Datawell BV, Haarlem, Netherlands
20.	Ms. Susmita Raulo Project Scientist-I, ARO	Plymouth (UK)	07-11 August 2023	Trevor Platt Science Foundation (TPSF) training course on Satellite-based tools for investigating aquatic ecosystems and TPSF symposium at the Plymouth Marine Laboratory
21.	Dr Apurva P Joshi, Project Scientist-I, MDA	Rwanda (Kigali)	23-27 October 2023	World Climate Research Programme Open Science Conference: Advancing Climate Science for Sustainable Future
		Oostende, Belgium	06-09 November 2023	Ocean Carbon workshop on the premises of the Flanders Marine Institute (VLIZ)
22.	Dr. Premkumar. R, Project, Scientist-I, ARO	Florida, USA	13-17 November 2023	Training course "SeaDAS" and 5th International Ocean Colour Science Meeting at University of South Florida, St. Petersburg
23.	Mr. Ashin Kuriakose, Project Scientist-I, OON	New Orleans, Louisiana, USA	18-23 February 2024	Ocean Science Meeting (OSM) 2024
24.	Ms Trishneeta Bhattacharya, Senior Research Fellow	Trieste, Italy	25 September - 22 December 2023	Visit to ICTP, Trieste, Italy under the ICTP/ IAEA Sandwich Training Educational Programme (STEP)

25.	Mr. Abhijith Raj, Senior Research Fellow, OON	Atlanta, Georgia, USA	06-09 November 2023	LI-COR Connect 2023 workshop
		San Francisco, California, USA	10-16 December 2023	AGU Fall Meeting 2023
26.	Ms. Meenakshi Sreejith Senior Research Fellow	Rwanda (Kigali)	23-27 October 2023	World Climate Research Programme Open Science Conference: Advancing Climate Science for Sustainable Future
27.	Ms Anjana S, Senior Research Fellow, MDA	Rwanda (Kigali)	22-28 October 2023	World Climate Research Programme Open Science Conference: Advancing Climate Science for Sustainable Future and the Early-to-mid Career Researcher (EMCR) Symposium
		New Orleans, Louisiana, USA during	18-23 February 2024	Ocean Science Meeting (OSM) 2024
28.	Mr. Sajidh C. K., Senior Research Fellow, MDA	New Orleans, Louisiana, USA	18-23 February 2024	Ocean Science Meeting (OSM) 2024
29.	Ms. Athulya K, Senior Research Fellow, OON	New Orleans, Louisiana, USA	18-23 February 2024	Ocean Science Meeting (OSM) 2024
30.	Mr. Rupam Kalita, Junior Research Fellow, OON	Hangzhou, Zhejiang Province, People's Republic of China	15-20 November 2023	"International Training Course on Principles and Applications of BGC-Argo"

10.16 Estate Management and Other Infrastructure Services

- A mural measuring 36' x 9' was constructed at the Main Building entrance and inaugurated by Shri Kiren Rijiju, Hon'ble Union Minister of Earth Sciences, on 14 February 2024, to commemorate INCOIS Silver Jubilee year (Figure 10.21).

Figure 10.21. INCOIS Mural on Ocean & life

- Work orders for the Construction of the Recording room for Installation of Emergency Communication and GPS & Strong Motion Sensors at East, Interview and Narcondum Islands have been issued by the Andaman Public Works Department (APWD) and the work is under progress. A simple scheme with very less civil construction is planned for these remote islands. The revised scheme is approximately costing 1/3rd of the initial scheme, resulting in substantial financial savings.
- Building permissions for existing buildings have been obtained from GHMC.
- A comprehensive geotechnical survey was conducted for the entire INCOIS campus, new bore wells were drilled, and efforts are ongoing to recharge the groundwater.
- UPS redistribution work has been completed, optimizing the battery Ampere Hour (AH) capacity. This initiative has resulted in significant savings, approximately Rs. 15 lakhs, by reducing capital cost for battery procurement. It has also improved energy efficiency by minimizing UPS losses and is expected to reduce Operation and Maintenance (O&M) CAMC costs by approximately Rs. 2 lakhs per annum.
- This revision aims to clearly convey the achievements and benefits of the UPS redistribution project undertaken by INCOIS.
- The old guest house has been renovated and made operational since January 2024 and is now in continuous use.
- Waterproofing works have been completed in the Main Building, and new signage boards were installed at Main Building, ITCOOcean and Main entrance gate.
- INCOIS's solar rooftop power plant, with a capacity of 614.50 kWp, generated approximately 800,000 kWh last year, contributing to about 25% of INCOIS's annual power consumption. This has resulted in preventing approximately 560 tonnes of carbon footprint (calculated at 0.7 kg of CO_2 per kWh). Furthermore, the adoption of the RESCO (Renewable Energy Service Company) model has led to significant financial savings, amounting to approximately Rs. 30 lakhs.

- A new 11 kV five panel HT board has been installed in the ITCOOcean sub-station building to facilitate power supply to the proposed INCOIS data centre (Figure 10.22).

Figure 10.22. INCOIS team after successful installation of 11 kV five panel HT board in the ITCOOcean sub-station

- INCOIS treated about 360,000 liters of water last year, which is utilized for plantation purposes. As a result of this, INCOIS received a sewerage rebate of Rs. 4.7 lakhs from Hyderabad Metropolitan Water Supply and Sewerage Board (HMWSSB).
- Water taps were fixed with the adapters that could control the flow rate to 1-2 LPM helped towards water conservation.
- An energy audit for all buildings has been conducted.

10.17 Compliance to Cyber Security guidelines

With the borderless cyberspace and the anonymity it provides, coupled with the rapid growth of the Internet, the rise in cyber-attacks and cyber security incidents has become a global phenomenon. Continuously evolving cyber threats have become a concern for the Government, as these threats can compromise the confidentiality, integrity, and availability of an organization's information and systems, potentially impacting essential services and national interests. The Indian Computer Emergency Response Team (CERT-In) has issued guidelines related to information security practices, procedures, prevention, and response, which are applicable to all Government entities. These guidelines are available on the websites of the Ministry of Electronics & Information Technology (MeitY) and CERT-In. It has been decided at the highest level that a status note on compliance with these cyber security guidelines should be included in the annual reports of all Ministries and Departments.

In line with this directive, INCOIS is formulating a formal cyber security policy document. A CERT-In empaneled agency is presently carrying out VAPT audit on Application and Network to indicate vulnerabilities. After fixing the indicated vulnerabilities, a document shall be formulated and

submitted to INCOIS by the agency. However, in the absence of a formal cyber security policy document, INCOIS has been following procedures to ensure compliance with the available guidelines for the safety and security of network and data. From time to time, the vulnerabilities, if any, pointed out by nodal agencies such as CERT-In, NCIIPC etc are being fixed and the action taken report is being submitted to them.

10.18 Human Capital

Regular positions

Table 10.4

Positions	Sanction of posts	Staff in Position (In-situ)	Vacant Posts
Director	01	01	00
Scientist – G	00	04	00
Scientist – F	01	08	01
Scientist – E	01	16	01
Scientist – D	03	08	01
Scientist – C	17	04	02
Scientist – B	26	03	00
Scientific Assistant	20	20	00
Administration	11	11	00
Total	**80**	**75**	**05***

*One Scientist is on lien

Vacant Posts:

Scientist – F – 1 No.

Scientist – E – 1 No.

Scientist – D – 1 No.

Scientist – C – 2 No. (including one lien position)

Project Mode positions

Table 10.5

Position	Sanctioned posts	Staff in position
Expert/ Consultant (Scientific)	4	4
Project Scientist – III	12	3
Project Scientist – II	26	14
Project Scientist – I	53	38
Project Assistant (Technical/Non Technical)	63	19
Senior Assistant (Technical/Non Technical/Admin)	9	0
Administrative Officer	1	0
Research Fellow	34	20
Research Associates	7	0
Expert/ Consultant (Admin)	1	0
Skilled Technical Assistant	1	0
Total	**211**	**98**

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
ANN	:	Artificial Neural Networks
APNGCR	:	Asia-Pacific Network for Global Change Research
APSDMA	:	Andhra Pradesh State Disaster Management Authority
ARO	:	Applied Research and Research to Operation
AS	:	Arabian Sea
BOB	:	Bay of Bengal
BGC Argo	:	BioGeoChemical Argo
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
CSC	:	Colombo Security Conclave
CSIR	:	The Council of Scientific & Industrial Research
DCC	:	Decade Collaborative Centre
DCC-IOR	:	Decade Collaborative Centre Indian Ocean Region
DIC	:	Dissolved Inorganic Carbon
DMO	:	Disaster Management Organization
DOM	:	Deep Ocean Mission
DOOS	:	Deep Ocean Observations System
DWSD	:	Directional Wave Spectra Drifter
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
EIO	:	Equatorial Indian Ocean
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
HOOFS	:	High-resolution Operational Ocean Forecast and reanalysis System
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
IIOE-2	:	Second International Indian Ocean Expedition
IISF	:	India International Science Festival
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 System
IO	:	Indian Ocean
IOC	:	Intergovernmental Oceanographic Commission
IOCINDIO	:	IOC Regional Committee for the Central Indian Ocean
IOCON-24	:	Indian Ocean Regional Decade Conference
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
MAHAS	:	Marine Heat Wave Advisory Service
MARSIS	:	Marine Satellite Information Service
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	:	National Institute of Oceanography
NIOT	:	National Institute of Ocean Technology
NOAA	:	National Oceanic and Atmospheric Administration
NODC	:	National Oceanographic Data Centre
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
OON	:	Ocean Observation Network
OOSA	:	Online Oil Spill Advisory System
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
RECCAP-2	:	REgional Carbon Cycle Assessment and Processes Phase 2
RIMES	:	Regional Integrated Multi-Hazard Early Warning System for Asia and Africa
ROMS	:	Regional Ocean Modeling System
RSMC	:	Regional Specialized Meteorological Centre
RSMT	:	Regional Subprogramme Management Team
SAHF	:	South Asia Hydromet Forum
SAMUDRA	:	Smart Access to Marine Users for ocean Data Resources and Advisories
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
SLD	:	Sonic Layer Depth
SMA	:	Strong Motion Accelerometer
SOP	:	Standard Operating Procedure
SST	:	Sea Surface Temperature
STEP	:	ICTP/IAEA Sandwich Training Educational Programme
SUST	:	Shahjalal University of Science and Technology
SVAS	:	Small Vessel Advisory Services
SWAN	:	Simulating WAves Nearshore
SWFP	:	Severe Weather Forecasting Programme
SynOPS	:	Synergistic Ocean Observation Prediction Services
TEP	:	Tsunami Evacuation Planning
TRRP	:	Tsunami Ready Recognition Programme

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
UNFCCC	:	UN Framework Convention on Climate Change
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
WOSC	:	World Ocean Science Congress
WRF	:	Wave Rider Buoy
WTAD	:	World Tsunami Awareness Day
WQNS	:	Water Quality Nowcast System
WWIII	:	WaveWatch III
XBT	:	eXpendable Bathy Thermographs

12

FINANCE

K. PRAHLADA RAO & CO.
CHARTERED ACCOUNTANTS

H.No. 3-6-84/12&13, Flat # 402, Legend Venkatesha, Beside Taj Mahal Hotel,
Himayath Nagar, 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,
ESSO-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, 2024, 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 miss-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 2024, 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 & CO. Chartered Accountants FRN No: 002717S Hyderabad

Ranjeet Kumar R.
Partner
M.No.227492
FRN No: 002717S

Place : HYDERABAD
Date : 14.08.2024
UDIN : 24227492BKCRFX8475

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 2024

Particulars	Schedules	Current Year (2023-24) ₹	Previous Year (2022-23) ₹
CAPITAL FUND AND LIABILITIES			
Corpus fund	1	65,68,32,317	68,34,02,817
Earmarked funds	2	0	4,74,80,479
Current liabilities & Provisions	3	15,55,65,857	17,14,38,475
Total		**81,23,98,174**	**90,23,21,771**
ASSETS			
Fixed Assets	4	47,83,96,595	52,32,10,085
Current Assets, Loans & Advances	5	33,40,01,579	37,91,11,686
Total		**81,23,98,174**	**90,23,21,771**
Notes forming part of Accounts	11	-	-

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

Ranjeet Kumar R.
Partner
M. No. 227492
FRN No: 002717S

Place : Hyderabad
Date : 14.08.2024

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

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 2024

Particulars	Schedules	Current Year (2023-24) ₹	Previous Year (2022-23) ₹
INCOME			
Income from Sales / Other Income	6	1,62,65,188	1,19,73,698
Interest Earned on Investments	7	19,77,802	30,61,214
Recurring Grants	8	26,81,96,704	23,36,36,881
TOTAL - A		**28,64,39,694**	**24,86,71,793**
EXPENDITURE			
Establishment Expenditure	9	15,99,93,986	14,57,28,760
Other Administrative Expenses	10	9,84,76,350	8,79,08,120
Depreciation	4	5,45,39,859	6,04,28,433
TOTAL - B		**31,30,10,195**	**29,40,65,313**
Excess of Income over expenditure (A-B)	1	**-2,65,70,501**	**-4,53,93,520**
Add / Less: Prior Period Items		-	-
Balance being net income / deficit transferred to Corpus Fund		**-2,65,70,501**	**-4,53,93,520**
Notes forming part of Accounts	11		

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

Ranjeet Kumar R.
Partner
M. No. 227492
FRN No: 002717S

Place : Hyderabad
Date : 14.08.2024

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

(S. Nageswara Rao)
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Head-ESS (Addl. Charge)

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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 2024

RECEIPTS	CURRENT YEAR 2023-24		PAYMENTS	CURRENT YEAR 2023-24	
Opening Balance			**Establishment Expenses**		
Current A/c-SBI-10442424456	18,81,39,959		Pay, Leave, Salary and Allowances	13,73,67,726	
UBI Savings A/c No.171410100132670	36,65,468		Leave Encashment during LTC	2,39,173	
UBI Consultancy A/c No.171410100022294	84,77,102		Contribution to NPS	1,59,88,744	
IOGOOS-Local No.171410100022355	9,26,757		Children Education Allowances	19,26,375	
IOGOOS-Foreign No.171410100022346	54,98,474		Medical - IP	5,77,715	
CPF Account A/c No.10442327815	2,91,09,819		Medical - OP	11,03,441	
Short Term Deposits with UBI (Consultancy)	3,00,00,000		LTC Expenses	10,86,952	
CNA-OSMART A/c No.110050299930	42,39,92,480		EL Encashment & Gratuity transfer to LIC	17,03,860	**15,99,93,986**
CNA-REACHOUT A/c No.110053095516	12,06,69,592				
GEM POOL A/c No.39204543266	1,63,960				
Joint Consultancy Project-NCCR A/c No.110095370804	20,35,200		**Administrative Expenses**		
Bank of Maharashtra -ACROSS A/c No. 60430283661	40,66,834	**81,67,45,645**	Telephone Expenses	7,26,100	
			Printing and Stationery	6,466	
			Advertisement and Publicity	92,545	
Earmarked Funds			Audit Fees	23,600	
Ocean Observation Networks - OON	28,36,00,000		Legal Suit/Court	1,09,616	
International Training Centre (ITCOOcean)	7,57,26,617		Office Expenses	2,85,19,353	
Deep Ocean Mission (DOM)	21,62,77,862		Bank Charges	2,365	

Ocean Modelling and Advisory Services (OMAS)	45,32,77,071		General Expenses	6,09,717	
Monsoon Mission	1,49,59,235	**1,04,38,40,785**	International Interface	93,678	**3,01,83,440**
Recurring Grants (Operation & Maintenance of INCOIS)	26,81,96,704	**26,81,96,704**			
			Operation & Maintenance		
			House Keeping, Plumbing & Garden Expenses	96,28,054	
Funds/Grant Receipts from others			Security Expenses	1,40,84,029	
National Conference of Ocean Society of India (OSICON)	59,82,162		Water Expenses	28,11,621	
G20 – Research and Innovation Initiative Gathering (RIIG) Meeting-REACHOUT	21,33,060		Electricity Expenditure	2,37,85,798	
MoES Chair Scientist/Professorship-Dr SSC Shenoi	15,39,000		Maintenance & Repairs	13,54,488	
Installation of MoES 3D Selfie Points	2,50,75,100		Material Consumable	84,488	
Indian Ocean Regional Decade Conference (IO-CON)	11,03,000	**3,58,32,322**	HVAC & Electrical Operational & Maintenance charges	1,65,44,432	**6,82,92,910**
Other Receipts			**Purchase of Fixed Assets**	97,26,368	**97,26,368**
Consultancy Projects					
Afcons Infrastructure Limited	2,15,920				
Dept of Environment & Climate Change, Govt of Tamil Nadu	41,61,235		**Ocean Modelling and AdvisoryServices(OMAS)**		
Proclaim Insurance Surveyors and Loss Assessors	-		Equipments	6,93,67,040	
Directorate General of Hydrocarbons	1,16,640		Computers/Software	8,27,53,554	
Structural Specialities & Projects Limited	-		Other Assets	2,50,016	
Nuclear Power Corporation of India Ltd	4,04,750		Technical support	6,55,88,680	

Jawaharlal Nehru Port Trust	8,90,400		Administrative expenses	9,80,84,316	
Chennai Port Authority	27,45,762		Travel	48,34,564	
Indian Port Rail & Ropeway Corporation	6,86,484		Consumable Materials/Data	1,13,63,701	
Director, Department of Environment	22,65,600		Advance against subprojects	1,17,22,414	
Adani Vizhinjam Port Pvt Ltd	20,43,360		Advance for Purchase-PO closure in Transit	10,93,12,785	**45,32,77,070**
McDermott International Management	1,10,160				
National Institute of Oceanography	69,600				
Oil & Natural Gas Corporation	-		**Ocean Observation Networks - OON**		
National Institute of Ocean Technology	4,10,400	**1,41,20,311**	Equipments	4,95,60,887	
			Other Assets	5,00,000	
			Technical support	8,07,80,348	
Other Receipts			Administrative expenses	5,01,59,136	
Interest on Savings Account	1,91,197		Travel	60,88,506	
Interest on UBI Consultancy Account	4,87,768		Consumable Materials/Data	3,07,72,026	
GEM Pool Account Interest	42,004		Advance against subprojects	1,84,16,749	
Joint Consultancy Project-NCCR A/c No.110095370804	76,244		Advance for Purchase	2,58,32,348	
Interest on TDS refund	1,20,699		Margin Money against LC	2,14,90,000	**28,36,00,000**
Interest on SBI CPF Account	4,87,712				
Interest on PORSEC Account	2,81,625				
Interest on ISPRS Account	28,086		**International Training Centre (ITCOOcean)**		
Interest on INCOIS Medical Scheme (for Retd. Staff) TDR	2,62,487		Equipments	63,60,208	
Interest on IOGOOS Foreign Accounts	1,58,912		Computers/Software	1,72,70,893	
Interest on IOGOOS Local Account	19,192		Technical support	42,33,512	
Earnest Money Deposit	76,94,563		Administrative expenses	3,49,25,193	
Security Deposit	72,050		Travel	1,10,778	
Income from Staff Quarters	1,62,123		Consumable Materials / Data	1,28,26,033	**7,57,26,617**
Income from Guest Houses	7,66,231				

MoES Chair Scientist/Professorship-Dr SSC Shenoi	15,39,000				
Dr PA Francis NPS Contribution	84,214	**1,24,74,107**	**Monsoon Mission**		
			Administrative Expenses	1,30,58,291	
			Travel	8,52,624	
IOGOOS			Consumable Materials/Data	10,48,320	**1,49,59,235**
United National Educational, Scientific and Culture Organisation (UNESCO)	6,22,696				
Salary reimbursement from NCESS	86,49,885	**92,72,581**			
			Deep Ocean Mission (DOM)		
			Equipments	7,23,79,035	
NODAL AGENCY BANK ACCOUNTS RECEIPTS			Administrative expenses	2,70,65,003	
CNA-INCOIS-OSMART Canara Bank Account	2,80,59,88,252		Travel	93,22,610	
CNA-INCOIS-REACHOUT Canara Bank Account	44,63,80,551		Consumable Materials/Data	1,05,18,800	
CNA-INCOIS-ACROSS-BoM Account	-	**3,25,23,68,803**	Advance against subprojects	3,00,000	
			Advance for Purchase	14,41,72,893	**26,37,58,341**
IT Refund					
TDS Refund for Assessment Year 2022-23	18,56,931	**18,56,931**	**Other Payments**		
			Inspire Fellowship	5,74,350	
			LTC Advance	6,03,897	
Interest			Dept. Contingency/Temporary Advance	84,85,531	
Interest earned on CNA-INCOIS-OSMART	1,62,85,331		MoES Chair fellowship	15,39,000	
Interest earned on CNA-INCOIS-REACHOUT	20,29,066	**1,83,14,397**	CPF to NPS transfer	1,69,68,891	
			CPF withdrawal	3,75,000	
			National Post Doc Fellowship	3,45,960	

Fellowships received for Research Fellows			Interest Refund to CFI (MoES)	1,16,19,431	**4,05,12,060**
Inspire Fellowship	5,74,350				
National Post Doc Fellowship	3,45,960	**9,20,310**			
			NODAL AGENCY Bank Accounts		
			Expenditure met from CNA-INCOIS-OSMART	3,16,22,79,265	
Refund of Unspent Balances from PIs Sub-Projects (CNA)			Expenditure met from CNA-INCOIS-REACHOUT	56,12,71,995	
NIO-Goa	30,26,455		Interest refunded to CFI on CNA-INCOIS-OSMART	1,62,85,331	
Andhra University	1,80,516	**32,06,971**	Interest refunded to CFI on CNA-INCOIS-REACHOUT	20,29,066	
			Interest refunded to CFI on INCOIS-NCCR Consultancy A/c	3,54,102	
			Interest refunded to CFI on INCOIS Sub-Projects	45,954	**3,74,22,65,713**
Income from Scrap sale	4,32,700	**4,32,700**			
			Expenditure from Other Grants Received from MoES		
Refund of Unspent Balances from PIs Sub-Projects (INCOIS)	2,67,891	**2,67,891**	National Conference of Ocean Society of India(OSICON)	59,82,162	
				21,33,060	
			MOES CHAIR	15,39,000	
			Installation of MoES 3D Selfie Points	2,50,75,100	
			Indian Ocean Regional Decade Conference (IO-CON)	11,03,000	**3,58,32,322**
			Closing Balance		
			INCOIS Current A/c-SBI-HAL Campus Br.	13,25,35,450	
			UBI Savings A/c	1,68,28,335	

			UBI Consultancy A/c	3,93,57,250	
			INCOIS IOGOOS Secretariat- Local	9,52,436	
			INCOIS IOGOOS Secretariat- Foreign	55,03,288	
			INCOIS- CPF Account	1,05,41,176	
			INCOIS SBI GEM POOL A/C	18,27,546	
			CNA-INCOIS-OSMART Canara Bank Account	7,46,67,675	
			CNA-INCOIS-REACHOUT Canara Bank Account	56,57,449	
			Canara Bank (INCOIS-NCCR Joint Consultancy Project)	1,15,79,152	
			CNA-INCOIS-ACROSS BoM Account	2,72,640	**29,97,22,397**
Total	**5,47,78,50,458**	**5,47,78,50,458**	**Total**	**5,47,78,50,458**	**5,47,78,50,458**

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

Ranjeet Kumar R.
Partner
M. No. 227492
FRN No: 002717S

Place : Hyderabad
Date : 14.08.2024

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 (BO), Nizampet (SO), Hyderabad - 500 090

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31st MARCH 2024

SCHEDULE 1 – CORPUS FUND

Particulars	Current Year (2023-24) ₹	Previous Year (2022-23) ₹
Corpus Fund at the beginning of the year	68,34,02,818	72,87,96,337
Add: Net income transferred from Income & Expenditure Account	-2,65,70,501	-4,53,93,520
BALANCE AS AT THE YEAR END	**65,68,32,317**	**68,34,02,817**

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

Ranjeet Kumar R.
Partner
M. No. 227492
FRN No: 002717S

Place : Hyderabad
Date : 14.08.2024

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	Ocean Modelling and AdvisoryServices (OMAS)	Ocean Observation Networks	International Training Centre (ITCOOcean)	Monsoon Mission	RIMES	Deep Ocean Mission	Funds/Grants Receipts from others	TOTALS Current Year (2023-24)	TOTALS PreviousYear (2022-23)
a) Opening balance of the funds	0	0	0	0	0	4,74,80,479	0	4,74,80,479	28,79,92,685
b) Additions to the Funds:									
i. Grants	45,32,77,071	28,36,00,000	7,57,26,617	1,49,59,235	0	21,62,77,862	3,58,32,322	1,07,96,73,107	39,63,98,915
ii. Interest if any	0	0	0	0	0	0	0	0	0
a) Interest Apportioned during 2023-24	0	26,50,393	0	0	0	79,60,326	0	1,06,10,719	94,43,185
b) Interest credited Direct to projects 2023-24	6,40,437	0	0	0	0	0	0	6,40,437	11,53,449
iii. Advance for sub projects utilised/refund	0	0	0	0	0	0	0	0	3,24,55,216
iv. Advance for purchase Utilised	0	0	1,74,03,866	0	0	0	0	1,74,03,866	1,16,26,767
v. Margin Money Reversed	0	0	0	0	0	12,68,44,340	0	12,68,44,340	0
vi. Deposit Advance Utilized/refund	0	0	0	0	0	0	0	0	0
vii. Mobilization Advance Reversed	0	0	0	0	0	0	0	0	0
viii. Other Revenue	0	0	0	0	0	0	0	0	0
TOTAL (a+b) - A	**45,39,17,508**	**28,62,50,393**	**9,31,30,483**	**1,49,59,235**	**0**	**39,85,63,007**	**3,58,32,322**	**1,28,26,52,948**	**73,90,70,217**
c) Utilisation/Expenditure									
i. Capital Expenditure									
W.I.P	0	0	7,70,293	0	0	0	0	7,70,293	27,81,290
Architect fee	0	0	0	0	0	0	0	0	0
Equipments	6,93,67,040	4,95,60,887	55,89,915	0	0	7,23,79,035	2,50,75,100	22,19,71,977	6,38,61,012
Computers / Software	8,27,53,554	0	3,46,74,759	0	0	0	0	11,74,28,313	4,56,14,282
Other Assets	2,50,016	5,00,000	0	0	0	0	0	7,50,016	92,398
Total(i)	**15,23,70,610**	**5,00,60,887**	**4,10,34,967**	**0**	**0**	**7,23,79,035**	**2,50,75,100**	**34,09,20,599**	**11,23,48,982**
ii. Revenue Expenditure									
Technical support	6,55,88,681	8,07,80,348	42,33,512	0	0	0	0	15,06,02,541	6,15,00,663
Administrative expenses	9,80,84,316	5,01,59,136	3,49,25,193	1,30,58,291	0	2,70,65,003	91,71,918	23,24,63,857	10,94,34,679
Travel	48,34,564	60,88,506	1,10,778	8,52,624	0	93,22,610	15,85,304	2,27,94,386	1,62,49,235
Consumable Materials / Data	1,13,63,701	3,07,72,026	1,28,26,033	10,48,320	0	1,05,18,800	0	6,65,28,880	4,47,19,974
Total(ii)	**17,98,71,262**	**16,78,00,016**	**5,20,95,516**	**1,49,59,235**	**0**	**4,69,06,413**	**1,07,57,222**	**47,23,89,664**	**23,19,04,551**
iii. Others									
Advance against subprojects	1,17,22,414	1,84,16,749	0	0	0	3,00,000	0	3,04,39,163	1,08,12,877
Advance for Purchase	10,93,12,785	2,58,32,348	0	0	0	27,10,17,233	0	40,61,62,366	2,57,98,995
Deposit Works (APWD & RITES)	0	0	0	0	0	0	0	0	0
Margin Money against LC	0	2,14,90,000	0	0	0	0	0	2,14,90,000	27,07,72,000
Total(iii)	**12,10,35,199**	**6,57,39,097**	**0**	**0**	**0**	**27,13,17,233**	**0**	**45,80,91,529**	**30,73,83,872**
TOTAL (i+ii+iii) - B	45,32,77,071	28,36,00,000	9,31,30,483	1,49,59,235	0	39,06,02,681	3,58,32,322	1,27,14,01,792	65,16,37,405
Amount Refunded- C (Unspent Bal)	0	0	0	0	0	0	0	0	2,93,55,699
Interest to be refund - D (outstanding liability)	6,40,437	26,50,393	0	0	0	79,60,326	0	1,12,51,156	94,43,185
as per 238 of GFR	0	0	0	0	0	0	0	0	11,53,449
NET BALANCE AS AT THE PERIOD END {A-(B+C+D)}	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4,74,80,479**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE - 3 CURRENT LIABILITIES & PROVISIONS

Particulars	Current Year (2023-24) ₹	Previous Year (2022-23) ₹
A. CURRENT LIABILITIES		
Earnest Money Deposit	87,56,401	54,88,650
Security Deposit	1,08,22,853	1,13,01,011
Outstanding Expenses	1,40,18,439	2,58,52,139
INSPIRE/DISHA/NPDF Fellowship	-	8,26,786
Sundry Creditors	1,70,21,973	2,46,91,370
Other Bank Liability	38,74,603	46,23,465
Total – A	**5,44,94,269**	**7,27,83,421**
B. PROVISIONS		
Gratuity	4,62,11,350	4,45,63,020
Accumulated Leave Encashment	5,48,60,238	5,40,92,034
Total – B	**10,10,71,588**	**9,86,55,054**
Total (A+B)	**15,55,65,857**	**17,14,38,475**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE – 4 FIXED ASSETS

2023-24 (Amount in Rs.)

Description (% of Depreciation)	Rate	Gross Block				Depreciation			Net Block	
			Additions During The Year							
		As on 31.03.2023	>180 Days	<180 Days	As at 31.03.2024	As at 31.03.2023	For the Year 2023-24	As at 31.03.2024	As at 31.03.2024	As at 31.03.2023
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	4,54,92,291	1,09,690	4,56,01,981	6,21,574	7,31,264
3. Furniture & Fixtures (10%)	10.00%	1,72,67,084	-	-	1,72,67,084	1,41,80,676	3,08,641	1,44,89,317	27,77,767	30,86,408
4. Office Equipment (15%)	15.00%	34,84,725	-	-	34,84,725	31,18,011	55,007	31,73,018	3,11,707	3,66,714
5. Computer / Peripheral (40%)	40.00%	12,92,44,815	-	-	12,92,44,815	12,80,55,897	4,75,567	12,85,31,464	7,13,351	11,88,919
6. Electric Installations (10%)	10.00%	20,98,406	-	-	20,98,406	16,55,566	44,284	16,99,850	3,98,556	4,42,841
7. Library Books (40%)	40.00%	8,39,08,143	-	-	8,39,08,143	8,13,96,851	10,04,517	8,24,01,368	15,06,778	25,11,292
8. Other Fixed Assets (15%)	15.00%	70,60,861	26,26,937	70,99,431	1,67,87,229	55,72,314	11,49,780	67,22,094	1,00,65,135	14,88,547
9. Vehicles (15%)	15.00%	22,23,774	-	-	22,23,774	11,62,510	1,59,190	13,21,700	9,02,074	10,61,264
10. Building(10%)	10.00%	63,25,08,439	-	-	63,25,08,439	12,01,76,603	5,12,33,183	17,14,09,786	46,10,98,653	51,23,31,836
Total		**92,40,20,802**	**26,26,937**	**70,99,431**	**93,37,47,170**	**40,08,10,719**	**5,45,39,859**	**45,53,50,578**	**47,83,96,595**	**52,32,10,085**
Previous Year		**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**

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 01-04-2023	Additions 2023-24	Transfers to Fixed Assets based on prior approval of MoES	Grant Utilized/ Received till 31-3-24 (G/A -Gen/Capital)	As on 31.03.2023	For the Year 2023-24	Total Depreciation for the year end 31.03.2024	As at 31.03.2024	As at 31.03.2023
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	82,25,51,845	5,00,60,887	-	87,26,12,732	-	-	-	-	-
vii)	International Training Center- ITCOOcean	74,48,39,879	4,10,34,967	-	78,58,74,846	-	-	-	-	-
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	15,23,70,610	-	20,83,95,822	-	-	-	-	-
xi)	Deep Ocean Mission	1,83,06,179	7,23,79,035	-	9,06,85,214					
xii)	Installation of MoES-3D Selfie Points of		2,50,75,100	-	2,50,75,100					
	Total	**6,32,28,03,573**	**34,09,20,599**	**-**	**6,66,37,24,172**	**-**	**-**	**-**	**-**	**-**
	Previous year	**6,21,04,54,591**	**11,23,48,982**	**-**	**6,32,28,03,573**	**-**	**-**	**-**	**-**	**-**
	Grand Total	**7,24,68,24,375**	**35,06,46,967**	**-**	**6,66,37,24,172**	**-40,08,10,719**	**-5,45,39,859**	**-45,53,50,578**	**-47,83,96,595**	**-52,32,10,083**
	GRAND TOTAL (PREVIOUS YEAR)	**7,13,44,75,393**	**11,23,48,982**	**-**	**6,32,28,03,573**	**-34,03,82,286**	**-6,04,28,433**	**-40,08,10,719**	**-52,32,10,083**	**-58,36,38,516**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE - 5 CURRENT ASSETS, LOANS & ADVANCES

Particulars	Current Year (2023-24) ₹		Previous Year (2022-23) ₹	
A. CURRENT ASSETS				
1. Inventories (Valued at cost)	10,98,082	10,98,082	11,45,557	11,45,557
2. Cash & Bank Balance :				
a) With Scheduled Banks – Current Account				
State Bank of India HAL CAMPUS A/c	13,42,45,352		18,56,41,591	
Union Bank Pragathinagar SAVINGS A/c	1,68,29,820		36,65,468	
Union Bank Pragathinagar-Consultancy A/c	4,04,03,470		84,77,102	
State Bank of India - CPF Savings A/c	1,05,41,176		2,91,09,819	
CNA INCOIS REACHOUT A/c	0		0	
CNA INCOIS OSMART A/c	0		0	
Canara In 70804 A/C (INCOIS NCCR JOINT CONSULTANCY)	1,15,66,405		20,35,346	
State Bank of India – GeM Pool Account (GPA)	12,30,278	21,48,16,501	1,63,960	22,90,93,286
b) Short Term Deposits in CPF A/c	-			
c) Short Term Deposits with SBI	-			
d) Short Term Deposits with Union Bank Consultancy				3,00,00,000
3. LIC_FM GRATUITY	-	4,62,11,350		4,45,63,020
4. LIC_FM LEAVE ENCASHMENT		5,48,60,238		5,40,92,034
5. Sundry Debtors				36,57,720
TOTAL A:		**31,69,86,171**		**36,25,51,617**

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) Contingency Advance		2,00,000		-	
c) Tour Advance		83,900		49,707	
d) LTC Advance		83,500		1,39,500	
e) TDS					
Opening Balance	- Rs.84,34,940				
Less: Refund received	- Rs. 18,56,931				
Add: Current year accumulation	- Rs. 22,16,637	87,94,646		84,34,940	
i) Margin Money against Bank Guarantee		-	98,12,748	82,360	93,57,409
TOTAL B: (1+2)			**1,70,15,408**		**1,65,60,069**
GRAND TOTAL (A + B)			**33,40,01,579**		**37,91,11,686**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 6 - INCOME FROM SALES / OTHER INCOME

Particulars	Current Year (2023-24) ₹	Previous Year (2022-23) ₹
a) Other Receipts	19,82,754	33,57,186
b) Consultancy Services	1,41,20,311	85,44,158
c) Income from staff quarters	1,62,123	72,354
TOTAL	**1,62,65,188**	**1,19,73,698**

SCHEDULE 7 - INTEREST EARNED

Particulars	Current Year (2023-24) ₹	Previous Year (2022-23) ₹
a) Interest on Deposits & Others	10,59,910	25,16,008
b) Bank Accounts	9,17,892	5,00,206
d) Interest on Vehicle Advance	-	45,000
TOTAL	**19,77,802**	**30,61,214**

SCHEDULE 8 - IRRECOVERABLE GRANTS & SUBSIDIES RECEIVED

Particulars	Current Year (2023-24) ₹	Previous Year (2022-23) ₹
a) Central Government (Recurring Grant Assignment received from MoES)	26,81,96,704	23,36,36,881
TOTAL	**26,81,96,704**	**23,36,36,881**

SCHEDULE 9 - ESTABLISHMENT EXPENDITURE

Particulars	Current Year (2023-24) ₹	Previous Year (2022-23) ₹
a) Salaries, Wages & Allowances	13,90,44,196	12,66,02,060
b) Staff Welfare Expenses	17,90,772	28,33,249
c) Contributory Provident Fund	9,70,060	21,21,442
d) New Pension Scheme	1,59,88,744	1,15,90,421
e) Leave Travel Concession	22,00,214	25,81,588
TOTAL	**15,99,93,986**	**14,57,28,760**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 10 - OTHER ADMINISTRATIVE EXPENSES

Sl No.	Particulars	Current Year (2023-24) ₹	Previous Year (2022-23) ₹
1	Electricity & Power Expenses	3,13,75,748	3,08,49,608
2	Water Charges	36,47,337	34,70,911
3	Operation & Maintenance expenses	93,54,488	92,05,424
4	Garden Expenses	6,41,147	4,84,332
5	Vehicle Hiring Expenses	-	1,46,717
6	Postage, Telephone, Fax & ISDN Charges	41,790	1,178
7	Printing & Stationery	6,466	11,79,399
8	Travelling Expenses (Inland)	-	96,655
9	Seminar/Workshops Expenses	-	-
10	General Expenses	1,66,65,459	1,11,98,957
11	Audit Fee	23,600	23,600
12	House Keeping & Plumbing	1,31,39,164	1,04,86,803
13	Security Expenses	1,93,61,262	1,61,34,385
14	Advertisement & Publicity	12,20,782	10,17,318
15	Internet Expenses	-	-
16	Legal Expenses	-	16,000
17	Papers & Periodicals	-	-
18	Material /Consumable	29,05,429	24,21,191
19	International Interface	93,678	10,51,642
20	Others (Honorarium to External Experts)	-	1,24,000
	TOTAL	**9,84,76,350**	**8,79,08,120**

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 through RBI Assignment Account 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 2023-24, the Society received Rs.26,81,96,704/- towards Recurring Grant as shown in the Schedule-8. For the Financial year 2023-24, the RBI Assignment was received for Rs.27,00,00,000/- and utilized only Rs.26,81,96,704/- and savings are to the tune of Rs.18,03,296/- and became ZERO on 31.3.2024 in compliance to JUST-IN-TIME fund concept.

The remaining Grant-in-aid of Rs.107,96,73,107/- received from Ministry of Earth Sciences through Central Nodal Agency (CNA) Zero Balance Account is being utilized for specific purposes for which they were intended to and are disclosed under the Earmarked Funds- Schedule-2. For the Financial year 2023-24, the CNA Assignment was received for Rs.113,17,00,000/- and utilized only Rs. 107,96,73,107/- and savings are to the tune of Rs.5,20,26,893/-. The Ear-marked funds in the Schedule-2 and also in the Balance showing ZERO balance in compliance to the JUST-IN-TIME fund concept.

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 2024.

ii) Leave Encashment:

The present value of the INCOIS obligations under Leave Encashment is recognized on the basis of an actuarial valuation given by the LIC of India Ltd., as on 31 March 2024.

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 2023-24, an amount of Rs.1,06,10,719/- 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 earned against LC Margin Money OSMART-OON-Programme- Rs.79,60,326 DOM Programme - Rs.26,50,393	-	Rs.1,06,10,719
b.	Interest transferred to other available funds	-	Rs.14,13,810
c.	Interest transferred to Society	-	Rs.5,63,992
	Total		**Rs.1,25,88,521**

The apportioned interest amount of Rs. 1,06,10,719/- for the said earmarked funds in Schedule 2, 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 2023-24 and the same will be deposited in the CFI.

The details are furnished below: -

(Amount in Rs.)

a.	Interest earned on regular STDRS closed in FY 2023-24	1,07,16,380
b.	Add: Net Interest accrued in other bank accounts	14,13,810
c.	Add: Net Interest accrued in transferred to Society	5,63,992
d.	Less: Transfer of outstanding Accrued Interest for the F.Y 2022-23	1,05,661
	Total Interest Earned for the FY 2023-24	**1,25,88,521**

2. Notes on Accounts:

a. EARMARKED FUNDS:

The Society during the year 2023-24, received Rs.107,96,73,107/- 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.

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.1,74,03,866/- of advances was adjusted and the value of "Advance for Purchase" as on 31-03-2024 was only Rs.50,61,46,438/-.

The accumulated value of the capital expenditure as on 31-03-2024 (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.

S. No	Name of the Fund/Project	As on 01-04-2023 Rs.	Capital Expenditure incurred during 2023-24	Total Amount as on 31.03.2024
i)	MDC & Equipment Fund	6,59,21,618	-	6,59,21,618
ii)	OMAS	2,93,09,18,917	15,23,70,610	3,08,32,89,527
iii)	Ocean Observation Network	82,25,51,845	5,00,60,887	87,26,12,732
iv)	International Training Center-ITCOOcean	74,48,39,879	4,10,34,967	78,58,74,846
v)	HPC System-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	7,23,79,035	9,06,85,214
xiv)	Installation of MoES-3D Selfie Points	0.00	2,50,75,100	2,50,75,100
		6,32,28,03,573	**34,09,20,599**	**6,66,37,24,172**

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 31 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 31 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 the properties of M/s Victory

Genset Pvt. Ltd. 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 05 October 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 remand period undergone by the accused shall be set off under Section 428 of Cr. P.C. The accused is appraised of his right to appeal.

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

Ranjeet Kumar R.
Partner
M. No. 227492
FRN No: 002717S

Place: Hyderabad
Date: 14.08.2024

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

(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

Indian National Centre for Ocean Information Services

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

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