INCOIS

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

ANNUAL REPORT
2020-21

Front Cover

INCOIS activity spectrum ranging from observations to operational oceanography services. INCOIS continued to provide uninterrupted services despite challenges brought on by the COVID-19 pandemic being identified as the center for carrying our essential services by MHA. INCOIS lived up to the expectation by closely monitoring two earthquakes in the Indian Ocean declaring no "Tsunami Threat". Storm Surge, Ocean State Forecasting services were continued and extended to all the coastal population during the Amphan, Nisarga and Nivar cyclones. The highly ambitious observational platform "Flux Mooring" deployed in the Bay of Bengal measured extremely valuable data on air-sea fluxes and oceanographic parameters continuously and was successfully recovered. In preparation towards implementing the Deep Ocean Mission (DOM), INCOIS also procured and deployed 2 deep ocean gliders in the Bay of Bengal. The operational oceanography activities of INCOIS continues to benefit the coastal population under all circumstances.

Cover concept and description: Mr. N Kiran Kumar

Back Cover

International Training Centre for Operational Oceanography (ITCOocean)/INCOIS Main Building: A Category-II Centre of UNESCO primarily engaged in providing training in operational oceanography and capacity building of oceanic communities.

Photo Courtesy- Knowledge Resource Centre, INCOIS

Annual Report 2020-21

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

Contents

From Director's Desk (2020-21)

Twenty three years into its establishment, the Indian National Centre for Ocean Information Services (INCOIS) has grown into one of the leading institutes world-over in the field of operational oceanography, and is pursuing a focussed mandate on ocean observations, modelling, information and advisory services. The services provided by INCOIS, such as the Tsunami and Storm Surge Early Warnings, Ocean State Forecasts (OSF), Potential Fishing Zone (PFZ) advisories and Ocean Data Services have proven to have immense socio-economic benefits for a wide range of stakeholders, and enhance the lives and livelihoods of coastal communities. The tsunami early warning centre of INCOIS is identified as a Tsunami Service Provider (TSP) for the Indian Ocean region, by the Intergovernmental Oceanographic Commission (IOC-UNESCO). The International Training Centre for Operational Oceanography (ITCOocean) at INCOIS is recognized as a UNESCO Category-2 Centre (C2C) for training young researchers from all over the world. During the period under report, INCOIS continued to provide uninterrupted services despite challenges brought on by the COVID-19 pandemic.

The Tsunami Early Warning Centre at INCOIS continued to function efficiently detecting every global tsunamigenic earthquake. Two earthquakes in the Indian Ocean were closely monitored and declared as "No Threat", thus avoiding unnecessary evacuation of the coastal population. In addition, INCOIS has also placed a huge focus on enhancing community awareness and response through several capacity-building activities, biannual communications tests, biennial Indian Ocean-wide tsunami drills and more importantly spearheading the UNESCO-IOC "Tsunami Ready" initiative. With the recognition of two communities viz., Venkatraipur and Noliasahi in Odisha as Tsunami Ready by the UNESCO-IOC, India became the first country in the Indian Ocean Region to achieve this distinction. This concept has to be expanded to other vulnerable coastal communities. Being prepared for a tsunami hazard enhances the capacities of communities to respond effectively to other coastal hazards.

Another creditable achievement is the development of "Digital Ocean" portal by INCOIS which was inaugurated by the Honorable Minister of Health & Family Welfare, Science & Technology and Earth Sciences Dr. Harsh Vardhan on 29 December 2020. The Digital Ocean serves as a one stop-solution for all the ocean data related needs of a wide range of users including research institutions, operational agencies, strategic users, academic community, maritime industry, policy makers and the public. INCOIS continued the acquisition of data on various ocean parameters from the coastal and open ocean waters by deploying Argo floats, wave rider buoys, sea level gauges, ADCPs, drifters, XBTs, ship board AWS, etc. In October 2020, scientists of INCOIS, with support from NIOT recovered the INCOIS flux mooring, which was deployed in the Bay of Bengal from May 2019 and measured extremely valuable data on air-sea fluxes and oceanographic parameters continuously for 16 months. The long time series of air-sea fluxes measured by this observational platform will provide very important insights on the ocean-atmosphere processes in the Bay of Bengal, which will help us to improve their representation in the ocean/atmosphere models.

Another important achievement in the past one year was the launching of a focussed Ocean Modelling Mission, which is aimed at setting up a unified ocean modeling and forecasting framework for operational services of INCOIS. A detailed implementation plan was prepared with eight work packages for implementing different activities envisaged under this mission. As a preparatory work towards implementing the Deep Ocean Mission (DOM) of the Ministry of Earth Sciences (MoES), INCOIS implemented Local Ensemble Transform Kalman Filter (LETKF) data assimilation in high-resolution global configuration of Modular Ocean Model (MOM5) for the downscaling of sea level projections. INCOIS also procured and deployed 2 deep ocean gliders as part of the DOM in the Bay of Bengal in February 2021.

The ITCOocean conducted seven online courses and two webinars. It was successfully recognized as the Regional Training Centre (RTC) by Ocean Teacher Global Academy (OTGA) for 3 more years from 2020-2023. INCOIS continued its association with the Indian Ocean Global Ocean Observing System (IOGOOS), regional coordination of Argo programme, Partnership for Observation of Global Ocean (POGO), Regional Integrated Multi-hazard Early warning System (RIMES) and the Intergovernmental Coordination Group (ICG) for the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) of the Intergovernmental Oceanographic Commission (IOC)/UNESCO. INCOIS continued hosting the secretariats of IOGOOS, Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) as well as the Indian node of Joint Programme Office (JPO) for International Indian Ocean Expedition (IIOE)-2 to coordinate the IIOE-2 project (2016-2025) sponsored by IOC, Scientific Committee on Ocean Research (SCOR) and IOGOOS. INCOIS is playing a major role in the United Nations Decade of Ocean Science for Sustainable Development 2021-2030 (UN Ocean Decade) launched by the UNESCO-IOC, which is a unique opportunity to engage the ocean science community in achieving the Sustainable Development Goals (SDG) - globally, regionally and locally.

INCOIS commemorated its 23rd Foundation Day on 03 February 2021. The prestigious 'INCOIS Foundation Day Lecture' on the "UN Ocean Decade" was delivered by Dr. Vladimir Ryabinin, Executive Secretary, IOC of UNESCO and Assistant Director-General of UNESCO. INCOIS organized three scientific sessions as part of Vaishwik Bharatiya Vaigyanik Summit (VAIBHAV), an initiative of Government of India to get active involvement of non-resident Indian scientists/ academicians in the R&D activities in government laboratories and academic institutions in India. INCOIS also coordinated and organized the Vigyan Yatra outreach event in Hyderabad on 13 December 2020 as part of the India International Science Festival (IISF) 2020 in collaboration with Vijnana Bharathi (VIBHA), National Geophysical Research Institute (NGRI), International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI) and National Institute of Animal Biology (NIAB). INCOIS celebrated Hindi Pakhwada from 01-14 September 2020 and organised various competitions like e-poster, essay, extempore speech, Hindi poem, etc. via virtual mode. The Official Language Implementation Committee (OLIC) organized three lectures in Hindi by experts to promote the usage of Hindi in office. I am happy to report that 80% of INCOIS staff are now qualified to perform their official duty in Hindi. INCOIS received first prize among all the MoES institutes for exemplary performance during Swachta Pakhwada-2020 which INCOIS observed during 01–15 July 2020.

INCOIS scientists published 72 research papers in reputed national and international journals with a cumulative impact factor of 214.26. Dr. Rohith Balakrishnan, Project Scientist-B, INCOIS was

awarded the prestigious World Meteorological Organization (WMO) Young Researcher award in 2020. Dr. Kunal Chakraborty, Scientist-E, INCOIS has been elected as an Associate Fellow of the Indian Academy of Sciences, Bangalore. Dr. Abhisek Chatterjee received MoES Merit Certificate in Ocean Sciences and Shri. T. V. Rajesh, Scientific Assistant INCOIS and Shri. Santosh Kumar, Senior Executive INCOIS received MoES best employee awards in 2020.

Looking into the future, accurate prediction of essential ocean variables holds paramount importance for driving blue economy initiatives and for sustainable management of oceans through science-informed policy responses. The design of our ocean observing networks, modelling and research efforts should be driven by "user needs" and "national priorities". In the near and medium term, we need to work towards incorporating an ecosystem approach to PFZ, forecast of bio-geo-chemical parameters in OSF, developing multi-hazard early warning products and delivering impact-based services. Our long-term priorities should focus on development of a fully unified modelling and operational forecasting system to forecast anything from local beach conditions to regional currents and waves, and oceanic circulation on a global scale across a range of time scales. Gearing up to these challenges, and to achieve operational and research efficiencies across the full spectrum of activities encompassing the institutional mandate and future aspirations, a strategic transformation of INCOIS activities and human resources was undertaken in the past year. A major competency development initiative was also implemented to train our technical staff across all operational activities of INCOIS.

Dedicated efforts of our scientists, scientific and administrative support staff ensured that INCOIS remained at the helm of operational oceanography. I sincerely acknowledge the unflinching support and guidance of Dr. M. Rajeevan, Chairman of INCOIS Governing Council (GC) and the members of GC. I also thank the chairs and members of the Finance Committee and Research Advisory Committee for their advice and support in conducting the financial and scientific affairs of INCOIS. Colleagues in Ministry of Earth Science, especially the Programme Officer and his team, and at the MoES centres: NIOT, NCPOR, IITM, NCESS, NCMRWF, IMD, NCS, CMLRE, and NCCR continue to be integral part of our success. I thank them all.

The Annual Report was prepared by Uday, Francis, Nagaraja Kumar, Satyaprakash, Suprit, Prerna, Nimit and Sidhartha. I thank them for doing a wonderful job.

Thank you

Jai Hind

T. Srinivasa Kumar

2. INCOIS Organizational Structure

INCOIS is an autonomous institute under the administrative control of 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

Secretary to Government of India, MoES	President
Director, National Remote Sensing Centre (NRSC), Hyderabad	Vice President
Joint Secretary, MoES	Member
Advisor, MoES	Member
Director, National Institute of Oceanography (NIO), Goa	Member
Director, NIOT, Chennai	Member
Director, NCPOR, Goa	Member
Director, INCOIS	General Secretary

2.2 INCOIS Governing Council

1.	Secretary, MoES	Chairman (Ex-officio)
2.	Additional Secretary & Financial Advisor/ Joint Secretary & Financial Advisor, MoES	Member (Ex-officio)
3.	Additional Secretary/ Joint Secretary, MoES	Member (Ex-officio)
4.	Dr. Satish R Shetye, Former Vice Chancellor, Goa University & Chairman, INCOIS – RAC	Member
5.	Dr. R. R. Navalgund, Honorary Distinguished Professor, ISRO, Bangalore	Member
6.	Director, NRSC, Hyderabad	Member (Ex-officio)
7.	Director, IITM, Pune	Member (Ex-officio)
8.	Director, NIO, Goa	Member (Ex-officio)
9.	Head, NCMRWF, Noida	Member (Ex-officio)
10.	Programme Head (INCOIS), MoES	Permanent Invitee (Ex-officio)

11.	Representative, NITI Aayog	Invitee
12.	Director, INCOIS	Member Secretary

2.3 INCOIS Finance Committee

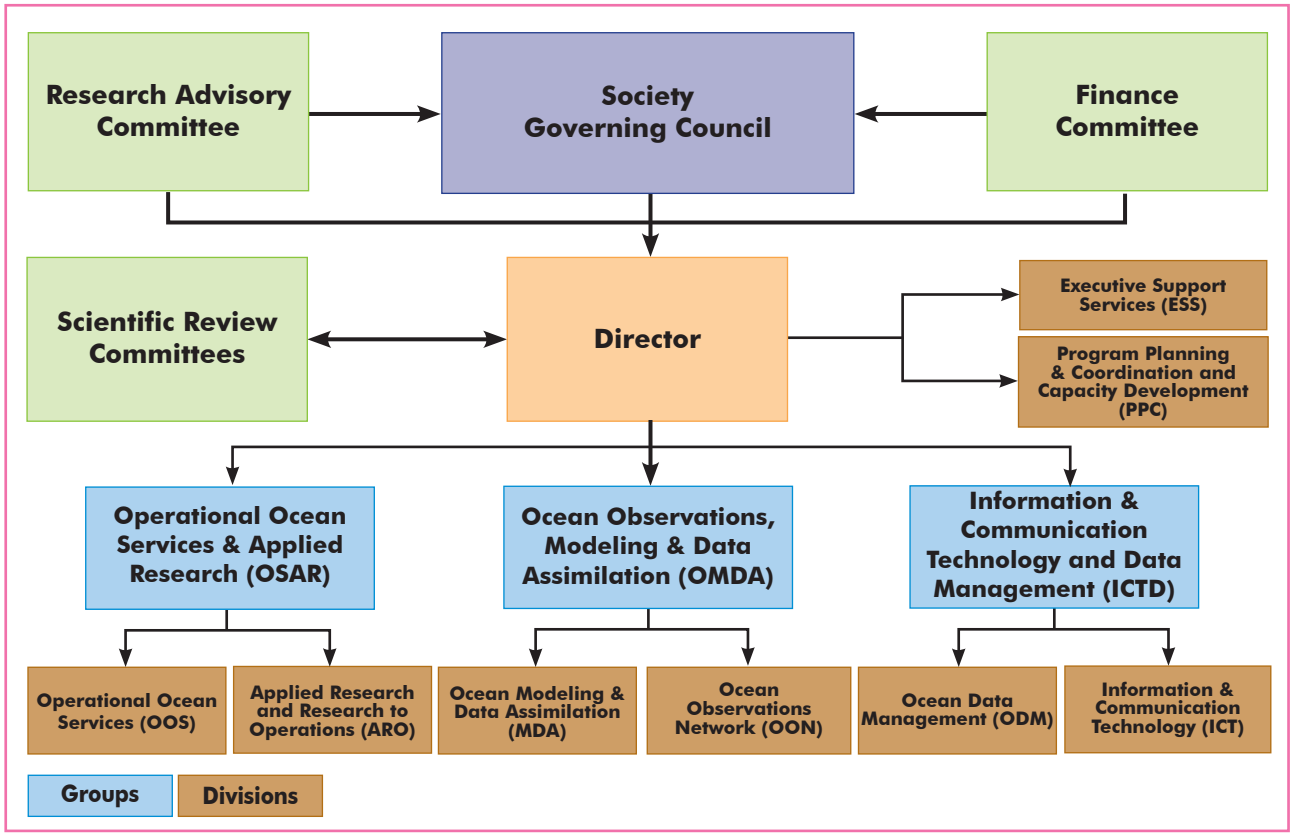
1.	Additional Secretary & Financial Advisor/ Joint Secretary & Financial Advisor, MoES	Chairman (Ex-officio)
2.	Additional Secretary/ Joint Secretary, MoES	Member (Ex-officio)
3.	Programme Head (INCOIS), MoES	Member (Ex-officio)
4.	Director (Finance) /Deputy Secretary (Finance), MoES	Member (Ex-officio)
5.	Director, INCOIS, Hyderabad	Member (Ex-officio)
6.	Dy. Chief Administrative Officer, INCOIS	Member (Ex-officio)
7.	Sr. Accounts Officer, INCOIS	Member (Ex-officio)

2.4 INCOIS Research Advisory Committee

1.	Dr. Satish R Shetye, Former Vice Chancellor, Goa University	Chairman
2.	Dr. Prakash Chauhan, Director, IIRS	Member
3.	Dr. Raj Kumar, Director, NRSC	Member
4.	Dr. A Gopalakrishnan, Director, CMFRI, ICAR, Kochi	Member
5.	Dr. Vineet Kumar Gahalaut, Chief Scientist, NGRI, Hyderabad	Member
6.	Dr. D. Sivanand Pai, Scientist 'G', CRS, IMD, Pune	Member
7.	Prof. Raghu Murtugudde, Professor, UML, USA	Member
8.	Dr. Shubha Sathyendranath, Scientist, PML, UK	Member
9.	Dr. Eric D' Asaro, Professor, APL, UW USA	Member
10.	Dr. T. Srinivasa Kumar, Director, INCOIS	Member
11.	Dr. Sudheer Joseph, Scientist 'F', INCOIS	Member Secretary

2.5 Scientific and Administrative structure of INCOIS

INCOIS has undertaken a major overhaul in the structure of scientific and administrative grouping. The institute now has three major scientific groups headed by respective Group Directors and each group has two divisions headed by respective Division Heads. In addition to the scientific groups, there are two divisions, one division to support the program planning & coordination and capacity building and another division to tender administrative support for the functioning of the organization. This is the first major restructuring of INCOIS since its inception to enhance operational efficiencies keeping in view its aspirations and plans for the coming years.



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 coordinate 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

The Indian National Centre for Ocean Information Services (INCOIS), Ministry of Earth Sciences (MoES) is committed to provide the best possible ocean information and advisory services to society, industry, the government and the scientific community through sustained ocean observations and constant improvement through systematic and focused research. To achieve this, we will continue to align our actions with organizational values & shall ensure our commitment to continually improve our performance with our Quality Management System, by setting and reviewing quality objectives.

3. Highlights

- **Services:** Sustained 24 x7 operation and delivery of key ocean information and advisory services of INCOIS, including Tsunami and storm surge warnings, OSF, PFZ, and data services etc., despite the challenges of COVID-19.
- **Tsunami advisories:** INCOIS monitored two tsunamigenic earthquakes of magnitude more than 6.5 Mw in the Indian Ocean and 'No Threat' messages were issued to India and Indian Ocean countries on both the occasions.
- **Tsunami Ready Community Recognition Program:** With the initiative of INCOIS, together with NDMA and OSDMA, two villages in Odisha (Venkatraipur in Ganjam District, Noliasahi in Jagatsingpur District) are now declared as Tsunami Ready by UNESCO-IOC. This is the first in India as well as the entire Indian Ocean region.
- **COMM Tests:** 21st Communications (COMMs) test of ICG/IOTWMS was conducted on 10 June 2020 to validate the TSPs (Tsunami Service Providers) dissemination process to NTWCs (National tsunami Warning Centres), validate the dissemination processes for tsunami notification messages.
- **IOWAVE20:** India participated in a major Indian Ocean tsunami exercise IOWave20 scheduled during October 2020 by the IOTWMS/IOC-UNESCO.
- **OSF during cyclones:** INCOIS monitored the evolution of sea state during the passages of cyclones Amphan and Nisarga and issued necessary high-wave alerts and warnings to the public.
- **Digital Ocean:** The "Digital Ocean" portal developed by INCOIS to serve oceanographic data was inaugurated by the Honorable Minister of Health & Family Welfare, Science & Technology, Earth Sciences Dr. Harsh Vardhan on 29 December 2020.
- **Ocean Modelling Mission:** INCOIS launched an Ocean Modelling Mission to develop a unified ocean modelling framework for the operational ocean forecast and advisory services on 01 January 2021. The development activity is divided into eight work packages.
- **Deep Ocean Mission:** INCOIS initiated the preparatory work towards implementing the Deep Ocean Mission, by deploying two deep ocean gliders in the Bay of Bengal.
- **Recovery of INCOIS Flux mooring:** The INCOIS Flux Mooring, which was deployed in the Bay of Bengal in 23 May 2019 was successfully retrieved by INCOIS scientists in collaboration with NIOT scientists on 07 October 2020. This observational platform collected continuous data of air-sea fluxes and other oceanographic parameters for 16 months.
- **IRMS Lab:** INCOIS has setup an Isotope-Ratio Mass Spectrometer (IRMS) and Elemental Analyser laboratory to study the P-I (Photosynthesis-Irradiance) parameters from the water samples collected from the coastal waters around India. The laboratory for IRMS-EA and

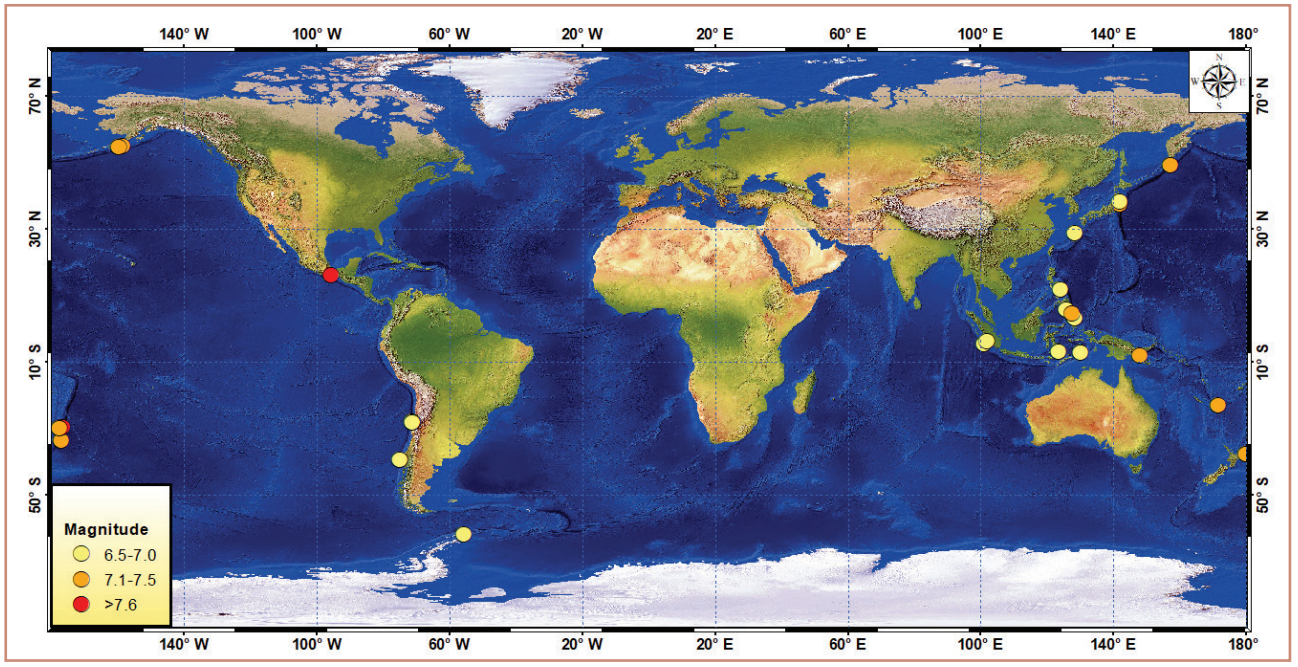
Continuous Flow Nutrient Analyzer (CFNA) was inaugurated by Dr. M. Rajeevan (Secretary, MoES) during INCOIS- GC meeting on 11 September 2020.

- **ITCOocean:** ITCOocean was recognized as RTC by OTGA for 3 more years from 2020 – 2023. The new ITCOocean campus has been made ready for use. Scientists and students have now occupied the office spaces in the campus.
- **Restructuring of Groups:** In order to gear up to meet the emerging challenges in ocean observation and ocean modeling, and to achieve operational and research efficiencies across the full spectrum of activities encompassing the institutional mandate and future aspirations, a strategic transformation of INCOIS activities and human resources was undertaken. A major competency development initiative was also implemented to train our technical staff across all operational activities of INCOIS.
- **INCOIS Foundation day:** INCOIS commemorated its 23rd Foundation Day on 03 February 2021. The prestigious 'INCOIS Foundation Day Lecture' was delivered by Dr. Vladimir Ryabinin, Executive Secretary, IOC-UNESCO and Assistant Director-General of UNESCO on the "UN Ocean Decade".
- **UN Ocean Decade:** Being the coordinating agency for the national activities of UN Ocean Decade, INCOIS organized an "in-camera" kick-off meeting of the members of India's National Decade Coordination Committee (NDCC) on 03 February 2021.
- **IISF 2020:** INCOIS coordinated and organized the Vigyan Yatra outreach event in Hyderabad on 13 December 2020 as part of the IISF 2020 in collaboration with VIBHA, NGRI, ARCI and NIAB.
- **VAIBHAV:** INCOIS organized three scientific sessions in connection with the VAIBHAV, an initiative of the Government of India in October 2020.
- **Publications:** During the reporting period, scientific staff of INCOIS published 72 papers in reputed SCI journals with a cumulative impact factor of 214.26.
- **Superannuation of Dr. S.S.C. Shenoi:** Dr. Satheesh Shenoi, who lead INCOIS for 11 years from 2009 to 2020 superannuated on 31 May 2020.
- **New Director for INCOIS:** Dr. T. Srinivasa Kumar, assumed charge as full-time Director on 28 August 2020.
- **Gazette of India notification for INCOIS:** The Government of India has notified INCOIS in its gazette, as the office where more than 80% of its staff have acquired a working knowledge of Hindi.
- **Awards/Honors:** Dr. B. Rohith has been selected for the prestigious WMO Research Award-2020 for Young Scientists constituted by WMO. Dr. Kunal Chakraborty has been elected as an Associate Fellow of Indian Academy of Sciences in 2020.

4. Services

4.1 Tsunami Early Warning Services (TEWS)

The Indian Tsunami Early Warning Centre (ITEWC) monitored 29 earthquakes (Ocean and near coast) of magnitude ≥ 6.5 Mw during the period April 2020 to March 2021. Out of 29 earthquakes, 2 earthquakes occurred in the Indian Ocean region. ITEWC assessed the situation carefully during each of the earthquakes in the Indian Ocean and declared that there would not be any tsunami threat for India. Being TSP for the Indian Ocean, necessary bulletins were also sent to Indian Ocean rim countries and IOC through Emails, GTS, FAX and SMS.



Location map of earthquakes of magnitude ≥ 6.5Mw monitored at ITEWC during 2020-21

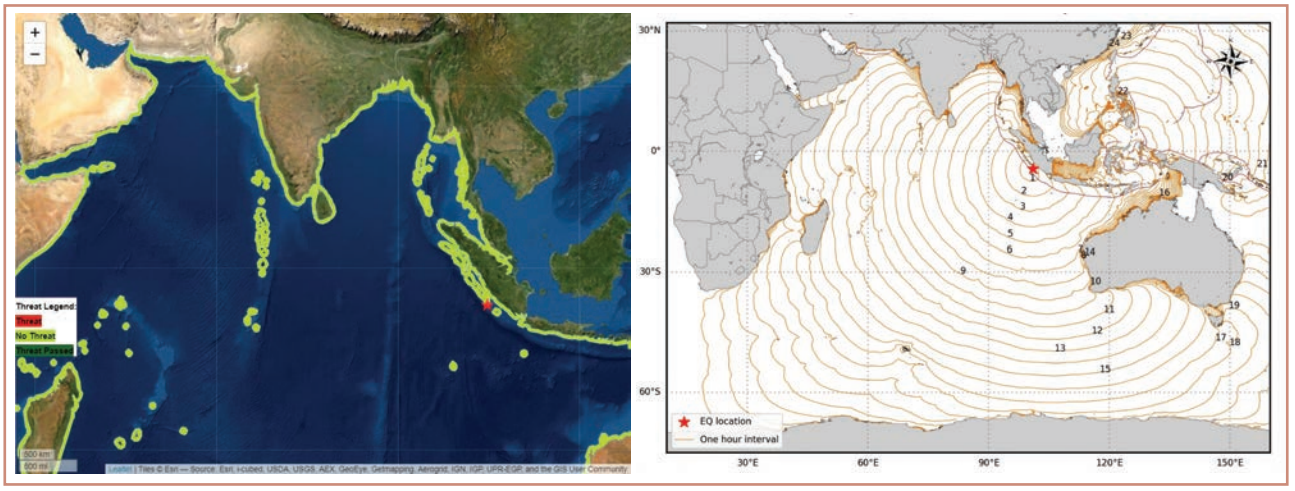
4.1.1 Key Performance Indicators (KPI) of ITEWC

S. No.	Key Performance Indicator	Target	ITEWC Performance
KPI 1	Elapsed time from earthquake to issuance of first Earthquake Bulletin	10 Min	9.1
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	0.18
KPI 4	Accuracy of earthquake hypocenter depth in comparison with Final USGS parameters	30 Km	29.0
KPI 5	Accuracy of earthquake hypocenter location in comparison with Final USGS parameters	30 Km	19.4
KPI 6	Elapsed time from earthquake to issuance of first Threat Assessment Bulletin	20 Min	25

4.1.2 Monitoring of Tsunamigenic Earthquakes

Indian Ocean:

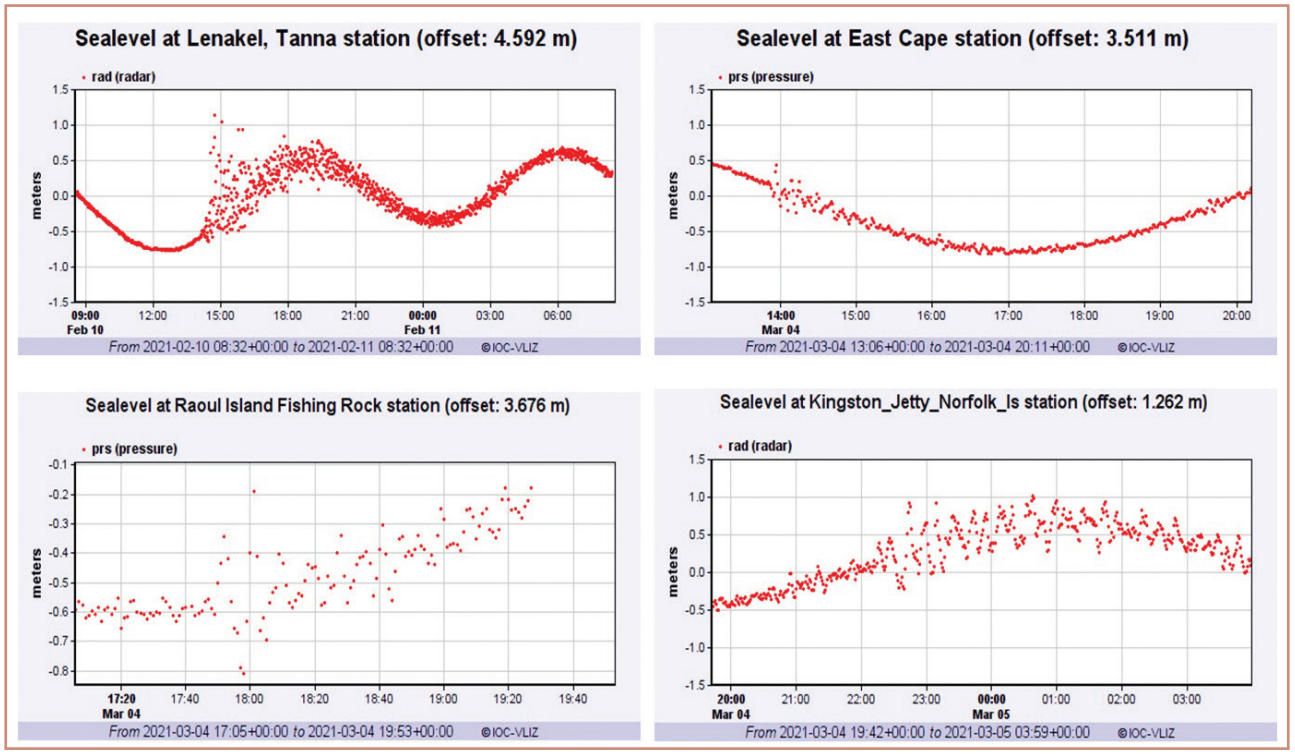
An earthquake of magnitude 6.5 Mw occurred off the Southern Sumatra, Indonesia on 18 August 2020 at 22:23 UTC (19 August 2020 at 03:53 IST). The epicenter of the event was 4.41°S, 101.06°E with focal depth of 10 km. ITEWC issued the first bulletin at 22:32 UTC (9 min) with a tsunami evaluation statement. The second bulletin was issued at 22:48 UTC (25 min) evaluation of NO THREAT to India and to countries in the Indian Ocean. One more earthquake of magnitude 6.9 Mw occurred at 22:29 UTC on the same day (within 6 min from first earthquake) at the same location 3.48°S, 101.82°E with focal depth of 163 km. ITEWC issued its first bulletin at 22:39 UTC (10 min) with evaluation of NO THREAT to India and to countries in the Indian Ocean.



Tsunami Threat details and Travel time Map for Southern Sumatra, Indonesia event on 18 August 2020

Outside Indian Ocean:

During the reporting period, 5 earthquakes generated minor tsunamis with observed water level



Minor sea level variations observed at tide gauges during few tsunamigenic events (Courtesy: IOC-Sea level)

changes at nearest tide gauges in a range of 8-75 cm. The events were (i) Magnitude 6.9 at Dodecanese Islands, Greece on 30 October 2020 at 11:51 UTC, (ii) Magnitude 7.3 at Southeast of Loyalty Islands on 10 February 2021 at 13:20 UTC, (iii) Magnitude 7.2 at Off E. Coast of N. Island, N.Z. on 04 March 2021 at 13:27 UTC, (iv) Magnitude 7.2 Earthquake at Kermadec Islands, New Zealand on 04 March 2021 at 17:41 UTC, and (v) Magnitude 7.6 Earthquake at Kermadec Islands Region on 04 March 2021 at 19:28 UTC.

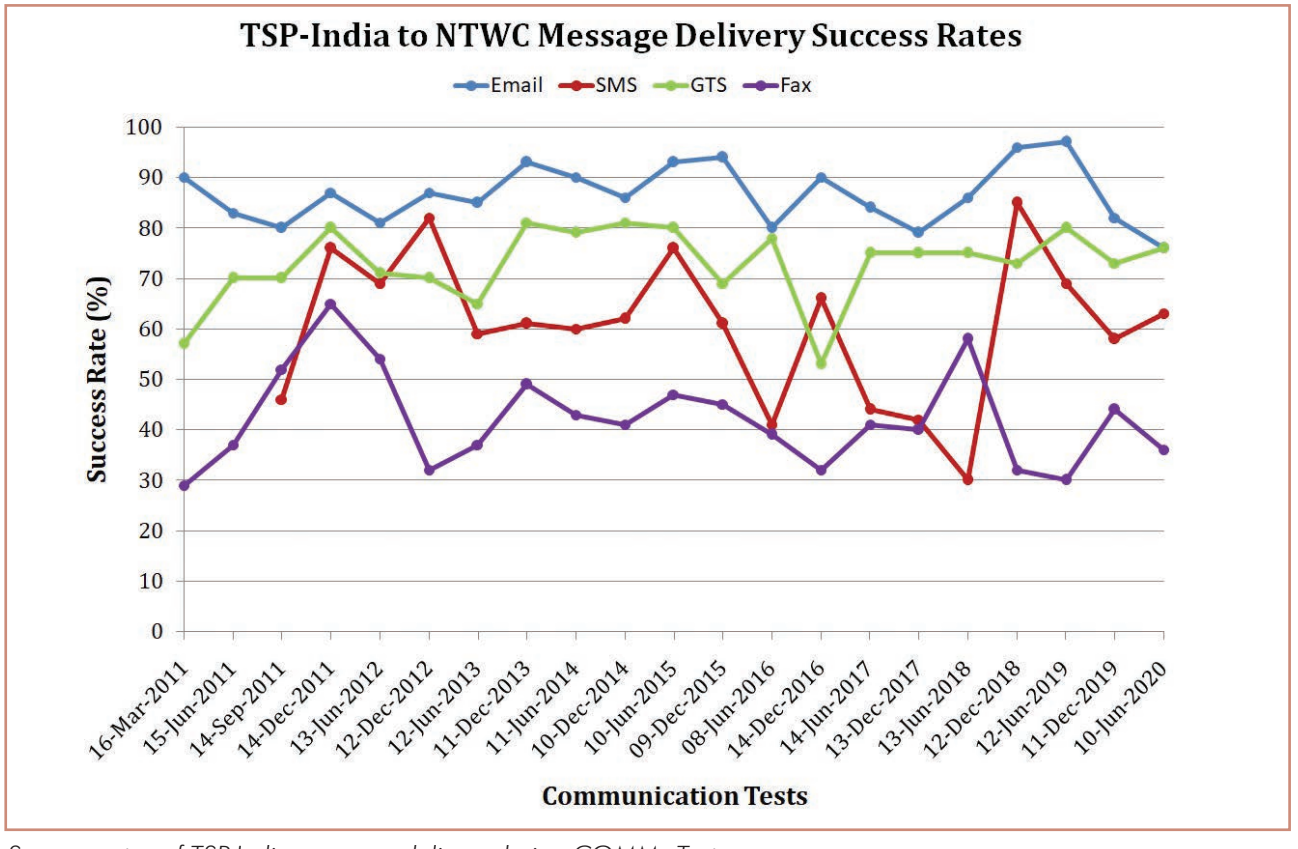
4.1.3 Supporting activities for the Indian Ocean Tsunami Warning and Mitigation System (IOTWMS)

INCOIS, as one of the TSP for the Indian Ocean Region under the IOTWMS framework, continued to provide timely tsunami advisories. INCOIS scientists contributed to various activities of the ICG/IOTWMS as Vice Chairs and members of its Working Groups and Task teams as below

- Preparation of Guidelines for Tsunami Warning Services & Evacuation during COVID-19
- Preparation of Impacts of COVID-19 Pandemic on IOTWMS Monitoring Networks, etc.
- Provided TSP-India test bulletins of three scenarios for preparation of IOWave20 Manual.
- Delivered online Lectures on IOC-UNESCO Tsunami Ready Indicators conducted by the Indian Ocean Tsunami Information Centre (IOTIC) during September-October 2020.
- Participated in various virtual meetings & workshops and provided related inputs & training.
- Contributed to the Probabilistic Tsunami Hazard Assessment (PTHA) work of Makran Subduction Zone (MSZ) Project.

4.1.4 Communication Test

The 21st Communications (COMMs) test of ICG/IOTWMS was conducted on 10 June 2020 to



Success rates of TSP-India message delivery during COMMs Tests

validate the TSPs dissemination process to National Tsunami Warning Centres (NTWC), validate the dissemination processes 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, ITEWC disseminated notification messages through email, fax, GTS, SMS as well as website to 25 NTWCs and including two TSPs (Australia & Indonesia) for a M9.0 earthquake scenario at Nicobar Islands. The ITEWC success rate was highest (76%) for email and GTS, followed by SMS (63%) and a mere for fax (36%).

4.1.5 IOWave20 Tsunami Exercise

India has participated in a major Indian Ocean tsunami exercise IOWave20 scheduled during October 2020 by the IOTWMS of IOC-UNESCO. Considering the present COVID-19 pandemic situation, the exercise was limited to test communication channels instead of full-scale exercise.

Table: Scenarios details for IOWave20 Exercise

	Scenario 1 – Java Trench	Scenario 2 – Andaman Trench	Scenario 3 – Makran Trench
Date:	Tuesday, 06 October 2020	Tuesday, 13 October 2020	Tuesday, 20 October 2020
Time:	0830 IST	0930 IST	1130 IST
Magnitude:	9.1 M	9.2 M	9.0 M
Depth:	10 km	10 km	10 km
Latitude:	10.40° S	12.63° N	24.80° N
Longitude:	112.80° E	93.50° E	62.20° E
Location:	Java Region, Indonesia	Andaman Islands, India	Off Coast of Pakistan

IOWave20 Exercise involved enacting three scenarios on (i) 06 October with earthquake magnitude 9.1 in Java Region, Indonesia, (ii) 13 October with earthquake magnitude 9.2 in Andaman Trench, India and (iii) 20 October with earthquake magnitude 9.0 off-coast of Pakistan. ITEWC participated in the exercise, both in its capacity as a NTWC for India as well as a TSP for the Indian Ocean region (25 countries). During the exercise, ITEWC generated and issued tsunami bulletins/notifications to both its National & Regional (IOTWMS) contacts through GTS, email, fax, SMS as well as website.

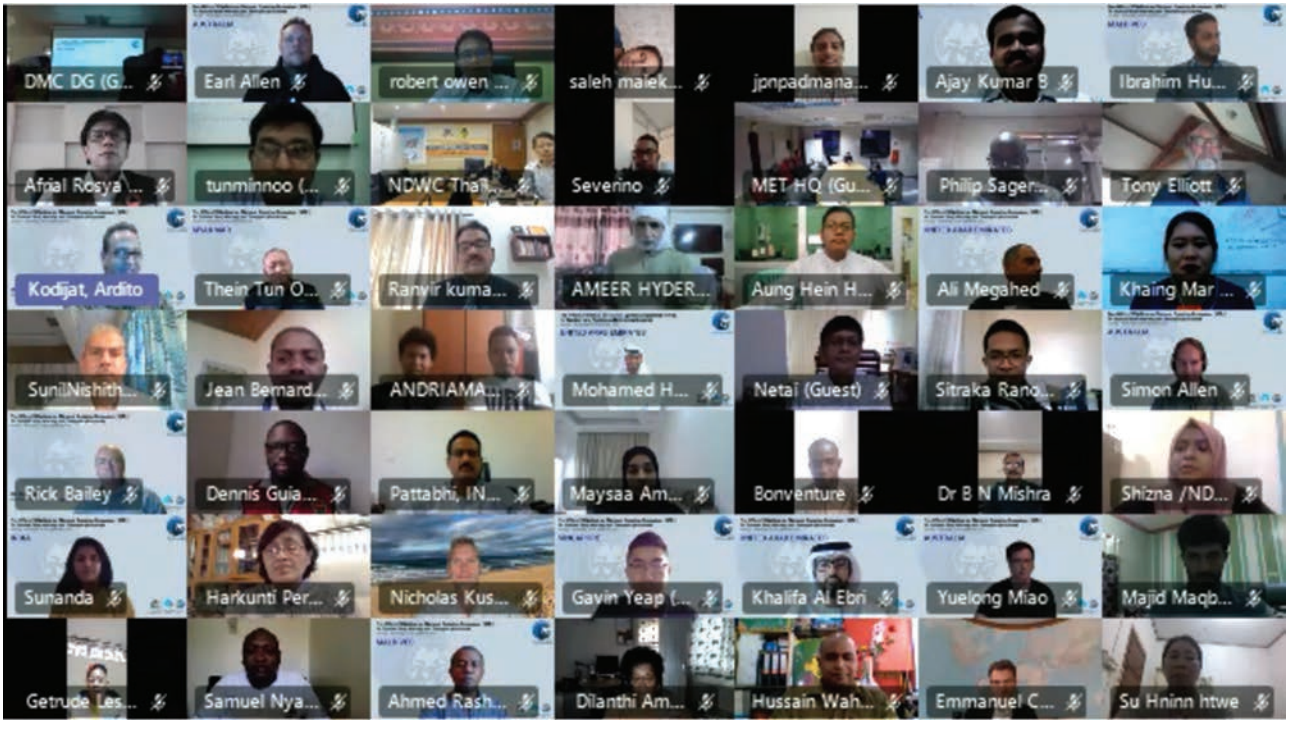
At National level the IOWave exercise was conducted on 13 October for east coast of India and Andaman & Nicobar Islands and on 20 October for the west coast of India and Lakshadweep Islands. Participants in the exercise are from NDMA, Andaman & Nicobar Islands, West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Puducherry, Kerala, Lakshadweep Islands, Karnataka, Goa, Maharashtra and Gujarat. In addition, Indian Navy, Coast Guard, National Disaster Response Force (NDRF), Nuclear power plants and port & harbours also participated in the exercise. Disaster management organizations have tested their communication protocols and conducted "virtual" tabletop exercises as a minimum to assess the organizational SOPs, plans and policies for tsunami warning and emergency response. Using IOWave20 exercise as an opportunity, Odisha State Disaster Management Authority (OSDMA), Odisha evaluated IOC-UNESCO Tsunami Ready indicators in all piloted Tsunami Ready villages with limited number of participation.

IOWave20 exercise participation at various States & UTs

4.1.6 Tsunami Webinars and Meetings

a) Pre and Post IOWave20 Webinar

In preparation to the IOWave20 exercise, ICG/IOTWMS and Indian Ocean Tsunami Information Centre (IOTIC) of the IOC-UNESCO organized a Pre-IOWave20 Webinar on "Standard Operating Procedures (SOP) for Tsunami Early Warning and Emergency Response" during 28-30 September 2020. INCOIS took active part in the webinar and scientists from the Indian ITEWC participated as trainers to deliver presentations on TSP, preparation for IOWave20 exercise, end-to-end national tsunami warning chains, and timeline based tsunami early warning SOPs. More than 150 officials



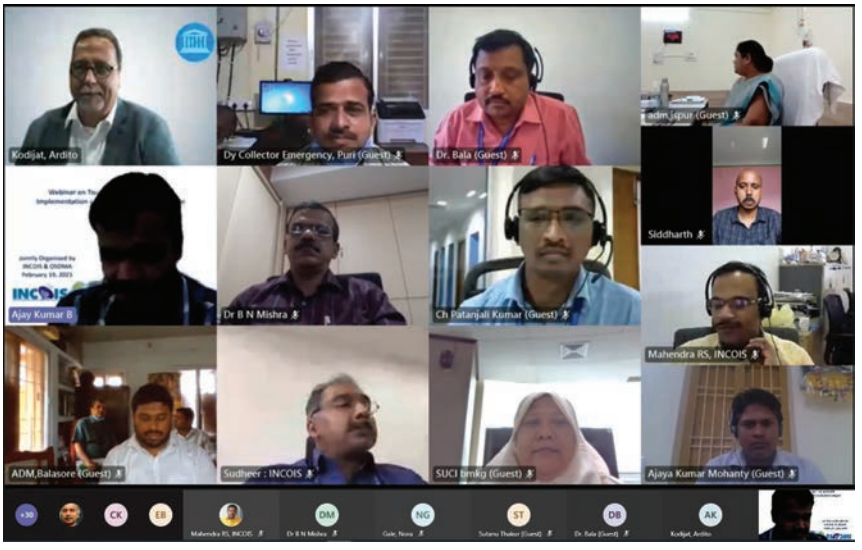
Screenshot of Tsunami SOP webinar participants during 28-30 September 2020

from 23 countries of the Indian Ocean region participated in the webinar, including 46 Indian officials representing coastal States/UTs, disaster management organizations, Indian Navy, Indian Coast Guard, NDRF, critical Installations and port & harbors.

The post-IOWave20 webinar on the 'Lessons Learnt from IOWave20 Exercise' was conducted by ICG/IOTWMS and IOTIC during 11-12 November 2020. INCOIS scientists participated and presented India's activities in the IOWave20 exercise.

b) Webinar on Tsunami Preparedness and Implementation of Tsunami Ready Program

INCOIS conducted a webinar on "Tsunami Preparedness and Implementation of Tsunami Ready Program" to Odisha disaster management officials in coordination with Odisha State Disaster Management Authority (OSDMA) on 19 February 2021. Shri. Pradeep Kumar Jena, IAS, Development Commissioner-cum-Addl. Chief Secretary, Odisha and Managing Director, OSDMA and Dr. T. Srinivasa Kumar, Director, INCOIS inaugurated the events and Mr. Ardito M. Kodijat, Head - IOTIC presented a keynote lecture on "IOC-UNESCO Tsunami Ready Programme and Recognition". INCOIS scientists made presentations on INCOIS activities, Tsunami Preparedness, Tsunami Ready Indicators and implementation. Around 40 participants of coastal Districts/Block level disaster management officials from Odisha attended this webinar. Few participants from BMKG (Meteorology Climatology and Geophysics Council), Jakarta, Indonesia also participated in the webinar to observe the webinar and implement Tsunami Ready Program in Indonesia.



Webinar on Tsunami Preparedness and Implementation of Tsunami Ready Program conducted on 19 February 2021

4.1.7 World Tsunami Awareness Day

On the occasion of the 5th World Tsunami Awareness Day on 05 November 2020, INCOIS conducted a Webinar on "Tsunami Awareness & Preparedness" in coordination with NDMA and OSDMA. The distinguished Speaker Shri G.V.V Sarma, IAS, Member Secretary, NDMA and Shri Pradeep Kumar Jena, IAS, Managing Director, OSDMA & Addl.


Webinar on Tsunami Awareness & Preparedness conducted on 05 November 2020

Chief Secretary, Govt of Odisha and Dr. T. Srinivasa Kumar, Director, INCOIS delivered talks on this special occasion. The talks focused on Tsunami Early Warning Mechanism, Implementation of Tsunami Ready and Tsunami Preparedness in India. Around 190 participants from Coastal disaster management organizations, scientific and academia attended this webinar.

4.1.8 IOC-UNESCO Tsunami Ready Implementation and Recognition

The IOC-UNESCO Tsunami Ready Programme is a community performance based programme. The programme aims to strengthen tsunami preparedness of coastal communities through a structural and systematic approach through fulfilling a few best-practice indicators (11 Nos) set by ICG/IOTWMS. The main objective of the Tsunami Ready programme is to improve coastal community preparedness for tsunami emergencies and to minimize the loss of life and property.

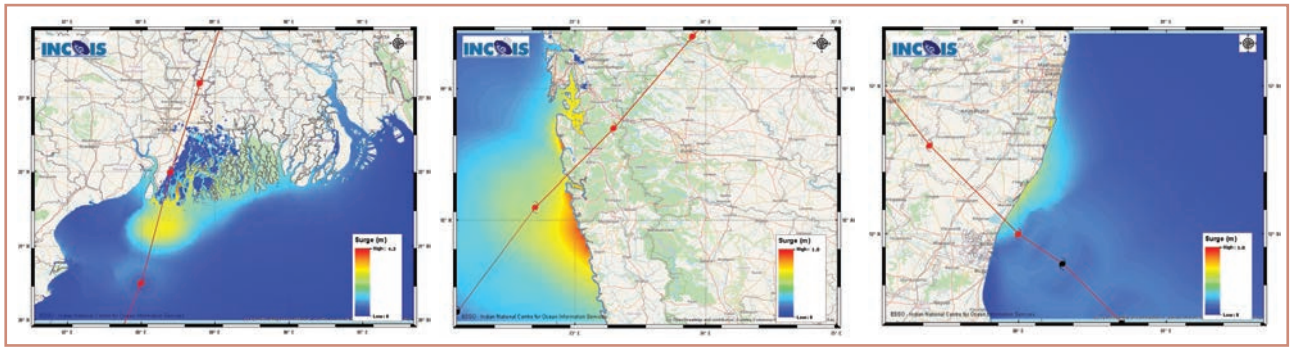
In India, a National Board was constituted under the Chairmanship of Director, INCOIS with members drawn from Ministry of Earth Sciences (MoES), NDMA, Ministry of Home Affairs (MHA), OSDMA, Andaman & Nicobar Islands, Directorate of Disaster Management (DDM) and INCOIS. Based on the recommendations of the National Board after the evaluation process, the IOC-UNESCO has recognized Venkatraipur and Noliasahi villages from Odisha as Tsunami Ready communities. To confer the IOC-UNESCO's Certificate of Recognition and Certificate of Appreciation to Venkatraipur and Noliasahi communities, OSDMA Officials, a virtual event was organized and certificates were conferred on 07 August 2020. With the IOC-UNESCO recognition, these two communities are the first in India and the Indian Ocean region to receive this distinction.

Venkatraipur and Noliasahi of Odisha recognized as Tsunami Ready communities

4.1.9 Storm Surge Early Warning Service

During 2020-21, real-time storm surge warnings were issued to IMD for Amphan, Nisarga and Nivar cyclones. The details of storm surge services are given below:

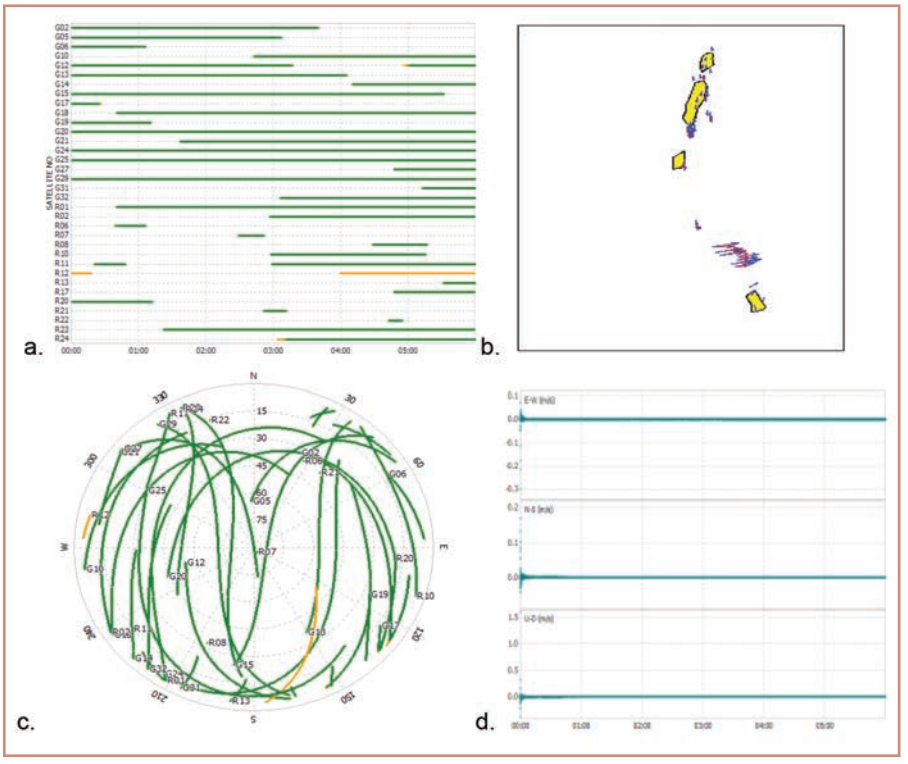
Cyclone Name	Period	No. of bulletins issued
Amphan	May 2020	16
Nisarga	June 2020	8
Nivar	November 2020	18



Real-time storm surge and inundation forecast during the cyclones Amphan, Nisarga and Nivar

4.1.10 Crustal Velocity of Andaman & Nicobar Islands using GNSS data

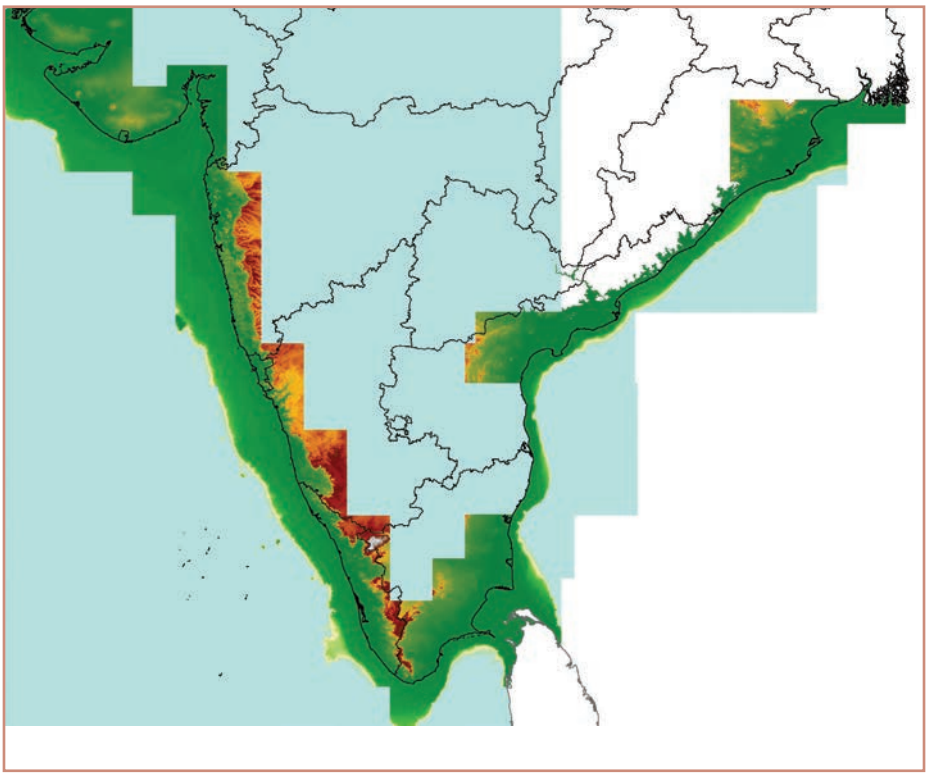
A real-time network of continuous GNSS stations was installed in Andaman & Nicobar Islands to improve the tsunami early warning services of India. The data was analyzed using GAMIT to understand the kinematic behavior of the tectonic settings of Andaman subduction zone. Different approaches are being tested to estimate the rates of present day crustal deformation. Individual solutions are aligned to the International Terrestrial Reference Frame (ITRF) to build time series producing velocity values for the points.



2018 Port Blair GNSS data analysis (a) Satellite availability plot (b) station position plot (c) Sky plot (d) Port Blair Positioning plot

4.1.11 Generation of blended high resolution coastal topography and bathymetry

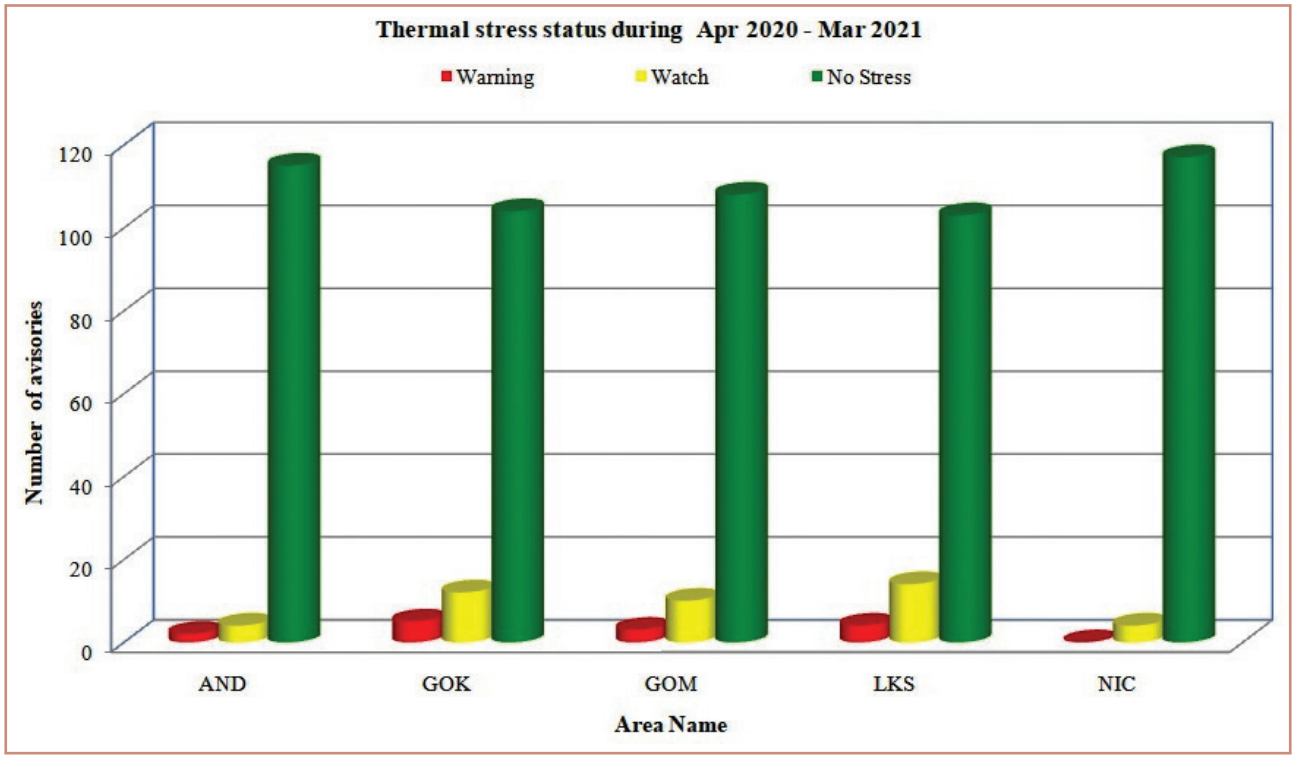
High resolution topographic data were blended using optimal interpolation technique by using ALTM, CARTOSAT, SRTM datasets. The Bathymetry was also merged using the available datasets from NHO, GSI and other surveyed data. Finally both topography and bathymetry were merged to cater the needs of coastal modeling of Tsunami and storm surge. This merging is completed for the entire mainland coast of India. The composite of the merged data is provided in the following figure.



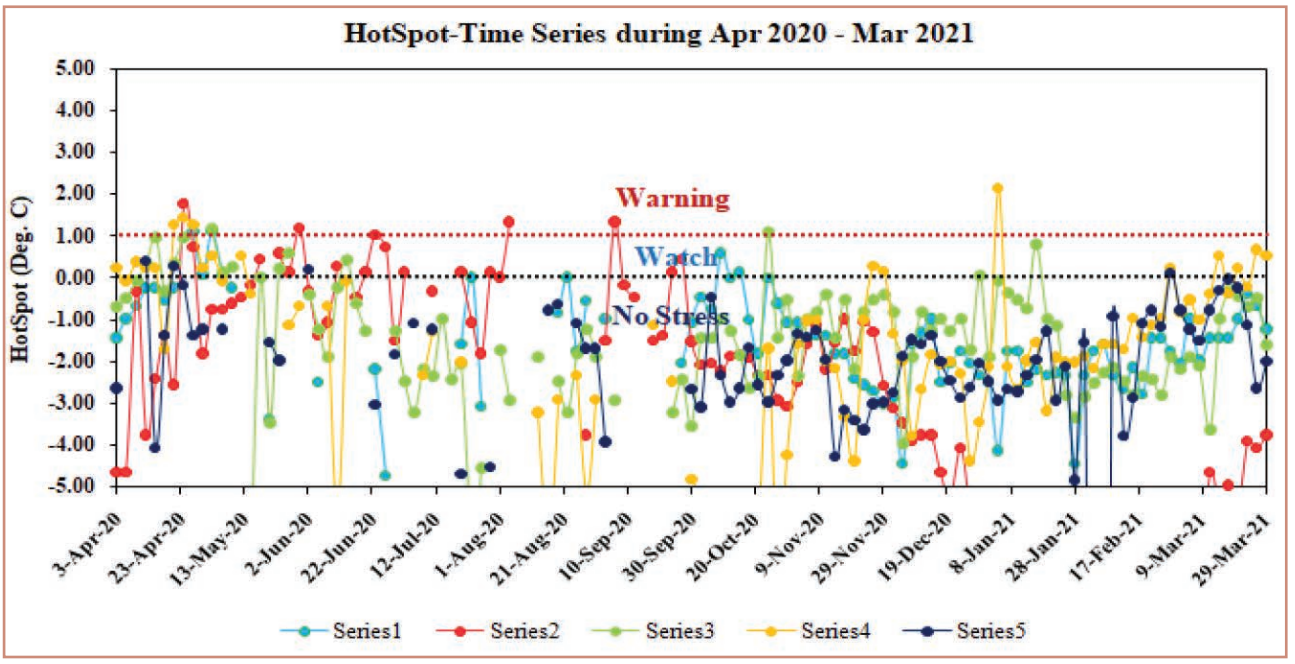
The merged topography and bathymetry of the mainland coast of India

4.2 Coral Bleaching Alert System

Coral Bleaching Alert System (CBAS) provided 121 advisories during April 2020 to March 2021. These advisories comprise hotspots and Degree of Heating Weeks (DHWs) estimated using SST anomalies derived from satellite data on a bi-weekly basis. Total 14 warnings of hotspots were observed, out of which two were at Andaman, five were at Gulf of Kutch, three were at Gulf of Mannar and four were at Lakshadweep.



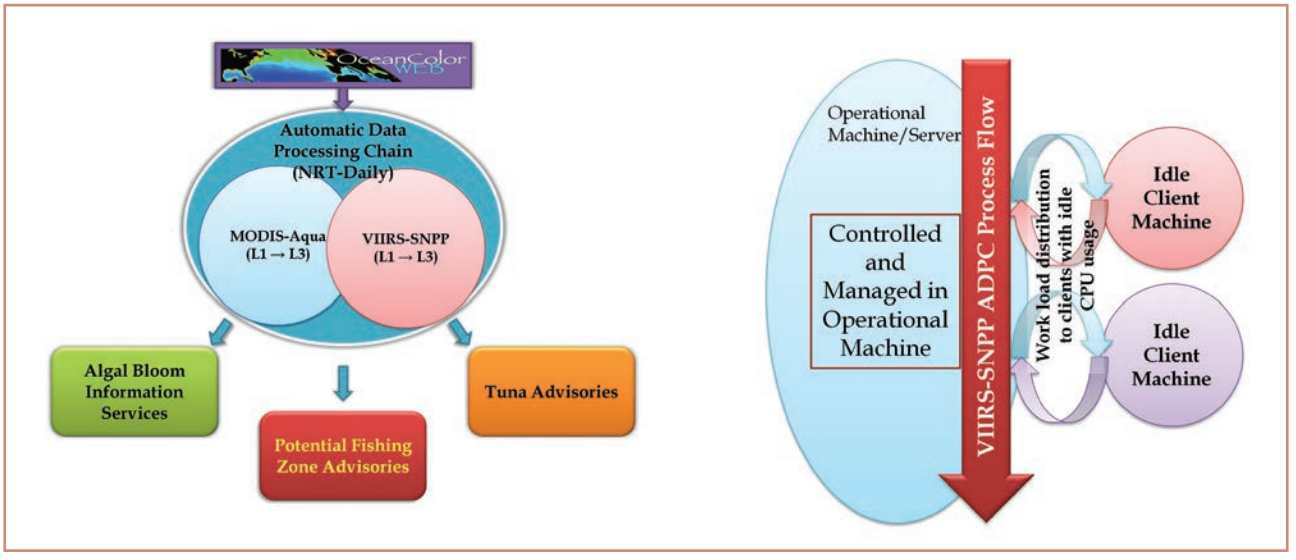
Total number of Coral Bleaching advisories generated and their alert status during 2020-21



Line-chart depicting variations of HotSpot (HS) values during 2020-21 pertaining to Indian coral environs

4.3 Algal Bloom Information Service (ABIS)

Processing of sensor data from Visible Infrared Imaging Radiometer Suite of The Suomi National Polar-orbiting Partnership (VIIRS-SNPP) is incorporated in Automatic Data Processing Chain (ADPC) in addition to MODIS-Aqua as per need of the PFZ advisory team. Due to limited processing resources of the operational machine, delivery of both MODIS-Aqua & VIIRS-SNPP data products to PFZ within the desired time frame became a challenge. To resolve this issue, script for VIIRS data processing has been modified significantly and in an innovative way to work under a server client structure, which allows the operational machine to communicate with the client machines to use their idle processing power by sharing workload to reduce the overall processing time. ABIS has been sustained and information on presence of algal bloom in the north Indian Ocean has been disseminated in the web on a daily basis.

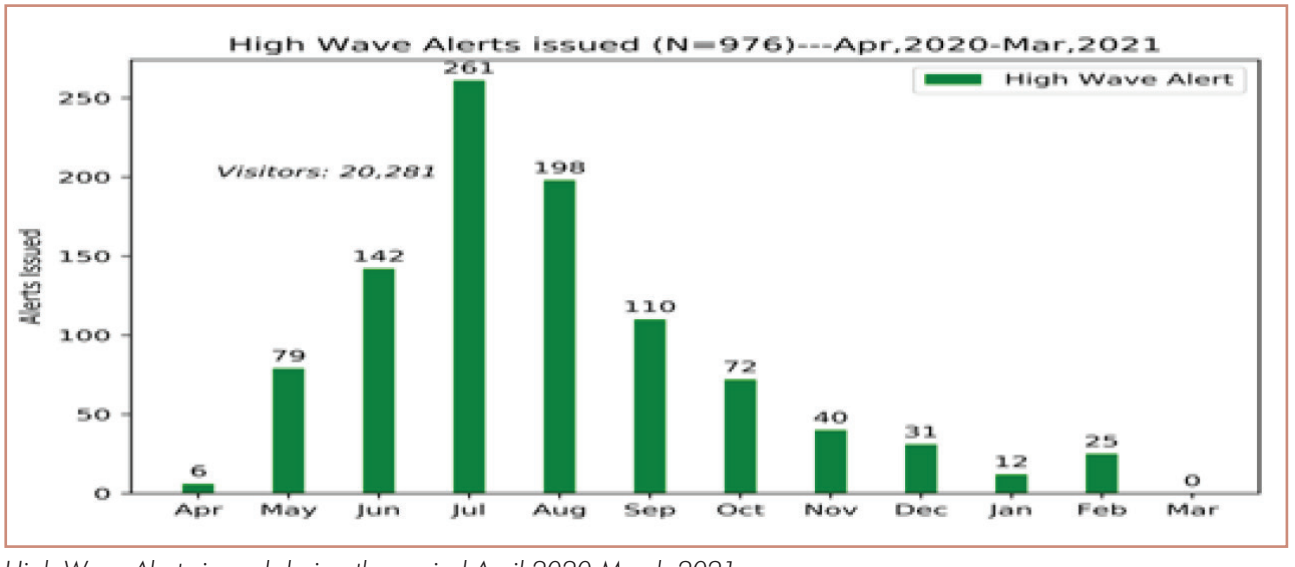


Service	Processed	Total Days	Remarks
ADPC (MODIS-Aqua)	328	365	Few days skipped due to the Aqua spacecraft anomaly, changes in processing codes and data access techniques. VIIRS processing started on 19 August 2020.
ADPC (VIIRS-SNPP)	220	225	
ABIS	328	365	

4.4 Ocean State Forecast

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

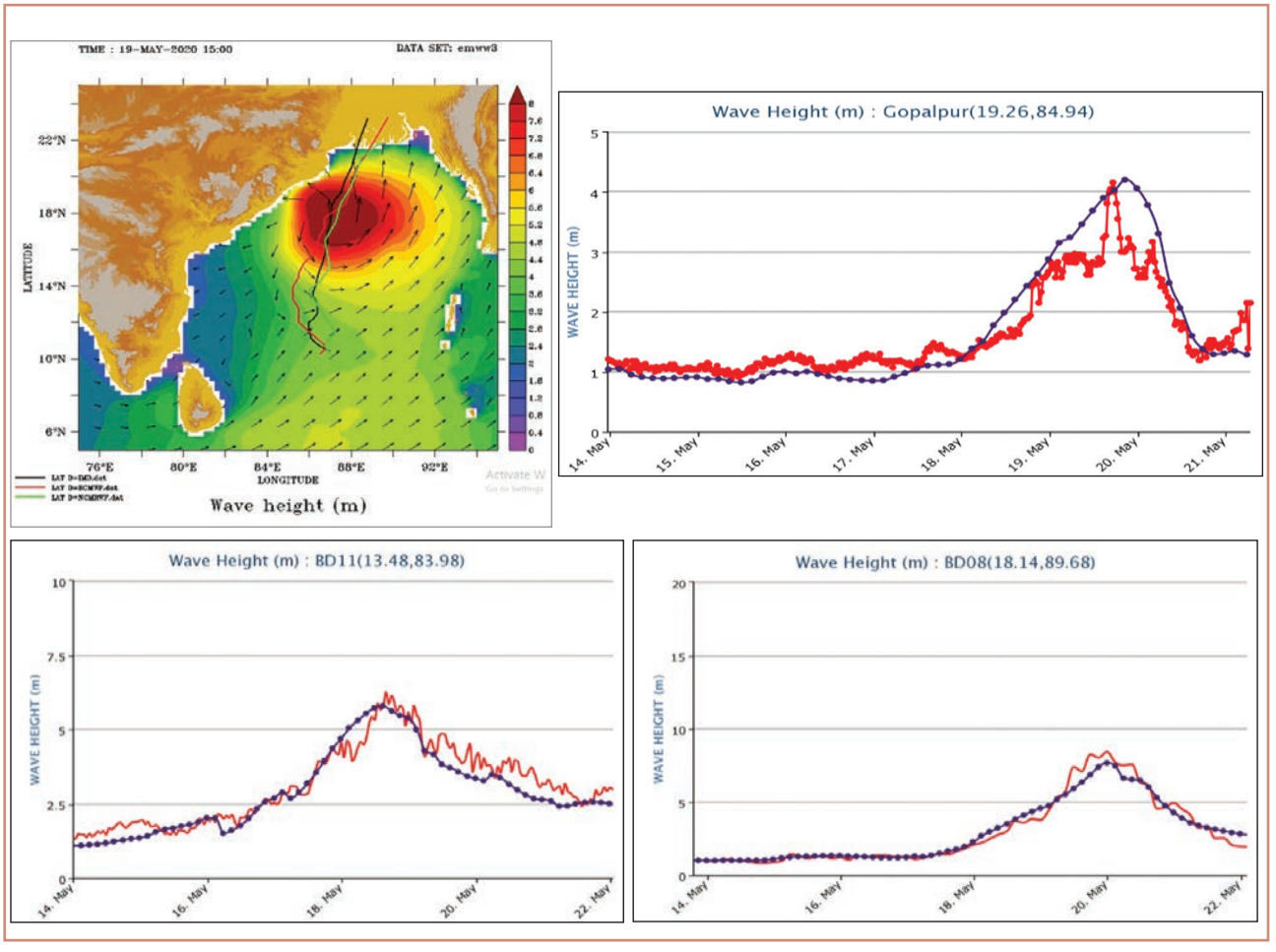
INCOIS continued to extend the necessary support required to the users through customization and providing location specific services. Since 25 June 2020, daily OSF and high wave warning services for Odisha state were provided through a customized web based GUI platform for OSDMA. During the reporting period INCOIS issued 976 high wave alerts, cautioning the users on the impending high waves on the coast. There were 20,281 visitors on the OSF webpage with the maximum user visits during the southwest monsoon season. INCOIS provided ocean state forecast services to NIOT for their 35 day cruise on board Sagar Nidhi as well as during mining trials at the test mining site. In addition, INCOIS provided data (i) on wave height and periods and tide data to Satish Dhawan Space Centre (SDSC), ISRO, SHAR, Sriharikota and (ii) on sea state forecast along the sea route from Kochi to Male, Maldives for the period 11-20 October 2020 to Indian Coast Guard vessel.



High Wave Alerts issued during the period April 2020-March 2021

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

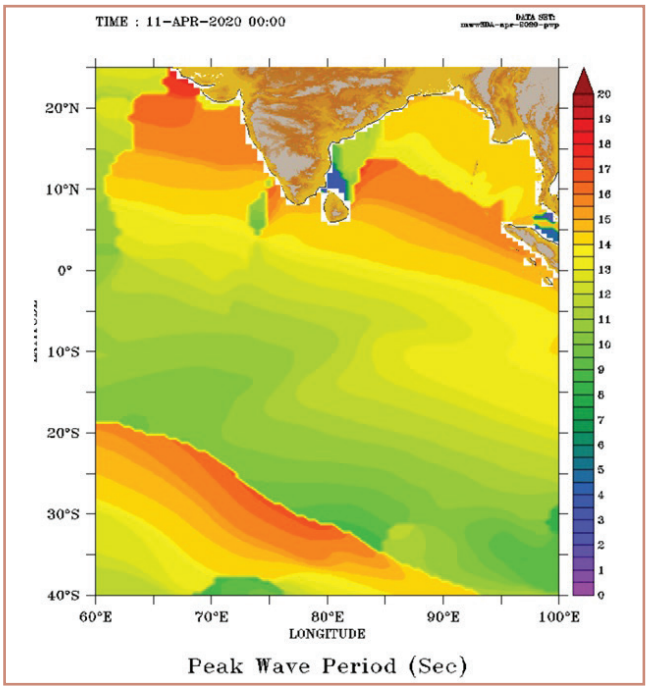
INCOIS continuously monitored the wave, wind, sea level and current regime in the nearshore region as well as far offshore for the super cyclonic storm Amphan during the period 13-21 May 2020 and severe cyclonic storm Nisarga during 29 May to 04 June 2020 using models, in-situ instruments as well as satellite observations. INCOIS issued ocean state forecasts and warnings to the public along the east and west coast of India during the period of Amphan and Nisarga cyclones. The observed and forecasted waves during the Nisarga Cyclone time were continuously monitored. The maximum wave heights were observed on 03 June 2020. The observed maximum wave heights at locations of open ocean buoys in the Arabian Sea AD07, AD09, AD06 and coastal location Karwar were 3.2, 2.5, 1.9 and 3.0 meters, which matched closely with the INCOIS forecasts. INCOIS also provided ocean state forecast services, high wave warning / alerts for the three depressions which occurred during 09-15 October 2020 and 21-24 October 2020 in Bay of Bengal and during 17-19 October 2020 in Arabain Sea. INCOIS disseminated these critical information services to the users through 99,62,644 SMS and 84,533 emails and issued a total of 122 INCOIS-IMD Joint Bulletins. The messages were also disseminated through the NAVIC and GEMINI Platforms so as to reach the users out at sea and beyond the reach of mobile signals.



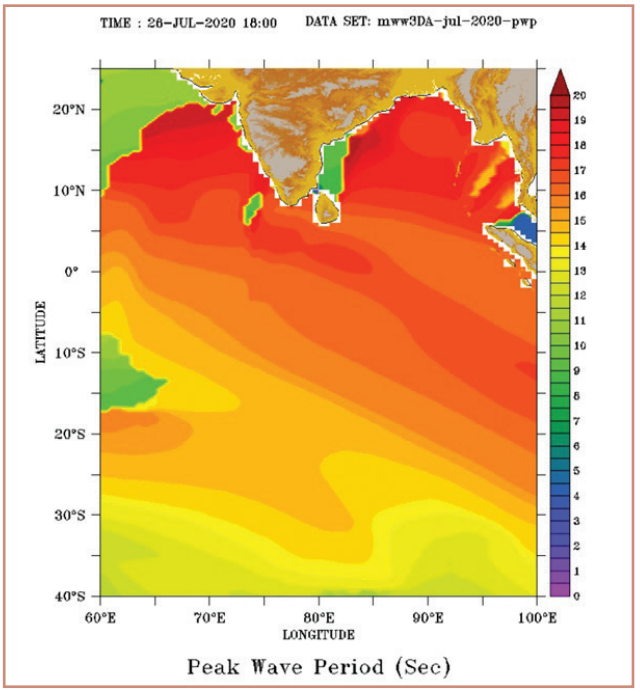
The Snapshot of the wave regime during the cyclone Amphan along with the validation of the forecasts with the observations from Wave Rider Buoys and deep sea buoys

4.4.2 Swell Surge Warnings and Rough Sea Alerts

INCOIS continued to monitor and issue Rough sea alerts for the states of Karnataka, Kerala, Lakshadweep and South Tamil Nadu in connection with the high period swells (15-20 sec) forecasted during the period 08-13 April 2020 and 18-21 July 2020. High swell waves during 18-21 July 2020 caused damage and flooding along the Kerala coast. The alerts were issued 3 days in advance for Lakshadweep, Kerala and South Tamil Nadu and feedback was received on damage.



Snapshot of Peak Wave Period (s) during the 08-13 April 2020 event



Snapshot of Peak Wave Period (s) during the 18-21 July 2020 event

In addition, it is reported that high period swell waves during 24-28 July 2020 created problems along the Kerala and Tamil Nadu coast, and INCOIS issued Rough sea alerts 3 days in advance for Lakshadweep, Kerala and South TamilNadu and the feedbacks received particularly for Kerala and Tamil Nadu (Kanyakumari) coast on the event are in agreement with INCOIS forecasts. A similar event occurred during 09-11 September 2020 and INCOIS issued the rough sea alerts (swell height 1.5 - 3.0 m, peak wave period 15-19 s), for the states Karnataka, Kerala, Lakshadweep, Tamil Nadu, Odisha, West Bengal and Andaman & Nicobar Islands.

Swell surge warnings were issued 3 days in advance for the period 12:30 hours of 09 January 2021 to 23:30 hours of of 11 January 2021 to Maharashtra, Goa, Karnataka, Kerala, Lakshadweep and South Tamil Nadu, and issued Swell surge alert was issued for all west coast states, South Tamil Nadu and Lakshadweep Islands during 15-17 February 2021.

4.4.3 Perigean Spring Tide

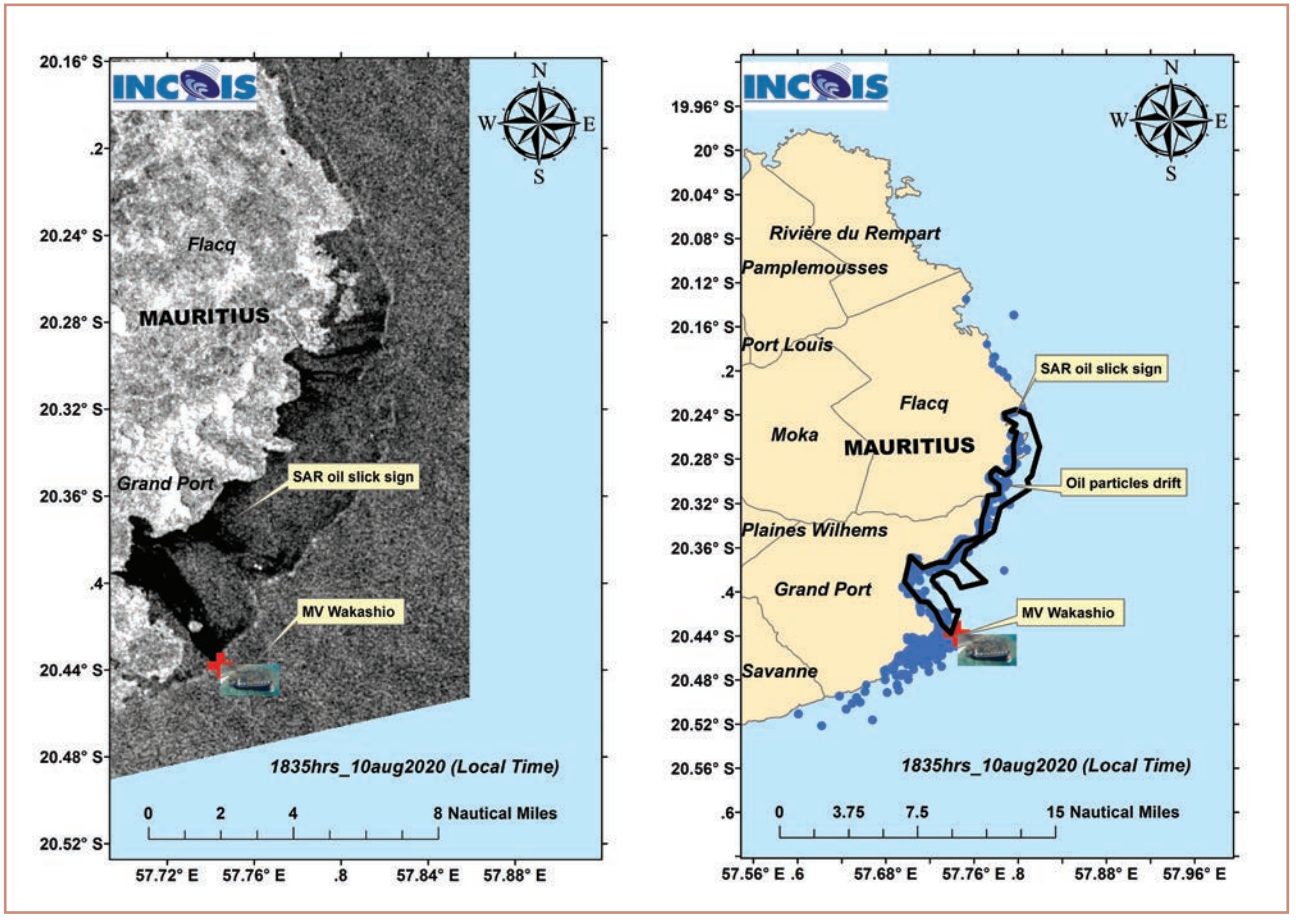
Sustained strong onshore winds, high nearshore waves/swells & heavy rainfall and its associated discharge can cause nuisance flooding especially at high tide times along low lying coastal areas,

during Perigean Spring Tide events, INCOIS issued alerts for the period 07-12 April 2020 and 15-22 October 2020 for entire Indian Coastline (including Islands), wherein the low lying areas of Kerala are particularly sensitive to this phenomenon.

4.4.4 Oil-spill trajectory advisories

4.4.4.1 To Mauritius Oceanographic Institute (MOI)

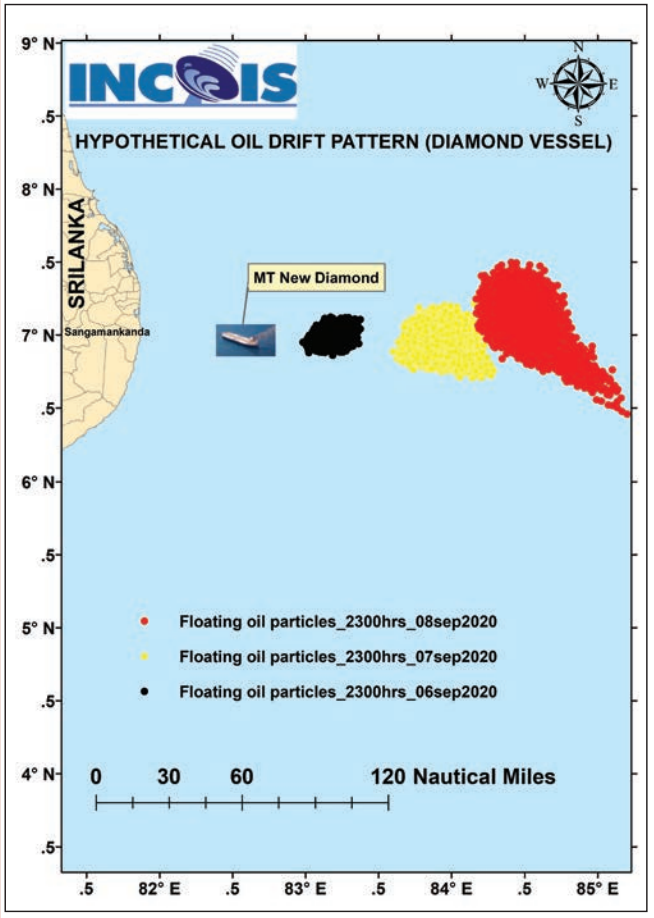
Vessel MV Wakashio with 3896 MT Fuel oil onboard struck the coral reef on 25 July 2020 at 20°26'17.2"S 57°44'40.7"E off Blue bay, Mauritius. The vessel started leaking oil pollutants continuously from 2310 hrs of 06 August 2020 until 16 August 2020. As per request from UNESCO-IOC & Mauritius Oceanographic Institute (MOI), INCOIS issued oil spill advisories as bulletins from 06 August 2020. As per the simulation, the southeast coast of Mauritius was under severe threat to receive oil pollutants from the stricken vessel.

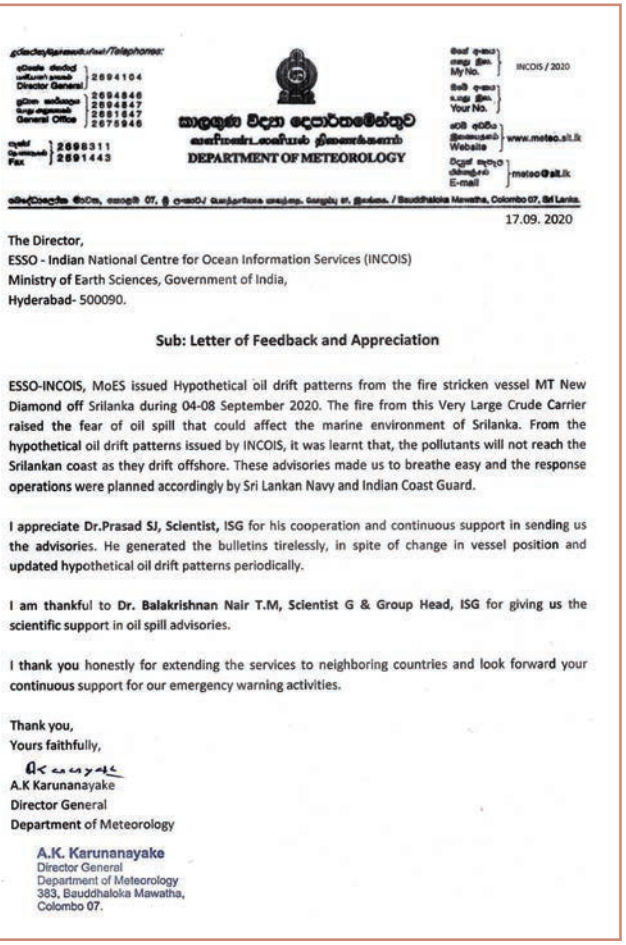


Oil slick signature (dark patches) retrieved from Sentinel -1A radar data on 10 August 2020 is shown in the left panel. Simulated oil drift pattern on 10 August 2020, 1835 hrs is shown as blue dots in the right panel, whereas the black polygon denotes the retrieved oil slick signature from radar data.

4.4.4.2 To Srilankan Meteorology Department, Srilanka

INCOIS provided a hypothetical oil drift pattern from the very large crude carrier MT New Diamond, which caught fire off Colombo during early hours of 03 September 2020. It had 2,70,000 Tons of Crude oil and 1700 Tons of Diesel Oil on Board, that raised the fear of oil spill in the Indian Ocean. Hypothetical oil drift patterns were generated from the wrecked position of the vessel during 03-08 September 2020. As per the hypothetical simulations of INCOIS oil spill model,





DEPARTMENT OF METEOROLOGY

17.09. 2020

The Director,
ESSO - Indian National Centre for Ocean Information Services (INCOIS)
Ministry of Earth Sciences, Government of India,
Hyderabad- 500090.

Sub: Letter of Feedback and Appreciation

ESSO-INCOIS, MoES issued Hypothetical oil drift patterns from the fire stricken vessel MT New Diamond off Srilanka during 04-08 September 2020. The fire from this Very Large Crude Carrier raised the fear of oil spill that could affect the marine environment of Srilanka. From the hypothetical oil drift patterns issued by INCOIS, it was learnt that, the pollutants will not reach the Srilankan coast as they drift offshore. These advisories made us to breathe easy and the response operations were planned accordingly by Sri Lankan Navy and Indian Coast Guard.

I appreciate Dr.Prasad SJ, Scientist, ISG for his cooperation and continuous support in sending us the advisories. He generated the bulletins tirelessly, in spite of change in vessel position and updated hypothetical oil drift patterns periodically.

I am thankful to Dr. Balakrishnan Nair T.M, Scientist G & Group Head, ISG for giving us the scientific support in oil spill advisories.

I thank you honestly for extending the services to neighboring countries and look forward your continuous support for our emergency warning activities.

Thank you,
Yours faithfully,

A.K Karunanayake
Director General
Department of Meteorology

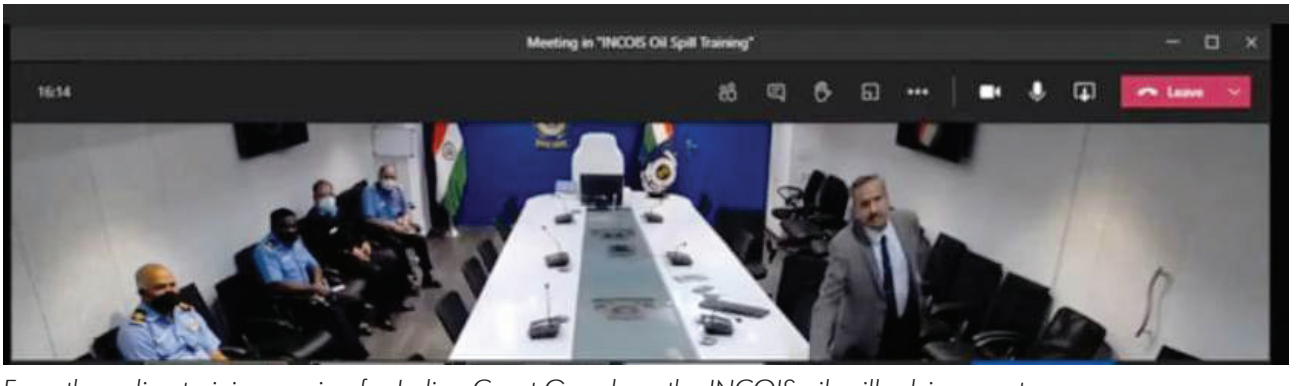
A.K. Karunanayake
Director General
Department of Meteorology
383, Bauddhaloka Mawatha,
Colombo 07.

The oil drift pattern from Hypothetical spill location (Black plus sign) during 06-08 September 2020 is shown in the left panel. Appreciation & feedback received from Srilankan Meteorological department is shown in the right panel.

considering the worst case scenario of spillage, Srilankan coast, Indian coast and Maldives were not under the threat of being affected by oil pollutants. The advisories were updated with the change in vessel position and the updated bulletins were uploaded at INCOIS website periodically. The response operations were planned accordingly by Srilankan Navy and Indian Coast Guard. The Director General, Colombo Meteorological department appreciated the efforts and support of INCOIS, in this regard.

4.4.4.3 Virtual training to Indian Coast Guard (North-West Region) on 30 December 2020

INCOIS offered virtual training on the INCOIS oil spill advisory system to Indian Coast Guard Officers of Northwest region on 30 December 2020. 178 participants/officers attended this virtual



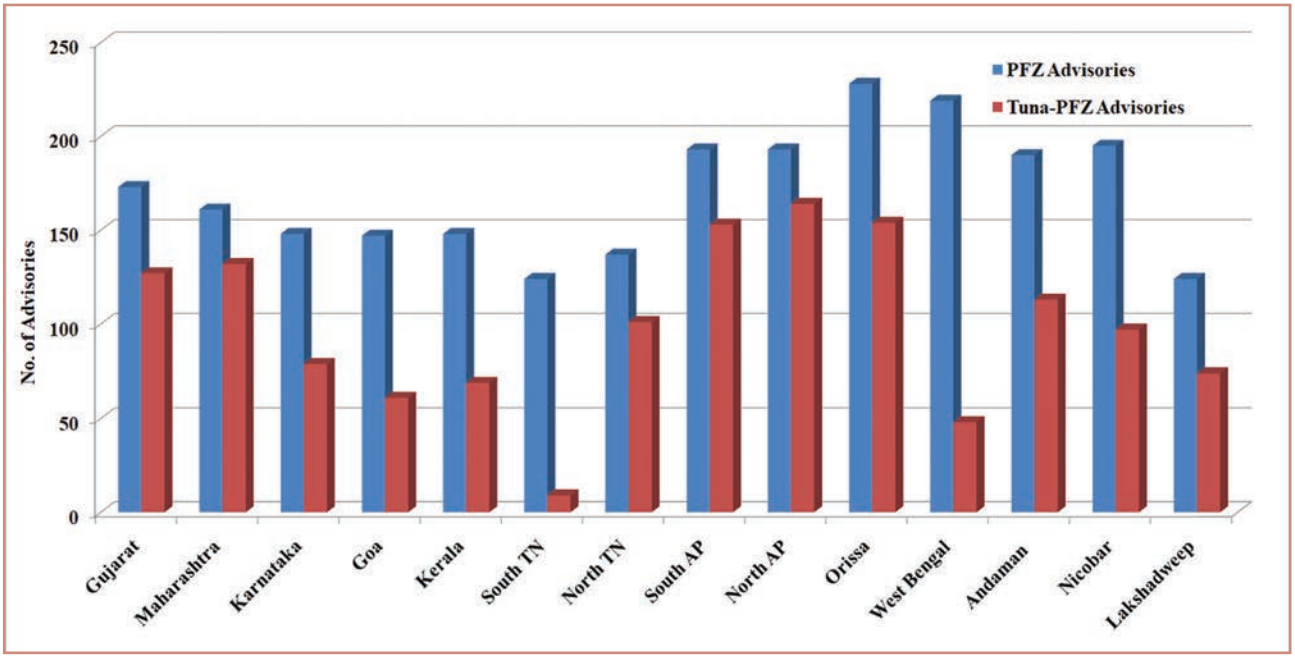
From the online training session for Indian Coast Guard on the INCOIS oil spill advisory system

training. A closed room discussion also took place between INCOIS scientists and officers of the Indian Coast Guard (Northwest region).

4.5 Marine Fisheries Advisory Services (MFAS)

4.5.1 Potential Fishing Zones and Tuna Advisories

PFZ advisory have become part of the value chain of the fishing community of India. Several studies have shown that high sea surface temperature (SST) gradient and high chlorophyll concentration in the ocean are the prospective areas for pelagic fish catch. INCOIS provides advisories on PFZ on a daily basis using remotely sensed SST and chlorophyll-a data. INCOIS continued to provide advisories on PFZ generated using the satellite derived Sea Surface Temperature (SST), chlorophyll concentration, water clarity and sea level. The advisories were disseminated in smart map and text form on a daily basis, except during fishing-ban period and during adverse sea-state conditions. During the period April 2020 to March 2021, multilingual PFZ advisories and Yellowfin Tuna advisories were provided for 318 and 267 days respectively.



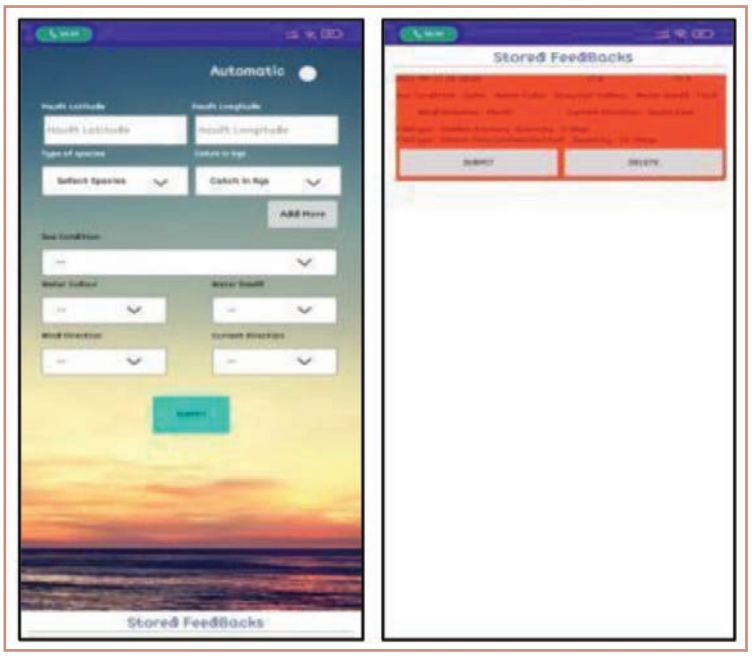
Number of PFZ and Tuna PFZ advisories issued during 2020-21

4.5.1.1 PFZ Dissemination

INCOIS has started providing advisory services through TELEGRAM platform by creating 09 broadcast channels for different coastal states i.e. Gujarat, Maharashtra, Karnataka & Goa, Kerala, Tamil Nadu, Andhra Pradesh, Odisha & West Bengal, Andaman & Nicobar, Lakshadweep. Daily advisory maps, along with textual information, is being broadcasted through these channels. Presently this service is being popularized as a complementary service to the SMS platform.

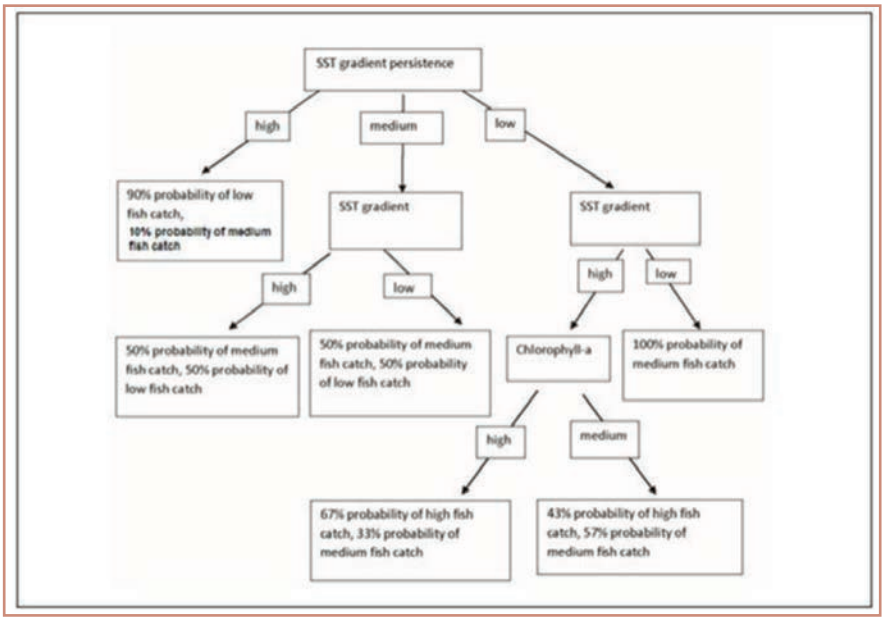
4.5.1.2 Android App for Fishermen Feedback

INCOIS designed a mobile app for collecting feedback from fishermen society which can help in improving & fine tuning of advisories. The feedback app facilitates collecting quantitative and geo-referenced fish catch data directly from the fishermen community. The storing facility serves as their electronic trip sheets for subsequent self reference.



Android App for Fisherman Feedback

4.5.1.3 Potential Fishing Zone Characterization in the Indian Ocean by Machine Learning Approach



Decision tree for PFZ characterization

The limitation of this advisory is that it does not give any information about the probable quantity of the fish. In order to overcome this, a hybrid decision tree model was developed for characterizing PFZ in the Indian Ocean. If SST gradient, persistence of SST gradient and chlorophyll concentration of any PFZ are given as the input variables, this model can classify the corresponding PFZ in terms of low, medium or high category of fish catch. It has been observed that a low SST gradient persistence and high SST gradient indicates possibility of high fish catch.

4.5.2. Species specific research efforts

Development of species specific fishery advisories for Hilsa shad has been taken onboard as key objectives during 2017-2021. Towards uniform fisheries, biological and climatic data collection along the east coast, INCOIS has outsourced two sub-projects to Andhra University and Vidyasagar University for regular sampling along the Godavari and the Sundarban estuaries respectively. For

Digha Field Station & Activities

Building where Lab is established

Dry area

Wet area

Hilsa fish samling at Digha Mohona Market

smooth operation of ongoing sampling, validation of experimental advisories and user interaction, establishment of a coastal laboratory at Digha, West Bengal as field station, has been completed in collaboration with Govt. of West Bengal and Vidyasagar University.

4.5.3. Ecosystem-based Fishery Advisory Services (EFAS)

4.5.3.1 Modelling Marine Primary Productivity

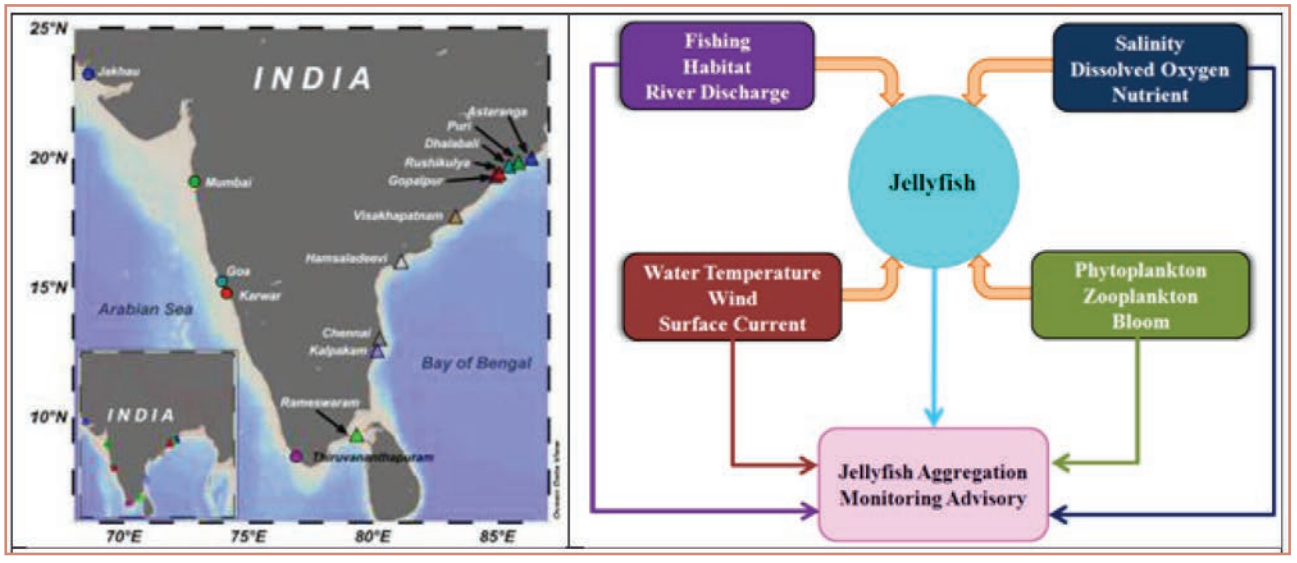
INCOIS has setup an IRMS and Elemental Analyser laboratory to study the P-I (Photosynthesis-Irradiance) parameters from the water samples collected from the coastal waters around India. The PI parameters are important inputs for the primary productivity (PP) model proposed to be setup by INCOIS for improving the PFZ advisory services. The laboratory for IRMS-EA and CFNA was inaugurated by Dr. M. Rajeevan (Secretary, MoES) during INCOIS-GC meeting on 11 September

Glimpse of the newly established laboratories

2020. Further, the team participated in research cruise SN-162 aboard ORV Sagar Nidhi during Feb-Mar 2021 in the Bay of Bengal.

4.5.3.2 A synthesis on jellyfish aggregation with emphasis to Indian coastal waters

A review of jellyfish aggregations focused on India's coastal waters was conducted, with the aim to enhance understanding of conducive conditions and subsequent ecological impacts. The present review highlighted the environmental concerns associated with coastal jellyfish swarming and beach strandings. A variety of natural (winds, tidal fronts, surface currents, water temperature, salinity, turbidity, dissolved oxygen) and anthropogenic (water quality deterioration, overfishing, translocation, habitat modification) factors play pivotal roles in triggering jellyfish aggregations. Jellyfish aggregation events in the forms of their swarming in coastal waters and beach strandings have resulted in ephemeral nuisances such as water quality deterioration, food chain alterations, hindrance in seawater uptake by power plants, clogging of nets during fishing operations, and tourism declines. Several well-known Indian tourist beaches (e.g., Puri, Chennai, Goa, and Mumbai) have experienced beach strandings. Despite recurrence of such events, jellyfishes are relatively less scientifically investigated and monitored in Indian coastal waters. Therefore, it is important to determine the environmental conditions that trigger jellyfish swarming, in order to develop effective monitoring and prediction strategies. This study additionally proposes a conceptual framework towards development of a jellyfish monitoring system for Indian waters using satellite and model data.



Jellyfish swarming and beach stranding events reported along Indian coast (left panel) and a conceptual framework for development jellyfish aggregation monitoring advisory (right panel)

4.6 Deep Ocean Mission (Preparatory work)

In order to harness socio-economic benefits from the Oceans around us and mitigate the increasing vagaries of extreme weather due to climate change, MoES will be implementing the "Deep Ocean Mission (DOM)" over the next 5 years. The DOM has six major activities of which INCOIS leads the "Development of Ocean Climate Change Advisory services (OCCAS)". The most important objective of OCCAS component of DOM is to deliver the projections of various oceanic parameters like change in sea level, the intensity of cyclone, storm surge and waves, marine productivity and water quality parameters in multidecadal timescales considering the

changing climate. Tide gauge and satellite observations suggest that sea level is rising rapidly (~3.1-5 mm/ yr) along the coast of India. Such drastic rise in sea level will lead to coastal inundation, increased flooding, coastal erosion, destruction of drainage systems, in effectiveness of regional water management as well as saltwater intrusion into the aquifers and local water supply wells. These effects will increase the vulnerability of coastal regions and thereby, will affect the lives of millions of people living near these regions. Therefore, the outcome of OCCAS component of DOM is crucial for sustained coastal zone management, understanding the future potential migration of fishing zones and finally, contributing to marine driven economy along the coastline of India. It is proposed that as part of this component of DOM, high resolution maps depicting the future projections will be prepared and updated regularly for all coastal states and important coastal cities. A GIS based interactive advisory tool also will be developed to facilitate future coastal management planning and policymaking. In addition to proving climate advisories, this programme will contribute significantly to large scale capacity building.

In order to achieve the goals of DOM, INCOIS has already initiated the preparatory work in setting up numerical models required to generate projections of extreme events and sea level rise, prepare atmospheric fields required to force these models and take necessary observations in the deep oceans to monitor water type properties and fine tune their representation in the numerical models. The important achievements during the reporting period are deployment of ocean gliders in the Bay of Bengal, assessment of sea level projections from CMIP6 simulations for the Indian Ocean and setting up of numerical models for dynamical downscaling of sea level projections for the Indian coasts.

4.7 Data Services

INCOIS, designated as the National Oceanographic Data Centre (NODC) by the International Oceanographic Data Exchange (IODE) Programme of the IOC, continued serving as the central repository for oceanographic data in the country. INCOIS also sustained and enhanced the reception and processing of data from in-situ observing systems and dissemination to the users for INCOIS operational and research activities in real-time. Data requests from the users through Ocean Data and Information System (ODIS) portal were also served. In-situ datasets were disseminated to the Indian Navy on quarterly basis through secured channels. INCOIS data centre also continued to provide on-demand oceanographic data and related support and software to the Indian Navy and other national institutions.

4.7.1 In situ data products

The INCOIS data centre sustained and strengthened real-time data reception, processing, and quality control of surface meteorological and oceanographic data from a wide variety of ocean observing system such as Argo floats, moored buoys, drifting buoys, wave rider buoys, tide gauges, wave height meter, ship mounted autonomous weather stations and HF radars. Further, surface met-ocean data has been regularly disseminated to various operational agencies in the country through email/web-site/FTP in near-real time. Data centre also served the ocean science community in their various R&D endeavours by providing tailor-made data and products via request based offline data dissemination mode. The data centre obtained and archived real

time in situ data from the various ocean observing systems. The data centre also obtained and archived delayed mode data from various observing systems such as XBT/XCTD observations, Met observations (NODPAC), OMM cruise data, ADCP data, OMNI hard-disk data etc. Details of data received in the present reporting period is provided.

Details of data received from April 2020 to March 2021

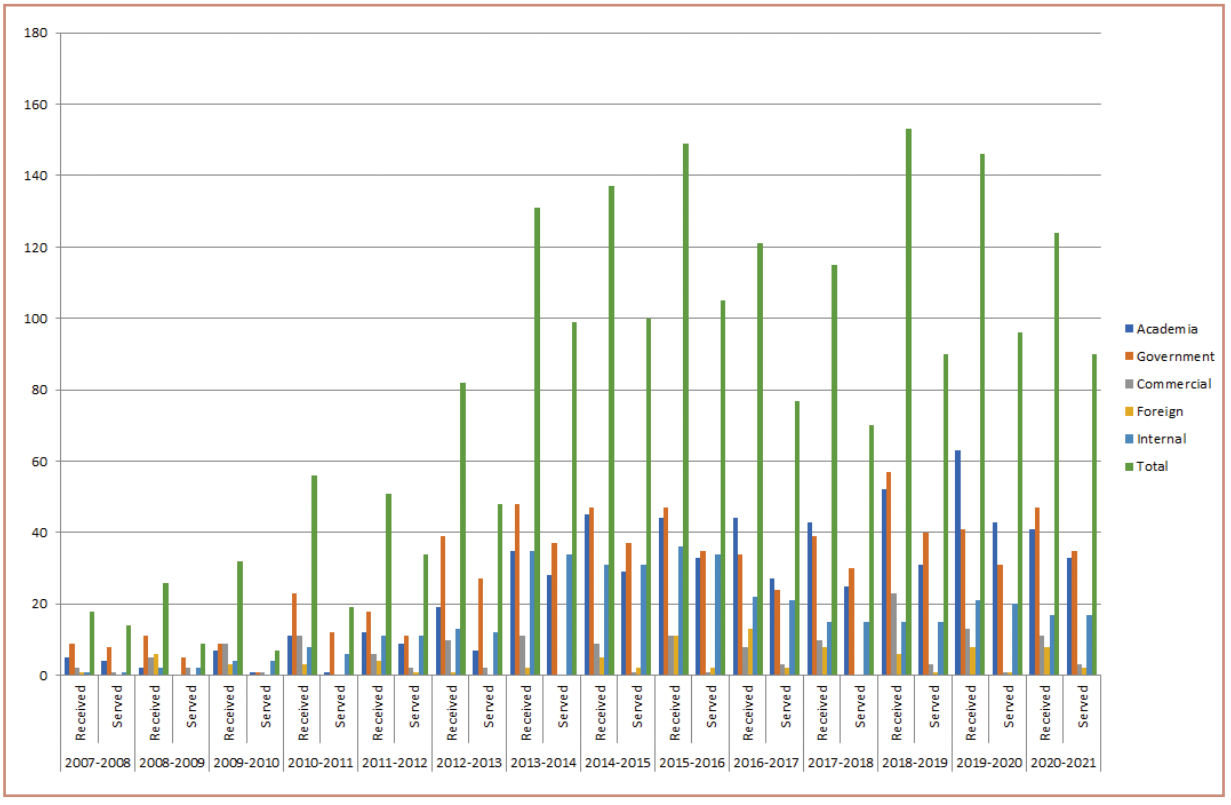
Institute / Programme	Parameters	Period of Observation	No. of Platforms / Stations Reported	Status
NODPAC (Met Observations along Ship track)	Surface met parameters	Jan 2020 – Dec 2020	5262 observations	Archived
NODPAC (XBT data)	Temperature profiles	Jan 2018 – Sep 2018	1253 profiles	Archived
NIOT - NDBP (Moored buoys)	Met-ocean parameters	Apr 2020 – Mar 2021	17 buoys	Added to the database
NIO (Drifting buoys)	Met-ocean parameters	Apr 2020 – Mar 2021	14 buoys	Added to the database
INCOIS (Ship-mounted AWS)	Met parameters	Apr 2020 – Mar 2021	28 stations	Added to the database
INCOIS (Wave rider buoys)	Wave parameters	Apr 2020 – Mar 2021	17 stations	Added to the database
INCOIS (Tide gauges)	Sea level	Apr 2020 – Mar 2021	33 stations	Added to the database
INCOIS-NIOT (Tsunami Buoy)	Sea level	Apr 2020 – Mar 2021	05 stations	Added to the database
NIOT (HF RADAR)	Currents	Apr 2020 – Mar 2021	05 pairs of stations	Added to the database
INCOIS (Argo CTD)	Temperature and Salinity	Apr 2020 – Mar 2021	32963 profiles	Added to the database
INCOIS-OMM	Ocean Monsoon Mixing Cruise Data			Archived

4.7.2 Ocean Remote sensing data products

Remote sensing data from various sensors flown on board Oceansat-2, NOAA, METOP Terra and Aqua, and Suomi-NPP satellites are received in real-time at the ground stations established at INCOIS. The data are processed and made available to in-house operational activities as well as to other operational agencies in the country in near-real time: e.g., to IMD for developing composite satellite products, AVHRR-SST for INCOIS data assimilation project RAIN (Regional Analysis of Indian OceaN), and AVHRR-SST and Oceansat-2 OCM Chlorophyll data for INCOIS PFZ forecasting system. The INCOIS ground station also served request based off-line data products to many research and operational organizations. Upgrade of the existing ground station capabilities for remote sensing data, namely: X/L ground station hardware up-gradation, up-gradation of X-NPP ground station to acquire NOAA-20 satellite data, and ground station for Oceansat-3 is also in final stages.

Details of remote sensing data holdings till date

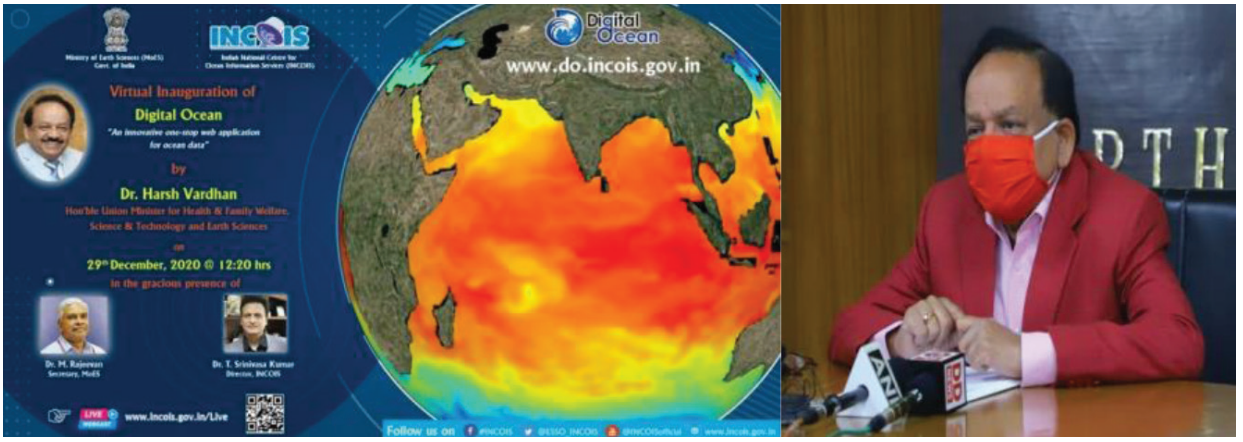
Satellite	Sensor	Products	Time period
MetOp-A&B NOAA-18&19	AVHRR	• L1b • Sea Surface Temperature • FOG • Cloud top Temp • Normalized Difference Vegetation Index (NDVI)	September 2006 to Till date
Oceansat-2	OCM	• L1b • Chlorophyll-a • Total Suspended Sediments • Diffuse Attenuation Coefficient (Kd490) • Aerosol Optical Depth (AOD)	February 2011 to Till date
Suomi-NPP	VIIRS, CrIS & ATMS	• L1b • Ocean Color (chlor_a, chl_ocx, Kd_490, par, pic, poc) • SST (Split Window, Triple Window) • Other (Fire Points, FOG, NDVI, Cloud products etc...) • Short Wave (SW) • Medium Wave (MW) • Long Wave (LW)	May 2016 to Till date



Growth of data request over the years

4.7.3 Earth System Data Portal and Digital Ocean

- Honorable Minister of Health & Family Welfare, Science & Technology, Earth Sciences Dr. Harsh Vardhan inaugurated a web-based application "Digital Ocean (www.do.incois.gov.in)" during a Virtual Meeting held at Nirman Bhawan, New Delhi on 29 December 2020. The Digital Ocean (DO) will serve as a one stop-solution for all data related needs of a wide range of users including research institutions, operational agencies, strategic users, academic community, maritime industry, policy makers and the public. The DO is expected to bring a sea-change in how oceanographic data is served for a better understanding of oceans surrounding us. It will play a central role in sustainable management of our oceans and expanding our "Blue Economy" initiatives. The DO is also a first of its kind platform for ocean data management and contributes to the Digital India programme of the Government of India to transform India into a digitally empowered society and knowledge economy with a vision of Atmanirbhar Bharat.



Inauguration of Digital Ocean portal

- Development of MoES Earth System Science Data (ESSD) Portal is completed. MoES Earth System Science Data Portal aims to link all the geo-spatial datasets available across multiple MoES data portals at an easily navigable central repository. This portal is developed for the ease of search and discovery of various data-sets collected and maintained under the different MoES programmes over the years. A joint MoES-NOAA OMNI-RAMA web portal to serve moored buoy data is also developed. Maintenance and development of IIOE-2 metadata portal was also done.

4.8 ICT Services

4.8.1 Computing Facilities

INCOIS hosts state-of-the-art computational facilities that include a high performance computer and its allied infrastructure, 415 TB 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 computer infrastructure are set up in such a manner that no single point of failure can affect the operational services. INCOIS continued to maintain the computing and network infrastructure with an up-time of 99% to support the operational and R & D projects.

4.8.2 Tech Refreshment of IT facility in ITEWS

Technology Refreshment of IT and system software at ITEWS is done successfully and the applications are migrated onto the new hardware and operationalised the same. The primary workflows needed to issue tsunami bulletins are ported on the systems at the disaster recovery site located at Pune for operations in case of an unforeseen incident happening at the main data centre at INCOIS. The wired and wire-less LAN activity for the ITCO ocean building is successfully completed and INCOIS users are using the same.

4.8.3 e-Office – A Digital workplace solution at INCOIS

The eOffice product of National Informatics Centre (NIC) along with its various sub-systems were successfully deployed at INCOIS. The eOffice setup at INCOIS consists of File Management System (eFile), Knowledge Management System (KMS), eFile MIS Reports and other eServices such as Master Data Management and online forms.

4.8.4 Web based services

INCOIS provides its ocean information and advisory services through its web portals viz., www.incois.gov.in, www.tsunami.incois.gov.in, www.iioe-2.incois.gov.in, www.do.incois.gov.in and www.isgn.gov.in INCOIS continued to manage the web services besides developing various value-added web applications based on the user requirements. Some of the notable activities during this period are:

- Security Audit of INCOIS Website (www.incois.gov.in & www.iioe-2.incois.gov.in) in coordination with M/s C-DAC, Hyderabad.
- Maintained web applications for online recruitment, operational products such as Biogeochemical State of the Indian Ocean (BIO), PFZ forecast, swell surge forecasts, ABIS, small vessel advisory and forecast system, etc.
- Maintained the developed web portals for distribution of different datasets such as tropflux, OMM, OMNI-RAMA joint data portal.
- Streamlined the multilingual web application for Marine Fishery Forecast System (MFFS).
- Maintained web application for online project proposal submission & reviewer's evaluation for the Coastal Monitoring (CM) project.
- Login based web application for the participants applying for ITCOocean Training courses as well as for academic projects.
- Maintained webpages of "Internal Complaints Committee", "Official Language Implementation Committee" as well as 'Contributory Medical Scheme & Reimbursement'.

4.8.5 Communication Facilities

- Maintained the communication/network facilities such as the state-of-the art satellite and VSAT communication hub to receive continuous data from Tide gauge network, AWS, Wave raider buoy network and other observational platforms, which are used by INCOIS services. These communication channels include INSAT (MSS & DRT) Hub Stations, VSAT aided emergency

communication system (VECS) network for the Emergency Operational centers (07 EOC's), Service Data Adaptation Protocols (SDAP), NPP and Oceansat-2 ground stations.

- Maintained the 100 Nos of Digital Display Systems (DDS) and contributed towards dissemination of INCOIS services such as PFZ, OSF and Tsunami Advisories.
- INCOIS extended technical support to NIO for integration of INSAT UHF transmitter for real time reception of XBT / XCTD data from ship to INCOIS.

4.8.6 Application Software Development

4.8.6.1 Tsunami Application Software and Website

The mission-critical application software pertaining to Tsunami Early Warning centre is supported in-house. The tsunami website (https://tsunami.incois.gov.in) acts as the primary medium that serves India and 25 Indian Ocean rim countries. A separate section for the Indian Ocean tsunami Ready program was developed, and associated guidelines are also published to benefit the disaster management officials of India. INCOIS also developed the necessary software application to ingest the real-time data of INCOIS and NIOT tsunami buoys to the NOAA-NDBC website. INCOIS is the first international partner to set up data ingestion over the endpoint in the Indian Ocean.

4.8.6.2 Decision Support System for Tsunami and Storm Surge services

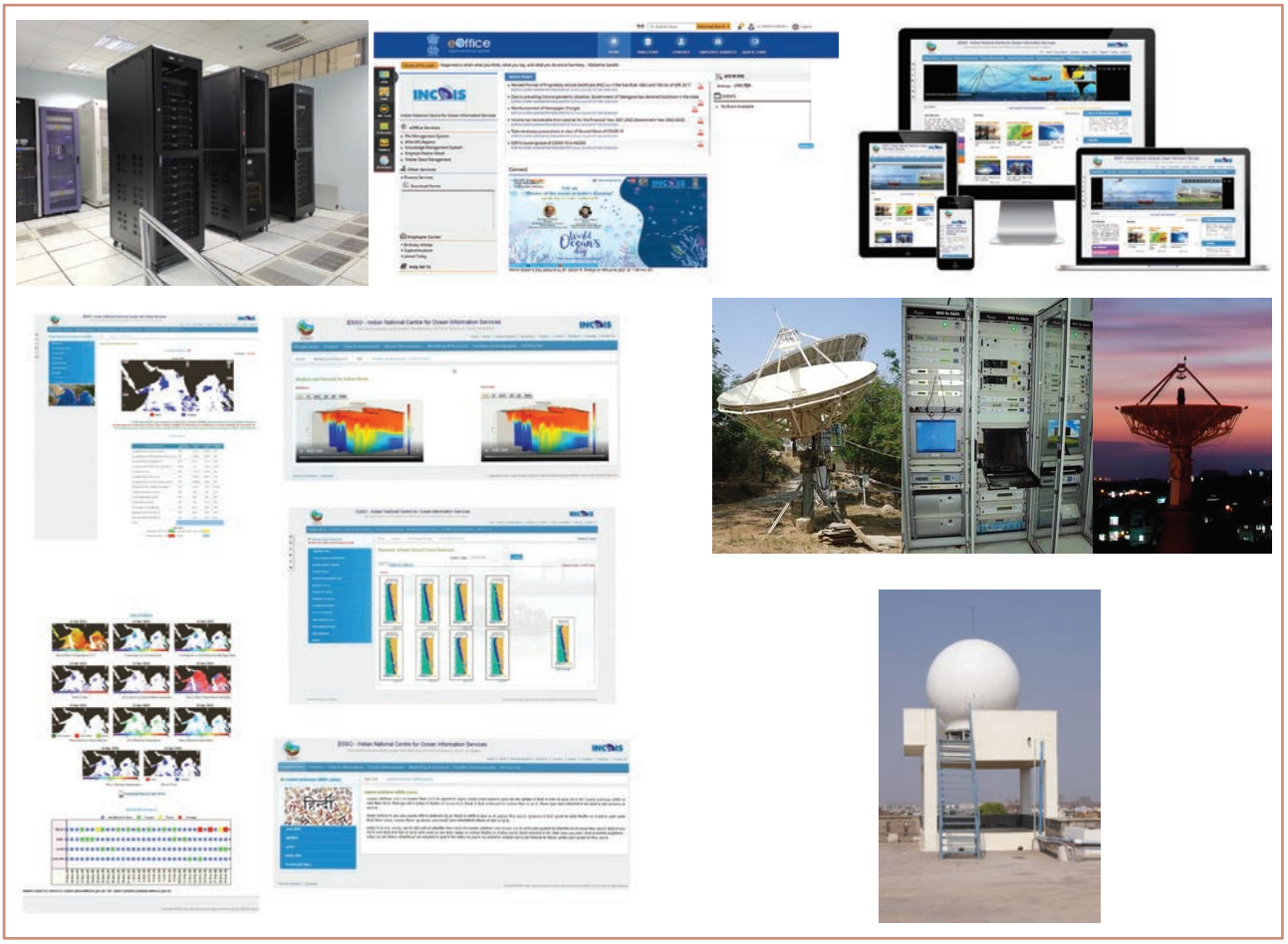
A decision support system(DSS) for Storm Surge service is maintained in-house. DSS handled 4 cyclone events (AMPHAN, NISARGA, NIVAR, BUREVI) during the reporting period and provided timely advisories to India Meteorological Department (IMD) for further dissemination to stakeholders.

Storm surge decision support tool is enhanced with new capabilities:

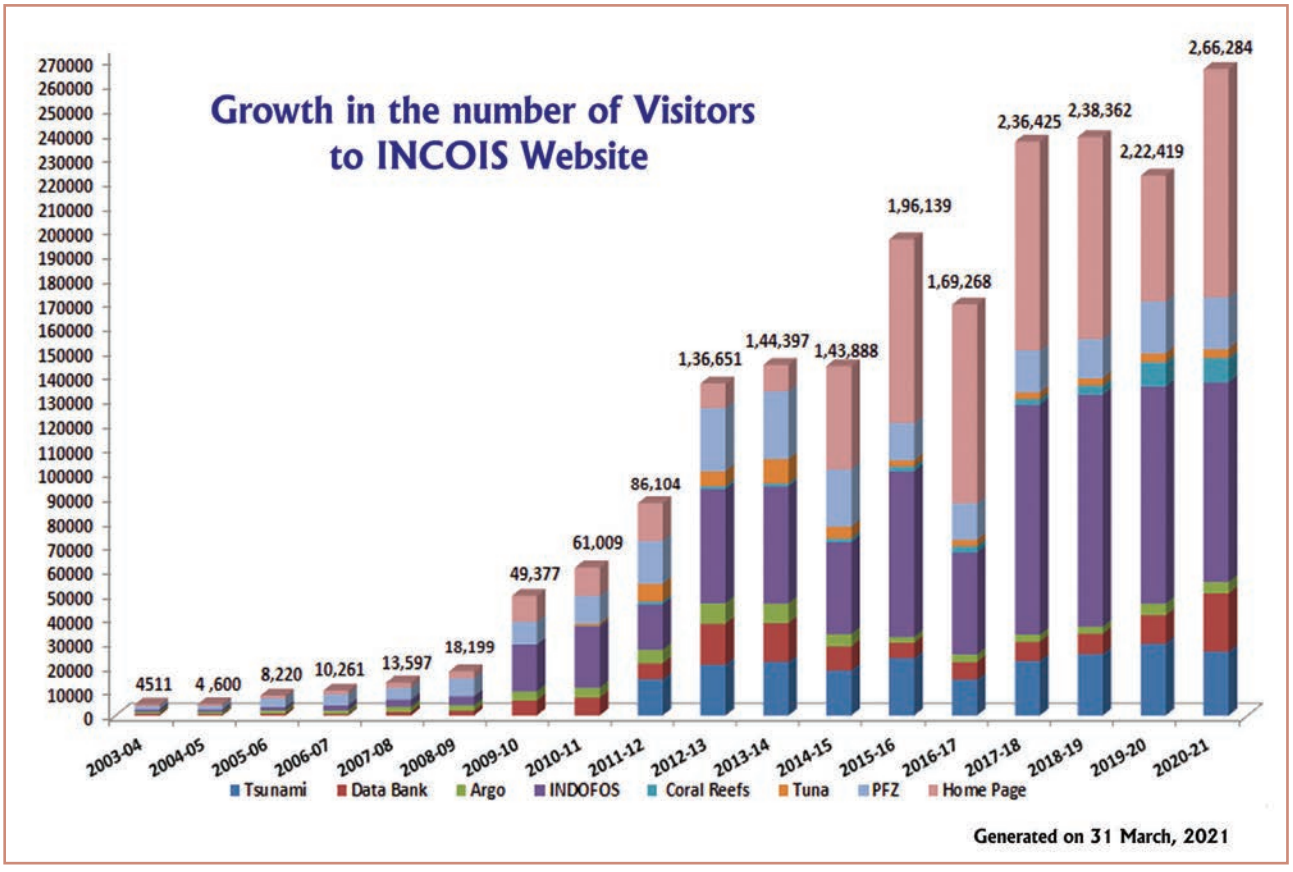
- DSS can now launch the model in real-time at three HPC facilities, namely Aditya, Mihir and INCOIS.
- New grids and regions are added to handle various cyclones on India's east and west coasts.
- Capable of generating the required advisories to ESCAP countries.
- Generate and issue timely advisories to India Meteorological Department (IMD).

4.8.7 Estate Management and other infrastructure services

- **Rooftop Solar Power plant over the ITCOocean Academic Block:** 214.50 kWp capacity Grid Connected Roof Top Solar Power plant over the ITCOocean Academic Block was put into regular usage since October 2020 and the plant is performing satisfactorily.
- **ITCOocean main building:** Landscaping works under the ITCOocean project has been completed successfully. For effective water usage, a drip irrigation system, which uses water from the sewage treatment plant, was also installed covering the entire campus. With the occupation of scientists and students, the academic block of ITCOocean is under regular usage from September 2020. The existing Library of INCOIS was also shifted to ITCOocean building from the main building.



Computational and communication facilities and web applications maintained by INCOIS



Growth of visitors to INCOIS web page over the past 15 years

5. Consultancy Projects

The table below presents the projects and services carried out during the report period.

Sl. No	Agency	Project/Data	Amount (in Lakhs INR)
Project done			
1	Maharashtra Maritime Board	Project on IVL & Subscription of Dynamic IVL (Project Report)	30.00
2	JNPT, Mumbai	Oil spill trajectory prediction and wind and wave data at the proposed Vadhavan Port, Maharashtra and assessing the probable spread towards Tarapur Atomic Power Station (Project Report)	14.59
3	Hindustan Consultancy Co. Ltd. (HCC), Mumbai	Data during cyclone Vaayu	0.43
4	HCC, Mumbai	Data during July-August 2019	1.34
5	Coastal Infrastructure – Port Construction	AFCONS	23.7
Project being executed (3 year project from Apr 2018)			
5	ONGC	Data Delivery on currents/ eddies for wells (daily forecast mode/ Project Report)	101.60*

** Total consultancy project cost for 3 years (continuing)*

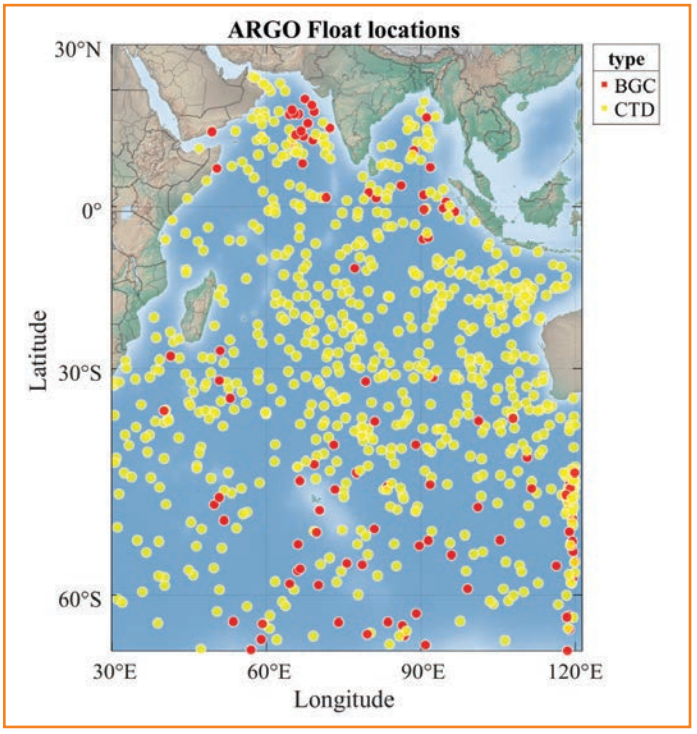
6. Ocean Observations

Sustained ocean observations are crucial to understand complex oceanic processes, continued monitoring of its variability, its interaction with the atmosphere, and for developing products and operational ocean services for the benefit of the society. In order to achieve that, INCOIS maintains an array of ocean observation platforms, most of which transmit data in real time. During 2020-2021, in-spite of various restrictions imposed due to COVID-19 pandemic, INCOIS continued its efforts to collect ocean data by mainly sustaining various observation platforms along with new deployments, whenever possible, in the Indian Ocean.

6.1 Mission Mode Observations

6.1.1 Indian Argo Programme

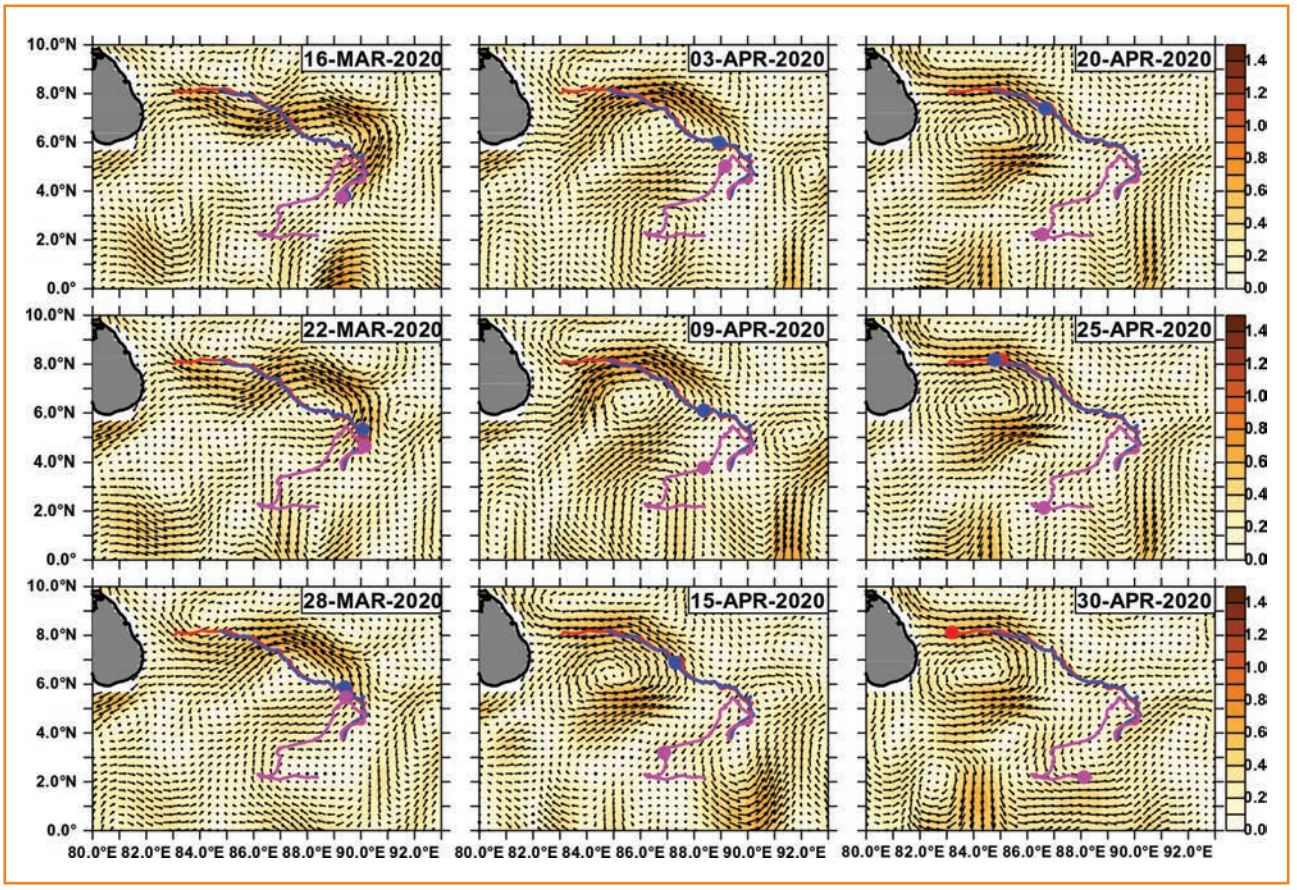
The Argo programme is a component of the Global Ocean Observing System (GOOS) and one of the largest multinational efforts to monitor ocean hydrography. During the 2020-21 period, INCOIS deployed one core Argo float at 9.9°N and 88.6°E in the Indian Ocean. With this deployment, the total contribution of India to the global Argo programme is 494 floats out of which 103 active floats are transmitting data in real time. INCOIS received 32963 temperature and salinity profiles from the Indian Ocean during the past year.



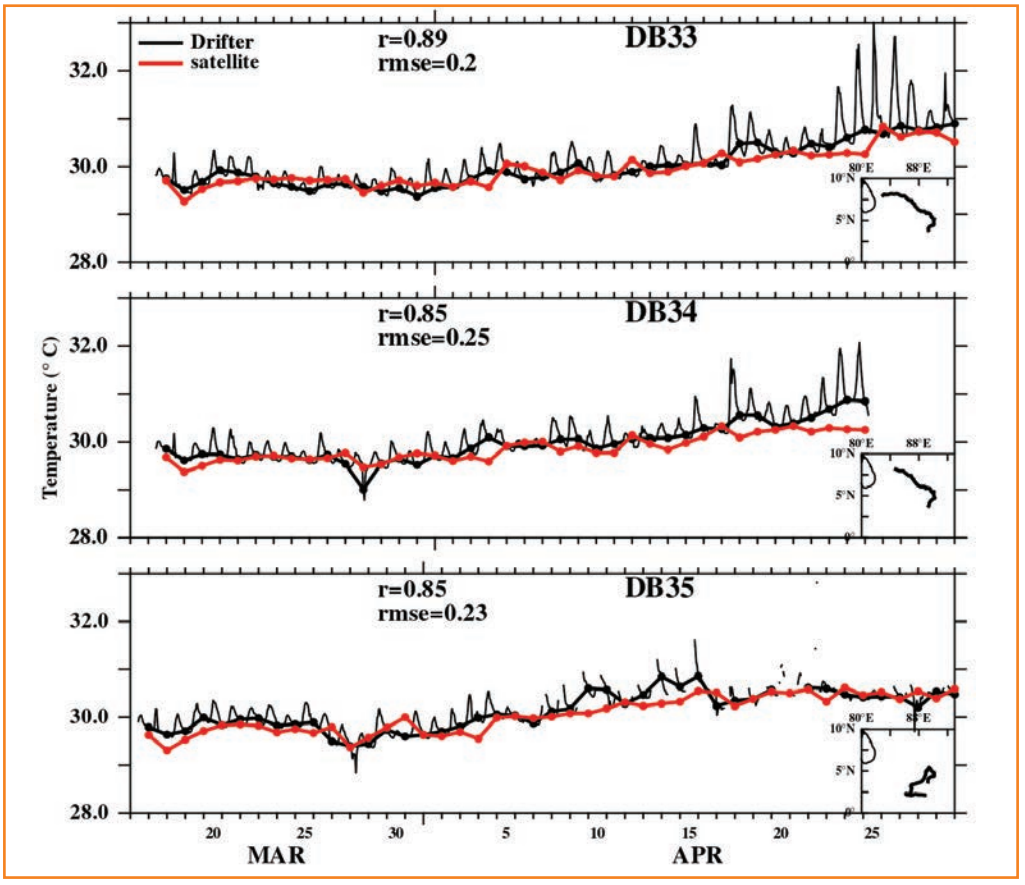
Latest locations of Argo floats in the Indian Ocean. Yellow circles indicate Core Argo floats (CTD only) and red circles indicate bio argo floats.

6.1.2 Indian Drifter Programme

Satellite tracked surface drifting buoys (commonly known as drifters) are an important component of the global ocean in-situ observation network having tremendous use in oceanographic studies and operational services. INCOIS deployed three drifters in the southern Bay of Bengal on 14 March 2020 supplied by M/s Azista Private Ltd, Ahmedabad, which was developed based on technology transferred from NIOT. These three floats provided continuous data with a one-hour interval until 30 April 2020. The performance and the quality of the parameters measured by these three buoys are evaluated using satellite and near-by in-situ data sets. The drifters followed the prevailing current pattern in the Bay of Bengal and eastern equatorial Indian Ocean and the temperature measurement showed good match with satellite and in-situ observations.



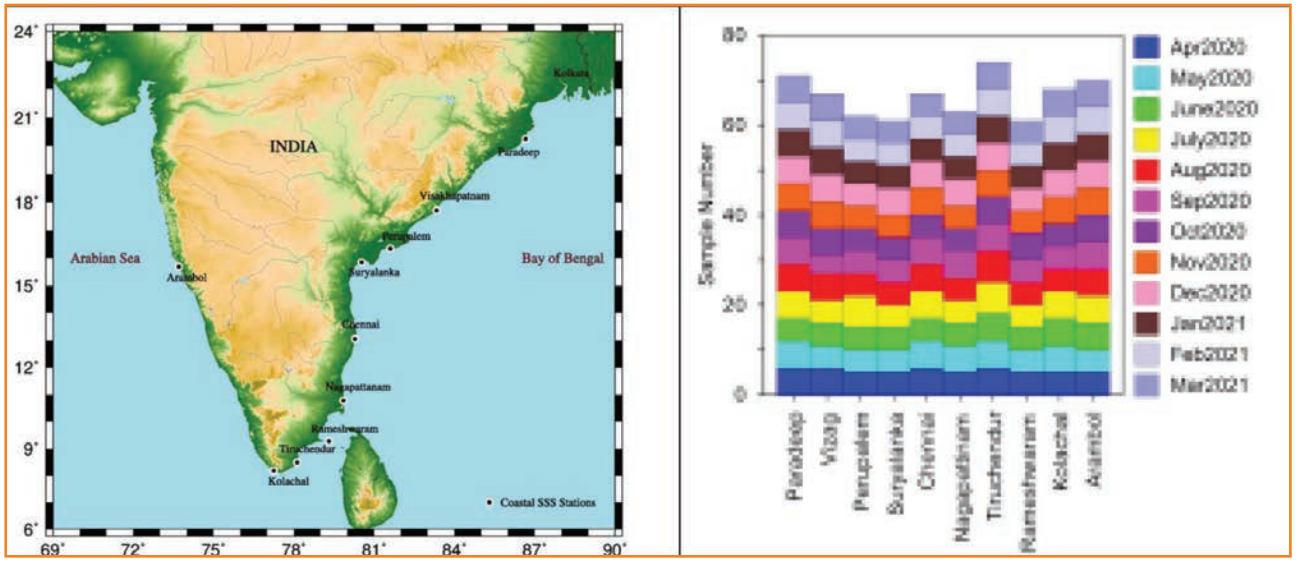
Track of drifters plotted over OSCAR currents. The circles indicate drifters' location as on the date scribed at the upper right corner of each box. Red, Blue, and Magenta trajectory indicates DB33, DB34, and DB35, respectively



The thick black line represents the SST at night, as observed by the drifters.
Satellite measured SST is plotted in thick red. Trajectories of each drifter are shown in the inset.

6.1.3 eXpendable BathyThermographs (XBT) / XCTD Programme

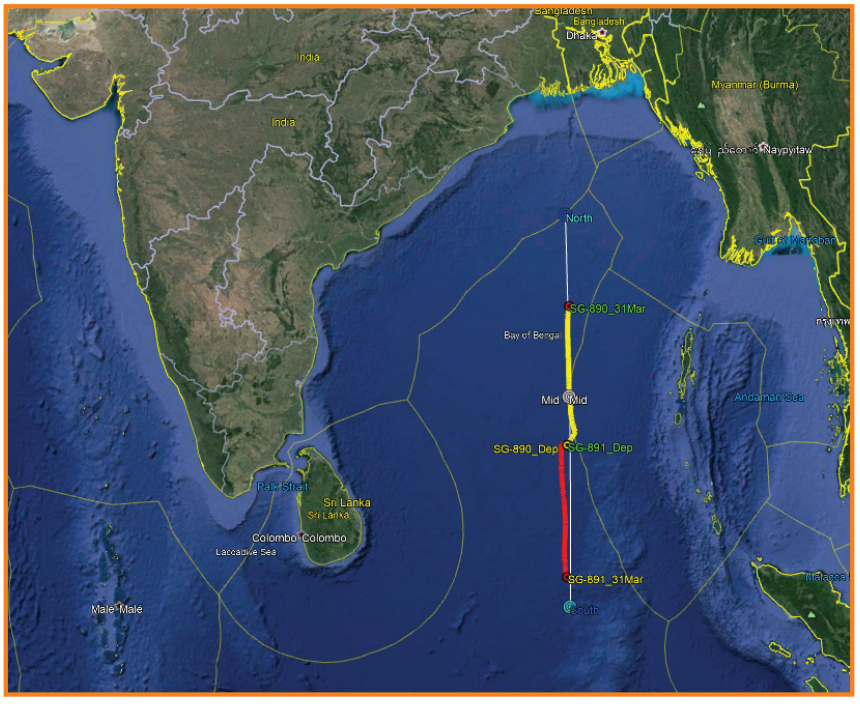
As a part of Ocean Observation network, INCOIS maintains three XBT/XCTD lines in the Indian Ocean along Kochi-Lakshadweep, Chennai-Port Blair and Port Blair-Kolkata in collaboration with CSIR-National Institute of Oceanography (NIO). There were no XBT/XCTD cruises conducted during April 2020 to March 2021 due to the restrictions imposed by the government in connection with ongoing pandemic. However the coastal time series sea surface salinity (SSS) sampling was continued along the east and west coast of India.



Left: Stations of coastal time series sea surface salinity sampling along the east and west coast of India. Right: Sampling frequency at each station.

6.1.4 Deep Ocean Gliders

As a part of Deep Ocean Mission, INCOIS procured two slocum gliders to monitor the deep ocean

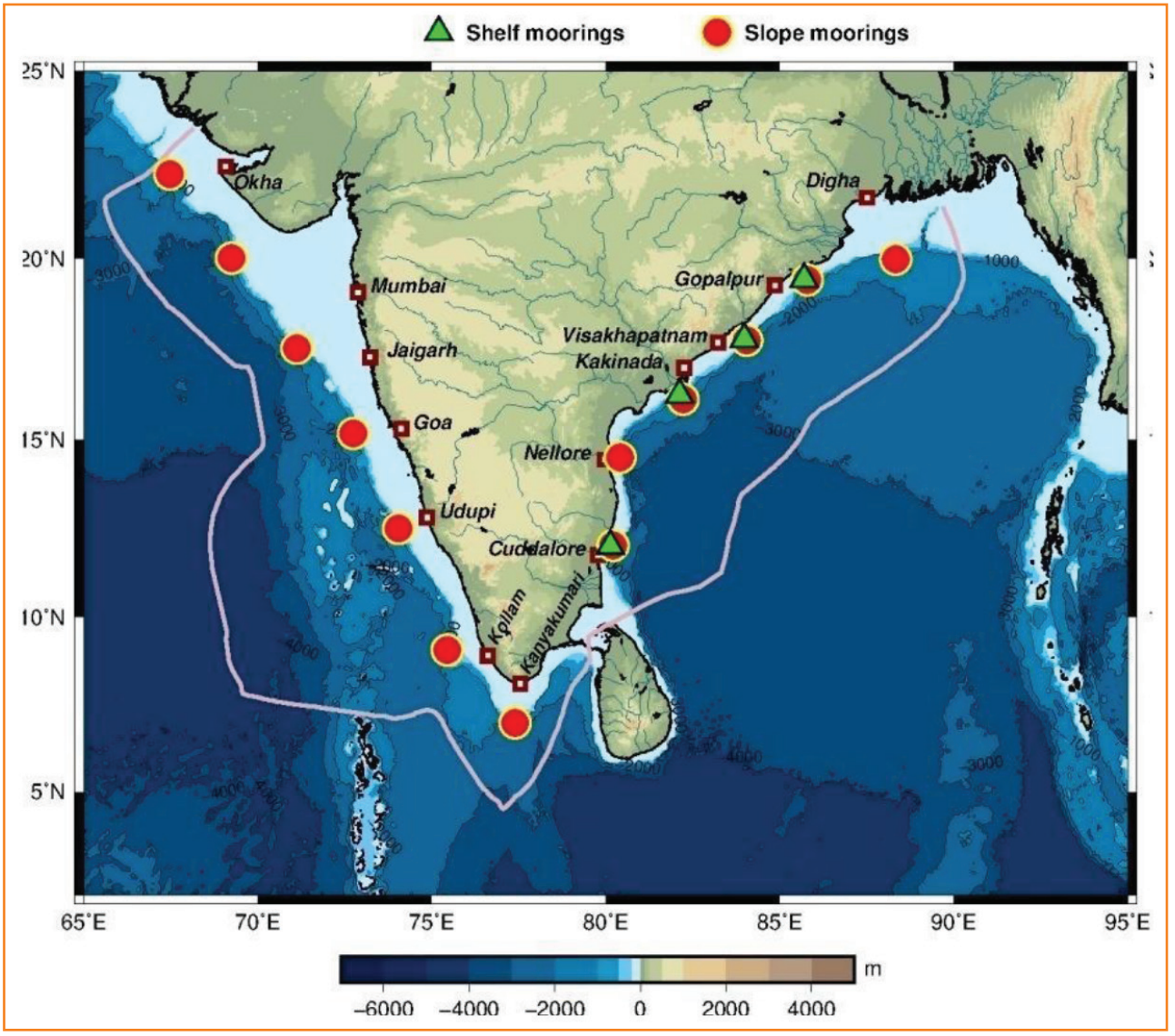


Glider tracks during 05-31 March 2021, the white vertical line is the proposed transect and Yellow & Red are actual transects from Gliders

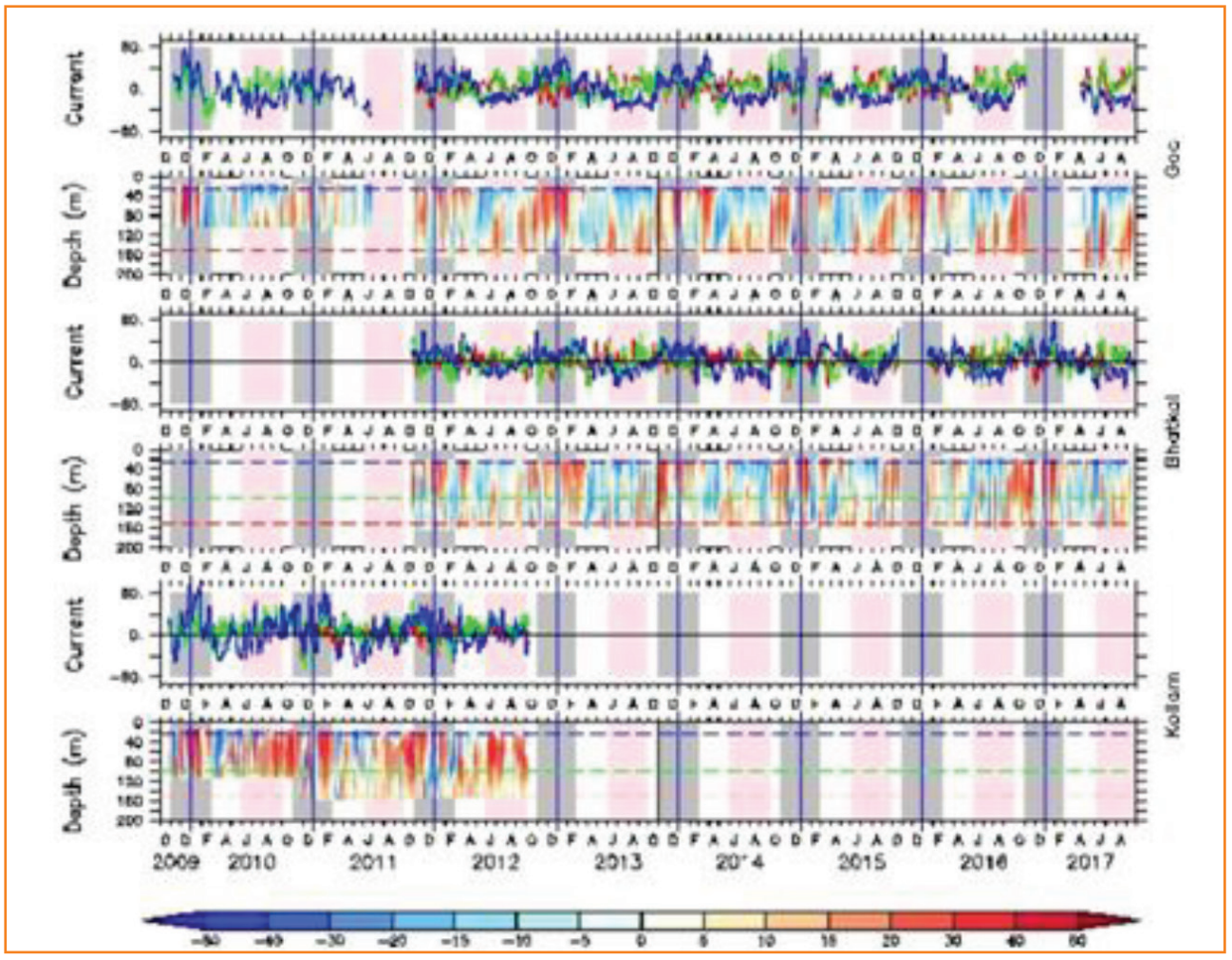
physical and biogeochemical parameters in northern Indian Ocean, understand the temporal and spatial variability of Oxygen Minimum Zone (OMZ) and to monitor water mass properties and ventilation processes of the North Indian Ocean. The glider ballasting test was performed at NIOT and the sea trial was performed on 29 and 31 January off-Chennai. Both the gliders (SG890 and SG891) were deployed for the real mission on 05 March 2021 onboard ORV Sagar Nidhi in central Bay of Bengal. The mission covered north transect (between 11.50°N, 88.79°E - 17.50°N, 88.79°E) with SG890 and south transect (between 11.50°N, 88.79°E - 4.50°N, 88.79°E) with SG891.

6.1.5 Coastal Current Meter Network

The ADCP network in Indian coastal waters was sustained in collaboration with CSIR – National Institute of Oceanography (NIO). The 17 ADCP moorings, deployed at shelf (10 moorings) and slope (seven moorings) locations were serviced during two cruises conducted onboard ORV Sindhu Sadhana (SSD-076, SSD-078). The ADCP measurements from the outer continental shelf of the Indian seas were analysed and documented.



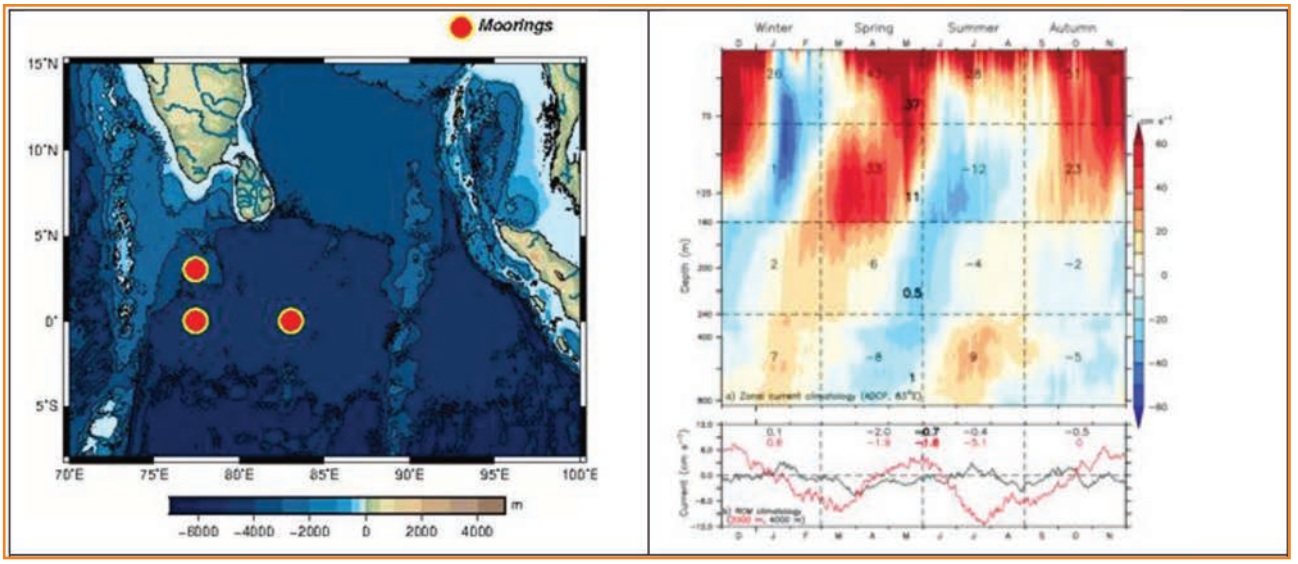
Schematic showing the locations of ADCP moorings in slope (red filled circles) and shelf (green filled triangles) regions of the Indian coastal waters. The pink line marks the Indian EEZ.



Sub-inertial alongshore current (cm s^{-1}) on the shelf off Goa, Bhatkal and Kollam.

6.1.6 Equatorial Current Meter Moorings

The equatorial current meter moorings were sustained in collaboration with CSIR-NIO. These moorings were designed to record currents at selected depths covering the entire water column.



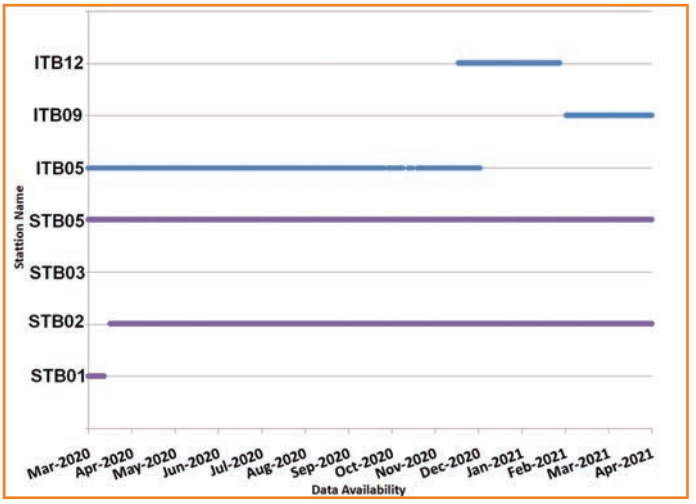
Left: Schematic showing active deep sea moorings in the equatorial Indian Ocean. Right: Climatology of zonal currents at 83°E (red shades imply eastward current), and at 2000 m (red) and 4000 m (black) by Rotor Current Meter (RCM). The numbers indicate the mean over a particular season (red for 2000 m and black for 4000 m), and numbers in bold font indicate the annual mean.

The depths were chosen such that information on current is available from the upper thermocline, main thermocline, intermediate, deep and near-bottom depths. Presently, three moorings are operational.

6.2 Observations for Services

6.2.1 Tsunami Buoy with Bottom Pressure Recorder

The network of four Tsunami Buoys with Bottom Pressure Recorder (BPR), deployed close to the tsunamigenic source regions, in Bay of Bengal and Arabian Sea was sustained. The data from these buoys are transmitted in real-time to the ITEWC at INCOIS via satellites. During the year 2020-21, two Tsunami Buoys (STB05 and STB02) were retrieved and redeployed along with the recovery of one buoy (STB03) during the cruise onboard Sagar Nidhi ((05 March-08 May 2020)). In addition, the INCOIS team also recovered one drifting surface buoy (STB01) in the Bay of Bengal. Further, INCOIS team attempted to recover BPR at STB01, which could not be achieved due to non-response of acoustic releaser.

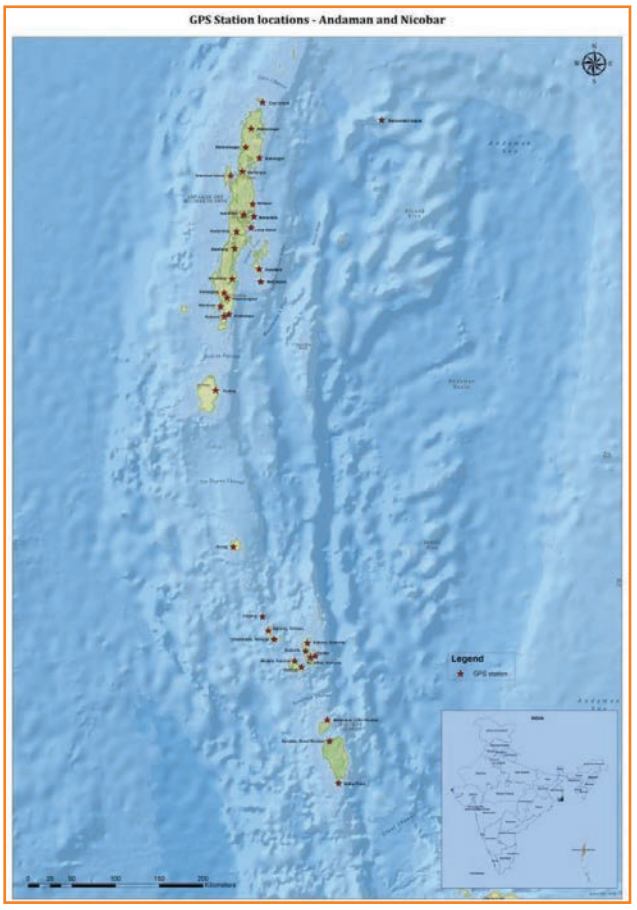


Data availability of tsunami buoys from April 2020 - March 2021

Recovery of STB01 Surface Buoy onboard Sagar Nidhi in April 2020

6.2.2 GNSS and Strong Motion Accelerometer

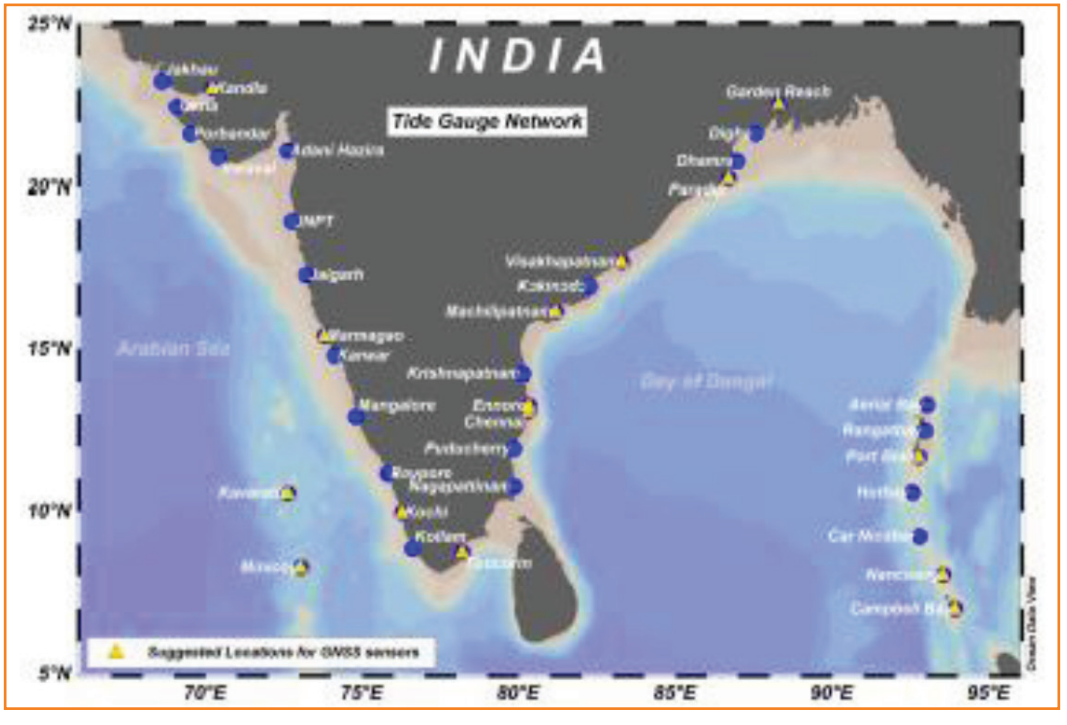
INCOIS completed installation of GNSS and SMA sensors at 31 locations in Andaman and Nicobar Islands with realtime communication over VSAT. The construction of the observatories at four locations is underway.



GNSS and Strong Motion Accelerometer (SMA) network in Andaman and Nicobar Island

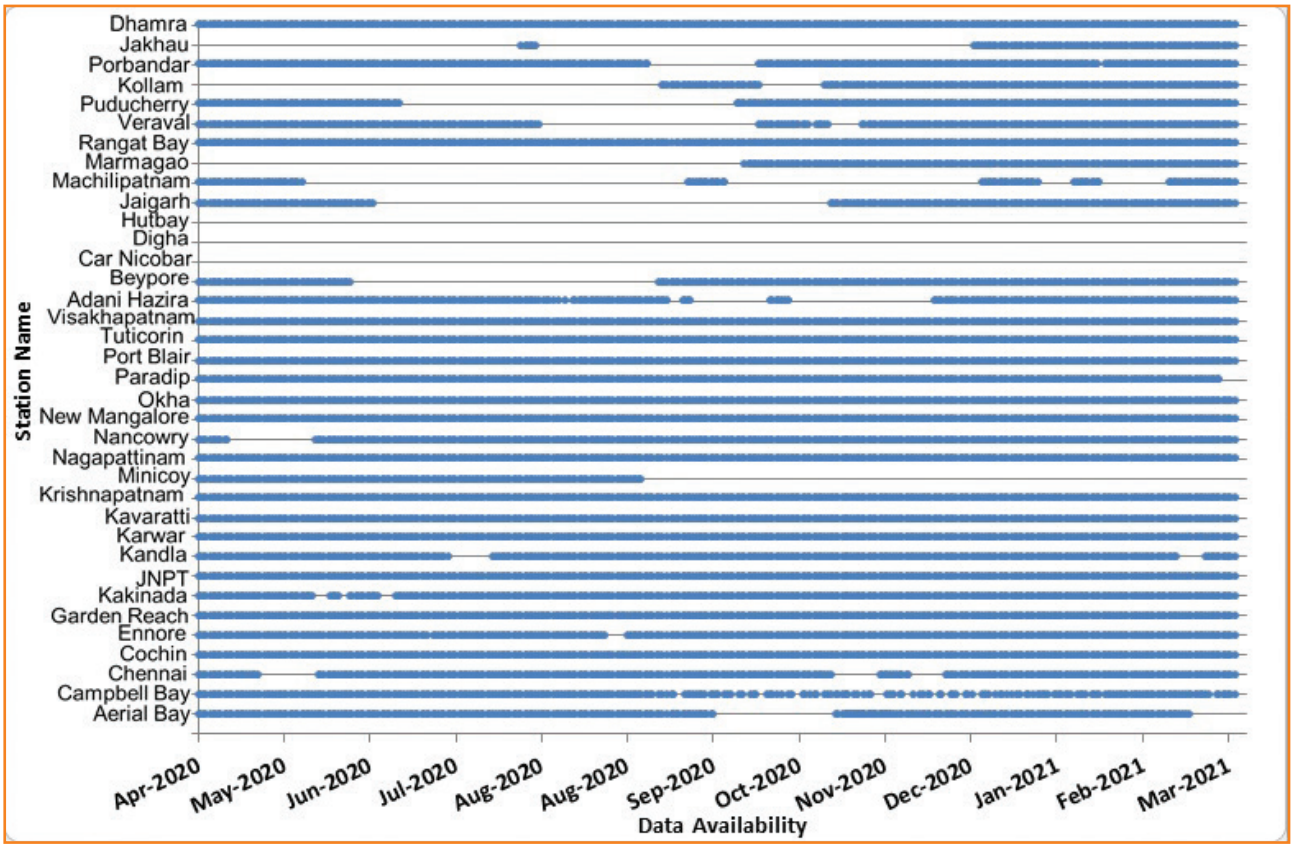
6.2.3 Tide Gauge Network

INCOIS tide gauge network of 36 stations, established along coasts of Indian mainland and islands, to monitor the sea level, was sustained. The real-time data from 36 tide gauges were



Schematic showing the locations of the Tide Gauges along the Indian coasts

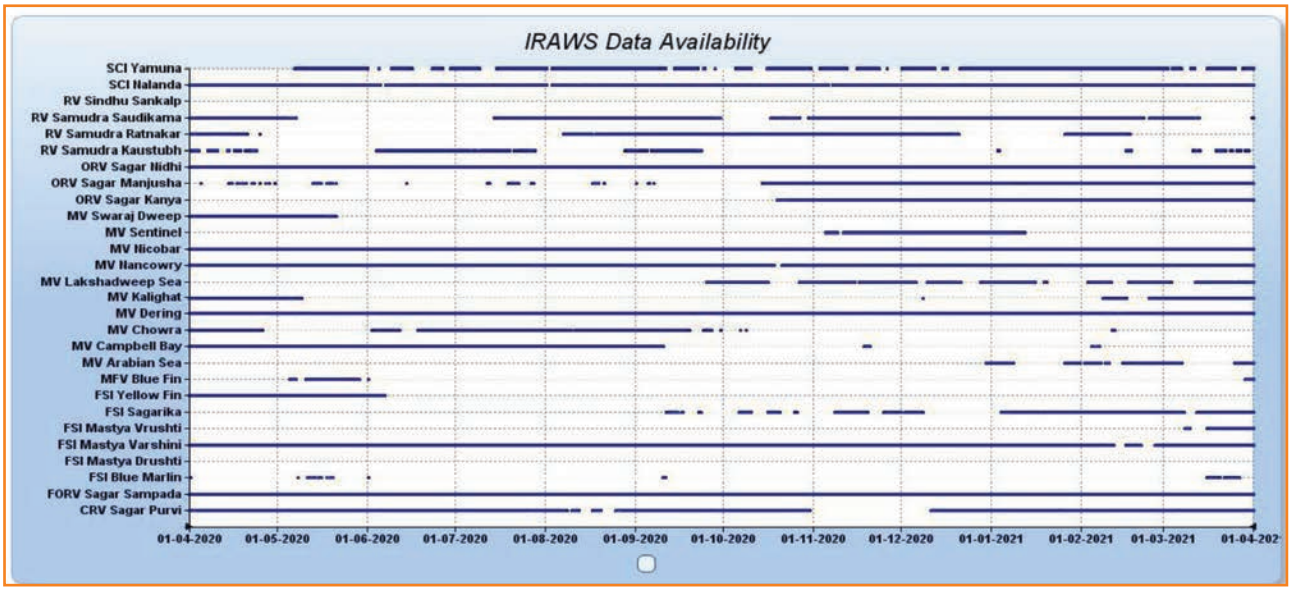
received at ITEWC through INSAT and GPRS mode of communication. In addition, INCOIS also received near-real time data from tide gauges installed and maintained by other countries. INCOIS also shared the real time data from eight tide gauges (Chennai, Kochi, Nancowry, Port Blair, Visakhapatnam, Minicoy, Marmagao and Veraval) with IOC Sea Level Monitoring Facility. During the year 2020-21, 57 regular maintenance visits, 26 breakdown visits and calibration of sensors at five locations were carried out to ensure the availability of quality data.



Schematic showing sea level data availability from tide gauge network during April 2020-March 2021.

6.2.4 Automatic Weather Stations (AWS) Network

The network of 34 Automatic Weather Station (AWS) systems, installed on different Government of India vessels, operating in the Indian Ocean region was sustained in collaboration with NCPOR, NIOT, GSI, NIO, CMLRE, SCI, FSI, LDCL and NHO. The AWS system is integrated with different sensors to measure true wind speed and direction, air temperature, humidity, long wave radiation (LWR), short wave radiation (SWR), rainfall, SST, turbidity, chlorophyll and barometric pressure. The measured data is transmitted to INCOIS through INSAT in real time mode. During 2020-21, 88 regular maintenance visits were carried out to ensure the availability of quality data along with two new installations onboard MV Lakshadweep Sea and MV Arabian Sea. However, the data availability was affected due to the pandemic and lock down constraints. Calibration was also performed for LWR (6 Nos), SWR (6 Nos), Wind (8 Nos), BARO (4 Nos), AT/RH (10 Nos) and RG (6 Nos) sensors. In addition, permissions were obtained from LDCL for installation of AWS in vessels plying off Lakshadweep region and the Department of Port, Shipping and Aviation for installation of AWS at the port control.

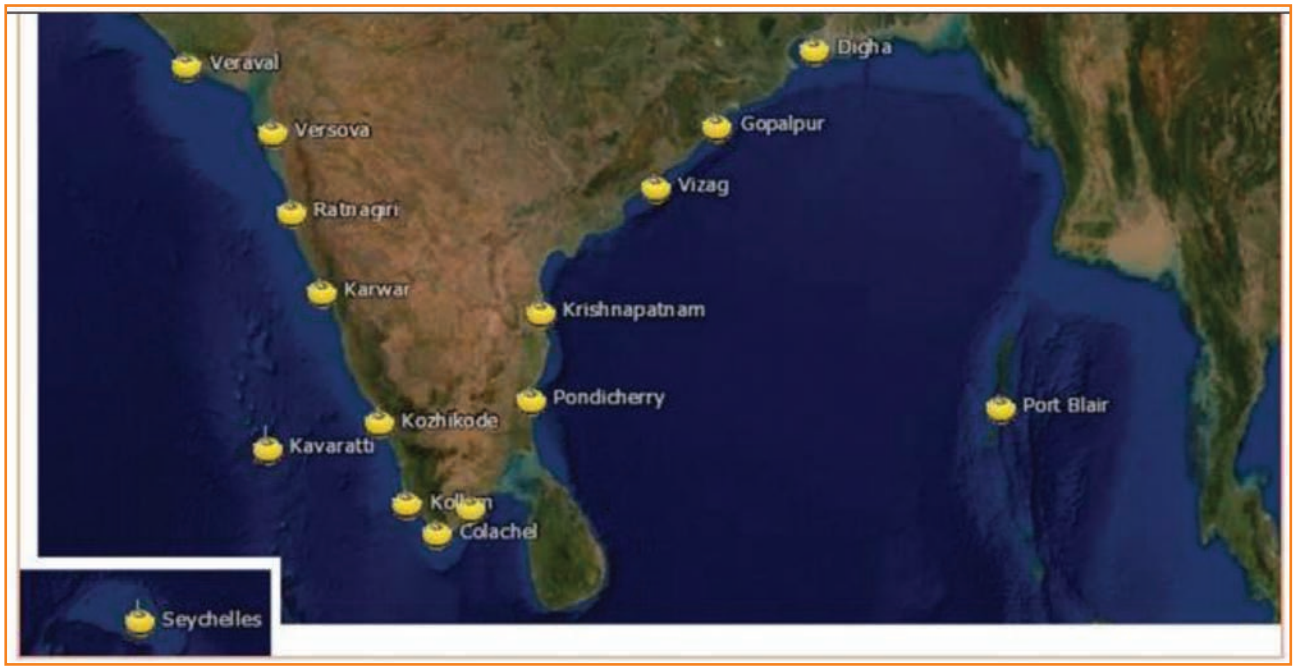


Schematic showing the AWS data availability during April 2020 to March 2021

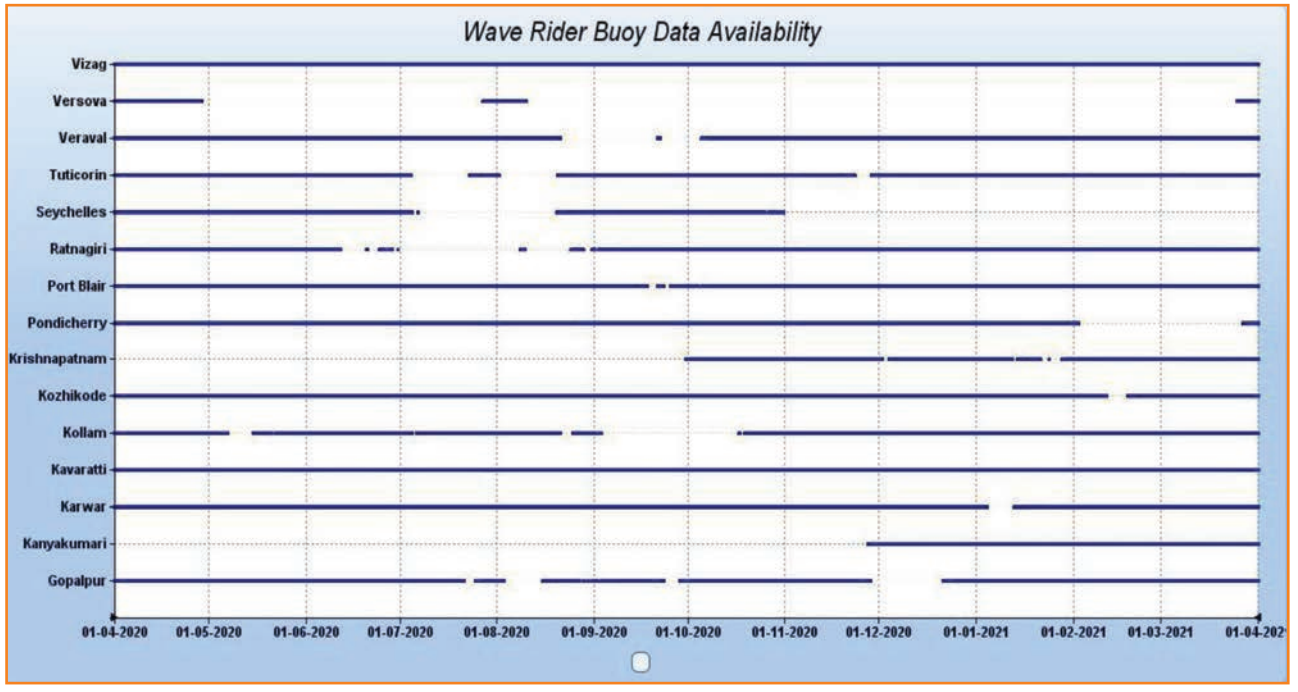
Schematic showing the installation of AWS onboard MV Lakshadweep Sea and MV Arabian Sea

6.2.5 Wave Rider Buoy Network

The network of 16 Wave Rider Buoys (WRB) established for monitoring the state of the ocean as well as to perform online/offline validations of the ocean state forecasts was sustained. The WRB network was maintained in collaboration with various research and academic institutes. Regular calibration of the systems at recommended intervals were performed to maintain the quality of the data from these *in-situ* observatories. The network was upgraded with new generation WRBs at five locations (Gopalpur, Visakhapatnam, Krishnapatnam, Kollam and Karwar) measuring current and air temperature. The new buoys were aligned with Coastal ADCP locations for fine tuning of coastal current forecasts. During the year 2020-21, five new deployments, eight drifts, 12 regular maintenance, 16 redeployment and three data failure inspections were carried out to ensure the availability of quality data.



Schematic showing the WRB deployment locations



Schematic showing the WRB data availability during April 2020 to March 2021

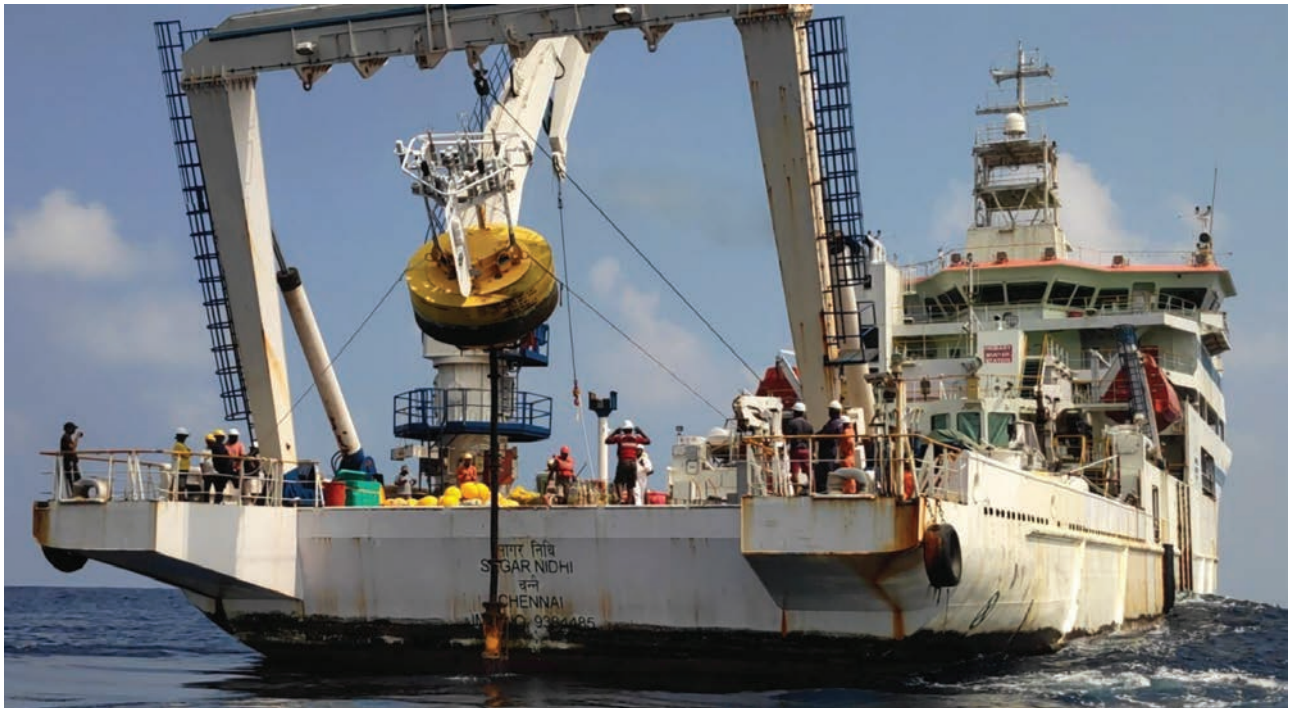
6.3 Observations for Process Studies

6.3.1 INCOIS flux mooring

As a part of Ocean Mixing and Monsoon (OMM) program, funded by MoES, under Monsoon Mission, INCOIS deployed flux mooring with support from Woods Hole Oceanographic Institution (WHOI), USA on 23 May 2019. The mooring is first of its kind deployed in the Indian Ocean to understand and document the air-sea interaction, upper ocean processes and dynamics of freshwater in the North Bay of Bengal (17.804°N, 89.504°E).

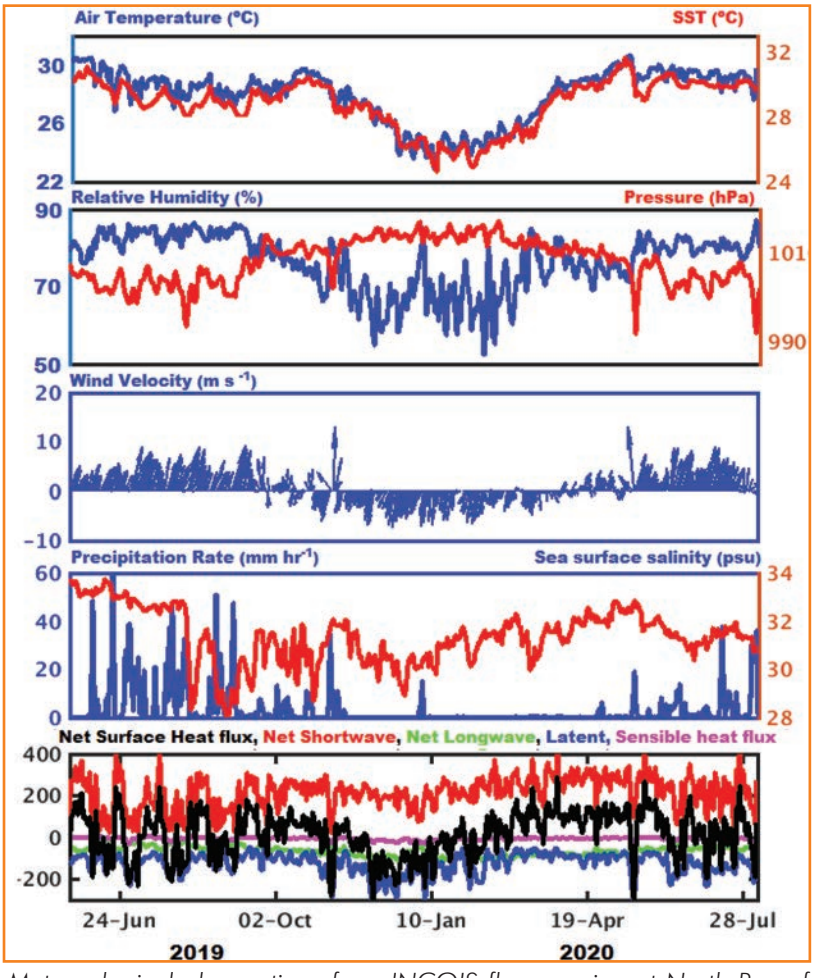
INCOIS flux buoy mooring is heavily equipped with surface marine meteorological sensor package

which comprises of 2 sets of ASIMET (Air Temperature, Barometric Pressure, Relative Humidity, Sonic Wind Module, Short Wave Radiation, Long Wave Radiation, Precipitation, Sea Surface Temperature and Sea Surface Salinity; with 1 min sampling and real-time data transmission at 1 hour interval)



Recovery of INCOIS Flux mooring onboard ORV Sagar Nidhi on 07 October 2020

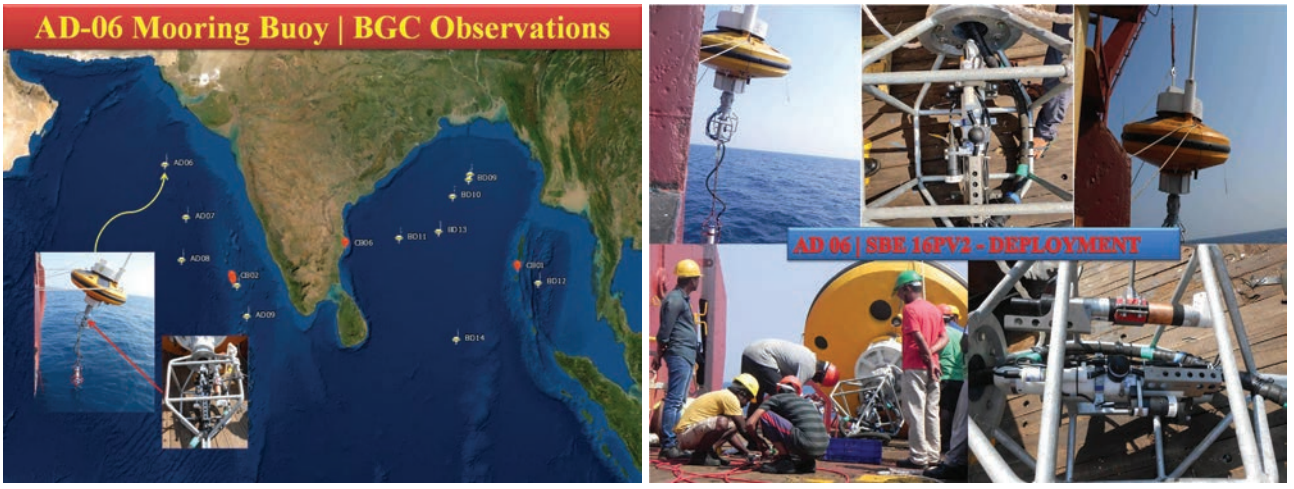
and sub-surface oceanographic sensors that comprises of 34 microcats temperature (10 no's), Temperature and conductivity (24 no's), current meters (3 no's) and current profiler (2 no's). Further, Direct Covariance Flux System (DCFS) developed by WHOI (fitted with Sonic Anemometer, Hygrometer, a controller and motion packages) mounted on the tower acquires data at 20 Hz sampling and real-time data transmission at 1 hour intervals. The Flux Mooring was successfully retrieved in the prevailing COVID-19 pandemic situation with joint collaboration between INCOIS and NIOT scientists on 07 October 2020, after successful data acquisition for 16 months.



Meteorological observations from INCOIS flux mooring at North Bay of Bengal

BioGeoChemical measurement over AD-06 Mooring in Arabian Sea

As part of Bio Geo Observation, SBE16PlusV2 sensor measuring temperature, conductivity, chlorophyll, backscattering and dissolved oxygen was deployed on AD-06 mooring at a depth of 1.5 m. The system was deployed in the northeastern Arabian Sea (18°29.89N and 67°27.33E) on 31 October 2018. The instrument recorded samples for every 3 hours. The system was re-deployed on AD-06 mooring on 24 November 2020.



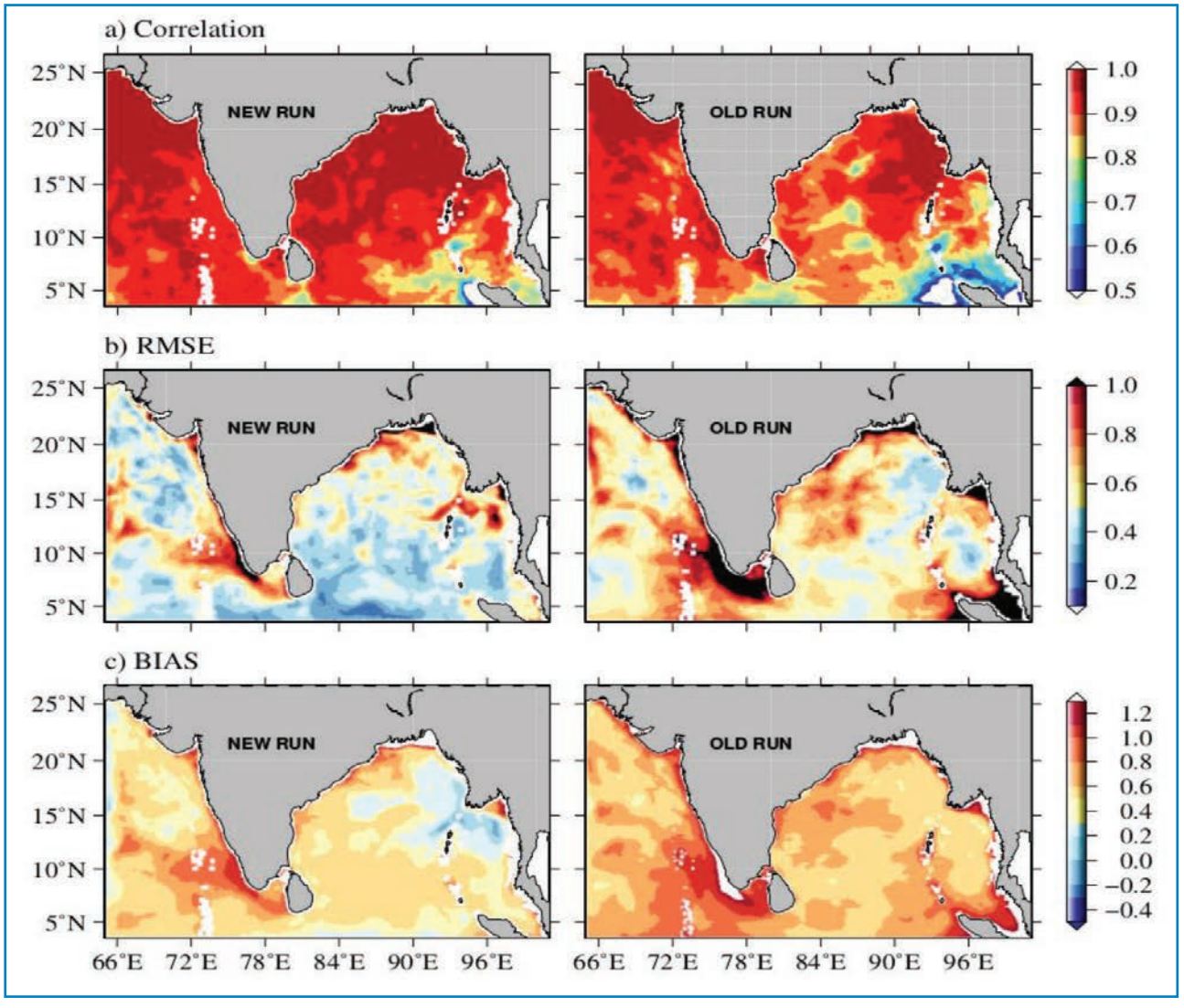
Deployment of SBE16Plus V2 Sensor onboard AD-06 Mooring

7. Ocean Modelling And Data Assimilation

7.1. Numerical Ocean Modelling for Operational Services

7.1.1 Updation of high-resolution operational model for the North Indian Ocean - NIO-HOOFS

INCOIS uses a very-high-resolution ocean general circulation model based on Regional Ocean Modelling Systems (ROMS), for the operational forecast of circulation and other oceanic parameters near the coastal region around India, called NIO-HOOFS. The horizontal grid-resolution of this model is 1/48° (~2.3 km) and it has 40 sigma levels in vertical. Daily-averaged values of tracer, momentum and sea level height anomalies fields from the LETKF-ROMS were applied at the open boundaries to pass the exterior forcing into the model domain. Wind and fluxes obtained from NCMRWF-Unified Model (NCUM) were used for atmospheric forcing. Since this very-high resolution model does not include data assimilation, it was planned during the development of NIO-HOOFS that initial conditions should be updated using LEKF-ROMS (RAIN) every two-year. As planned, NIO-HOOFS were updated using the initial condition derived from the LETKF-ROMS (RAIN) on

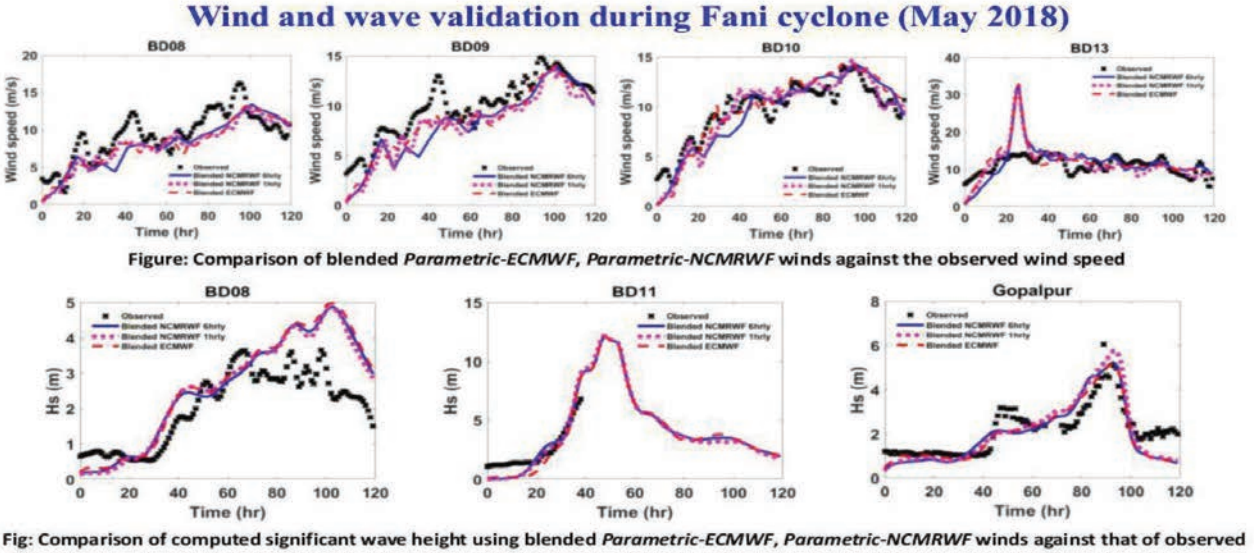


Comparison of a) Correlation, b) RMSE and c) BIAS for the old and new runs from NIO-HOOFS with observations (GHRSST) for the period of February-May 2020.

01 January 2020. The updated model run was carried out for seven months and a new initial condition for August 2020 was prepared. The model update with the new initial condition is successfully completed and simulations were compared with observations. The comparison of simulated Sea Surface Temperature (SST) with observation showed improvements in the updated NIO-HOOFS run. The updated model is implemented for operational use and presently the system is running in operational mode and generating forecasts of ocean circulation parameters in the north Indian Ocean.

7.1.2 Storm surge modeling

Towards the improvement in forcing the storm surge model, experiments were conducted in which the ADCIRC model was forced with blended wind, in which wind data from NWP were blended with parametric winds. Intercomparison of blended wind using NCMRWF and ECMWF was done and found that results from both of the wind fields were on par with each other. The prime advantage of using NCMRWF winds is that this wind field has a surface pressure value that was missing in ECMWF wind fields (which INCOIS is obtaining on a daily basis). Hence, the surface pressure value is empirically estimated using ECMWF wind fields. Ensemble based storm surge computations were performed to set up a probabilistic storm surge (P-Surge) forecasting system. Total 93 ensembles were identified for each case study. Each ensemble member will be required at least 128-256 minimum number of processors and hence, 11904 – 23,808 total number processors are needed for the real-time P-Surge forecasting.



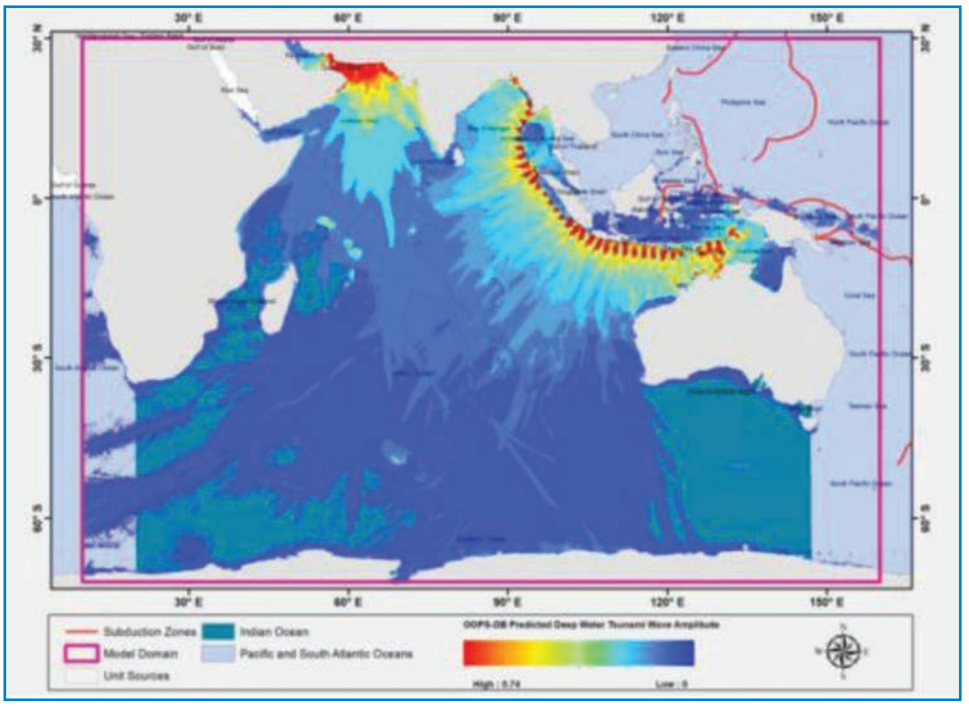
Spatial and temporal resolution		
	Spatial	Temporal
ECMWF	0.25°X0.25°	3 hr
NCMRWF 6 hr	0.125°X0.125°	6 hr
NCMRWF 1 hr	0.1758°X0.1172°	1 hr

Validation of wind and wave parameters simulated by the storm surge model setup during the passage of cyclone Fani

7.1.3 Operational Quantitative Tsunami Numerical Modeling

The backbone of entire tsunami warning center operations - Open Ocean Propagation Scenario Database (OOPS DB) generated by TUNAMI-FF model was successfully configured for OpenDAP

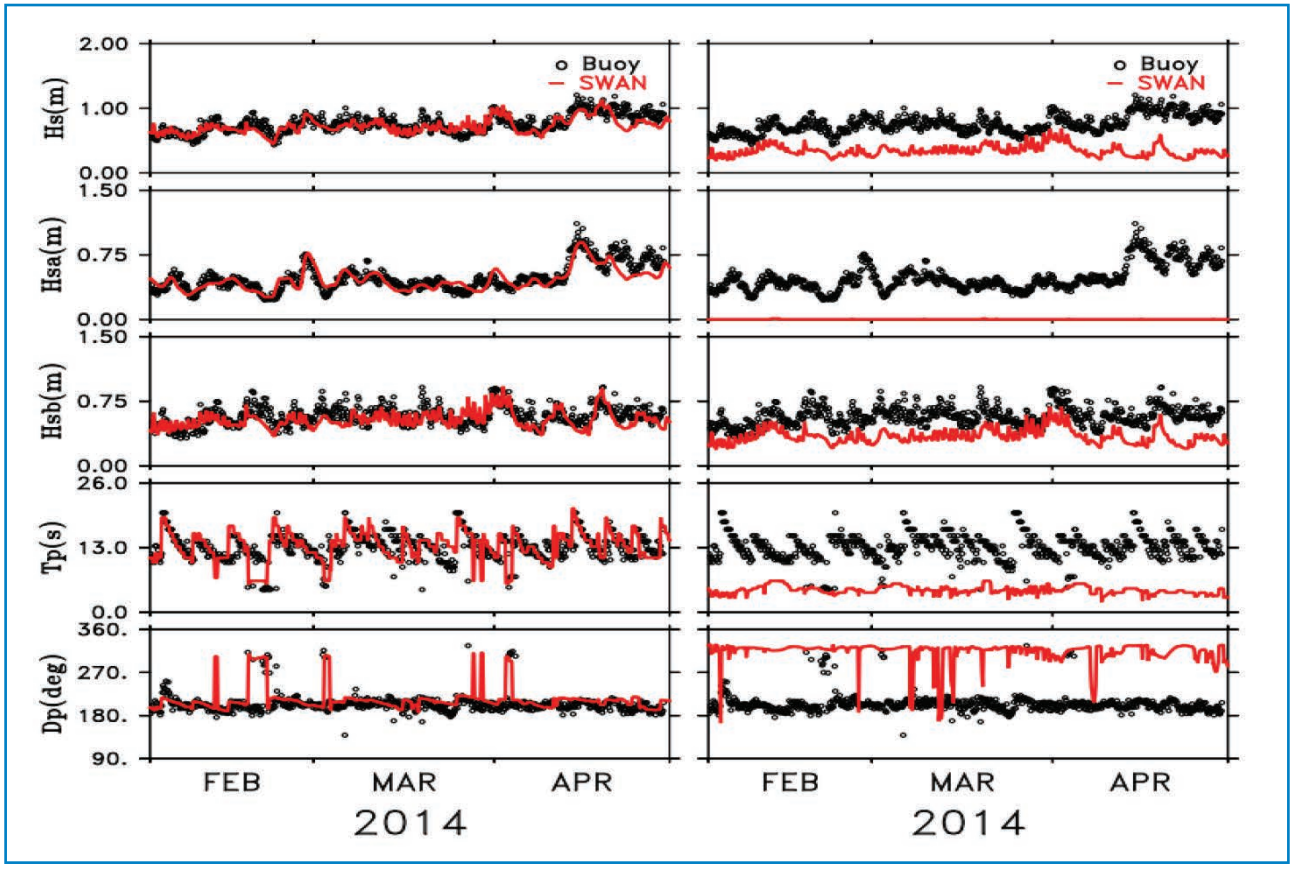
servers. Sensitivity analysis studies were carried out for seismic parameters viz., Strike, Dip and Rake as well Fault length, width, slip and focal depth using TUNAMI-FF for the numerical model output on coastal regions. ITWC has also completed the proof-of-concept for the application of neural networks for estimating Maximum wave deep water amplitudes, travel times and tsunami profiles at specific locations using OOPS DB scenarios for sources in the Andaman and Nicobar Islands.



Operational OOPSDB covering both subduction zones in Indian Ocean

7.1.4 Coastal wave modeling using SWAN model

Integrated SWAN+WAVEWATCH III model was operationalized for the east and west coasts of



Wave parameters simulated by SWAN+WAVEWATCHIII setup is compared with the insitu observations from wave rider buoy at Pondicherry.

India using unstructured mesh for the SWAN model. The performance of this system is much better than the stand-alone SWAN. The modeling system was tested for a number of cyclonic cases and found to be performing reasonably well.

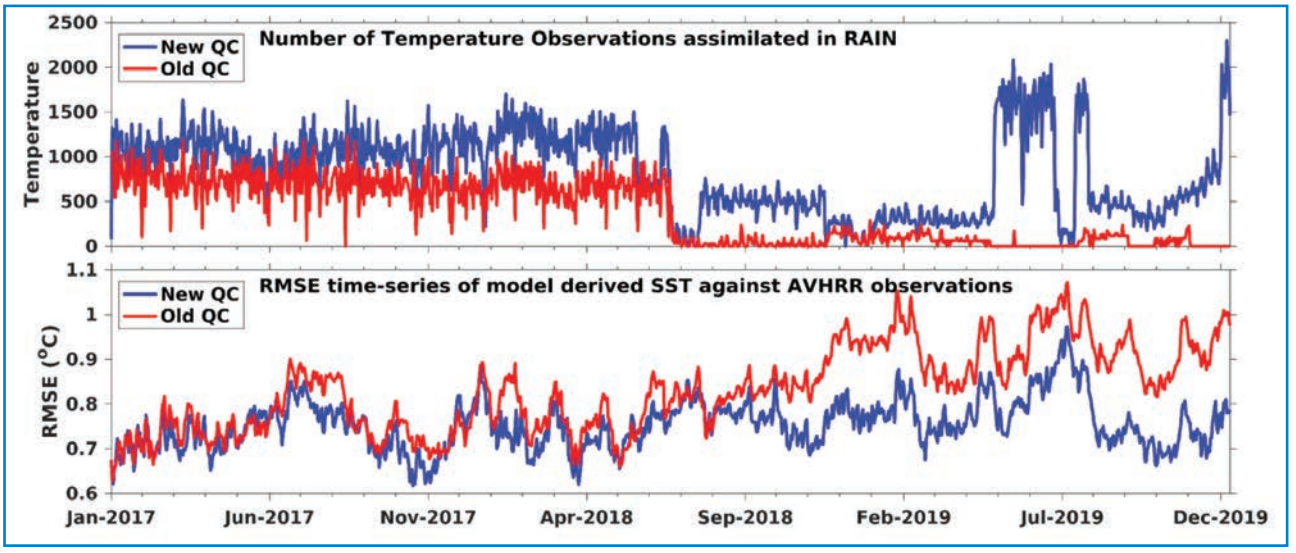
Table: Model error statistics for different tropical cyclones

Cyclone/parameter	BIAS	RMSE	R	SI
ROANU (Pondicherry, Krishnapatnam, Vizag, Gopalpur)				
Hs (m)	-0.106	0.39	0.89	0.22
Tp (s)	-0.72	2.23	0.83	0.21
KYANT (Pondicherry, Krishnapatnam, Vizag)				
Hs (m)	0.11	0.17	0.83	0.23
Tp (s)	-0.65	1.95	0.58	0.18
NADA (Pondicherry, Tuticorin)				
Hs (m)	0.02	0.17	0.97	0.14
Tp (s)	0.09	1.64	0.68	0.23

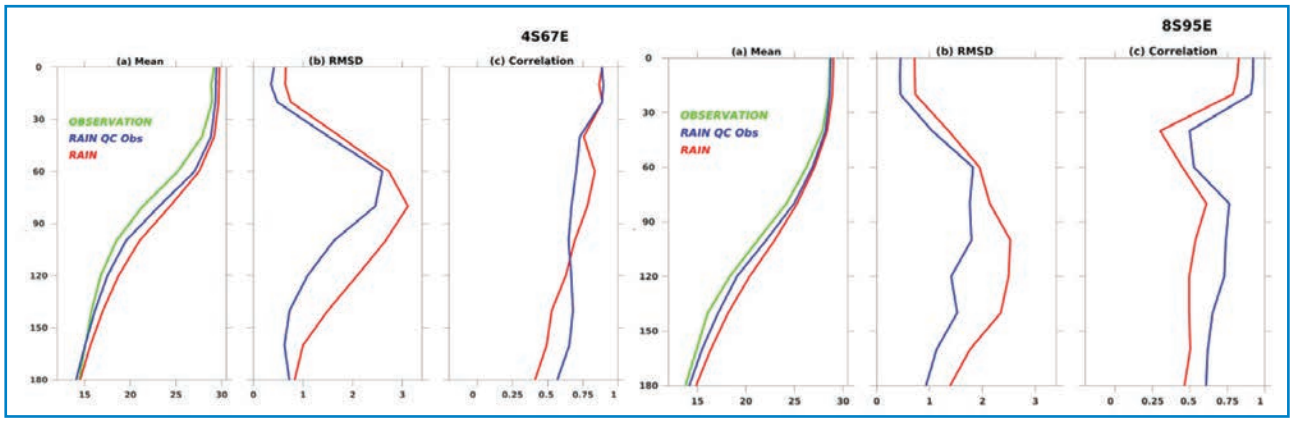
7.2. Data Assimilation

7.2.1 Regional Analysis of Indian OceaN (RAIN)

INCOIS is providing regional analysis based on assimilation scheme LETKF interfaced with ROMS. RAIN is operational at INCOIS, which assimilates sea surface temperature (SST) along with temperature and salinity profiles. It was identified that the observations being assimilated in RAIN had certain quality issues such as duplicate profiles, data gaps and also suffered from lack of quality checks. In this regard, INCOIS developed an improved quality control (QC) module to clean the observations before feeding them into the assimilation and QC module is integrated with the operational run. The quality checks include the removal of incomplete observations, duplicates and vertical inconsistency. The standard deviation check was also improved using the climatological means of available observational data sets. With these modifications in the QCs, the Regional analysis produced by RAIN has improved considerably.



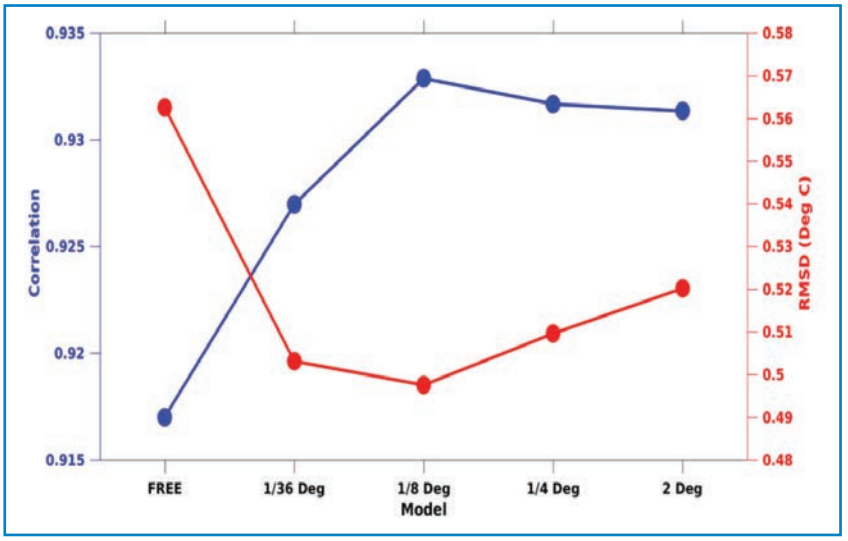
Top panel shows the time series of the number of temperature observations assimilated in RAIN. Bottom panel shows the time series of the domain averaged RMSE of SST (°C) derived from RAIN (New QC-blue; Old QC-red) against AVHRR observations.



Comparison of temperature estimates through mean vertical profile, root-mean-squared error and correlation with respect to RAMA observations at two locations - 4°S, 67°E (left panel) and 8°S, 95°E (right panel). RAIN with new QC (blue) showed improved correlation and reduced RMSD at both surface and subsurface.

7.2.2 Data Assimilation of SST in NIO-HOOFS

After successfully implementing data assimilation in the operational basin-wide Indian Ocean model, INCOIS is in the process of translating this success into the operational high resolution (1/48°) model (NIO-HOOFS). A LETKF scheme was developed and coupled (offline) to the NIO-HOOFS model wherein satellite track data of sea surface temperature (SST) obtained from GHRSST, along with temperature and salinity profiles, were assimilated. Since the SST data is of very fine resolution, it is coarse-grained and fed into the assimilation system. Multiple sensitivity experiments were conducted varying the coarse-graining length-scale to arrive at the optimal scale of coarse-graining length scale. The results of the ongoing sensitivity experiments are very promising. Coarse-graining the SST observation over a length scale of 13 km (1/8°) showed the least RMSE and the highest correlation.



Correlation and RMSE in the SST simulation in the free and data assimilated in NIO-HOOFS. Along track GHRSST with different coarse graining length scales are represented here.

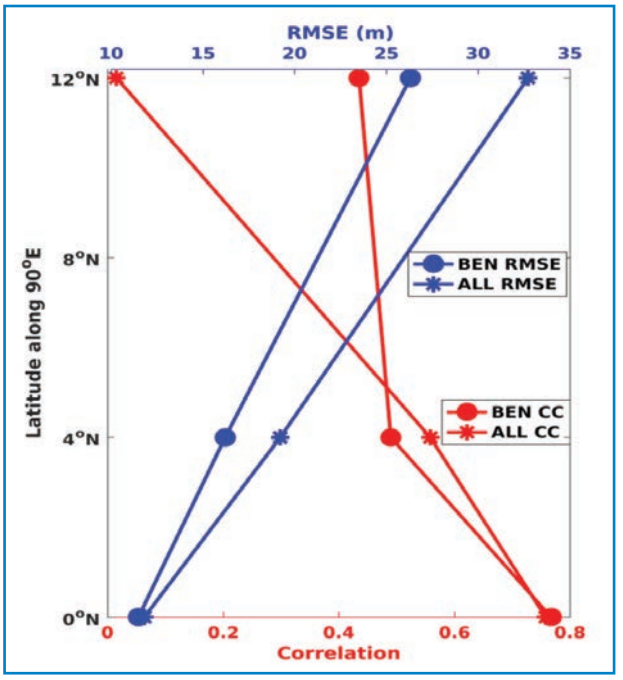
7.2.3 Ensemble forecast sensitivity to observations in Bay of Bengal

Ensemble forecast sensitivity to observations (EFSO) is a tool that can identify whether an observation can improve (beneficial observation) or degrade (harmful observation) the analysis. However this method has never been tested in ocean data assimilation systems. INCOIS attempted to use EFSO with RAIN (LETKF-ROMS) and came up with a specific formulation of EFSO that works well in the Bay of Bengal, which is known to be one of the most stratified regions with shallow mixed layer depth in the entire Indian Ocean. Assimilation of only the beneficial observations obtained from EFSO in LETKF-ROMS instead of all the available observations gives encouraging results.

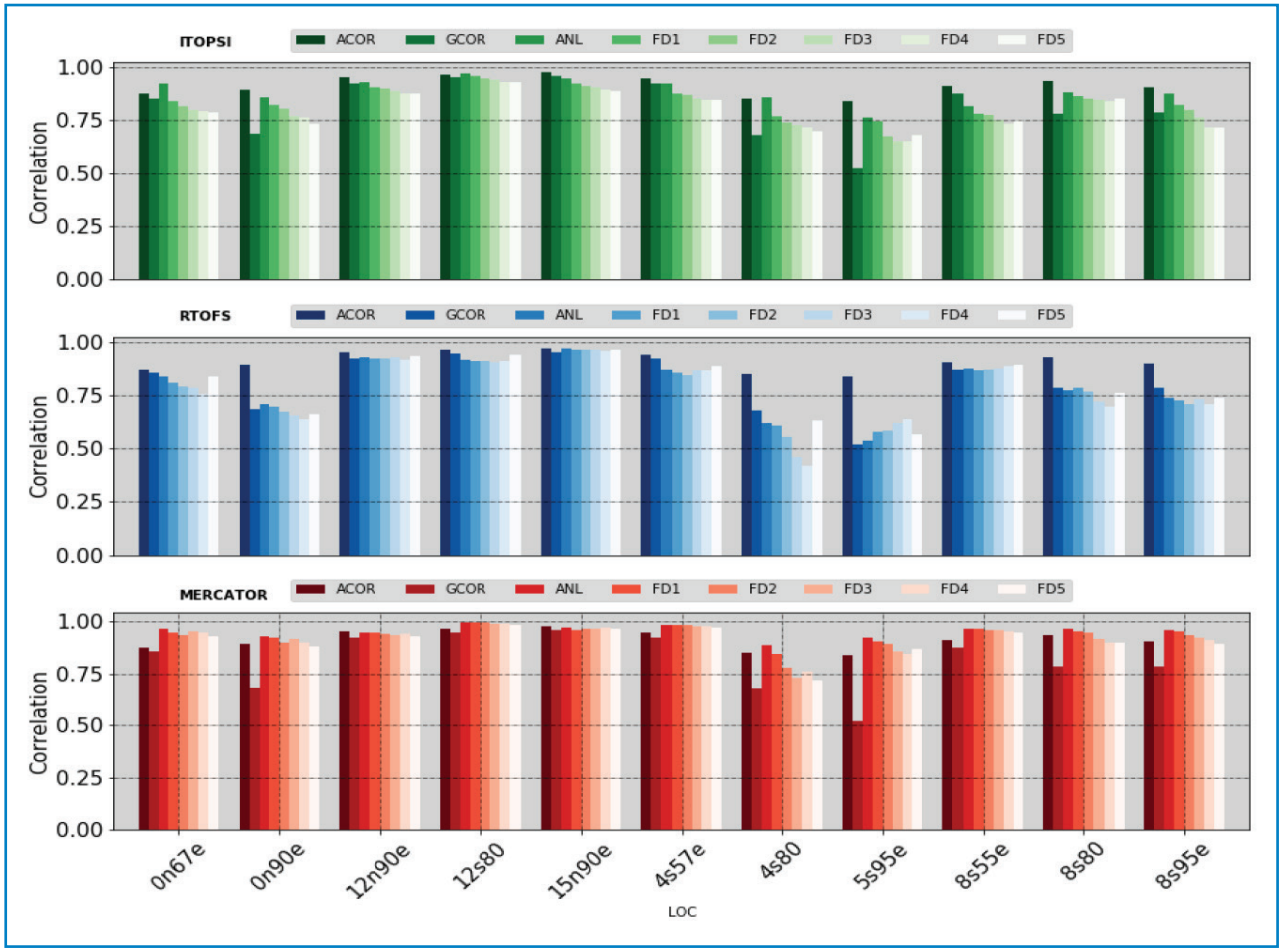
The simulation of the thermocline depth was improved considerably in higher stratified regions (head Bay), while the overall surface currents (top 30 m) were improved in the Bay.

7.2.4 Data Assimilation in HYCOM

Under HYCOM DA project's initial phase, data assimilation was carried out using surface satellite observations, along with temperature and salinity profiles from the Argo floats. At that stage temperature and salinity observations from various buoy networks were used for validation and they were not assimilated. Under the second phase of development during the current year, observations from other buoy networks were added to the assimilation scheme. Several experiments as part of INCOIS responsibility during the reporting year, in a parallel setup of



Correlation and RMSE in the SST simulation in the EFSO simulations. Differences in the correlation and RMSE at different latitudes along 90°E with all observations and only beneficial observations are represented in the diagram.

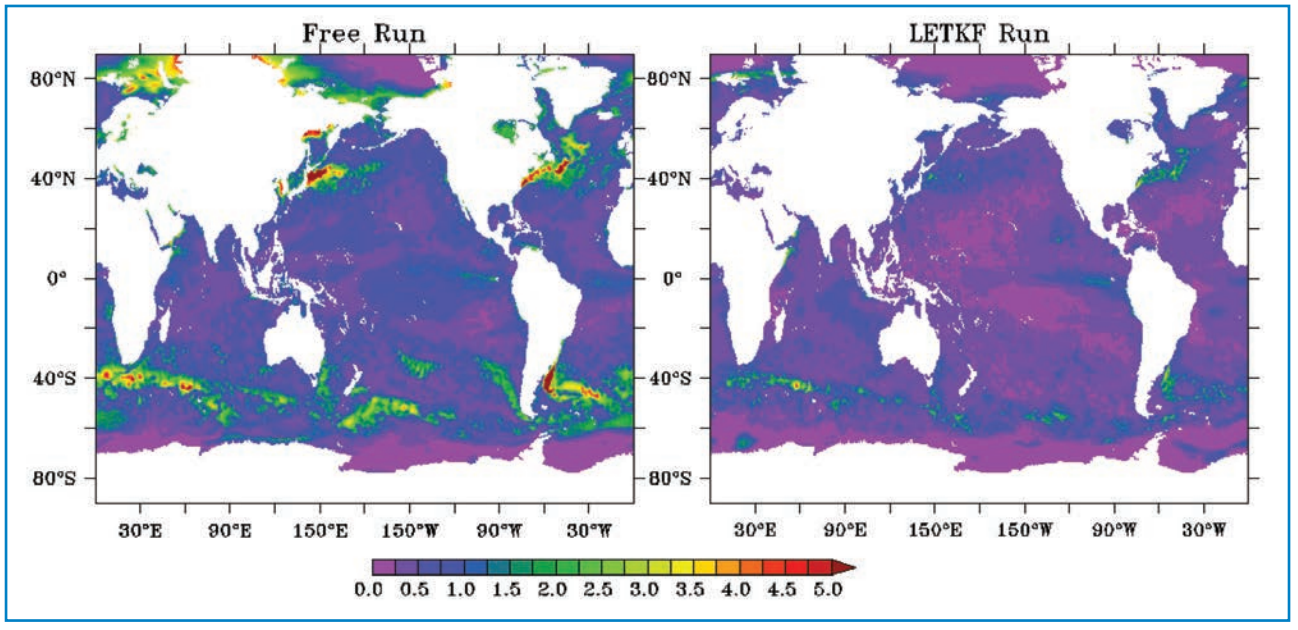


Comparison of correlations of analysis and 5 day forecasts from INCOIS HYCOM (ITOPSI), NCEP HYCOM (RTOFS) and Nemo of Mercator (MERCATOR) with RAMA buoys. Correlation of AVHRR and GHRSST (used in DA) with RAMA buoys are also presented as ACOR & GCOR

HYCOM and operational implementation of the upgraded system is in progress. The simulated parameters from INCOIS-HYCOM were compared with the same of other major international forecast centres, and most of them were comparable with other agencies.

7.3 Preparatory works in Ocean Modeling for Deep Ocean Mission

As a part of DOM of MoES, INCOIS is developing an ocean modeling system to project the sea level changes along the coast of India in seasonal to decadal timescales. This system consists of a suit of global and regional ocean models, forced by projected atmospheric forcing from CMIP. Accordingly, a high resolution regional (1/20°) and global (1/8°) OGCM based on MOM5.1, was configured at INCOIS. The global OGCM will provide initial and lateral boundary conditions to the regional OGCM. Hence, to generate the initial and lateral boundary conditions, for the regional Indian Ocean, as accurately as possible, LETKF based data assimilation scheme implementation in global MOM5.1 configuration is in progress. Initial analysis of the simulations from the assimilation system in global MOM5.1 shows a decrease in temporally averaged root mean squared error (RMSE) when compared to the free run. The assimilation also improved subsurface temperature and salinity profiles when validated with in situ moorings.



Spatial RMSE (in °C) with respect to OISST averaged over the period of May 2018 to Dec 2018. Left Panel marks the RMSE in free run and the right panel represents the LETKF run. Left Panel marks the RMSE in free run and the right panel represents the LETKF run.

In order to identify the most suitable atmospheric forcing fields to integrate the climate projection models, simulations of 29 models participating in CMIP6 exercises were analyzed. This analysis suggests that 4 models (CMCC, CNRM, HadGEM3 and MPI-ESM's) have least bias in the historical simulations of sea level in the Indian Ocean. Further analysis suggests that the models which simulate better wind stress curl over the basin are generally simulating improved dynamical sea level over the basin.

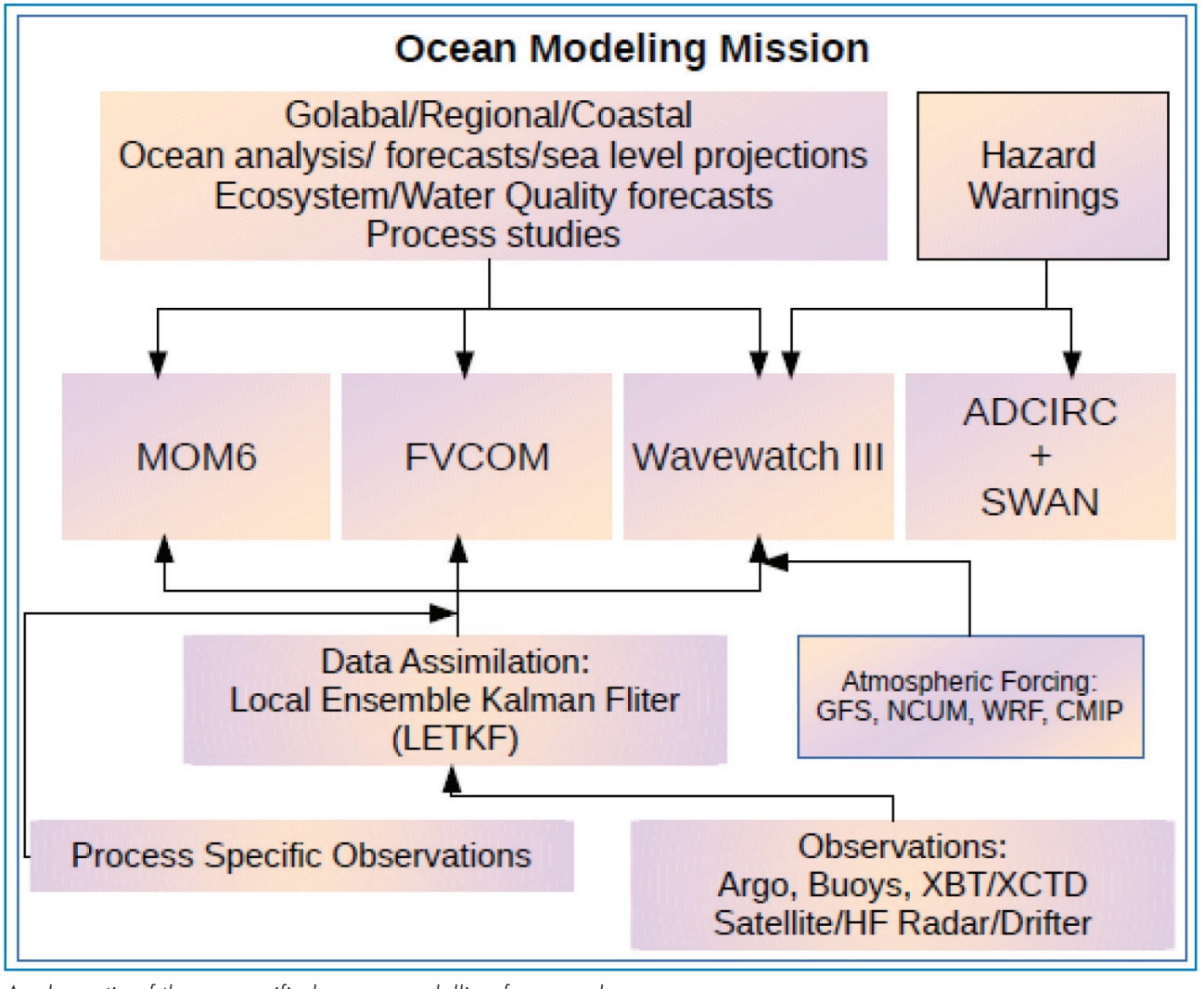
Dynamic mean sea Level bias for the CMIP6 models during the altimeter observation period between 1993-2015. MMM represents the multi model mean bias with respect to altimeter observation for the said period.

7.4. Ocean Modelling Mission- A focused mission to develop a unified operational ocean forecast system

INCOIS, being the nodal organization to provide operational oceanographic services, is actively involved in the numerical modelling of ocean circulation, waves, tsunami and storm-surge as well as regional coupled ocean-atmosphere models for the prediction of track and intensity of tropical cyclones. Taking the responsibility to provide ocean analysis, reanalysis and forecasts, INCOIS has been spearheading the research in numerical ocean modelling and ocean data assimilation in India for the past several years. This has led to the successful implementation of the High-resolution operational Ocean Forecast and reanalysis System (HOOFS), in which a suite of configurations of ROMS- to model the regional and coastal ocean processes- are setup and integrated with the data assimilation scheme, known as the LETKF. This configuration is used to generate RAIN and short term forecasts of ocean circulation parameters. INCOIS also uses the Global Ocean Data Assimilation System (GODAS), in which a ocean observations are assimilated to the global configuration of Modular Ocean Model (MOM4p0d) using 3DVAR method to generate global ocean analysis, which is extensively used for providing initial conditions for the Monsoon Mission models. GODAS is used to provide open boundary conditions to the RAIN. Another ocean analysis and forecast system being run at INCOIS is based on the HYCOM model and data assimilation using the Central Statistical Interpolation Scheme. HYCOM configuration for the global ocean at a lower resolution provides boundary conditions for the Indian Ocean configuration of HYCOM. Forecasts and early warning of wave parameters are being provided by the global configuration of WAVEWATCH III (WWIII) and the regional configuration of SWAN

models. For the early warning of swell surges, (Simulating Waves Near shore) SWAN model is nested within the Advanced Circulation Model (ADCIRC) model and takes boundary conditions from WWIII. Storm surge forecasts are generated using ADCIRC model configuration. Operational tsunami advisories in the Indian Ocean are provided based on a large database of pre-run scenarios based on TSUNAMI-N2 model.

In order to optimise the models and resources used in INCOIS for the operational ocean forecast/ analysis activities and to make a seamless prediction system from global to regional domains, it was decided to have a revisit on the ocean modelling efforts of INCOIS. Based on extensive review of the global systems and in-house capabilities, it has been decided to make use of MOM6 with LETKF data assimilation scheme to generate the operational analysis and forecast system for the ocean circulation parameters in the global as well as regional ocean. For building the forecast system for coastal waters and estuaries, FVCOM- a finite volume, unstructured grid ocean circulation model will be used. ADCIRC+SWAN will be continued for operational storm/swell surge forecasts. ADCIRC will be used to issue real time operational Tsunami and associated coastal inundation warnings. Wavewatch-III will be used for the wave forecasts in the global and coastal waters. An Ocean Modelling Mission, which includes 8 work packages, has been initiated in INCOIS in January 2021. A detailed implementation plan of the project is also now prepared. It is expected that the operational system will be ready by December 2025.



A schematic of the new unified ocean modelling framework

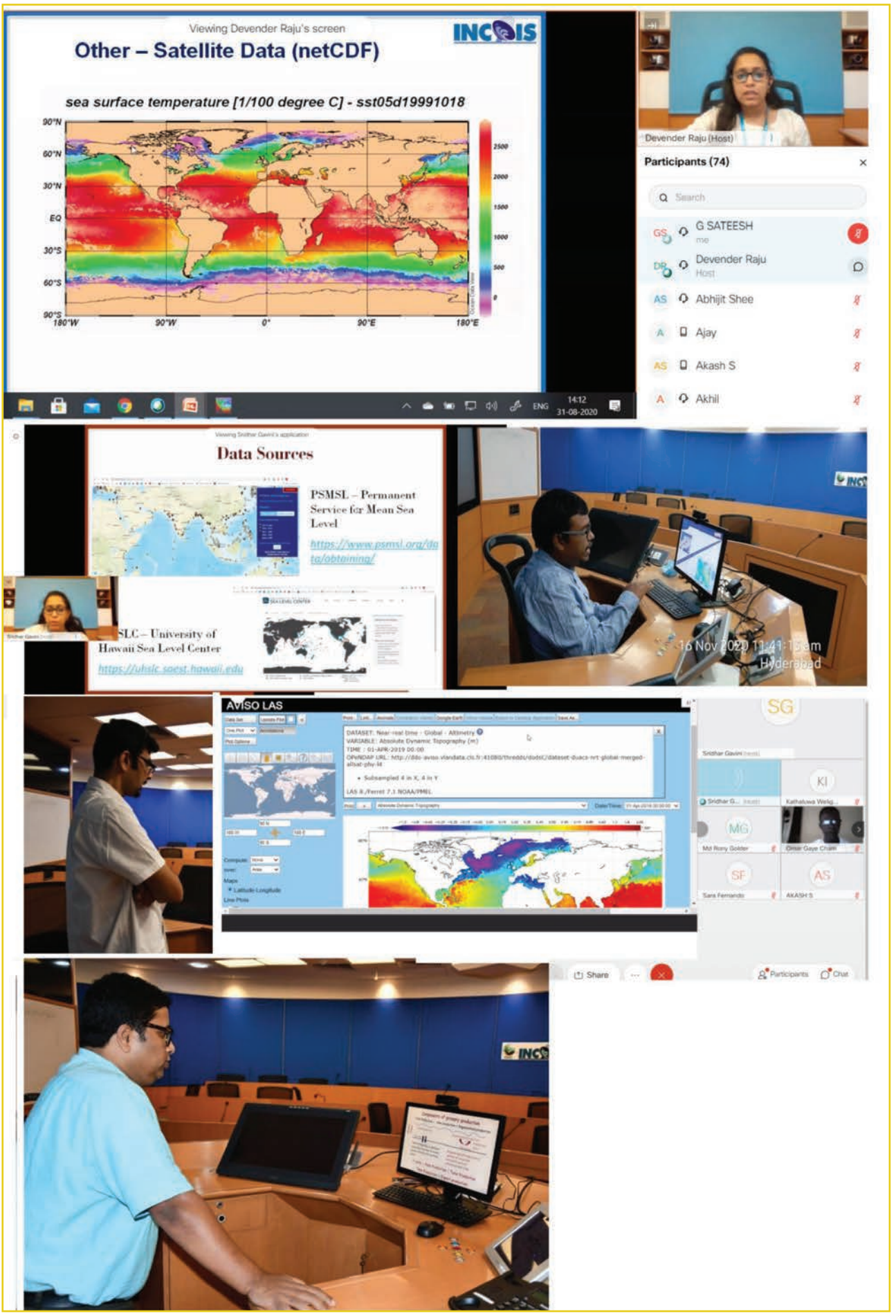
8. Outreach and Capacity Building

8.1 Courses conducted by ITCOocean

During the past year, owing to Covid-19 all the planned face-to-face training courses were cancelled. ITCOocean organized six online training courses and two (2) webinars, which covered various topics of operational oceanography. Altogether 2279 persons were trained during the reporting period, of which 1615 (Male: 1009, Female: 606) are from India and 664 (Male: 405, Female: 259) are from 83 other countries.

Details of the training courses conducted during the year and the brief details of them are given below:

- Training on "Discovery and Use of Operational Ocean Data Products and Services" held during 31 August - 04 September 2020. The focus of this training was on operational activities, various data and data products, outputs from INCOIS services, how to download them and use software to visualize.
- Training on "Understanding Sea Level: Data analysis and applications" held during 12-14 October 2020. This course demonstrated the usage and applications of sea level data for scientific research and is a mix of practical and theory highlighting on the active research areas of sea level science.
- Training on "Fishery Oceanography for future professionals", held during 16-20 November 2020. This course was devised, to familiarize the young professionals in the Indian Ocean-rim (IOR) countries with the latest developments in the field of fisheries.
- Webinar: "New Rhythms in the Tropical Indian Ocean", held on 28 December 2020.
- Specialized training on "Oil Spill advisory system", held on 30 December 2020. This course was exclusively conducted for the benefit of Coast Guard officers based on a special request from Indian Coast Guard.
- Training on "Fundamental Statistics for Oceanographers using Excel", held during 4-7 January 2021. The training was envisaged to teach all the possible statistical techniques that can be implemented with Excel to analyze and visualize the data.
- Webinar: "Indian Argo program - Past, Present and Future", held on 26 February 2021.
- Training on "Visualization of Marine Met data (using FERRET)", held during 15-19 March 2021. The course demonstrated the use of open-source software FERRET for generation of NetCDF data and visualization of various types of plots, save and reuse them at a later stage. The course was designed to be a mix of both practical and theoretical sessions.



Snaps of the online training programs conducted by ITCOocean

8.2 UNESCO - Ocean Teacher Global Academy 2 (OTGA2)

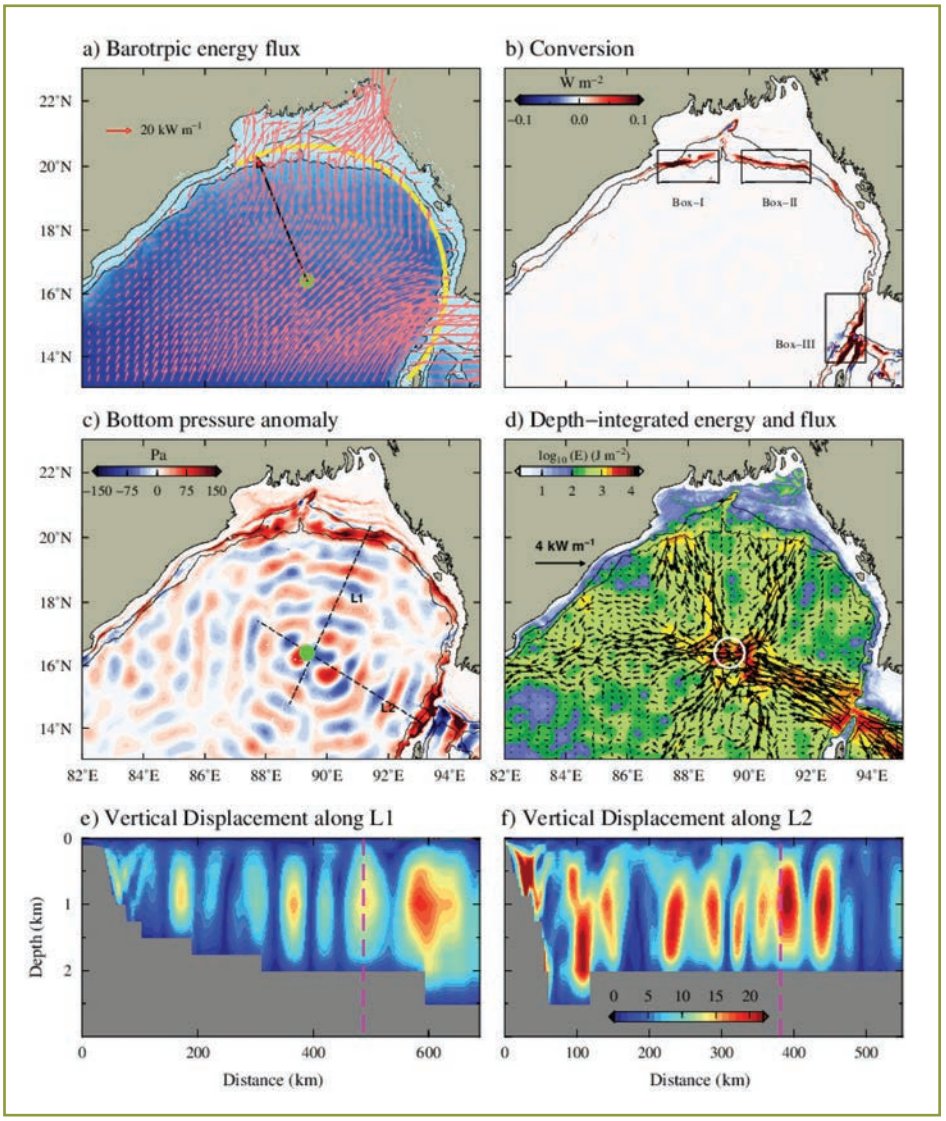
ITCOocean has been recognized as a Regional Training Centre (RTC) of the Ocean Teacher Global Academy project under International Oceanography Data Exchange (IODE) for a period of 3 years from 2020 – 2023. Following this the Steering Group (SG) meeting for the Ocean Teacher Global Academy 2 Project SG-OTGA2 was held between 5-7 October 2020 in online mode. Dr. TVS Udaya Bhaskar, Coordinator of ITCOocean was elected as Chair of Steering Group and ITCOocean has been identified as leader for Work Package 4 of OTGA2.

9. Research Highlights

9.1 Published Research Articles

9.1.1 Intensification of tidally-generated internal waves in the north-central Bay of Bengal

Flow of barotropic tidal currents over topographic features, such as continental slopes and submarine ridges, generates internal gravity waves at tidal periods known as internal tides. Amplitudes of these waves are generally large near the generation regions. In this study, spatial variability of the internal tide field is examined with the use of observations and numerical simulations. Analysis of Sea Surface Height (SSH) data, derived from satellite altimeter revealed the amplification of internal tides in the semidiurnal period in the north-central Bay of Bengal (BoB) (around 89°E,16°N), which is about 450 km away from their generation sites. SSH signals found in the north-central BoB (~3 cm) were comparable to the maximum amplitudes (2.5 to 3.5 cm) observed near their potential generation sites in the BoB such as continental slopes in the head of the bay and Andaman-Nicobar (AN) Ridge. Simulations from a high-resolution regional ocean model also confirmed the presence of large internal tide



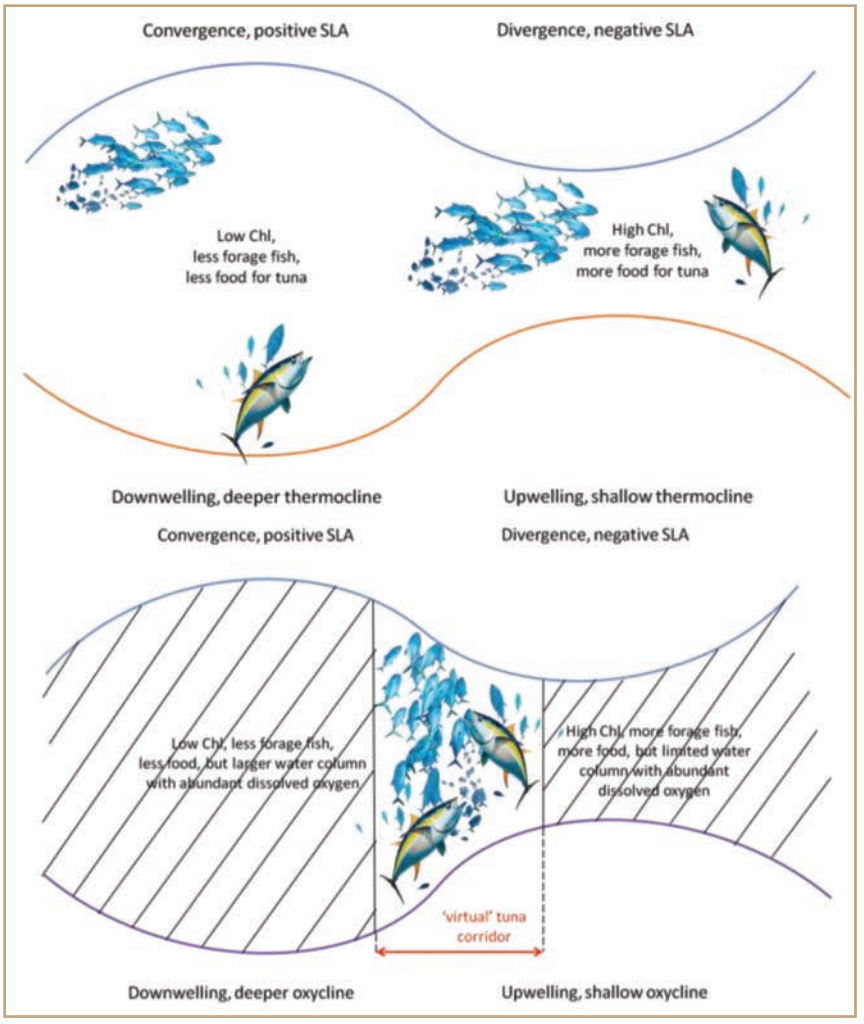
Barotropic energy flux vectors for M_2 tides in the northern BoB. Yellow curve indicates the arc-shape of the continental slope in the northern BoB and black arrow shows the radius (457 km) of the arc. (b) Barotropic to baroclinic tidal energy conversion rate for M_2 constituents. Boxes (I–III) represent the major internal tide generation sites. (c) Baroclinic M_2 bottom pressure anomaly (Pa) at the bottom and (d) total energy (E = APE + HKE) of M_2 internal tides. Blue circle in (d) represents the focal region. Bathymetric contours of 100 and 1000 m are shown. (e,f) Vertical displacement of isopycnals associated with M_2 internal tides along the transect L1 (e) and L2 (f) shown in (c).

Ref : Jithin, A. K., Subeesh M.P, Francis P. A., and Ramakrishna, S. S. V. S. (2020). Intensification of tidally generated internal waves in the north-central Bay of Bengal. Scientific Reports. 10 (6059). https://doi.org/10.1038/s41598-020-62679-4.

amplitude in the north-central BoB. Analysis using model simulations revealed that convergence of internal tides, which were generated along the concave-shaped source (continental slopes in the head of the bay and the northern parts of AN Ridge), into its focal region caused their amplification in the north-central BoB. It was also found that internal tide energy dissipation rates in this focal region were about 10 times larger than those in other open ocean regions.

9.1.2 INCOIS study provide vital clue on the possible fate of Yellowfin Tuna in the global oceans

Yellowfin tuna (Thunnus albacares, Bonnaterre, 1788; YFT) are highly sought after species with lucrative market. The YFT population in the seas is one of the least studied one. This has kept many questions related to the migration and movement of YFT in this region, open ended. The Indian National Centre for Ocean Information Services collaborated with the fishery research institutes in the country – CMFRI and FSI – in order to bridge this gap through satellite telemetry technology. For this study, PSATs (Pop-up Satellite Archival Tags) were used to study the behaviour of YFTs with regard to the oceanographic conditions. All the movements recorded were around the Indian peninsula and fishes did not undergo basin-wide migrations, as believed previously.



(Upper panel) previous knowledge on Yellowfin Tuna (YFT) movements in the ocean informed us that tuna prefer to stay above or around thermocline depth (orange line). (Lower panel) the YFT movement in the northern IO studies with PSATs and remote sensing data reveals that YFTs may have to accommodate themselves in (and undergo migration through) virtual tunnels or corridors in the ocean. This allows far less of an area than previously believed to be available for tuna habitat and increases their catchability exponentially.

Nimit, K., Masuluri, N.K., Berger, A.M., Bright, R.P., Prakash, S., Udaya Bhaskar TVS, T. Srinivasa Kumar, Rohit, P., Tiburtius. A., Ghosh, S., Varghese, S.P. Oceanographic preferences of yellowfin tuna (Thunnus albacares) in warm stratified oceans: A remote sensing approach (2020) International Journal of Remote Sensing, 41 (15), pp. 5785-5805.

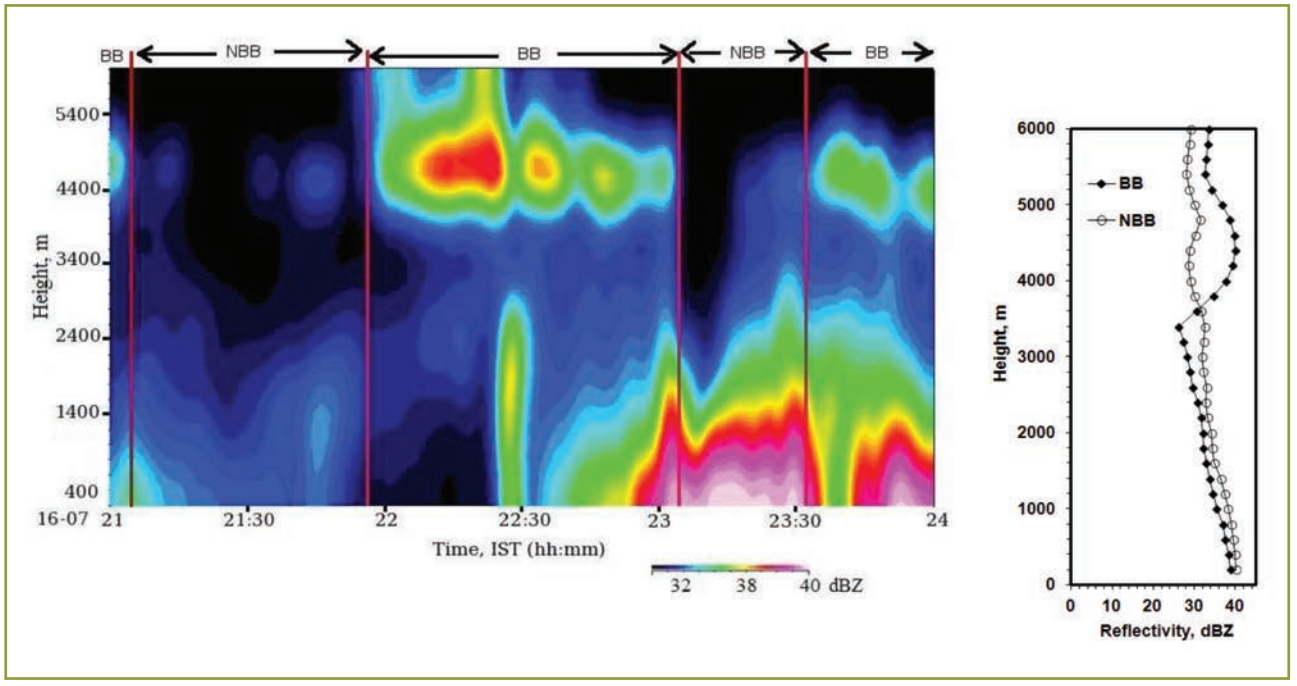
While affinity of YFT to the islands, reefs or even FADs (Fish Aggregation Devices) have been reported, the population we studied appeared to be resident within Indian EEZ regardless to presence of such features. Study of the movements with the help of remote sensing data showed that tagged fishes spent 60% of the time in the waters with sea surface temperatures ranging 26-29 °C and 70% of the time within the sea surface height-

anomaly of ±6 cm. The latter explains the YFTs tend to swim in the periphery of eddies rather than in the centre of cold core eddies (negative SLAs) where high productivity may lead to aggregation of more forage fishes. The tagged fishes were not found to often dive deep (300m) as reported in the other oceans. Similarly, there was no distinct diurnal behaviour. The tag data showed preferred ambient temperatures for movement to be in the ranges of 25-30 °C, which was much higher than reports from other basins. The deeper dives were found to be restricted beyond depth of oxycline (purple line, see Figure).

When it comes to stratified warm oceans the northern Indian Ocean (IO) can serve as live-simulation of future global oceans as predicted by various climate projections. As shown in the schematic herewith, the tuna habitat is not most of the region above thermocline, but actually comprised of three-dimensional corridors. This exposes YFTs to high fishing pressure in the far smaller regions than previously thought. With the oxygen minimum zones expansion, the habitat may further shrunk spatially as well as vertically. These findings will help improve future fishery management policies in the regions. This is an excerpt of a peer-reviewed paper published and available at https://www.tandfonline.com/doi/full/10.1080/01431161.2019.1707903.

9.1.3 Discernment of near Oceanic Convective and Stratiform Precipitating Clouds based on Z-R Model over an Asian Monsoon Tropical site

Type of precipitating near-oceanic clouds are found out and tracked by inferring it from the near-surface empirical relationships of Rainfall rate and Radar reflectivity (Z-R), which are established using a Micro Rain Radar (MRR) and a Joss-Waldvogel Disdrometer at a tropical coastal station Thiruvananthapuram (8.5° N, 76.9°E), an Asian monsoon near-oceanic site, almost at the tip of



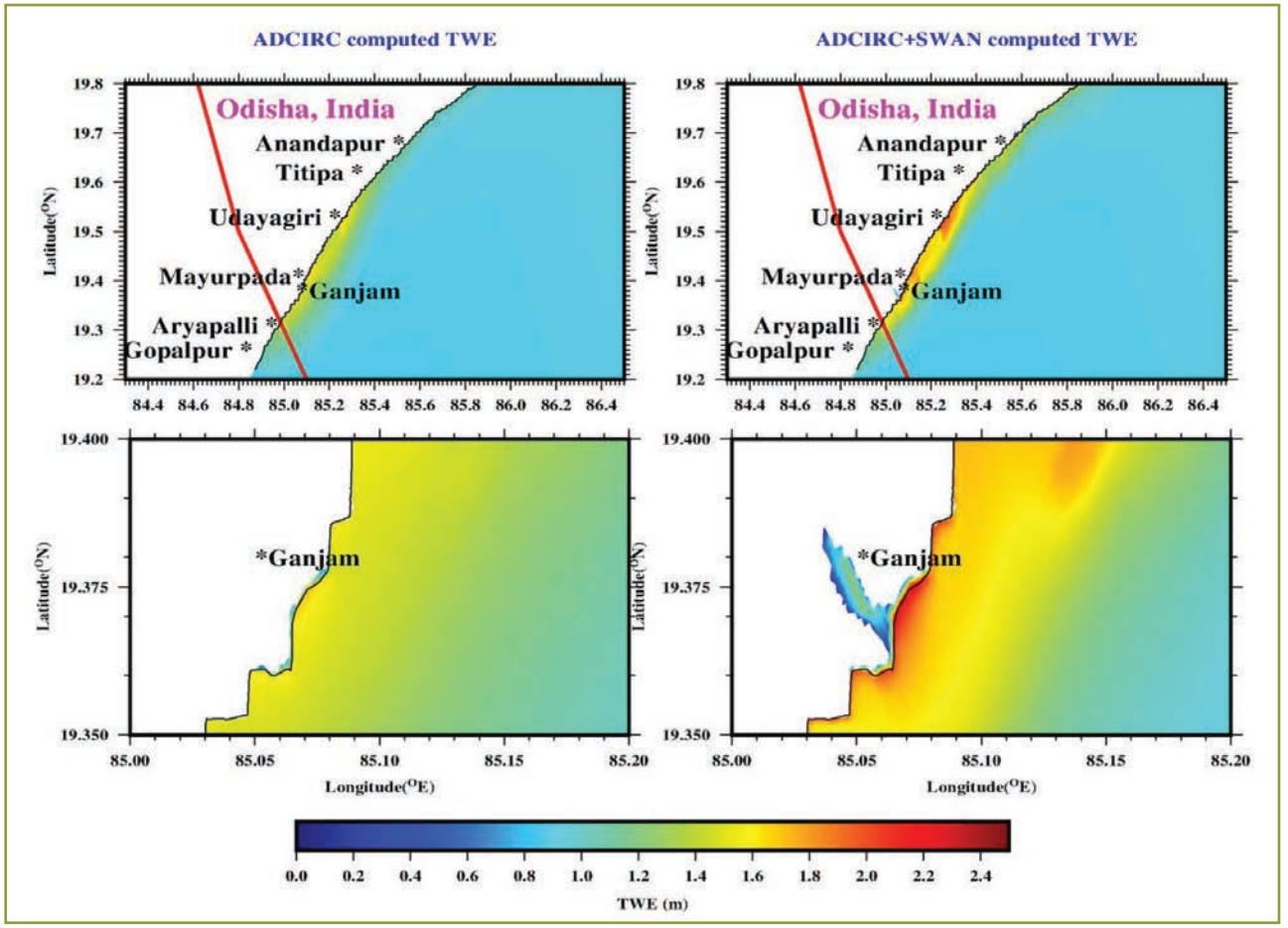
A typical distribution of radar reflectivity (dBZ) vertical profile obtained from the MRR (bright Band (BB) and Non Bright Band (NBB) regions of the rain event are marked and shown) and the temporally averaged vertical profile of radar reflectivity (right panel), separately for BB and NBB. Local time, Indian Standard Time (IST), is shown here, which is GMT+05:30 hrs.

Ref: R. Harikumar, 'Discernment of near-oceanic precipitating clouds into convective or stratiform based on Z–R model over an Asian monsoon tropical site', Meteorology and Atmospheric Physics, 132 (3), pp. 377–390 (2020), https://doi.org/10.1007/s00703-019-00696-3]

Indian peninsula. It is also found out from the vertical variation of Z-R relation that coalescence is prevalent than breakup, as a result of the collision of rain drops, along with evaporation of smaller drops existed as the rain comes down. The DSD/radar-reflectivity/rainfall data from the MRR, Disdrometer and manual rain gauge were inter-compared, and found to have good agreement. The MRR radar Bright Band signature, which is an indication of melting height, is validated using the Wyoming radiosonde data. The whole rain events from March to September 2007 were separated in to Bright Band (BB) and Non-Bright Band (NBB) cases. The variation of Z with R for all the heights (upto 6000m with 200m intervals) is modeled with a function $Z=AR^b$ corresponding to both BB and NBB cases; separately for pre-monsoon and southwest monsoon seasons. And, it is realised that there are two distinct fits with different slopes and intercepts are existed for Z-R relations corresponding to BB and NBB cases throughout aloft during both the seasons. It is found out that the presence of Radar BB or NBB signatures, with corresponding distinct Z-R relations even just at near-surface, which can be used as a proxy for discerning the clouds into stratiform or convective respectively.

9.1.4 Effect of Wave Radiation Stress in Storm Surge induced Inundation: a Case Study for the East Coast of India

In the present study, two case studies are presented to understand the significance and importance of wave radiation stress in storm surge modelling during two extreme weather events associated



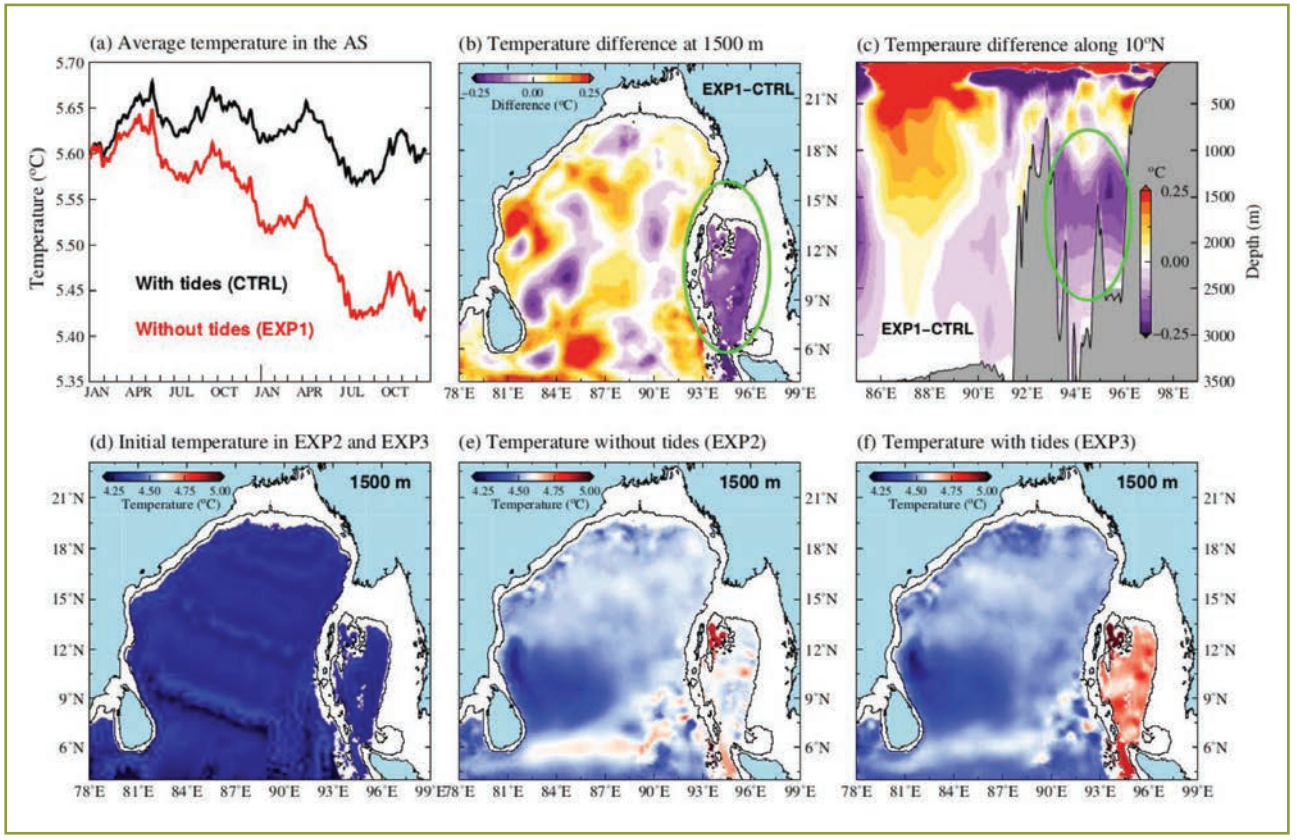
Spatial depiction of storm surge and computed inundation extents due to 'Phailin' by uncoupled (upper left) coupled simulations (upper right), respective enlarged views are given at Ganjam location is given in lower panel.

Ref: Murty, P.L.N., Rao, A.D., Srinivas, K.S., Rao, Rama Rao E.P, Bhaskaran, P.K. Effect of Wave Radiation Stress in Storm Surge-Induced Inundation: A Case Study for the East Coast of India (2020) Pure and Applied Geophysics,177 (6), pp. 2993-3012.

with *Phailin* and *Hudhud* cyclones. Model computations were performed using the Advanced Circulation Model (ADCIRC) and ADCIRC+SWAN (Simulating Waves Nearshore) for these two events. Meteorological and Astronomical forcing were used to simulate the hydrodynamic fields using ADCIRC model run in a standalone mode, whereas the coupled model ADCIRC+SWAN also incorporated the wave radiation stress attributed from wave breaking effects. Cyclonic wind fields were generated using the revised Holland model. Results clearly indicate an increase in the peak surge almost 20-30% by incorporating the wave radiation stress and resulting inundation scenario in the coupled model simulation. Key findings from the study indicate the importance of wave induced setup due to radiation stress gradients and also the role of coupled model in accurately simulating storm surge and associated coastal inundation especially along flat-bottom topography.

9.1.5 Role of internal tides in keeping the deep Andaman Sea warmer than Bay of Bengal

This study investigates the impact of internal tide mixing on the temperature distribution in the Andaman Sea using numerical simulations and observations. Vertical profiles of temperature obtained from various hydrographic datasets show that deep waters (below 1,200 m) in the Andaman Sea are warmer (about 2°C) than that of the Bay of Bengal. As a result, the biochemical properties in the deep waters also exhibit significant differences between these two basins. Higher



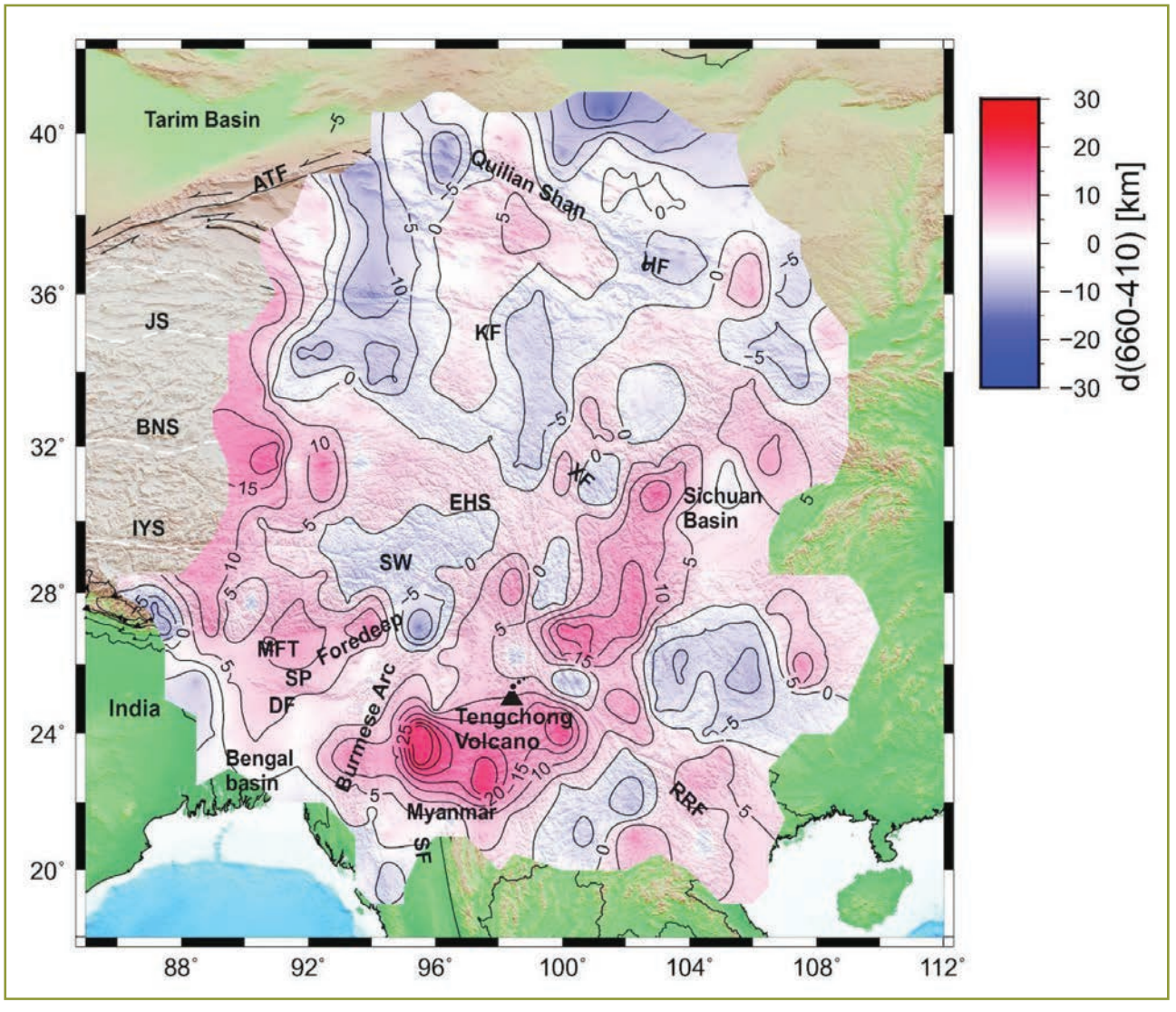
(a) Evolution of average temperature at 1,500 m in the AS with (CTRL) and without tidal forcing (EXP1) for a 2-year period (2013–2014). (b) Temperature difference between the model simulations without and with tidal forcing at 1,500 m (EXP1-CTRL) after 2 year (December 2014). (c) Temperature difference between the model simulations without and with tidal forcing along 10° N (EXP1-CTRL) after 2 years. Green circle represents AS, where the temperature cooling occurs when the tidal forcing is stopped. (d) Temperature distribution at 1,500 m in the initial conditions (01 January 2013) of EXP2 and EXP3. (e) Temperature at 1,500 m after 2 years of model simulation with tidal forcing (EXP2). (f) Temperature at 1,500 m after 2 years of model simulation without tidal forcing (EXP3).

Ref : Jithin, A.K., and Francis, P.A., (2020). Role of internal tide mixing in keeping the deep Andaman Sea warmer than the Bay of Bengal. Scientific Reports, 10, (11982). https://doi.org/10.1038/s41598-020-68708-6

temperature in the deep waters of Andaman Sea compared to the BoB had been widely attributed to the enclosed nature of the Andaman Sea. Dissipation rates inferred from the hydrographic data and internal tide energy budget suggests that the rate of vertical mixing in the Andaman Sea is about two-orders of magnitude larger than that in the Bay of Bengal. Internal tide energy budget estimated from numerical simulations show that strong tidal energy dissipation in the Andaman Sea compared to bay of bengal. The elevated internal tide induced vertical mixing results in the efficient transfer of heat into the deeper layers, which could play an important role in maintaining the higher temperatures in the deep waters. The effect of tidal mixing on the subsurface temperature distribution in the deep BoB and Andaman Sea is further examined by conducting a series of sensitivity experiments. Results show that the deep AS started cooling gradually when the tidal forcing stopped. These numerical experiments further confirms the role of internal tide mixing in maintaining the warmer temperature in deep Andaman Sea.

9.1.6 Palaeoslab and plume signatures in the mantle transition zone beneath Eastern Himalaya and adjoining regions

The topography of the mantle transition zone (660–410 km) discontinuities and its thickness



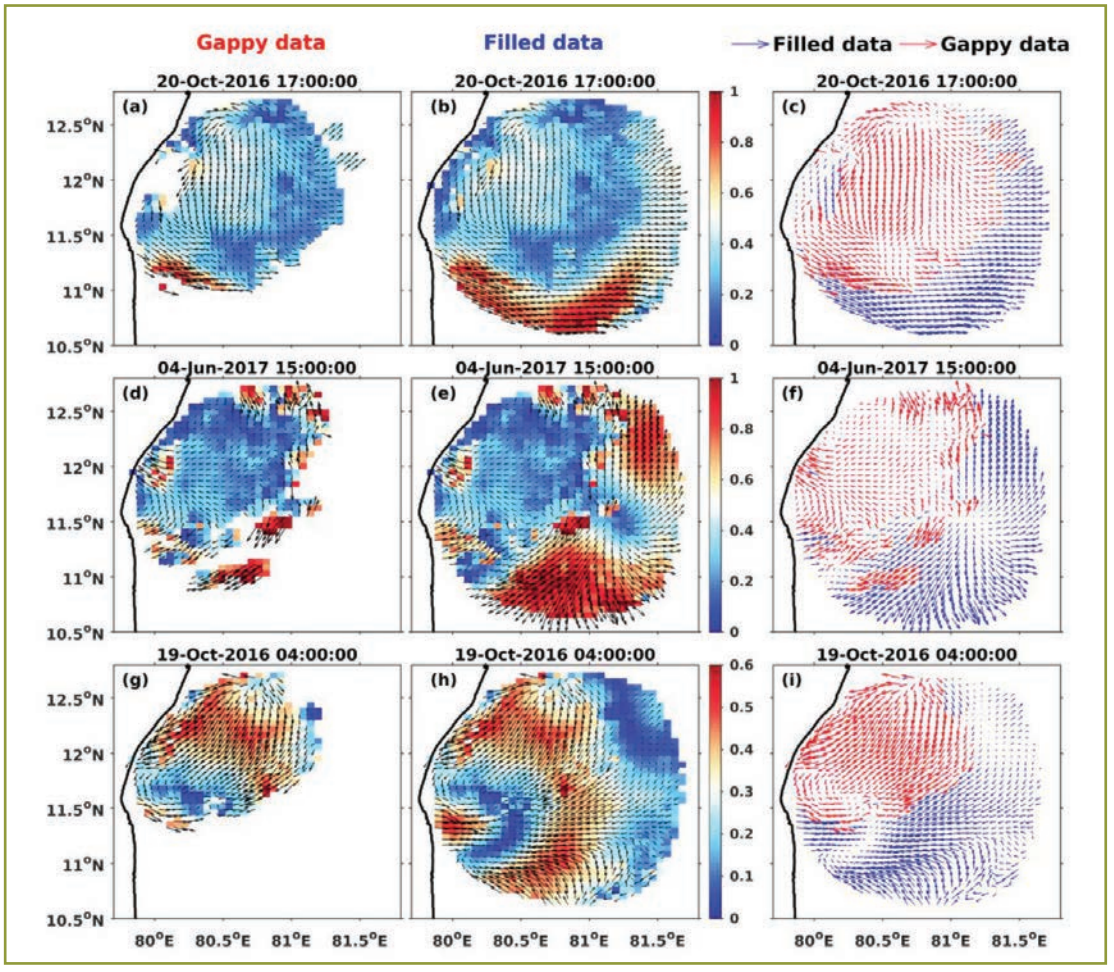
Lateral variation of the observed perturbation in the transition zone thickness (observed thickness - 250).

Ref: Saikia, D., Kumar, MR, Singh, A. Palaeoslab and plume signatures in the mantle transition zone beneath Eastern Himalaya and adjoining regions, (2020) Geophysical Journal International 221 (1), pp. 468-477

provide clues about the rheology and thermal state of the mantle, which control plate tectonics. This study imaged the mantle transition zone structure beneath the southern Tibet, eastern Himalaya, Assam valley, and the previously unexplored Burmese arc and Bengal basin regions using a comprehensive dataset of 327 stations with receiver function method. To image the lateral variation of the major upper mantle discontinuities (i.e., at 410 and 600 km), we migrated the receiver functions to depth using a 3D velocity model and binned them in circular regions having a radius of 75 km, at 0.5° horizontal intervals and 1 km depth interval. We observed a highly variable and perturbed mantle transition zone, with depressed 410 and 660 km discontinuities beneath the Bengal basin and east of the eastern Himalayan syntaxis. For most of the Tibet and Himalayan foredeep, the variation in 410 km discontinuity is in the range of ±5 km. In the Himalayan collision front the 410 km discontinuity is uplifted by ~10 km, whereas in northern Tibet and along the Red River Fault, a deepening of more than 10 km has been observed. Beneath the Arunachal Himalaya, both 410 and 660 km discontinuities are uplifted by nearly 10 km due to the presence of the remanence of subducting Indian lithosphere, which is also evident in the regional tomographic images. Beneath the Burmese arc and close to the Tengchong volcano of Myanmar, we observe a more than 20 km thick transition zone that requires slabs within the mantle transition zone for simultaneous upliftment and depression of the 410 and 660 km discontinuity. Observation of depressed 410 and 660 km discontinuities in the proximity of the Jinsha suture zone is consistent with the earlier results that invoke flow of a hot Tibetan asthenosphere into the mantle transition zone as an explanation. Interestingly, both the 410 and 660 km discontinuities deepen (~10 km) in the Bengal basin. Observation of similar results from other plume-affected regions suggests that this is a signature of the Kergulean plume.

9.1.7 Gaps Filling in HF Radar Sea Surface Current Data Using Complex Empirical Orthogonal Functions

The knowledge of speed and direction of coastal ocean currents are critical for carrying out search and rescue at sea, to respond to the hazardous marine oil spills, to estimate the dispersal pattern of pollutants, to issue warnings against tsunamis and cyclones, for real-time coastal monitoring etc. Such operations need uninterrupted observational data of sea surface currents over a wide area with high spatial and temporal resolution. The High frequency (HF) radars installed at the shore, sense the surface of the ocean using electromagnetic waves, and provide the speed and direction of ocean currents over a large spatial domain at high temporal resolution. However, the frequent gaps in the data are a concern for its usage. The gaps arise due to its dependence on the roughness of the sea and other electromagnetic interferences from unknown sources. Hence, it is necessary to fill the gaps for successful real-time monitoring of coastal currents and their applicability. The present work describes a method to fill the gaps in the HF radar data using complex empirical orthogonal functions (CEOF).

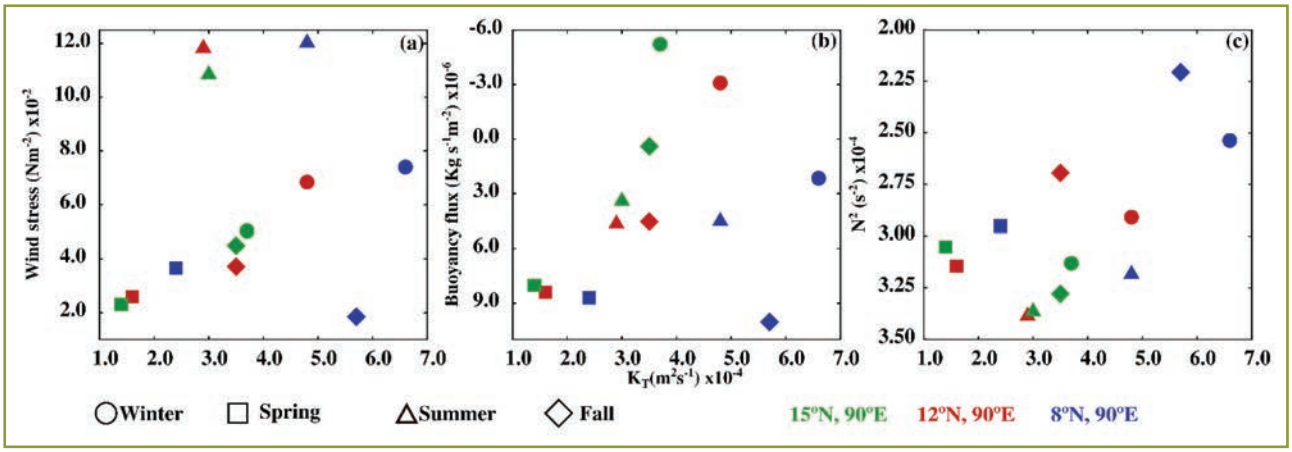


Ocean current fields from three random timestamps (a-c) 20 October 2016 17:00:00, (d-f) 04 June 2017 15:00:00 and (g-i) 19 October 2016 04:00:00 with data gaps of about 40%, 50% and 60% respectively. The first column shows the original (gappy data) HF radar ocean current vectors plotted on the resultant speed. The second column shows the (filled data) reconstructed current vectors plotted on the reconstructed resultant speed. The third column shows vector plots of original field (gappy data; red) and reconstructed field (filled data; blue).

Ref: Kolukula, S.S., Baduru, B., Murty, P.L.N., Kumar, J.P., Rama Rao, E.P., Shenoi, S.S.C. Gaps Filling in HF Radar Sea Surface Current Data Using Complex Empirical Orthogonal Functions (2020) Pure and Applied Geophysics, 177 (12), pp. 5969-5992.

9.1.8 Estimation of Vertical Heat Diffusivity at the Base of the Mixed Layer in the Bay of Bengal

The estimation of vertical heat diffusivity and diapycnal heat flux at the base of ML can be achieved through temperature microstructure measurements. Such measurements are primarily made through shipboard observations and they are relatively sparse in both space and time. An alternate approach to estimating the eddy heat diffusivity is through a mixed layer heat budget residual method. The present study showed that estimation of vertical heat diffusivity based on the mixed layer heat budget after applying certain filtering criterion is in good agreement with respect to fixed depth microstructure measurements, which gives us confidence to extend the analysis to two other RAMA mooring locations in the Bay of Bengal. It is found that the seasonal and spatial heterogeneity in vertical heat diffusivity which is lower during spring and higher during winter in comparison with summer and fall at respective mooring locations. The present study also shows that the seasonal and spatial variability of vertical heat diffusivity is modulated both by stratification at the base of mixed layer and by seasonal and spatial heterogeneity in atmospheric forcing, most notably wind stress and buoyancy flux.

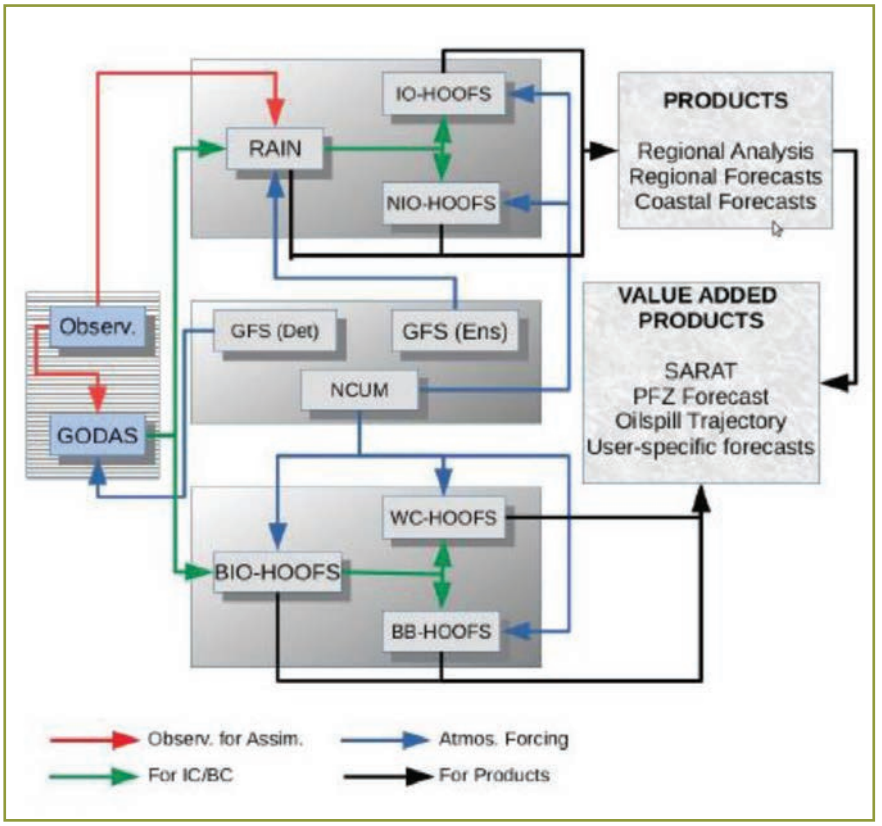


The seasonal (winter-circle; spring-square; summer-triangle and fall-diamond) median of vertical heat diffusivity (K_T) estimated from the residual of mixed layer heat budget against (a) wind stress (T x10^{-2} Nm^{-2}) (b) Buoyancy flux (B_0 x 10^{-6}; Kg s^{-1} m^{-2}) and (c) Brunt–Vaisala frequency (N^2 x10^{-4}; s^{-2}), at different RAMA mooring locations in the BoB. Note that y-axis is reversed in panels (b) and (c).

Ref: Girishkumar, M.S., Ashin, K., McPhaden, M.J., Balaji, B., Praveenkumar, B. Estimation of Vertical Heat Diffusivity at the Base of the Mixed Layer in the Bay of Bengal (2020) Journal of Geophysical Research: Oceans, 125 (5), art. no. e2019JC015402

9.1.9 High-resolution Operational Ocean Forecast and reanalysis System for the Indian Ocean

Considering the importance of providing accurate prediction of different oceanographic parameters for a wide spectrum of users ranging from traditional fisher folks to high-tech off-shore industries, INCOIS has developed the High-resolution Operational Ocean Forecast and reanalysis System (HOOFS), that comprises a suit of numerical ocean models to which near-real time ocean observations are assimilated. Major components of HOOFS are (i) a suite of numerical ocean models configured for the Indian Ocean and the coastal waters using Regional Ocean Modeling System (ROMS) for



A schematic representation of the components of HOOFS. GFS (Det.) : GFS deterministic atmospheric analysis. GFS (Ens.): GFS ensemble analysis. Observ. : Observations. IC : initial condition. BC : boundary condition. Red arrows represent the observational data used for data assimilation in numerical models. Green Arrows represent the source of initial and boundary conditions used in various model configurations. Blue arrows indicate the data sets used for the atmospheric forcing in the HOOFS. Black arrows represent the model output used for the generation of analysis, forecast and value products.

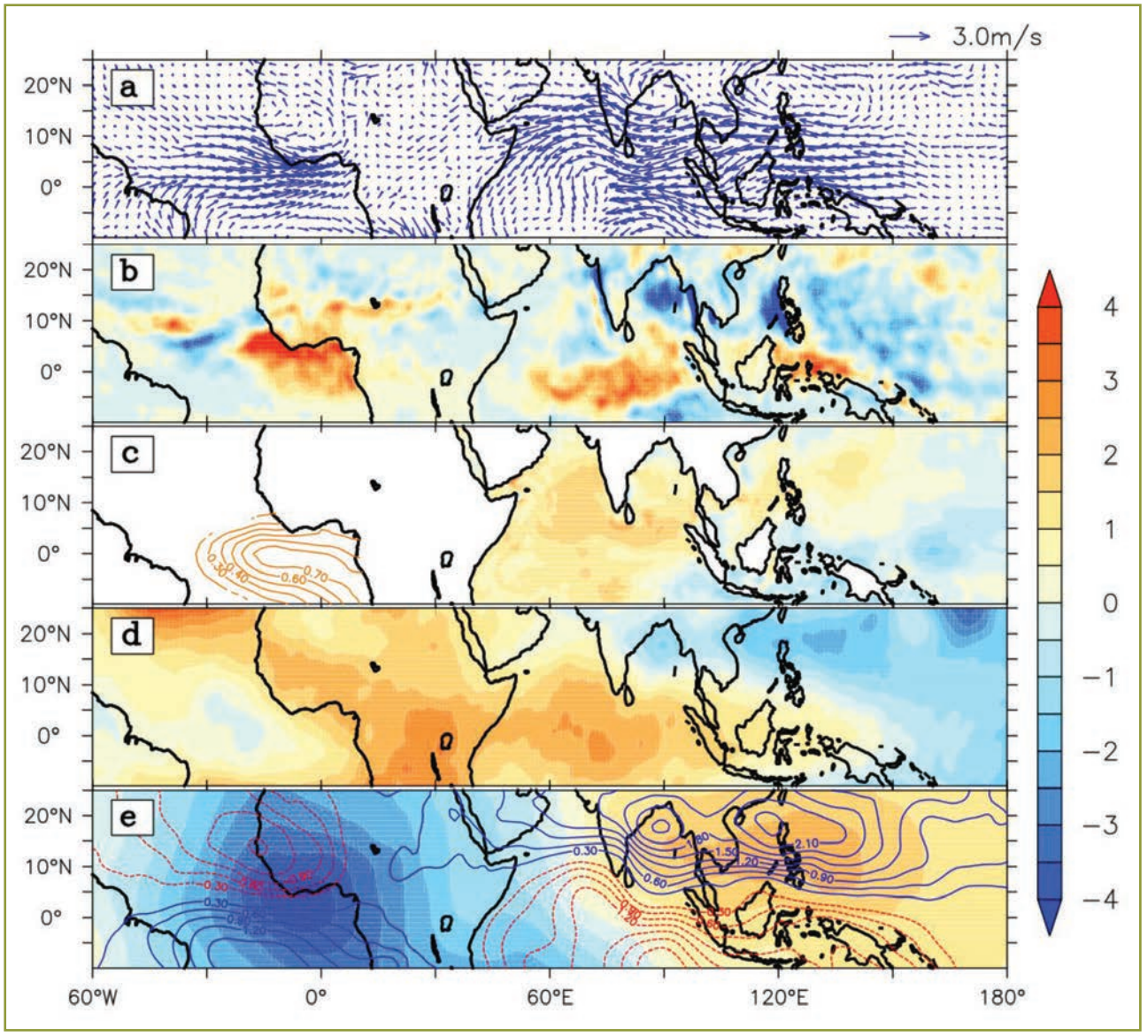
Ref: Francis P. A., Jithin A. K, Effy B. John, Abhisek Chatterjee, Kunal Chakraborty, AryaPaul, Balaji B, S. S. C. Shenoi, Biswamoy P, Arnab Mukherjee, Prerna Singh, Deepsankar B, Siva Reddy S, Vinayachandran P. N, Girish Kumar M. S, Udaya Bhaskar T. V. S, Ravichandran M, Unnikrishnan A. S, Shankar D, Amol Prakash, Aparna S. G, Harikumar R, Kaviyazhaku K, Suprit K, Venkat Shesu R, Kiran Kumar N, Srinivasa Rao N, Annapurnaiah K,Venkatesan R, Suryachandra Rao A, Rajagopal E. N, Prasad V. S, Munmun Das Gupta, Balakirishnan Nair T. M, Pattabhi Rama Rao E, Satyanarayana B. V (2020): High-resolution Operational Ocean Forecast and reanalysis System for the Indian Ocean, Bulletin of the American Meteorological Society, 101(8), E1340–E1356.

the analysis and forecasting physical and biogeochemical state of the ocean and (ii) the data assimilation based on Local Ensemble Transform Kalman Filter that assimilates in-situ and satellite observations in ROMS (Regional Analysis for Indian Ocean, RAIN). The Indian Ocean configuration of the HOOFS takes initial and boundary conditions from the Global Ocean Data Assimilation System (GODAS) configuration at INCOIS, in which the in situ ocean observations are assimilated to Modular Ocean Model (MOM4p0d) using 3D-VAR data assimilation system. The ocean analysis system (both GODAS and RAIN) are forced with 6-hourly GFS atmospheric forcing provided by National Centre for Medium Range Weather Forecasting (NCMRWF), while the forecast models are forced with 6-hourly NCUM atmospheric forcing provided by NCMRWF. Ten (10) tidal constituents are incorporated in the model for accurate simulation of tides. Since this system has a very high spatial resolution and is specifically configured to represent most of the physical processes in the coastal waters, it is capable of providing high quality forecasts of ocean circulation parameters such as currents, temperature and salinity structure, tides, depths of mixed layer and thermocline etc. The analysis and forecast products were statistically validated to make sure that they are useful for providing operational forecasts of different ocean parameters. The forecasts issued by INCOIS based on this system are extensively used by fishermen, maritime industries and shipping agencies. Apart from the routine forecasts of key oceanographic parameters, a few important applications such as (i) Potential Fishing Zone forecasting system and (ii) Search and Rescue Aid Tool were also developed as part of the HOOFS project. While developing the system, extensive research on the processes that are important to improve the quality of ocean forecasts and their representation in the numerical models were carried out.

9.1.10 Physical mechanisms for the interannual influence of the Atlantic Zonal Mode on Indian summer monsoon[1]

The livelihood of people living in India depends, to a great extent, on the Indian summer monsoon rainfall, the interannual variability of which is governed, partly, by external factors such as El Nino – Southern Oscillation (ENSO) in the tropical Pacific, Indian Ocean Dipole in the tropical Indian Ocean etc. Similar to but weaker than ENSO, there exists a coupled ocean-atmosphere phenomenon called the Atlantic Zonal Mode (AZM) in the tropical Atlantic active during boreal summer. The AZM has been shown to significantly influence the Indian Summer Monsoon (ISM). Using the Coupled Forecast System version 2 utilized for seasonal prediction of ISM in India, we examine whether the model simulates the AZM-monsoon link proposed in our earlier study: the AZM influence propagates in tropospheric temperature via Kelvin-like waves to the east to reach the Indian Ocean and influences the monsoon by modulating the mid-tropospheric land-sea thermal gradient and thereby the seasonal mean flow. In the experiment, a warm AZM SST anomaly is added over the tropical Atlantic in the boreal summer and the response of the ISM is studied. We find that the model simulates the important aspects of the AZM-monsoon link such as anomalous warming of the mid-troposphere over the Indian Ocean, warm SSTs, winds opposing the seasonal mean flow in the north Indian Ocean and a reduction in rainfall over India. The model also simulates a known dynamics-based mechanism wherein a warm AZM SST anomaly produces a Matsuno-Gill-type response, which in turn induces a sinking motion over India causing a reduction in rainfall. In addition to validating the physical mechanism, our study highlights the need for the improvement of mean state of the model in the tropical Atlantic to better

capture the AZM-ISM relationship which will ultimately improve the monsoon forecasts issued using this model.



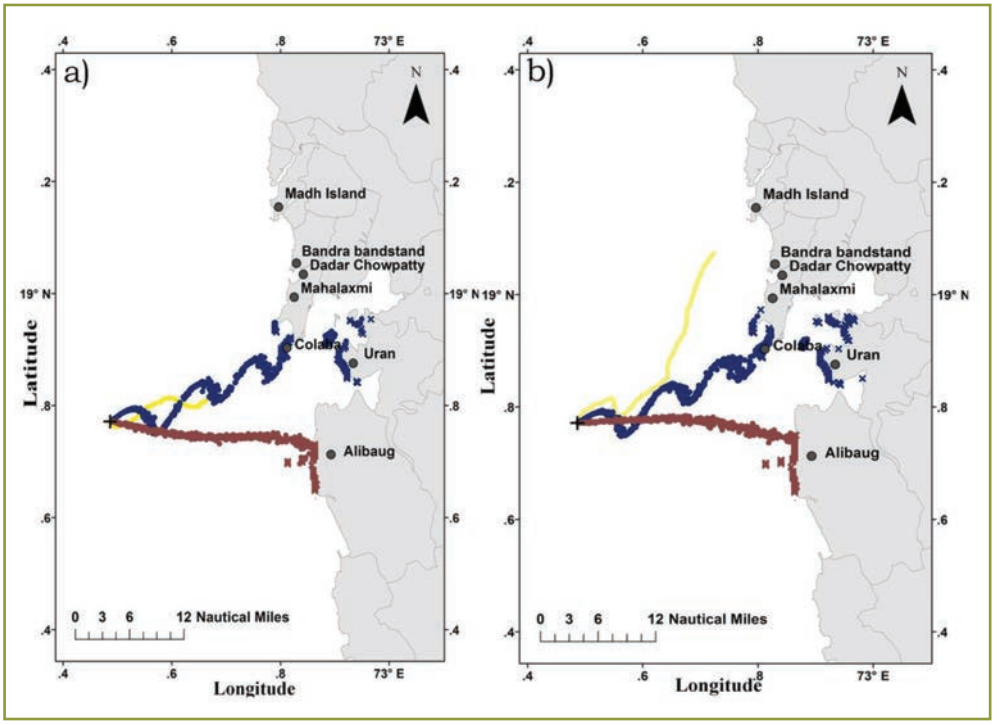
Influence of anomalous SSTs associated with the Atlantic Zonal Mode in the tropical Atlantic (a) on anomalies of winds (b), precipitation (c), SST (d), mid-tropospheric temperature (e), and upper velocity potential and low level stream function in the Indian Ocean.

Ref: Pottapinjara, V., Roxy, M.K., M. S. Girishkumar, Ashok, K., Sudheer Joseph, Ravichandran, M., and Murtugudde R., (2021): Simulation of interannual relationship between the Atlantic Zonal Mode and Indian Summer Monsoon in CFSv2. Climate Dynamics. https://link.springer.com/article/10.1007/s00382-021-05712-0

9.1.11 Oil spill trajectory prediction with high-resolution ocean currents

Merchant Vessel (MV) Rak sunk at 72.4865°E, 18.7715°N, on 04 August 2011. As per the information from Indian Coast Guard, ~122.5 tons of fuel oil was spilled from the vessel during 5 to 12 August 2011. Oil spill trajectory model, GNOME, was forced with ocean currents from Indian Ocean Forecasting System (INDOFOS) and High-resolution Operational Ocean Forecasting and reanalysis System (HOOFS) individually, to simulate the oil drift pattern from MV Rak during the spill period. Wind drift was obtained from the European Centre for Medium Range Weather Forecast (ECMWF). The trajectory obtained while forcing the oil spill model with wind drift and HOOFS currents is called HR track and the trajectory obtained from that of INDOFOS currents is called LR

track. It was found that, On 2300 hours of 8 August 2011, the Root Mean Square Error (RMSE) of the distance between the SAR track and LR track was ~3.24 NM and they were apart by a maximum distance of 3.9 Nautical Miles (NM). But the HR track was in agreement with the SAR track, which means RMSE is nil. The next day by 2300 hours, the RMSE of the distance between the SAR track and LR track was ~9.3 NM and a maximum distance of 18NM was found. But, with HR track a lesser RMSE (6.41 NM) was obtained with lesser separation distance of 12 NM. It was noticed from the above simulation that oil drift pattern obtained when forced with ocean currents from HOOFS was in better agreement with the actual track, compared to the one obtained while using INDOFOS currents.

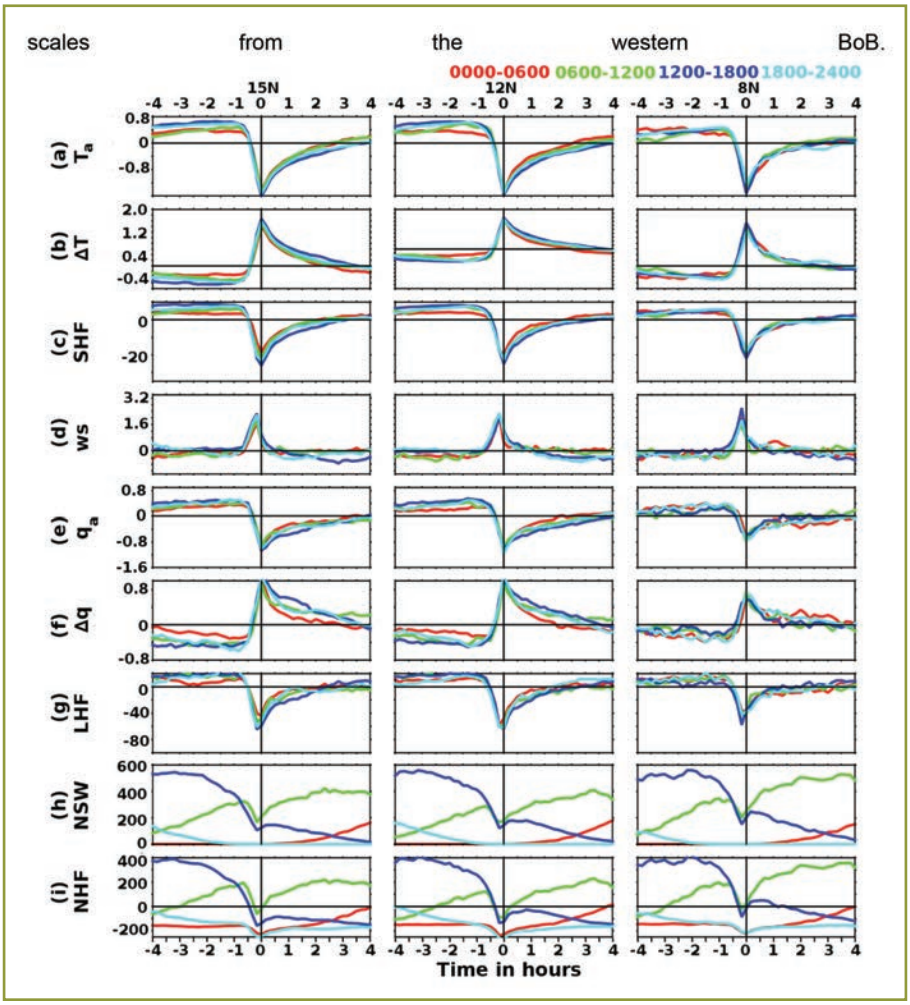


Comparison of LR and HR tracks with SAR observation: a) 08 August 2011, 23.00 hours, b) 09 August 2011, 23.00 hours. The black + symbol denote the spill location. The brown colored trajectory is generated from LR currents and the blue colored trajectory is generated from HR currents. The Yellow colored track is the observed track of the oil slick from SAR observation. The blue (brown) colored x symbol denotes the beached locations of oil slicks from HR (LR) track. The blue (brown) colored plots denote the floating locations of oil slicks from HR (LR) track.

Ref : Prasad, S.J., Francis, P.A., Balakrishnan Nair, T.M., Shenoi, S.S.C., Vijayalakshmi, T. Oil spill trajectory prediction with high-resolution ocean currents (2020) Journal of Operational Oceanography, 13 (2), pp. 84-99

9.1.12 Diurnal variability of atmospheric cold pool events and associated air-sea interactions in the Bay of Bengal during the summer monsoon

Atmospheric cold pools generated through downdrafts from convective systems can significantly modulate air-sea interaction processes over the ocean. However, the variability in cold pool events is not yet documented in the Bay of Bengal (BoB). In this study, the seasonal and diurnal variability of cold pool events (defined as a drop in air temperature greater than 1°C within 30 min) in the BoB is examined using moored buoy measurements with 10-min temporal resolution at 8°N, 12°N, and 15°N along 90°E. The analysis shows that cold pools are plentiful and frequent during summer (May–September) and fall (October–November) compared to winter (December-February) and spring (March–April). Results also indicate a significant diurnal variability at 15°N and 12°N (but not at 8°N) during summer, with more frequent and intense cold pool events in the afternoon. Cold pools lead to an intensification of turbulent heat exchange between the ocean and atmosphere, with increased latent heat loss (~ 80 Wm^{-2}) through both an increase in wind speed and reduction in air specific humidity and increased sensible heat loss (~ 40 Wm^{-2}) due



Composite evolution of anomaly of meteorological parameters 4-hr before and after the single cold pool events.

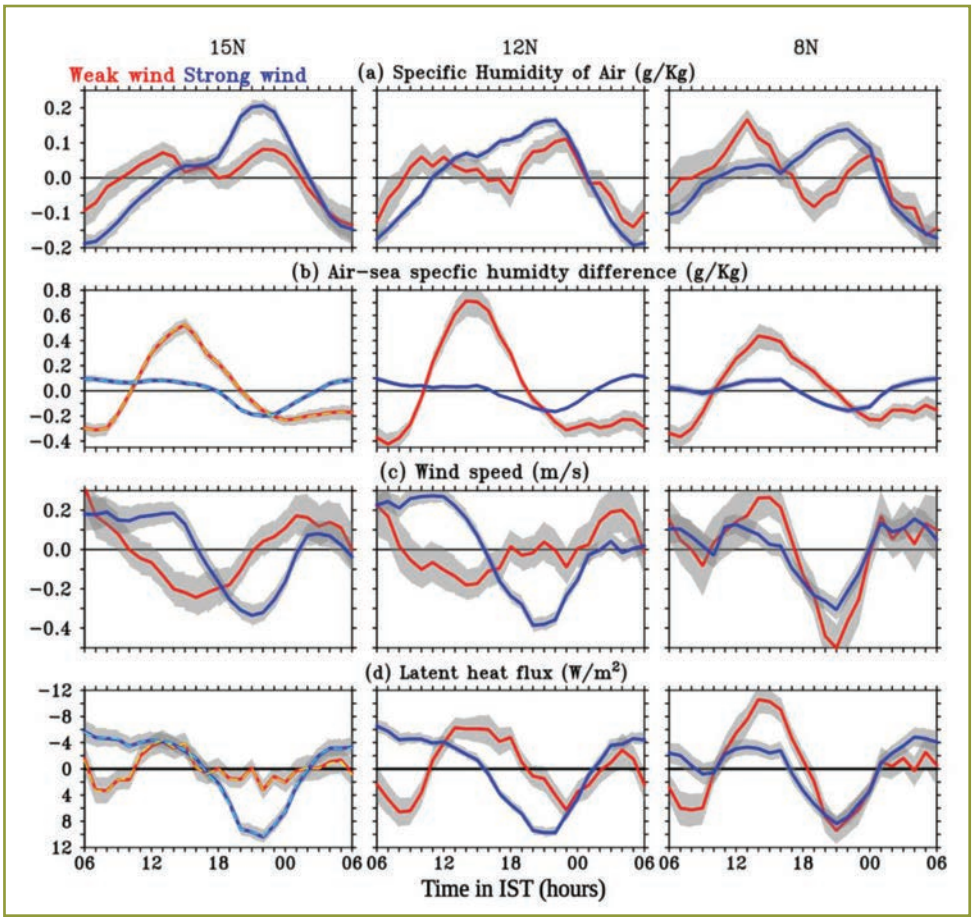
Ref: Jofia Joseph, MS Girishkumar, MJ McPhaden, E Pattabhi Rama Rao (2021), Diurnal variability of atmospheric cold pool events and associated air-sea interactions in the Bay of Bengal during the summer monsoon, Climate Dynamics, 56(3), 837-853.

primarily to air temperature drops. There is also significant diurnal variability in these air-sea exchanges during the summer, with a twofold enhancement in latent and sensible heat fluxes associated with afternoon vs. nighttime cold pools events. Finally, we establish the connection between the enhancement of afternoon cold pool events and south eastward propagating synoptic-scale rainfall activity on diurnal time scales from the western BoB.

9.1.13 Observed sub-daily variability of latent and sensible heat fluxes in the Bay of Bengal during the summer

A better understanding of the variability at the air-sea interface in the tropical climate can improve the ocean-atmosphere coupled model simulation. The variability at the air-sea interface ranges from diurnal to interannual time scales. The ocean-atmosphere coupling in the sub-daily time scale is one of the vital components in the climate system. Hence, it is imperative to document and understand the sub-daily variability of met-ocean parameters in the different tropical basins. In this study, the sub-daily scale variability of turbulent heat fluxes and the plausible causative mechanism responsible for its modulation in the central BoB during the summer (May-September) is examined using moored buoys data at 8°N, 12°N, and 15°N along 90°E. In the weak wind regime

(<6 ms^{-1}), Latent Heat (LHF) loss from the ocean shows semi-diurnal variability with a higher range at 8°N than at 12°N and 15°N. However, LHF depicts a diurnal variability in the strong wind regime (>6 ms^{-1}) at all mooring locations. In the strong wind regime, Sensible heat flux (SHF) shows heat gain by the ocean with a maximum (minimum) value during the daytime (night). In contrast, it shows heat loss from the ocean in the weak wind regime with maximum (minimum) value during the night (daytime). The diurnal range of SHF does not show significant meridional variation in the strong (~3.5 Wm^{-2}) and weak (~2 Wm^{-2}) wind regimes. The difference in sub-daily evolution of air temperature, air-specific humidity, and wind speed determines distinct evolutions of LHF and SHF in different wind regimes. Which appear to be driven by atmospheric boundary layer processes and eastward propagating land-sea breeze signals over the BoB. Finally, we also establish the relationship between sub-daily evolutions of turbulent heat fluxes in the different wind regimes with synoptic conditions associated with the active and break phases of the Indian summer monsoon.



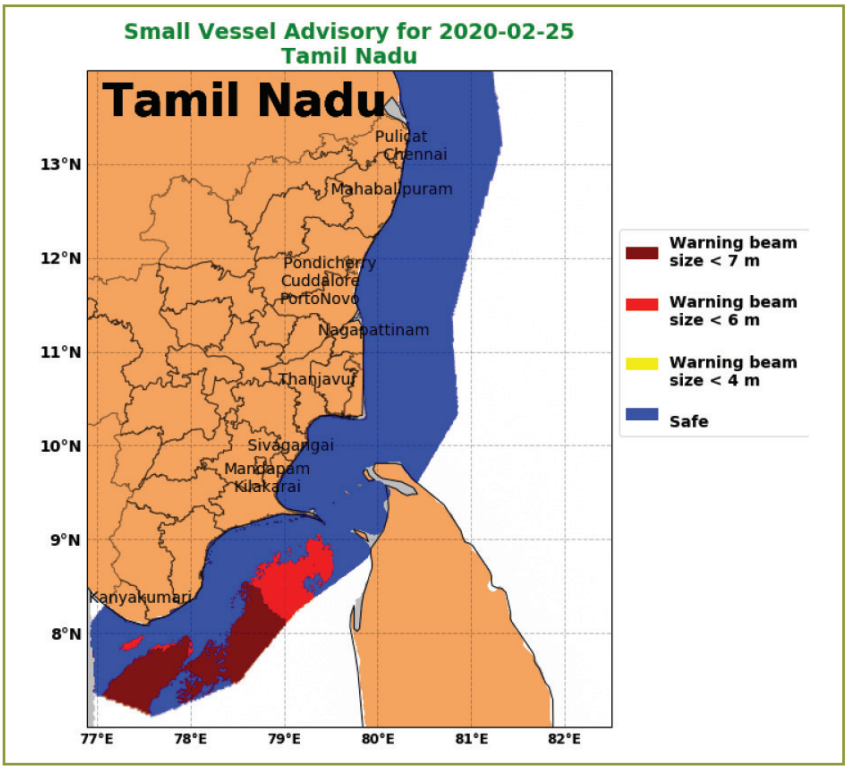
The composite of near-surface meteorological parameters concerning sub-daily variability of LHF in the strong wind speed (blue line) and weak wind speed (red line) regimes at 15°N, 12°N, and 8°N along 90°E.

Ref: Jofia Joseph, MS Girishkumar, Hamza Varikoden, VP Thangaprakash, S Shivaprasad, E Pattabhi Rama Rao, Observed sub-daily variability of latent and sensible heat fluxes in the Bay of Bengal during the summer, Climate Dynamics, 56 (3), 917-934.

9.1.14 Small Vessel Advisory and Forecast Services System for safe navigation and operations at sea

Small Vessel capsizing is a frequent incident which often leads to loss of human lives and livelihoods, apart from causing environmental pollution like oil spill. To reduce the number of accidents caused by capsizing of vessels, ESSO-INCOIS has designed and developed an impact-based advisory and forecast services system for the Indian ocean regime using outputs from the Simulating WAves Nearshore (SWAN) model. The Small Vessel Advisory and Forecast Services System (SVAS) is an innovative impact-based advisory and forecast service system for small vessels operating in

Indian coastal waters. The SVA system warns users about potential zones where vessel overturning can take place, ten days in advance. The advisories are valid for small vessels of beam width up to 7 m. This limit covers the entire range of beam widths of the fishing vessels used in all the 9 coastal states and union territories of India. The warning system is based on the 'Boat Safety Index' (BSI) derived from wave model forecast outputs such as significant wave height, wave steepness, directional spread and the rapid development of wind at sea which is boat-specific. The advisory system is also verified with a few real-life incidents of the past and the results show that the system is trustworthy, which gives confidence in using SVAS for operational purposes. Further, refinement of the advisory system is planned by updating suitable thresholds for the indices based upon regular feedback from users.



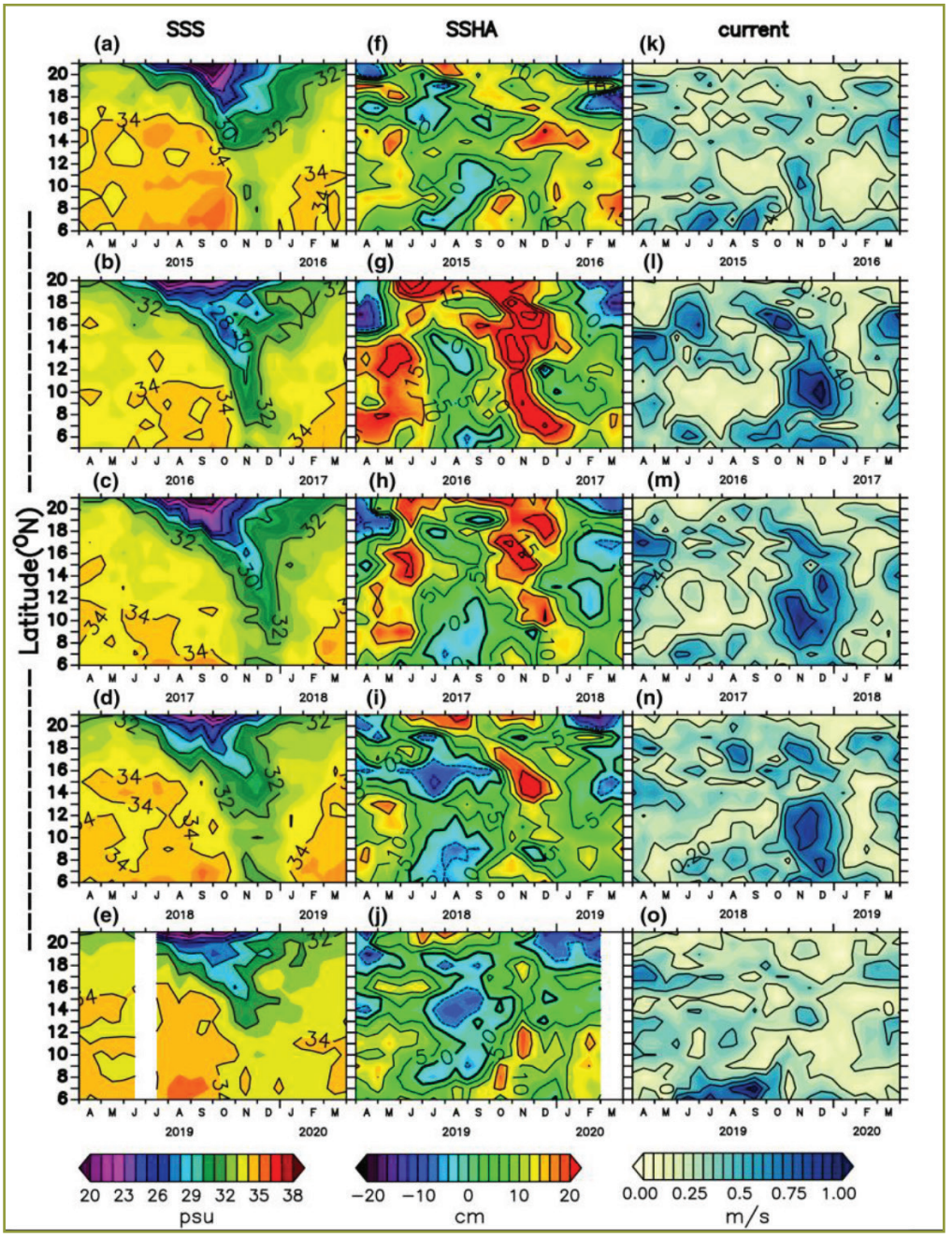
Sample SVAS operational image indicating the safe/warning regions off Tamil Nadu coast for various categories of boat sizes.

Ref: Aditya N. D., K. G. Sandhya, R. Harikumar, T. M. Balakrishnan Nair, Development of Small Vessel Advisory and Forecast Services System for safe navigation and operations at sea, Journal of Operational Oceanography (Taylor & Francis), Nov 2020, DOI: 10.1080/1755876X.2020.1846267

9.2 Ongoing Research

9.2.1 Impact of remote equatorial winds and local mesoscale eddies on the existence of "River in the Sea" along the East Coast of India inferred from Satellite SMAP

The year-to-year variations of River in the Sea ("RIS") and the governing forces responsible for the observed variability were examined. For that purpose, 1° × 1° box averaged SMAP SSS v4.3 data, together with SSHA and OSCAR currents at every latitude between 6°N and 21°N were used. Year-to-year variability of: SSS (RIS), SSH, and currents along the east coast of India, during 2015–2019 are depicted in Figures XBT_R1, respectively. It is evident from Fig. XBT_R1 that the southward extension of "RIS" exhibits year-to-year variability. The "RIS" becomes narrow while moving southward, extremely narrower south of 12°N. Thus, the spatial (north to south) and temporal variability (June to February) of "RIS" resembles a funnel shape where its northern end is wider (near GB mouth) and southern end is very narrow (near Sri Lanka) just like a funnel. During 2015, 2018, and 2019, the "RIS" has not been completely established all along the ECI, rather limited only up to 13.5°N, 12.5°N, 12.5°N, respectively. Whereas it extended southward all along the ECI (7°N) during 2016 and (8°N) during 2017. The 5 years' data analysed in this study have enlightened the processes that are responsible for this interannual variability. The



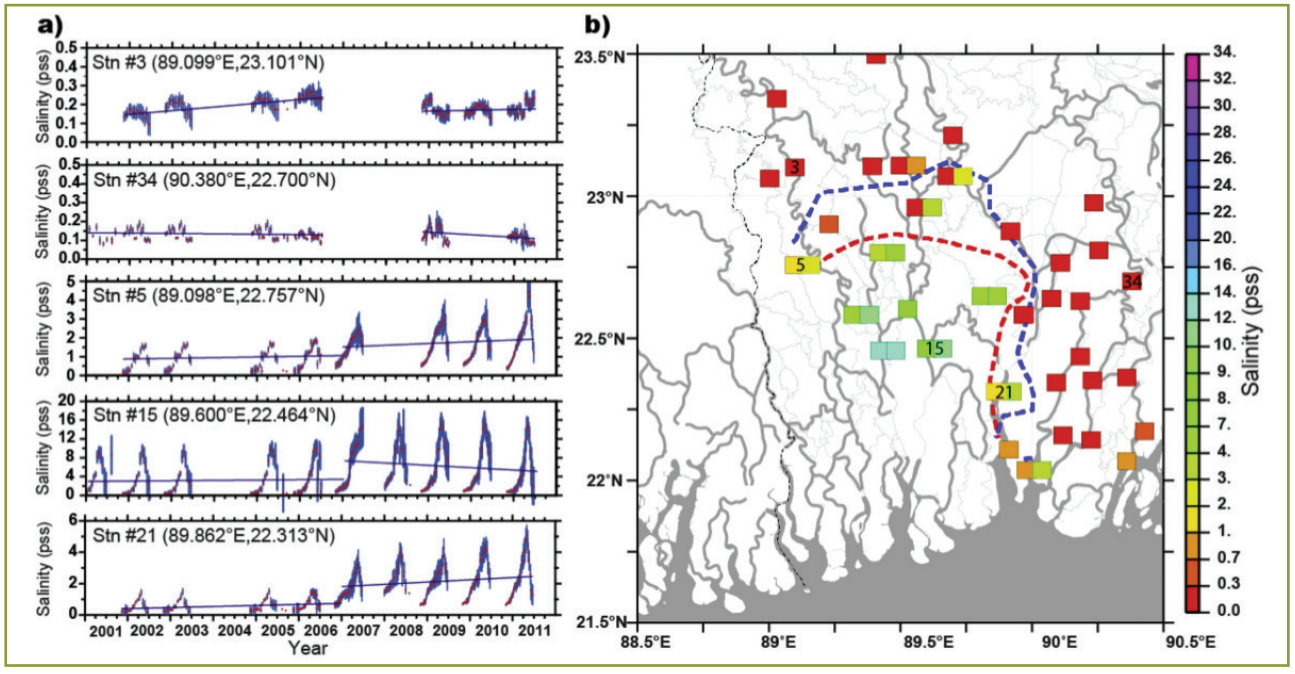
XBT_R-1. 1° × 1° box averaged (a–e) SMAP SSS, (f–j) SSHA, and (k–o) current speed (OSCAR) along the ECI between 6°N and 21°N at every latitude. Latitude-time sections of monthly means of SMAP SSS (illustrating the inter annual variability of "RIS"), SSHA (illustrating the inter annual variability of downwelling Kelvin waves) and current speed (illustrating the interannual variability of EICC) are illustrated in panels (a–e), (f–j), and (k–o), respectively. Figure depiction is from April to March during the years 2015–2020, respectively.

remote equatorial wind induced forces and the local mesoscale eddies play a major role in driving "RIS" southward along the ECI other than only pIOD/nIOD associated forcing. The presence of mesoscale eddies in the south-western Bay of Bengal interrupts and even restricts the southward propagation of "RIS".

9.2.2 Recent salinity intrusion in the Bengal delta: Observations and possible causes

In the case of low-lying deltaic plains such as the Bengal Delta, salinity exerts a prominent control on the economy and sanitary conditions of the riparian societies. It is widely accepted that, with

salinity beyond 0.6-1 unit the water is not suitable for drinking purpose. In the Bengal delta, water with salinity in excess of 2 units is not usable for irrigating rice fields. Hence, it is important to understand the modulation of salinity front in the delta and the contributive factors behind it. The 10 years long (2001-2011) record of river salinity data collected from Bangladesh Water Development Board (BWDB) and surface salinity samples collected from the Hooghly river by NIO, Goa was used for the study. Subsequently, the sudden salinization of the central part of the Bengal delta that occurred in 2006-2007 was described. This results in a sudden landward progress of the salinity front of about 20 km. In this study plausible causative factors that lead to this salinity shift is examined. The analysis indicates three possible forcing factors that lead to these phenomena: (1) the decrease in Ganges freshwater discharge, (2) the rise of sea level and (3) the depletion of the groundwater level. Our analysis further indicates that these factors may act independently or alongside each other. Given the threat of the ongoing climate change and its adverse effects expected in the course of the 21st century in the Bengal delta, this study contributes to set the observational basis for the development of the next generation of salinization modeling platforms.



(a) Time series of salinity observed at selected stations (red points). The blue vertical bars in all panels feature the year-to-year standard deviation, computed month-wise, separately over the 2001–2006 period and over the 2007–2011 period. For each of these two periods, we superimpose the linear fit in a thin solid line. (b) Salinity climatology in April, with the positions of the pre-2006 (red) and post-2007 (blue) 2 units isohaline. The right-shifted squares in certain stations show the April climatological salinity computed over the post-2007 period only.

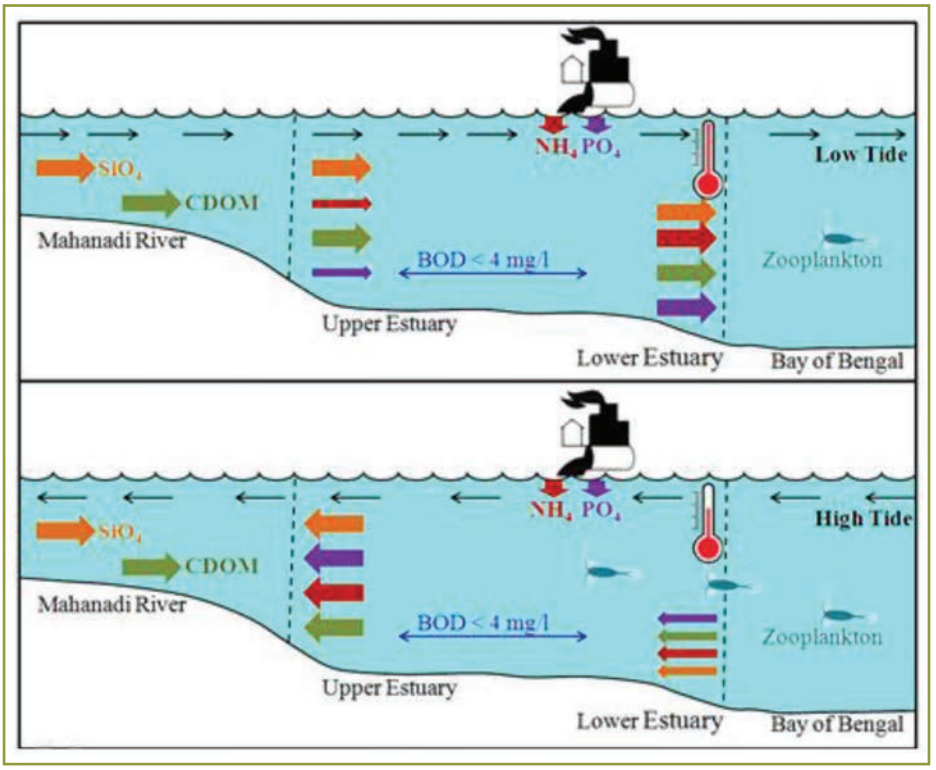
9.2.3 Evaluation of hydro-biological parameters in response to semi-diurnal tides in Mahanadi estuary

One significant aspect of estuarine water quality assessment is to discern the effect of tide on the environmental parameters. The variability of different physical, chemical and biological parameters, in response to semi-diurnal tides, over a tidal cycle was investigated in the Mahanadi Estuary. This estuary receives large quantities of anthropogenic materials, sewage and industrial effluents, which in turn influences the coastal water quality of the adjoining Bay of Bengal. This study is the first attempt on evaluating the variability of a suite of hydro-biological variables over a

semi-diurnal tidal cycle in Mahanadi estuary with a unique sampling design where two stations, with contrasting salinity, were sampled over a complete tidal cycle from highest high tide to lowest low tide. Significant variability was observed in salinity, phosphate concentration, picophytoplankton biomass between upper and lower estuaries irrespective of tides. A low salinity regime was observed in the upper estuary. Ammonium and phosphate distribution suggested anthropogenic influx at the lower/middle part of the estuary. Higher silica content in the upper estuary regardless of tides indicated a prominent riverine source. BOD levels signified estuarine water quality in between fairly-clean and moderately polluted. This study highlighted the significance of continuous sampling over the tidal cycle to understand the effect of tides on estuarine water quality, which will aid in developing forecast models.

9.2.4 Bacteriological water quality w.r.t. to semi-diurnal tidal cycle in the Mahanadi Estuary

A faecal indicator bacteria, *Escherichia coli (E. coli)*, is widely used in monitoring the health of estuaries, where tidal amplitude plays a critical role in its variability. The present study is the first comprehensive monitoring of *E. coli* over a semi-diurnal tidal cycle spanning over lowest low tide to highest high tide in upper as well as lower Mahanadi estuary. Tidal oscillation had considerable effect on the variability of *E. coli*. Higher *E. coli* count during low tide at lower estuaries was possibly attributed to the influx of domestic sewage and industrial waste. In addition, introduction of *E. coli* resting in the bottom sediments to the water column through sediment re-suspension could have played an important role during low tide. Accumulation of upstream-ward flux of *E. coli* abundant water from the middle part of estuary with the resilient population could have played a pivotal role in triggering *E. coli* counts during high tide at upper estuary. This work also reports a long-term trend of *E. coli* discerning a similar tidal pattern as the present study. *E. coli* levels exceeding the recommended limits signified the estuarine waters as unsafe for human contact. The higher *E. coli* counts during low tide with relative lower salinity at upper as well as lower estuary indicated riverine and anthropogenic source of this pathogenic bacteria. On the contrary, lower counts of

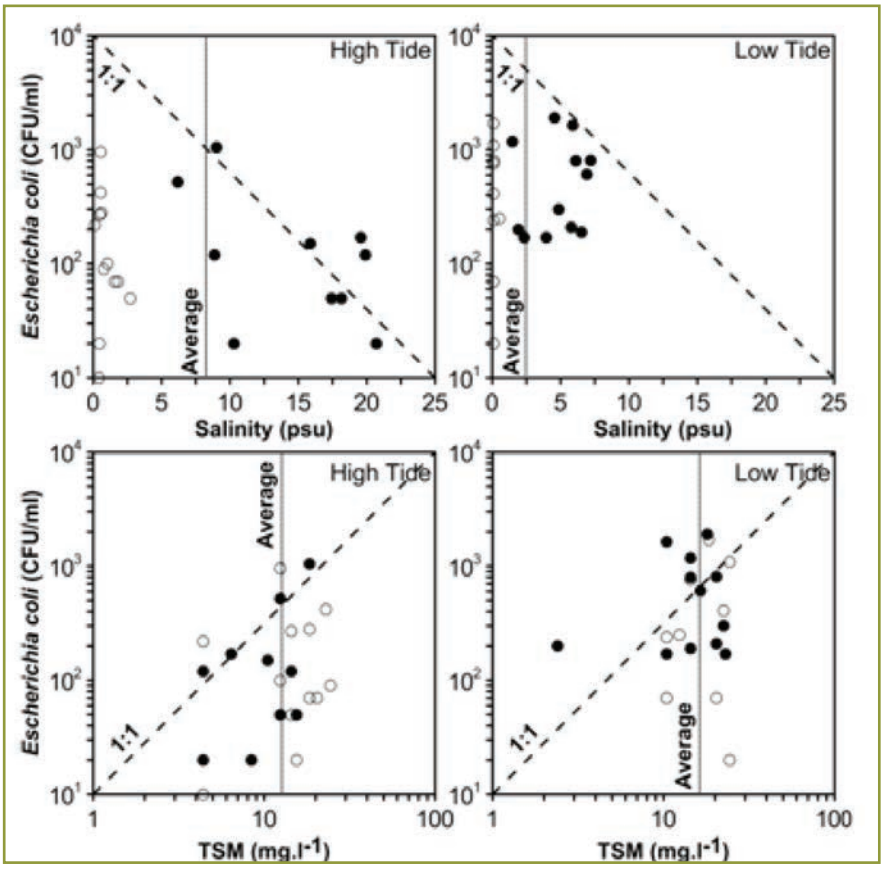


Schematic representation of tidal variability of hydro-biological variables in the Mahanadi estuary

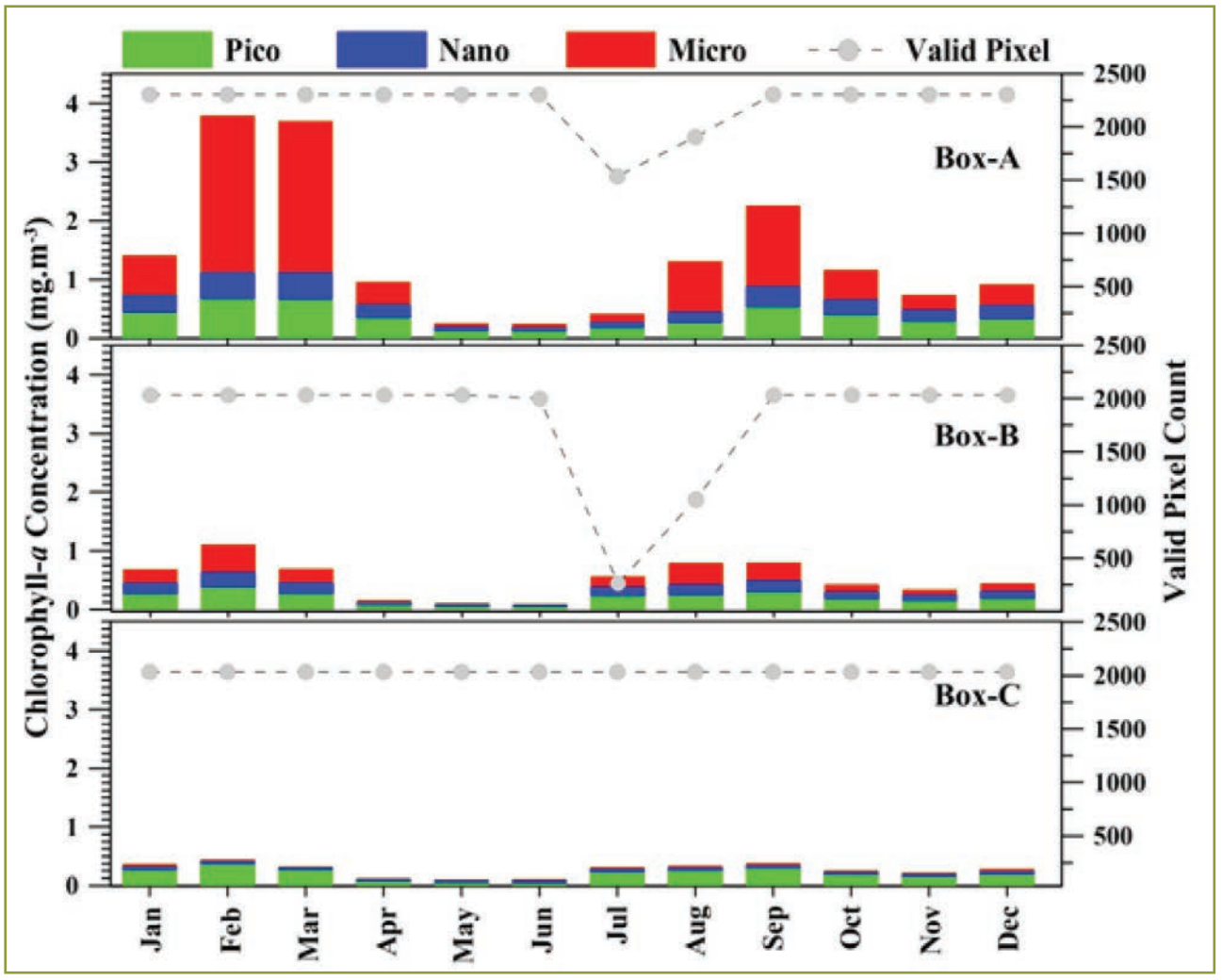
E. coli during high tide at lower estuaries signified the adverse effect of salinity on the bacteria. The present study emphasizes on the establishment of better sewage and industrial effluent treatment facilities prior to dumping into the estuary in order to control the levels of *E. coli*.

9.2.5 Spatio-temporal variability of phytoplankton size classes in the Arabian Sea

The ocean color remote sensing has been proven as an efficient tool in studying the long-term trend of oceanographic geophysical parameters. The present study analyses long-term trend in satellite retrieved phytoplankton size classes (PSC) such as picophytoplankton (PP), nanophytoplankton (NP), and microphytoplankton (MP) in the three zones falling under different ecological provinces in open ocean regions of the Arabian Sea. This study demonstrates effective use of a regionally tuned three-component "abundance" model in discriminating as well as quantifying three different PSC using MODIS-Aqua satellite data for the period of 2003 to 2019. The long-term analysis of PSC discerned a contrasting pattern in the distribution of PSC biomass in the ARAB and MONS ecological provinces of the Arabian Sea. The MONS ecological province experienced a sharp decline in the concentration of MP biomass during the onset phase of the summer monsoon period in comparison with other PSC. The MP predominated in the northern part of ARAB province attributed to convective mixing induced phytoplankton bloom. Monthly climatology revealed a rise and fall in the concentration of all PSC biomass during the winter monsoon and onset phase of the summer monsoon period, respectively in both ecological provinces of the Arabian Sea. This study recommends future work emphasizing on the validation of the existing PSC model in other parts of the Indian Ocean and subsequent regional parameterization, if necessary.



Scatter plot showing the relationship between Escherichia coli - salinity (top panel) and Escherichia coli – Total Suspended Matter (bottom panel) at upper (open circles) and lower (filled circle) Mahanadi estuary during high tide (left panel) and low tide (right panel). The dashed line indicate 1:1 trend. The vertical dotted line indicates the average of total population

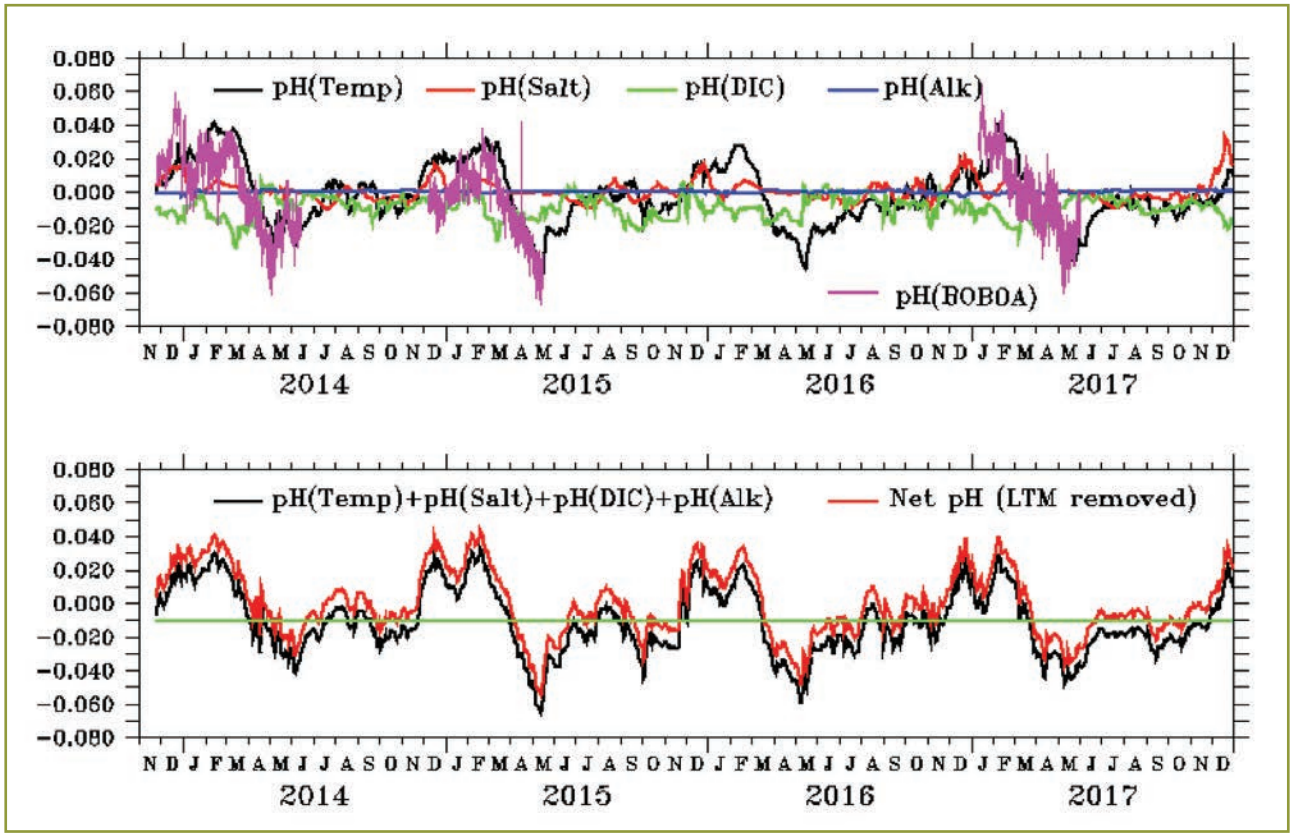


Satellite retrieved monthly climatology of phytoplankton size classes (pico, nano and microphytoplankton) in Box-A, B and C region of the Arabian Sea. Box - A falls in the ARAB province, Box-B in the transition zone of the ARAB and MONS province, and Box - C falls in the MONS ecological province defined by Longhurst

9.2.6 Modeling Indian Ocean carbon fluxes and acidification in a changing environment

A detailed analysis of the seasonal variability of surface ocean pCO_2 and pH in the northern Indian Ocean is carried out for the first time using a very high resolution, coupled state of the art regional ocean-ecosystem model simulated outputs of the Indian Ocean carbon cycle. The model faithfully reproduces the Indian Ocean carbon cycle as evident from its comparison with observations. The component form of pCO_2 and pH as contributed by the temperature, dissolved inorganic carbon, alkalinity, and salinity are decomposed to examine the seasonal variability. The maximum variance in the seasonal cycle of the northern Indian Ocean pCO_2 and pH are found in the western Arabian Sea. It is due to the seasonally driven upwelling/downwelling mechanisms. The effects of temperature and dissolved inorganic carbon complement each other in inducing seasonal variability in pCO_2 (with an amplitude ± 100 μatm) and pH (with an amplitude $\pm$ 0.2 pH unit). In the western Arabian Sea, the Arabian coastal upwelling is more influential in inducing a seasonal cycle in the northern Indian Ocean pCO_2 and pH. It is likely due to the intense coastal current in the Somali region, which transports the Somali coast's upwelled waters to the northern part of Great Whirl. In contrast, the Arabian coast's less intense coastal currents allow upwelled waters to remain in the vicinity and induce more variability in pCO_2 and pH. Among other variables, salinity controls the seasonal variability of pCO_2 and pH, and this is due to

the spreading of riverine freshwater input, which modifies the surface ocean buffer chemistry. This study also finds the spatio-temporal combined variability of all four variables in inducing a seasonal cycle in pCO_2 and pH. The maxima of seasonal amplitudes of pCO_2 and pH variability are found during April-May and August-September for both the basins. However, the governing mechanisms of the seasonal cycle of pCO_2 and pH in the Arabian Sea and Bay of Bengal are different, the former being an upwelling/downwelling mechanism and at the same time, the latter is due to the upper ocean mixed layer dynamics. The role of freshwater spreading into the northern head-bay stands out as a unique mechanism, which controls the pCO_2 and pH variability there.



Top panel: *Contribution of pCO_2 by individual factors such as temperature, salinity, DIC and alkalinity to the total pCO_2 expressed as pCO_2 reconstructed as in equation-1 and their difference with CTRL pCO_2 at (15°N, 90°E) where the Bay of Bengal Ocean Acidification (BOBOA) moored buoy is located. The observed pCO_2 is shown as the magenta line (annual mean subtracted).*

Bottom panel: *The sum of all terms in top-panel and net pCO_2 subtracted with as long term means (LTM). The residue is shown using green line. Units are in µatm.*

9.3 List of Publications (April 2020-March 2021)

1. Aditya N.D., Sandhya, K.G., Harikumar, R., T.M. Balakrishnan Nair, Development of Small Vessel Advisory and Forecast Services System for safe navigation and operations at sea (2020) Journal of Operational Oceanography. https://doi.org/10.1080/175587 6X.2020.1846267.
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11. Dash, M., Lotliker, A.A., Das, S.K., Sahu, K.C. Characterization of Aerosol Types by Columnar Optical Properties Analysis at a Coastal Site on Eastern Seaboard of India (2021) Aerosol Science and Engineering, 5 (1), pp. 56-69.
12. Francis, P. A., Jithin, A.K., Effy, J.B. et al. High-Resolution Operational Ocean Forecast and Reanalysis System for the Indian Ocean (2021) Bulletin of the American Meteorological Society, 101(8), E1340–E1356.
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22. Joseph, J., Girishkumar, M.S., Varikoden, H., Thangaprakash, V.P., Shivaprasad, S., Rama Rao, E.P. (2021) Observed sub-daily variability of latent and sensible heat fluxes in the Bay of Bengal during the summer. Climate Dynamics, 56 (3-4), pp. 917-934.
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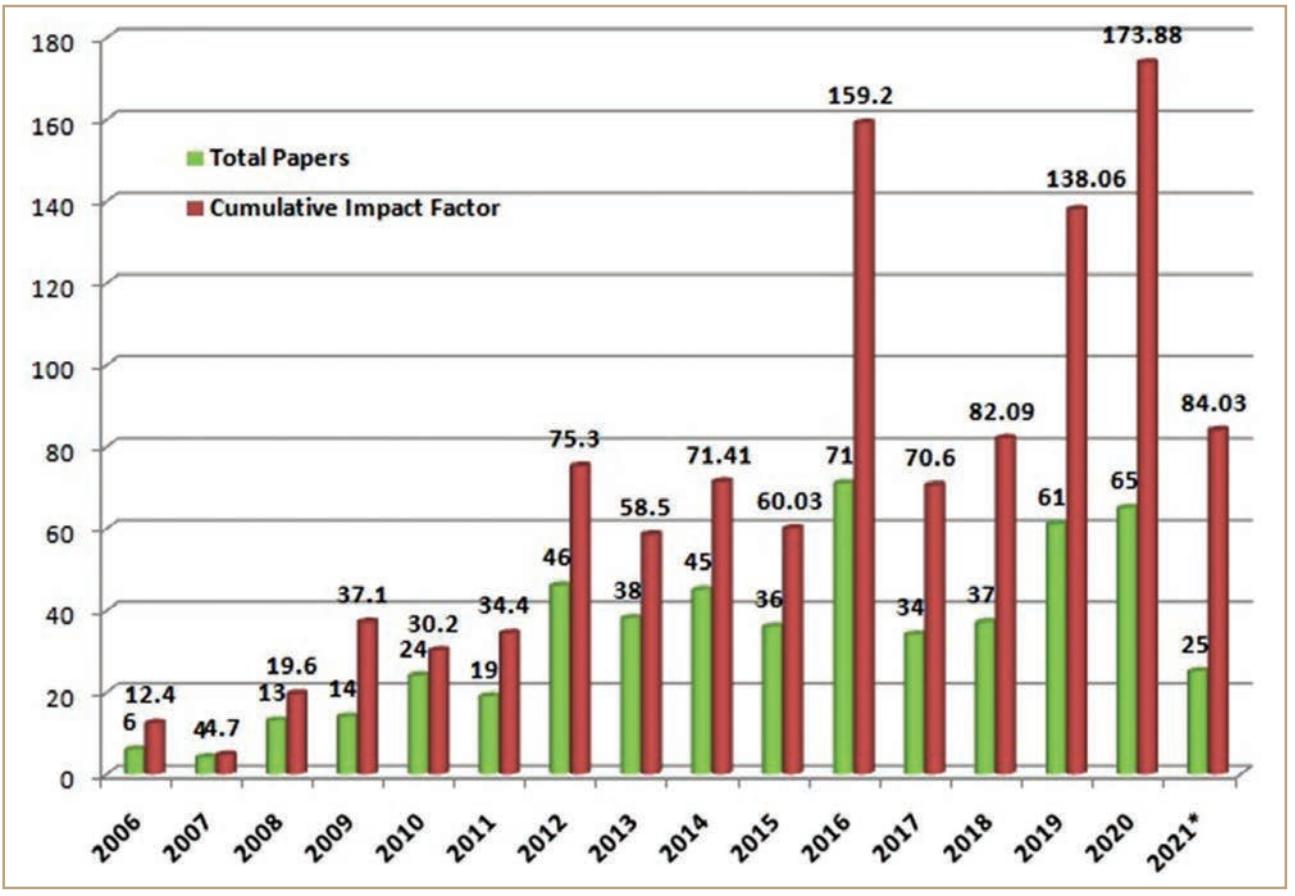


Growth of publications in peer review journals and their cumulative impact factor

10. Involvement in International Activities

10.1 IOGOOS Secretariat

INCOIS continued to host the secretariat of IOGOOS, a regional alliance formed by 29 institutions from 17 countries in 2002, for the 3rd term of six years (2015-2020). During the 16th Annual meeting of IOGOOS held virtually during 16 July 2020 and 02 February 2021, INCOIS, India was re-elected to host the Secretariat for the fourth term of six years (November 2020-October 2026). Dr. T. Srinivasa Kumar was elected as the IOGOOS Officer representing the Central Indian Ocean and the Interim-Chair. IOGOOS supports physical, biogeochemical, biological and climate related observations and related modelling aspects. Mr. M. Nagaraja Kumar, Scientist-E & Dr. Satya Prakash, Scientist-E were elected as co-Secretaries and coordinated the day-to-day activities of IOGOOS.

10.2 International Oceanographic Data Exchange

INCOIS continued to be the responsible NODC for India, as designated by IODE/IOC, UNESCO. Mr. E. Pattabhi Rama Rao acted as the National Coordinator for 'Data Management'. He also served as a member of IODE Quality Management Framework (SG-IODE QMF).

10.3 OceanSITES

OceanSITES as a component of the Global Ocean Observing System is a global timeseries programme and a recognized part of the international JCOMM. INCOIS has been designated as OceanSITES Data Assembly Centre (DAC). Shri. E. Pattabhi Rama Rao represented INCOIS on the OceanSITES Data Management Team responsible for ocean data management by devising appropriate standards, formats and quality controls.

10.4 Partnership for Observation of the Global Oceans (POGO)

INCOIS continued to be a member of the POGO created in 1999 by the Directors and leaders of major global oceanographic institutions, to promote global ocean observations and research. POGO focuses on the implementation components of international and integrated global ocean observing systems.

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

RIMES is an intergovernmental organisation registered with the United Nations, aiming to provide regional early warning services including early warning of tsunamis and hydro-meteorological hazards and to build the capacity of its Member States.

As per the MoU between MoES, Govt. of India and RIMES, INCOIS continued to provide the ocean

state forecasts for Comoros, Madagascar, Maldives, Mozambique, Seychelles and Sri Lanka and the tsunami early warnings to RIMES for its dissemination to members.

10.6 SIBER International Programme Office

INCOIS hosts the SIBER programme office which manages the organisation of annual Science Steering Committee (SSC) meetings and sharing of updates along with management of the SIBER website. INCOIS is represented at SIBER by Dr. Satya Prakash who also manages the programme office.

10.7 IIOE-2

The Second International Indian Ocean Expedition (IIOE-2) is a major global programme co-sponsored by IOC, the Scientific Committee on Oceanic Research (SCOR) and IOGOOS, with INCOIS serving as one of the two Joint Programme Offices (JPOs). Dr. Satheesh Shenoi continued as one of the co-chair of the IIOE-2 Steering Committee and Dr. Satya Prakash, Scientist E, INCOIS continued as JPO-India coordinator. Two issues of the half-yearly newsletter of IIOE-2 (11th and 12th issues), named, "The Indian Ocean Bubble-2" has been published from JPO-India. Shri Kiran Kumar and Dr. Satya Prakash contributed considerably in preparing and publishing the newsletters. Dr. E. Pattabhi Rama Rao, Scientist F, INCOIS was elected as Co-chair of Working Group 2 on Data and Information Management of IIOE-2.

10.8 Ocean Predict

Ocean Predict is a consortium of organizations working in the field of operational oceanography to promote ocean observations, ocean modelling, data assimilation and ocean predictions with its project office hosted by UK Met Office. INCOIS continued to contribute significantly to the activities of Ocean Predict. The Advisory Committee of Ocean Predict guides the Science Team to attain various targets and supports the project office. During the reporting period, Dr. Abhisek Chatterjee continued to be the member of the Ocean Predict Science Team (OPST) and Dr. Francis P. A, continued to serve as a member of the Ocean Predict Advisory Committee.

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

ITEWC at INCOIS serves as one of the Regional Tsunami Service Provider for the Indian Ocean under the Indian Ocean Tsunami Warning and Mitigation System framework of the IOC-UNESCO. Shri. E. Pattabhi Rama Rao continued as vice-chair of the group during this period. Shri Patanjali Kumar also continued as Vice-Chair for Working Group-2 (WG-2) on Tsunami Detection, Warning and Dissemination and as member of TT for Scientific Hazard Assessment for the Makran Subduction Zone. Ms. M.V. Sunanda continued as Vice-Chair for the Sub Regional Working Group for the North West Indian Ocean (WG-NWIO) and as a member of TT for Tsunami Preparedness for a Near-Field Tsunami Hazard. Similarly, Shri R. S. Mahendra and Shri. B. Ajay Kumar worked as the members of Working group-1 on Tsunami Risk, Community Awareness and Preparedness. Shri. J. Padmanabham is a member of WG-2 and Dr. Dipankar Saikia is a member of

WG-NWIO. Shri B. Ajay Kumar is also a member of TT for the Indian Ocean Wave 2020 (IOWAVE20) exercise.

10.10 Union Commission for Data and Information (UCDI) of International Union for Geophysics and Geodesy (IUGG)

UCDI is one of the eight commissions of IUGG established to enable a high level of cooperation within and between scientific communities. The President of IUGG appoints the Chair and members of the commissions. Dr. S.S.C. Shenoi, former Director, INCOIS, who served as the chair of UCDI during 2015-2019 is reappointed as its chair for the period 2019-2023.

11. General Information

11.1 Awards and Honours :

11.1.1 WMO Research Award-2020 for Young Scientists

Mr. B. Rohith was selected for WMO Research Award-2020 for Young Scientists for the paper entitled "Basin-wide sea level coherency in the tropical Indian Ocean driven by Madden-Julian Oscillation" by B. Rohith et al., published in Nature Communications, 2019, 10(1), 1257.

11.1.2 Associate of the Indian Academy of Sciences

Dr. Kunal Chakraborty, Scientist–E has been elected as an Associate of the Indian Academy of Sciences (IAS) in 2020.

11.1.3 Membership of the National Academy of Sciences, India (NASI)

Dr. Kunal Chakraborty has been selected for the membership of the National Academy of Sciences, India (NASI).

11.1.4 MoES Awards

Dr. Abhisek Chatterjee, Scientist-D was awarded Certificate of Merit 2020 for his outstanding contributions in ocean sciences during MoES Foundation Day-2020 celebrations at Prithvi Bhavan, New Delhi on 27 July 2020. Mr. T. V. Rajesh, Scientific Assistant B and Mr. Santosh Kumar, Senior Executive received the best employee awards for their outstanding contributions in INCOIS.

11.1.5 Swachta Pakhwada-2020 Prize

INCOIS received first prize for exemplary performance during Swachta Pakhwada-2020 among the MoES institutes. Swachh Bharat committee members of INCOIS attended the prize distribution ceremony organized at MoES through virtual mode on 19 November 2020. Dr. M P Wakdikar, Programme Head of INCOIS received the prize on behalf of INCOIS.

11.1.6 Certificate for Fit India Freedom Run

INCOIS received certification from the Ministry of Youth Affairs & Sports, Government of India for successfully organising the “Fit India Freedom Run” programme at INCOIS.

11.2 Memorandum of Understanding

11.2.1 INCOIS signed an MoU with Andhra University for establishment of INCOIS field centre within Andhra University Campus on 24 December 2020.



11.2.2 A Letter of Intent (LoI) was signed between INCOIS and the Shipping Corporation of India Ltd. (SCI) for research and development towards ocean observation and forecasting services on 01 March 2021. INCOIS and SCI mutually agreed to work together to strengthen long term collaborations in the area of safety at sea, optimum ship route forecasts, weather forecasts during extreme events etc.

11.2.3 Indian Navy signed a Memorandum of Understanding (MoU) with INCOIS for sharing of ocean services, data, and expertise in the field of operational oceanography and the agreement will benefit both Indian Navy and INCOIS in furthering meaningful interactions and professional exchanges in future.



11.3 Official Language Implementation

11.3.1 Gazette of India notification for INCOIS

In pursuance of sub-rule (4) of Rule 10 of the Official Language (use for official purposes of the union), Rules 1976, the Central Government has notified the INCOIS as office having more than 80% staff with working knowledge in Hindi in its Gazette of India.

11.3.2 Hindi Training

In accordance with the official language rules, INCOIS strictly follows the provision of training in Hindi to all staff members. A training session was conducted at INCOIS from January 2020 to May 2020 (in online mode) by the Department of Official Language, Ministry of Home Affairs, Hindi Teaching Scheme, Hyderabad. Twelve employees finished the Hindi Parangat training programme and 4 employees completed Hindi Pragya training programme in November 2020. There are now 25 employees registered for the Parangat training session and one employee registered for the Pragya training session of January-May 2021.

11.3.3 Hindi Workshop/Seminars

- Dr. Ravi Mishra, Scientist 'D', National Centre for Polar and Ocean Research (NCPOR) delivered an invited lecture on the topic 'Vigyan & Lokprasar' on 07 September 2020.
- Shri. Deshpal Singh Rathore, Chairman, Parivarthan Rajbhasha Academy, New Delhi (Former Special Invitee, Hindi Advisory Committee, Ministry of Steel, Govt. of India) and Shri K.P. Satyanandan, Member, Parivarthan Rajbhasha Academy (Former Deputy Director, Official Language, Ministry of Railways) were speakers for the Hindi Workshop which was conducted on 30 December 2020 on the topic "Official Language Policy of Government of India, Hindi Correspondences".

11.3.4 Hindi Pakhwada (Fortnight) Celebrations

INCOIS celebrated Hindi Pakhwada from 01-14 September 2020. During the Pakhwada, various competitions like E- Poster, Essay, Extempore Speech, Hindi Poems were organized at INCOIS via virtual mode. Hindi Poems competition was also organized for the children of INCOIS employees. Winners of the competitions were felicitated with prizes during the concluding ceremony held on 14 September 2020.

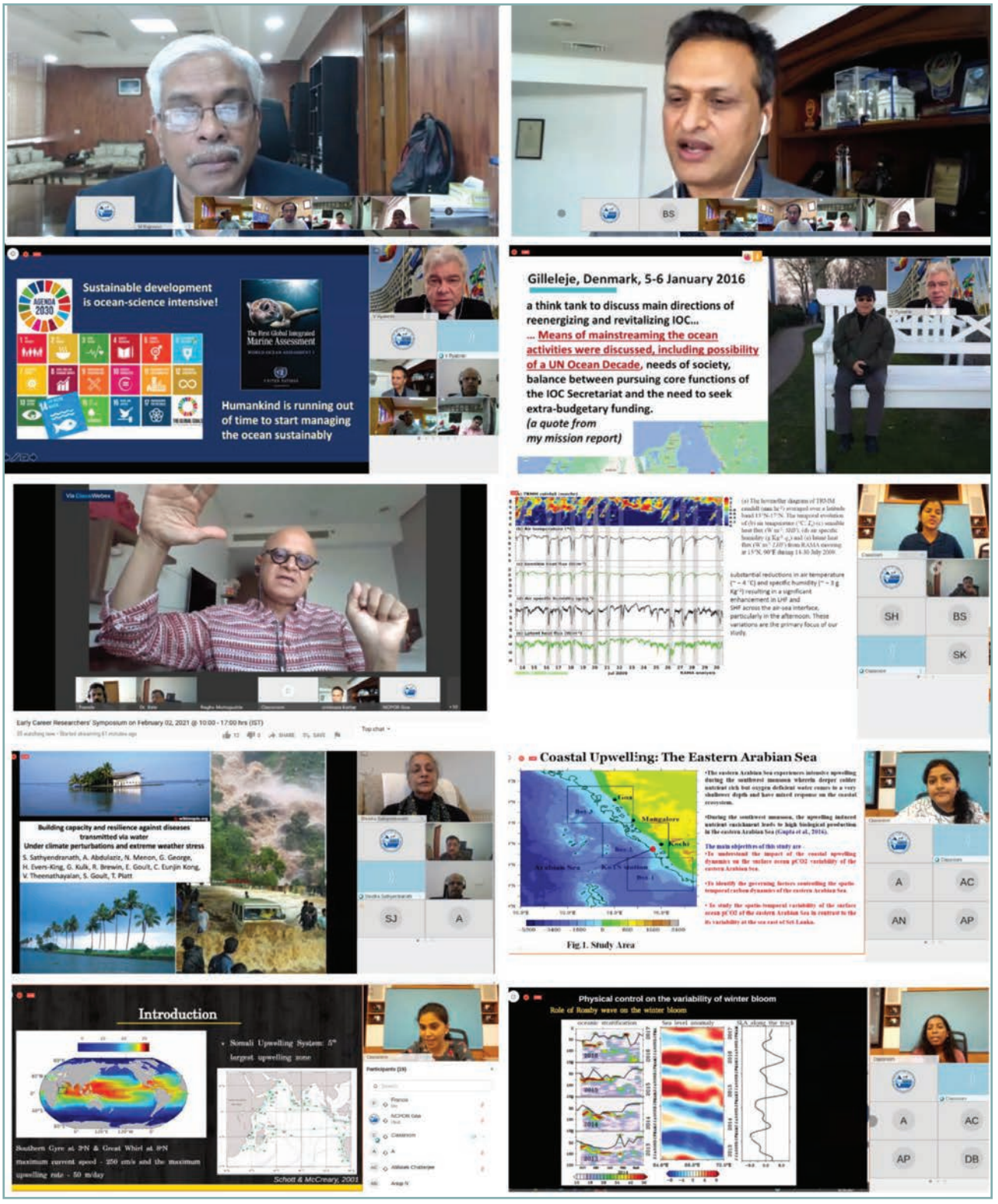
11.3.5 Official Language Implementation Committee meetings

The meetings of the OLIC to evaluate the progress of work being done in Hindi was organized at regular intervals. Four meetings of the OLIC were conducted during the reporting period. Quarterly reports for the quarter ending on 31 March 2020, 30 June 2020, 30 September 2020 and annual progress report for the year ending on 31 March 2021 on the continued use of Hindi in INCOIS were prepared and sent to MoES within the specified period of time. The half yearly reports to the Town Official Language Implementation Committee (TOLIC) were submitted on regular intervals. Director, INCOIS and the members of OLIC attended the meeting of TOLIC on 04 December 2020. Shri Manoj Abusaria, Joint Director (OL), MoES conducted the inspection of Official language Policy at INCOIS during 18-19 February 2021. The inspection included the action taken report on last inspection, report regarding the Implementation of O.L. Act/Rules/ Annual programme and other orders/instructions.

11.4 INCOIS Foundation Day

INCOIS celebrated its 23rd Foundation Day on 03 February 2021. Dr. Vladimir Ryabinin, Executive Secretary, of the IOC-UNESCO and Assistant Director-General of UNESCO delivered the Foundation Day Lecture on "United Nations Decade of Ocean Science for Sustainable Development", an important initiative that was recently launched by the UN and is being spearheaded by the IOC. Dr. M. Rajeevan, Secretary, MoES and Chairman, INCOIS Governing Council presided over the event. The virtual event was attended by many senior scientists and researchers across MoES institutes and other national and international oceanographic institutions. An "in-camera" kick-off meeting of the Members of India's National Decade Coordination Committee (NDCC) followed the foundation day lecture.

INCOIS organized 'Early Career Researchers' Symposium on 02 February 2021 as part of 23rd Foundation Celebration. Dr. T. Srinivasa Kumar, Director, INCOIS delivered the Inaugural address. Prof. Raghu Murtugudde (UML, USA) and Dr. Shuba Sathyendranath (PML, UK) delivered plenary talks in this symposium. Nine research scholars of INCOIS and INCOIS funded extramural projects made presentations on their recent research findings.



11.5 Women's Day Celebrations

INCOIS celebrated International Women's Day on 08 March 2020. On this occasion, an interactive session was held virtually with Dr. Usha Varanasi, Former Science & Research Director, NWFSC, NOAA, Department of Chemistry and School of Aquatic and Fishery Sciences, University of Washington. As part of the celebrations E-poster competition for employees of INCOIS was also held.

11.6 Rashtriya Ekta Diwas

INCOIS celebrated the birth anniversary of Shri Sardar Vallbhbhai Patel and observed "Rashtriya Ekta Diwas" (National Unity Day). As per the Instruction of Govt. of India, "Rashtriya Ekta Diwas" pledge was organized on 29 October 2020 for all the staff of INCOIS. Dr. T. Srinivasa Kumar, Director, INCOIS led the pledge taking ceremony.

11.7 Swachch Bharat Programme

INCOIS observed Swachhata Pakhwada during the first fortnight of July 2020 (01–15 July 2020). During this event INCOIS carried out 11 different activities covering all working days. The activities include three webinars from eminent scientists of INCOIS as well from outside the institute. Two days of plantation drive, campus sanitization in coordination with COVID Task Force of INCOIS, an event on "Discouraging single use plastic" and awareness on personal hygiene among INCOIS outsourced staff were conducted by the INCOIS Swachhta Pakhwada committee chaired by Dr. Aneesh A. Lotliker. Three competitions (e-poster, drawing and essay writing) for school children and for children of INCOIS employees were arranged online. All the activities were carried out with minimal physical gathering keeping in mind all the instructions and guidelines issued by the M/o Home Affairs and M/o Health and Family Welfare in current Covid-19 pandemic.

11.8 Vigilance and RTI Activities

Shri B.V. Satyanarayana, Scientist 'G' & Head, CWG continued to serve as Vigilance Officer of INCOIS. No new complaints were received during the period 01 April 2020 to 31 March 2021. INCOIS observed "Vigilance Awareness Week 2020" from 27 October-02 November 2020 with the theme "SATARK BHARAT, SAMRIDDH BHARAT" (VIGILANT INDIA, PROSPEROUS INDIA). As per the instructions of GoI guidelines, an Integrity Pledge was organized for all the staff of INCOIS on 28 October 2020. Dr. T. Srinivasa Kumar, Director, INCOIS led the pledge taking ceremony.

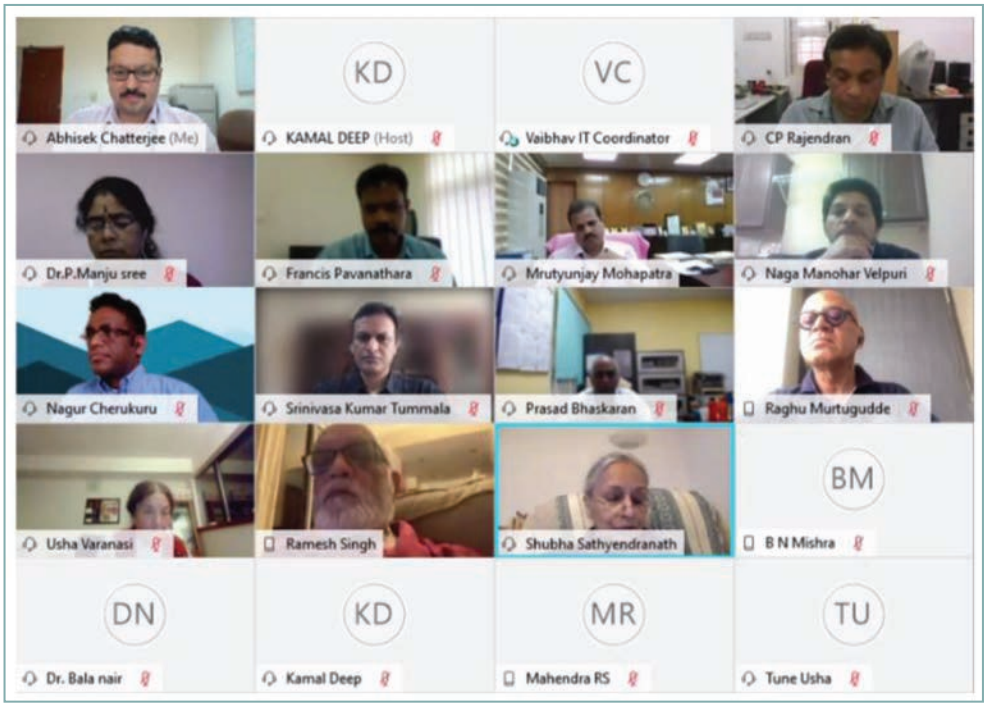
In respect of the Right to Information Act (RTI) 2005, INCOIS related queries were regularly updated on the INCOS website in prescribed format. Shri. E. Pattabhi Rama Rao, Scientist F & Head, ODG functioned as the Public Information officer and Dr. T. Srinivasa Kumar, Director, INCOIS as the first appellate authority. Under RTI, 21 requests were received and the required information were provided. One first appeal was also received and disposed off under RTI act during this period.

11.9 IISF-2020

INCOIS coordinated the Vigyan Yatra outreach event in Hyderabad on 13 December 2020 as part of the India International Science Festival (IISF) 2020 in collaboration with VIBHA, NGRI, ARCI and NIAB. Dr. Shailesh Nayak, Former Secretary MoES & Director, National Institute of Advanced Studies (NIAS) delivered a talk on "Earth Science for Self-reliant India". The event also included a virtual tour of INCOIS and Science-Expo under the theme "Science for Aatmanirbhar Bharat (Self-Reliant India) and Global Welfare".

11.10 VAIBHAV

VAIBHAV is an initiative of Government of India to get active involvement of non-resident Indian scientists/academicians in the R&D activities in government laboratories and academic institutions in India. There were 18 verticals in this summit, in which Earth Sciences, lead by MoES, was one of the verticals. In connection with this summit, INCOIS organized three sessions in the Ocean Science and Technology horizontal., viz.- 1. Studies on Marine Ecosystem,



Fisheries and Marine Pollution towards Integrated Fisheries and Water quality Information System; 2. Modeling, Observation, Evaluation and Synthesis towards Indian Ocean Prediction; and 3. Multi Hazard Vulnerability and Mitigation in the coastal areas towards Impact based multi hazard warning system. The virtual sessions were held during 16, 19 and 20 October 2020. Twenty two (22) Indian researchers and 19 foreign researchers attended the sessions and discussed possible areas of mutual collaborations. A consolidated document on the outcome of the sessions is submitted to MoES for further follow up.

11.11 Superannuation

Dr. Satheesh Shenoi after leading INCOIS for 11 years, superannuated on 31 May 2020. A virtual farewell event was held with INCOIS staff on 29 May 2020 to facilitate Dr. Shenoi. Director-in Charge, Dr. T.M. Balakrishnan Nair presided over the same.

11.12 Taking charge as Director

Dr. T. Srinivasa Kumar, assumed charge as full time INCOIS Director on 28 August 2020, taking over from Dr. T. M. Balakrishnan Nair who was acting as in-charge Director since 01 June 2020.

11.13 Rooftop solar system

In an endeavour to increase its solar energy utilization, INCOIS installed a solar power system of 214.50 kWp capacity on the newly built ITCOocean buildings. This system is expected to generate approximately 3 lakh units of green energy in its 1st year of operation. Clean Max Enviro Energy Solutions Pvt. Ltd. supported INCOIS to install this facility. The grid connected rooftop solar power plant was inaugurated by Dr. M Rajeevan, Secretary, MoES (online mode).

11.14 Academic Projects carried out by students at INCOIS (Online Mode)

Sl No.	Student Name	Institute	Project Guide
1	Aneeta Thomas	Kerala University of Fisheries and Ocean Studies (KUFOS)	Sandhya K G
2	Anju Sebastian	Cochin University of Science and Technology (CUSAT)	Sudheer Joseph
3	Annapoorna J	Andhra University	Udaya Bhaskar TVS
4	Aparna A R	Cochin University of Science and Technology (CUSAT)	Girish Kumar M S
5	Bali Madhu	Andhra University	Udaya Bhaskar TVS
6	Greeshma S	University of Hyderabad	Francis P A
7	Gouri Anil	Cochin University of Science and Technology (CUSAT)	Abhisek Chatterjee

8	Harin R Nair	Mangalore University	Patanjali Kumar CH
9	Jaya Sai Papolu	VRSEC, Vijayawada	Geetha G
10	Koundinya M	Indian Institute of Technology, Kharagpur	Padmanabham J
11	Lekheshwar B	Jawaharlal Nehru Technological University, Hyderabad	Kiran Kumar N
12	Meka Bhanu Prasad	VRSEC, Vijayawada	Geetha G
13	Mohit Mohanta	Central University of Karnataka	Mahendra R S
14	Naga Varun	VRSEC, Vijayawada	Venkat Shesu R
15	Sai Pravallika	VRSEC, Vijayawada	Vighneshwar B
16	Saishyam M	Central University of Karnataka	Ajay Kumar B
17	Sandeep N	VRSEC, Vijayawada	Venkat Shesu R
18	Shabarinath K	Mangalore University	Prasad SJ
19	Sreya Basu	Pondicherry University	Venkat Shesu R
20	Sreeraj M	Mangalore University	Shiva Kumar H
21	Srivthsa	Mangalore University	Ajay Kumar B
22	Sridhar A	Bharathidasan University	Mahendra R S
23	Subhasri Indira P	Central University of Karnataka	Patanjali Kumar CH
24	Tejaswani Naiki	University of Hyderabad	Kiran Kumar N
25	Vasil	Cochin University of Science and Technology (CUSAT)	Kunal Chakraborty
26	Vineesh S	Indian Institute of Information Technology, Sri City	Annapurniah K
27	Vineetha Gurunath	Savitribai Phule Pune University	Mahendra R S
28	Vivek Vardhan D	Jawaharlal Nehru Technological University, Hyderabad	Vighneshwar B
29	Vishnu Vytla	VNR-VJIT, Hyderabad	Balaji B

11.15 Deputation Abroad

Ms. L. Jyothi, SRF, INCOIS was deputed to undertake Overseas Visiting Doctoral Fellowship program at Purdue University, USA during 01 February-31 July 2021.

List of International Meeting attended by INCOIS Official (Virtual Mode)

- Dr. S.S.C. Shenoi, Dr. T. M. Balakrishnan Nair, and Shri M. Nagaraja Kumar participated in the 16th Annual Meeting of the Indian Ocean Global Ocean Observing System (IOGOOS) held on 16 July 2020.
- Dr. Nimit Kumar participated in 'Fish and Ships Workshop', organized jointly by Stanford University and Global Fishing Watch during 27-29 July 2020.
- Dr. Nimit Kumar participated in virtual workshop 'Marine Spatial Planning : Balancing social, economic, cultural and ecological objectives' organized by IMBeR-IMECaN (Integrated Marine Biosphere Research-Interdisciplinary Marine Early-Careers' Network) during 17-19 August 2020.

- Dr. Nimit Kumar participated in '2020 PACE Applications Workshop' organized by NASA during 23-24 September 2020.
- Director, INCOIS and several senior scientists of INCOIS participated Vaibhav Summit in three sessions on Ocean Sciences and Technology organized by INCOIS on 16-17 October and 19 October 2020.
- Dr. Nimit Kumar participated in a 4-week MOOC (Massive Open Online Course) 'Ocean Science in Action: Addressing Marine Ecosystems and Food Security in the Western Indian Ocean' (FutureLearn portal) organized by NOC, UK during October 2020.
- Dr. T. Srinivasa Kumar, Mr. Pattabhi Rama Rao, Ms. M V Sunanda, Mr. B Ajay Kumar and Mr. Ch Patanjali Kumar participated in National Consultation Meeting of the project entitled "Strengthening tsunami early warning in the North West Indian Ocean region through regional cooperation" funded by United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) on 19 November 2020.
- Dr. T. Srinivasa Kumar, participated in the 3rd ESCAP Sustainable Business Network (ESBN) Augmenting Tsunami Monitoring Steering Committee meeting held virtually on 23 November 2020.
- Dr. T. Srinivasa Kumar, participated in a meeting for the action plans for India to be undertaken for the contributions to the United Nations Decade of Ocean (2021-2030) program of the IOC-UNESCO on 25 November 2020.
- Dr. Nimit Kumar participated in 'International Virtual Conference on the use of Environmental DNA (eDNA) in Marine Environments: Opportunities and Challenges' organized by POGO (Partnership for Observation of the Global Ocean) during 30 November-03 December 2020.
- Dr. Abhisek Chatterjee attended Annual meeting of the Ocean Predict Science Team Meeting (OPST) during 7-10 December 2021.
- Dr. T. Srinivasa Kumar, Shri. E. Pattabhi Rama Rao, Mr. Ch Patanjali Kumar, Scientist 'E' and Ms. MV Sunanda, attended (ICG/IOTWMS) steering group virtual meeting conducted during 16-17 December 2020.
- Dr. T. Srinivasa Kumar and Dr. Satya Prakash, participated in the preparatory meeting of 53rd Session of Intergovernmental Oceanographic Commission (IOC) of UNESCO Executive council meeting to be held during 3-9 February 2021.
- Dr. T. Srinivasa Kumar, attended the virtual preparatory meeting for the UN Ocean Decade held on 29 January 2021.
- Dr. T. Srinivasa Kumar, Shri E. Pattabhi Rama Rao and Ms. Sunanda M.V. participated the ICG IOTWMS Steering Group meeting on UN Decade for Ocean Science call for action, which was held on 11 January 2021 to discuss about the feasibility of proposing a Programme for Tsunami within the United Nations Decade of Ocean Science for Sustainable Development.
- Dr. T. Srinivasa Kumar, participated in the 4th meeting of the UNESCO Category 2 RCOWA Governing Board on 12 January 2021.
- Dr. T. Srinivasa Kumar, participated in the discussion meeting of MoES-Cefas on 22 January 2021 to discuss collaboration between MoES and Centre for Environment, Fisheries

and Aquaculture Science (CEFAS), UK on the use of satellite imagery to identify and track marine litter.

- Dr. T. Srinivasa Kumar, participated in the 22nd annual meeting of Partnership for Observation of the Global Ocean (POGO-22) on 25 January 2021.
- Dr. Nimit Kumar participated in 'Copernicus Marine Service General Assembly' organized by Mercator Ocean international during 26-28 January 2021.
- Dr. T. Srinivasa Kumar and Shri. E. Pattabhi Rama Rao attended the virtual preparatory meeting for the Arabian Sea International Collaboration workshop.
- Dr. T. Srinivasa Kumar participated in the virtual meeting of 53rd Session of the IOC Executive Council and related meetings during 3-9 February 2021.
- Dr. Nimit Kumar participated in an online workshop 'FiSAT (Fish Stock Assessment Tool) by UN-Food and Agriculture Organization (FAO)' organized by Univ. of Jafna, Sri Lanka on 10 February 2021.
- Dr. T. Srinivasa Kumar participated in IOC Regional Committee for the Central Indian Ocean (IOCINDIO) preparatory meeting held virtually on 11 February 2021 on activities being done by India in the Indian Ocean region together with other IOCINDIO member States and other collaborations.
- Dr. T. Srinivasa Kumar, participated in the IOCINDIO consultation meeting to consider its elevation as sub commission on 16 February 2021.
- Shri Pattabhi Rama Rao, attended ICG/IOTWMS meeting in preparation for TTDMP, TTTWO, and 14th Working Group on Tsunamis and other hazards related to Sea-Level Warning and Mitigation Systems (TOWS-WG) during 16-17 February 2021.
- Dr. T. Srinivasa Kumar participated in the SC-WMO Meeting of WMO during 17-18 February 2021.
- Shri Pattabhi Rama Rao attended a meeting of the IOC-UNESCO, Task Team on Tsunami Watch Operations (TTTWO) on 23 February 2021.
- Dr. T. Srinivasa Kumar participated in the preparatory meeting for discussing the proposed India-US joint program on Arabian Sea Boundary Layer Dynamics Studies during 22-23 February 2021. Other senior scientists from INCOIS also attended the meeting.
- Dr. T. Srinivasa Kumar and Shri Pattabhi Rama Rao participated in the meeting of the Indian Ocean Observing System (IndOOS) Resource Forum (IRF-12) on 16 March 2021.
- Dr. Nimit Kumar participated in recurring meetings as part of a) PORSEC Scientific Organizing Committee (Exec. Sec. for Membership, Education and Outreach Chair); b) as founder and core-committee member of IIOE-2 ECSN (Early-Career Scientists' Network) and c) as member of GEO Blue Planet Working Group on Fisheries during April 2020-March 2021.

11.16 INCOIS Human Capital

Category/Designation	Regular	Category/ Designation	Project Mode
Scientific Staff			
Director	01	Project Sci - D	01
Scientist 'G'	03 *	Project Sci - C	04
Scientist 'F'	05	Project Sci - B	23
Scientist 'E'	17	Project Assistant	27
Scientist 'D'	14 #	Admin Assistant/ Office Assistant/ Jr. Office Asst.	10
Scientist 'C'	00 #@	Lab Attendants	6
Scientist 'B'	00 @	Driver-cum-Attendant	4
Scientific Support Staff		Consultants	0
Scientific Assistant B	16	Research Fellows (Ph.D Programme/ Women Scientist/Post Doctoral Fellow)	18
Scientific Assistant A	3		
Administrative Staff			
Manager	1		
Jt. Manager	2		
Asst. Manager	4		
Sr. Executive	3		
Total	**69**	**Total**	**93**

* Dr. M. Ravichandran, Scientist 'G' is on lien.

Excluding CAT Trainee appointments

@ one post of Scientist – C and one post of Scientist – B is vacant due to resignation and recruitment is under process.

12. Acronyms

ADCP	Acoustic Doppler Current Profiler
APL	Applied Physics Laboratory
ARCI	International Advanced Research Centre for Powder Metallurgy and New Materials
AWS	Automated Weather Station
C2C	Category 2 Centre
CFNA	Continuous Flow Nutrient Analyzer
CMFRI	Central Marine Fisheries Research Institute
CMLRE	Centre for Marine Living Resources and Ecology
DOM	Digital Ocean Mission
ECMWF	European Centre for Medium-range Weather Forecast
FSI	Fisheries Survey of India
GC	Governing Council
GODAS	Global Ocean Data Assimilation System
GSI	Geological Survey of India
HOOFS	High-resolution Operational Ocean Forecast and reanalysis System
ICAR	Indian Council for Agricultural Research
ICG	Intergovernmental Coordination Group
IIOE2	International Indian Ocean Expedition-2
IIRS	Indian Institute of Remote Sensing
IISF	India International Science Festival
IITM	Indian Institute of Tropical Meteorology
IMD	India Meteorological Department
INCOIS	Indian National Centre for Ocean Information Services
IOC	Intergovernmental Oceanographic Commission
IODE	Intergovernmental Oceanographic Data Exchange
IOGOOS	Indian Ocean Global Ocean Observation System
IOTWMS	Indian Ocean Tsunami Warning and Mitigation System
IRMS	Isotope-Ratio Mass Spectrometer
ITCOocean	International Training Centre for Operational Oceanography
ITEWS	Indian Tsunami Early Warning System
JPO	Joint Program Office
LDCL	Lakshadweep Development Corporation Ltd.
LETKF	Localized Ensemble Transform Kalman Filter
MLD	Mixed Layer Depth
MoES	Ministry of Earth Sciences
NCCR	National Centre for Coastal Research

NCESS	National Centre for Earth System Sciences
NCMRWF	National Centre for Medium Range Weather Forecast
NCPOR	National Centre for Polar and Ocean Research
NCS	National Centre for Siesmology
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NGRI	National Geophysical Research Institute
NHO	National Hydrographic Office
NIO	National Institute of Oceanography
NIOT	National Institute of Ocean Technology
NOAA	National Oceanic and Atmospheric Administration
NODC	National Ocean Data Centre
NODPAC	Naval Oceanographic Data Processing and Analysis Centre
NRSC	National Remote Sensing Centre
OMZ	Oxygen Minimum Zone
OSDMA	Odisha State Disaster Management Authority
OSF	Ocean State Forecast
OTGA	Ocean Teacher Global Academy
PFZ	Potential Fishing Zone
PML	Plymouth Marine Laboratory
POGO	Partnership for Observation of Global Ocean
RAIN	Regional Analysis of Indian Ocean
RIMES	Regional Integrated Multihazard Early warning System
ROMS	Regional Ocean Modelling System
RTC	Regional Training Centre
SCI	Shipping Corporation of India
SCOR	Scientific Committee on Ocean Research
SDG	Sustainable Development Goals
SIBER	Sustained Indian Ocean Biogeochemistry and Ecosystem Research
SST	Sea Surface Temperature
TSP	Tsunami Service Provider
UML	University of Maryland
UN Ocean Decade	United Nations Decade of Ocean Science for Sustainable Development (2021-2030
UW	University of Washington
VAIBHAV	Vaishwik Bharatiya Vaigyanik Summit
VIBHA	Vijnana Bharathi
WHOI	Woods Hole Oceanographic Institute
WMO	World Meteorological Organization
XBT	Expendable Bathythermograph

13. Finance

Chartered Accountants
PPKG & Co

Batgach
& AFFILIATES
A NETWORK APPROVED BY ICAI

AUDITORS' REPORT

To

The Chairman and Members,
Governing Council,
INDIAN NATIONAL CENTRE FOR
OCEAN INFORMATION SERVICES,
Ocean Valley, Pragathinagar (BO), Nizampet (SO)
Hyderabad-500 090, India

We have audited the attached Balance Sheet of **The INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES** as at 31st March 2021, and also the Income & Expenditure Account and Receipts & Payments Account for the year ending on that date annexed thereto. These financial statements are the responsibility of the Society's Management. Our responsibility is to express an opinion on the financial statements based on our Audit.

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

1. We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purpose of our Audit.
2. In our opinion, proper books of accounts as required by the Society, have been kept by the Society so far as appears from our examination of such books.
3. The Balance Sheets, Income & Expenditure Account, Receipts & Payment 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 Notes forming part of Accounts, the Balance Sheet as at 31st March 2021, Income & Expenditure Account and Receipts & Payments Account for the year ending 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 **PPKG & CO**
Charted Accountants

PPKG & CO. CHARTERED ACCOUNTANTS

(Giridhari Toshniwal)
Partner
M.No.: 205140
FRN No.: 0099665S

Date : 23.08.2021
Place : Hyderabad
UDIN : 21205140AAAAJS3224

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(Ministry of Earth Sciences, Govt. of India)

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

BALANCE SHEET AS AT 31st MARCH 2021

Particulars	Schedules	Current Year (2020-21) ₹	Previous Year (2019-20) ₹
CAPITAL & LIABILITIES			
Corpus fund	1	11,83,97,544	16,69,53,884
Earmarked funds	2	10,69,28,671	22,62,76,901
Current liabilities & Provisions	3	23,75,29,115	16,94,35,304
Total		**46,28,55,330**	**56,26,66,089**
ASSETS			
Fixed Assets	4	1,96,39,484	2,75,37,317
Current Assets, Loans & Advances	5	44,32,15,845	53,51,28,772
Total		**46,28,55,330**	**56,26,66,089**
Notes forming part of Accounts	11	-	-

As per our report of even date

For PPKG & Co.

Chartered Accountants

Giridhari Toshniwal

Partner

M. No. 205140

FRN No: 009655S

Place: Hyderabad

Date: 19.08.2021

For and on behalf of

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(S. Nageswara Rao)

Sr. Accounts Officer

S. Nageswara Rao

Senior Accounts Officer

(T. Srinivasa Kumar)

Director

Dr. T. Srinivasa Kumar

Director, INCOIS

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(Ministry of Earth Sciences, Govt. of India)

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

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 2021

Particulars	Schedules	Current Year (2020-21) ₹	Previous Year (2019-20) ₹
INCOME			
Income from Sales / Other Income	6	53,42,066	83,49,056
Interest Earned on Investments	7	26,38,425	32,29,306
Recurring Grants	8	22,60,00,000	21,80,00,000
TOTAL - A		**23,39,80,491**	**22,95,78,362**
EXPENDITURE			
Establishment Expenditure	9	15,94,94,491	13,17,10,821
Other Administrative Expenses	10	11,48,48,687	10,75,33,088
Depreciation	4	81,93,654	1,27,64,696
TOTAL - B		**28,25,36,832**	**25,20,08,605**
Excess of Income over expenditure (A-B)	1	**-4,85,56,340**	**-2,24,30,243**
Balance being net income / deficit transferred to Corpus Fund		**-4,85,56,340**	**-2,24,30,243**
Notes forming part of Accounts	11		

As per our report of even date

For PPKG & Co.

Chartered Accountants

Giridhari Toshniwal

Partner

M. No. 205140

FRN No: 009655S

PPKG & CO. CHARTERED ACCOUNTANTS

For and on behalf of

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(S. Nageswara Rao)

Sr. Accounts Officer

S. Nageswara Rao

Senior Accounts Officer

(T. Srinivasa Kumar)

Director

Dr. T. Srinivasa Kumar

Director, INCOIS

Place: Hyderabad

Date: 19.08.2021

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 2021

RECEIPTS	"CURRENT YEAR 2020-21"		PAYMENTS	"CURRENT YEAR 2020-21"	
	₹	₹		₹	₹
Opening Balance			**Establishment Expenses**		
INCOIS Current A/c-SBI-HAL Campus Br.	3,67,23,541		Pay, Leave Salary Allowace	12,97,44,674	
AB Savings A/c	67,71,226		NPS & CPF	1,29,64,058	
AB Consultancy A/c	55,18,087		Staff Welfare (Medical IP & OP)	8,75,680	
Short Term Deposits with Bank	41,58,00,000		Leave Travel Concession Expenses	29,85,563	**14,65,69,975**
INCOIS IGOOS Secretariat- Local	8,64,570				
INCOIS IGOOS Secretariat- Foreign	24,71,049		**Administrative Expenses**		
INCOIS- CPF Account	75,41,216		EL encashment during LTC	3,92,416	
INCOIS- IDBPS Account	1,10,655		Children Education Allowance	11,01,585	
CPF STDRs	1,10,00,000		Travel Expenses - Inland	70,872	
INCOIS SBI GEM POOL A/C	-	**48,68,00,343**	Foreign	-	
			Others	46,710	
			Telephone & Fax Expenditure	4,62,600	
Margin Money TDR Received			Postage & Telegraphs	42,339	
Margin Money Reversal	3,92,784		Printing & Stationery	9,20,148	
Margin Money TDR Rs.118.00 Lakhs	1,95,733		Honorarium to External Experts	1,12,000	
Margin Money TDR Rs.21.00 Lakhs	53,105	**6,41,622**	Advertisement & Publicity	3,81,001	
			Subscription to Newspapers/Journals	4,331	
			Seminar, Conference & Workshop Expenses	-	
Earmarked Funds			Audit Fee	26,225	
Ocean Information and Advisory Services (OASIS)	9,50,00,000		Office Expenses	1,50,22,158	
Ocean Observation Systems (OOS)	9,00,00,000		General Expenses	12,30,253	
ITCOO	6,50,00,000	**25,00,00,000**	International Interface	88,240	**1,99,00,878**

Recurring Grants	22,60,00,000	**22,60,00,000**	**Operation & Maintenance**		
			Vehicle Hiring	4,06,668	
			House Keeping, Plumbing & Garden Expenses	2,47,55,587	
			Security Expenses	38,65,445	
Other Receipts:			Water Expenses	2,35,48,911	
Consultancy Projects:			Civil Services	-	
MAHARASHTRA MARITIME BOARD	13,81,072		Electricity Expenditure	2,26,48,609	
DRDO	2,90,000		Pest Control Expenses	1,40,182	
JNPT	81,780		Maintenance & Repairs	85,33,468	
AFCONS INFRA	22,18,840		Material Consumable	20,81,808	
ONGC Consultancy for hiring of services	2,46,450	**42,18,142**	Emoluments to Consultants	5,17,355	
			Air & Electrical Expenses	-	
			Payment of GSLIS to Dr. SSC Shenoi	-	
Other Receipts:			Expenditure of ICG/IOTWS	-	
Interest on Short Term Deposits	1,69,19,774		Refund of unspent balance to ICG/IOTWS	-	
Interest on IOGOOS Foreign A/c	62,249		Bank charges	16,584	
Interest on IOGOOS Local A/c	21,684		Sponsorship of TA/DA reimbursement	-	**8,65,14,616**
Interest on AB Savings A/c	1,13,518				
Interest on AB Consultancy A/c	1,83,875				
Interest on SBI CPF A/c	1,13,773		PF transfer to Shri.V. Subrahmanyam	2,00,000	
Interest on IDBPS	8,021		PF transfer to Dr. SSC Shenoi	97,35,617	**99,35,617**
Interest earned on ICD-TSSPDCL	2,87,010				
Vehicle Advance to Employees (Recovery)	72,000				
Earnest Money Deposit	5,58,000		**Payments Against Earmarked Funds**		
Security Deposit	18,84,011				
Tender Fee	2,500		**Construction of New Building (Phase II)**		
Income from Guest House	88,300		Construction buildings	-	0
BG Encashment	35,10,802				
Refund from 36th IGC	3,34,530				
Cancellation of BG and Interest of VSAT	58,10,941		**OASIS**		
Refund of Subscription Fee	1,28,516		Equipments	-	

IDBPS Master Policy Closure (Transfer from IDBPS to SBI A/c)	6,70,76,877		Hardware/Software	-	
Reimbursement of rent by KUFOS	1,000		Technical Support	2,61,54,474	
Refund from Swamy's Publishers	1,204		Administrative Expenses	5,27,34,215	
Salary reimbursement from NCESS	57,23,577		Travel	18,21,825	
Refund of TA charges	3,975		Consumable Material / Data	1,45,93,408	
Received for Himakantha grant	3,86,640		Advance against subprojects	3,68,84,696	
Refund from WOS-A Balance fund	8,90,000	**10,41,82,777**	Advance for Purchase	-	
			Depository Work (APWD)	-	
			Margin Money against LC	1,94,00,000	
CK Sajid Atulya - Salary reimbursement for Jan & Feb 20	1,53,760	**1,53,760**	Interest Refunded	61,370	
			Other Assets	5,33,718	**15,21,83,706**
Refund of IGC Registration Fee by Dr. Sudheer Joseph	52,156				
Reimbursement of travel expenses by Rohit	1,38,774				
Reimbursement of travel fellowship by Afroosa Balkies Bai	38,161				
NPDF 2nd Grant of Dr. Charls Antony	2,75,000	**5,04,091**	**Ocean Observation Networks - OON**		
			Technical Support	3,65,50,112	
			Administrative Expenses	4,00,32,180	
CPF - TDRs Interest	21,57,691	**21,57,691**	Equipment	13,89,169	
			Travel	11,25,551	
			Consumable Material / Data	-	
TDS Refund for AY 18-19	55,29,862	**55,29,862**	Advance for Purchase	-	
			Margin Money against LC	-	
			Interest Refunded	72,709	
Contribution received to CPF A/c			Other Assets	-	**7,91,69,721**
CPF contribution received from Dr. T. Srinivasa Kumar	1,21,310				
Dr. M. Ravichandran CPF Employer contribution for FY 2019-20	2,51,680				

Amount received from NCPOR towards CPF employer contribution of Dr. M. Ravichandran	1,06,620		**Satellite Coastal and Oceanographic Research**		
Received form Dr. MRC - CPF & GSLIS	4,20,580		Technical Support	54,29,693	
CPF recovered from Employees in March & April 2020	21,12,967	**30,13,157**	Administrative Expenses	63,28,756	
			Equipment	-	
			Travel	5,10,932	
Grant received for Research Fellows:			Consumable Material / Data	26,58,812	
Science & Engineering Research Board (SERB)	9,56,240		Advance for Purchase	-	
Inspire	20,11,535		Margin Money against LC	-	
National Post Doctoral Fellow	-	**29,67,775**	Interest Refunded	85,40,303	
			Other Assets	-	**2,34,68,496**
			International Training Centre (ITCOocean)		
			Technical support	45,85,995	
			Administrative Expenses	24,48,824	
			Travel	99,895	
			Consumable Materials / Data	8,56,014	
			Depository Work (RITES)	4,42,84,742	
			Margin Money against LC	-	
			Interest Refunded	54,81,740	
			Equipments	38,09,194	
			Computers / Software	58,76,886	**6,74,43,290**
			O-MASCOT		
			Technical support	20,19,646	
			Adminisrtrative expenses	97,89,483	
			Travel	5,73,374	
			Consumable Materials / Data	34,44,192	
			Advance against subprojects	-	

			Computers / Software	-	
			Advance for Purchase	-	
			Interest Refunded	24,49,570	**1,82,76,265**
			V Sat Terrestrial Link		
			Interest Refunded	94,22,597	**94,22,597**
			Multi Hazard Vulnerability		
			Technical support	1,80,000	
			Interest Refunded	-	**1,80,000**
			Monsoon Mission		
			Technical support	6,89,949	
			Adminisrtrative expenses	6,000	
			Advance for Purchase	-	**6,95,949**
			RIMES Afro Asian Region		
			Computers / Software	-	
			Other Assets	-	
			Technical support	37,44,463	
			Adminisrtrative expenses	-	
			Travel	-	
			Advance for Purchase	1,54,223	
			Interest Refunded	6,93,500	**45,92,186**
			CSS		
			Interest Refunded	5,82,437	**5,82,437**

			IIOE2 & IIOSC		
			Adminisrtrative expenses	-	
			Travel	-	
			Interest Refunded	-	**0**
			NCFS		
			Interest Refunded	6,20,134	**6,20,134**
			DOM		
			Adminisrtrative expenses	18,56,827	
			Advance for Purchase	2,91,80,844	
			Interest Refunded	8,05,003	**3,18,42,674**
			Expenditure on Fixed Assets		
			Plant & Machinery	23,998	
			Office Equipment	31,860	
			Computer / Peripheral	2,03,055	
			Library Books	36,909	
			Vehicles	-	**2,95,822**
			Other Payments		
			Refund of Earnest Money Deposit	26,58,053	
			Security Deposits	70,89,057	
			Inspire Fellowship (Regn. Fee, travel etc.)	95,959	
			LTC Advance	10,08,809	
			SERB Prude University Fellowship	1,46,000	
			IOGOOS Account Audit Fee	11,272	
			Refund of Unspent Balance to UNESCO	1,93,990	
			Payment of Travel Expenses to Foreign Participants from UNESCO Fund	29,136	**1,12,32,276**

			Closing Balance		
			INCOIS Current A/c-SBI-HAL Campus Br.	2,66,07,263	
			AB Savings A/c	1,21,20,837	
			AB Consultancy A/c	97,47,238	
			Short Term Deposits with Bank	35,64,00,000	
			INCOIS IGOOS Secretariat- Local	8,74,905	
			INCOIS IGOOS Secretariat- Foreign	25,33,262	
			INCOIS- CPF Account	1,48,40,399	
			INCOIS- IDBPS Account	1,18,676	
			CPF STDRs	-	
			INCOIS SBI GEM POOL A/C	-	**42,32,42,580**
Total	**1,08,61,69,220**	**1,08,61,69,220**	**Total**	**1,08,61,69,220**	**1,08,61,69,220**

As per our report of even date
For PPKG & Co.
Chartered Accountants

Giridhari Toshniwal
Partner
M. No. 205140
FRN No: 009655S

Place: Hyderabad
Date: 19.08.2021

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

(S. Nageswara Rao)
Sr. Accounts Officer
S. Nageswara Rao
Senior Accounts Officer

(T. Srinivasa Kumar)
Director
Dr. T. Srinivasa Kumar
Director, INCOIS

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(Ministry of Earth Sciences, Govt. of India)

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

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31st MARCH 2021

SCHEDULE 1 – CORPUS FUND

Particulars	Current Year (2020-21) ₹	Previous Year (2019-20) ₹
Corpus Fund at the beginning of the year	16,69,53,884	18,93,84,127
Add: Net income transferred from Income & Expenditure Account	-4,85,56,340	-2,24,30,243
BALANCE AS AT THE YEAR END	**11,83,97,544**	**16,69,53,884**

As per our report of even date
For PPKG & Co.
Chartered Accountants

Giridhari Toshniwal
Partner
M. No. 205140
FRN No: 009655S

Place: Hyderabad
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For and on behalf of
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Director
Dr. T. Srinivasa Kumar
Director, INCOIS

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 2 - EARMARKED FUNDS

(Amount in ₹)

Particulars	FUND-WISE BREAK UP													TOTALS	
	Building Fund	OASIS	Ocean Observation Networks	SATCORE / CMI	ITCOO	O-MASCOT	V SAT Node	"MH Vulnerability"	Monsoon Mission	RIMES	CSS	IIOE2 & IIOSC	NCS	Deep Ocean Mission	"Current Year 2020-21"	"Previous Year 2019-20"
a) Opening balance of the funds	3,54,887	-1,35,31,249	-1,84,40,617	15,16,51,742	96,61,601	1,26,16,683	66,11,656	10,86,465	2,17,99,604	86,94,782	5,82,437	37,63,773	6,20,134	4,08,05,003	22,62,76,901	-4,59,66,254
b) Additions to the Funds:																
i. Grants	-	9,50,00,000	9,00,00,000	-	6,50,00,000	-	-	-	-	-	-	-	-	-	25,00,00,000	70,07,39,000
ii. Interest if any	21,455	46,694	8,31,591	87,25,391	16,87,879	14,58,479	28,10,941	60,239	12,96,813	4,05,282	-	2,27,532	-	15,56,930	1,91,29,226	2,03,60,534
iii. Advance for sub projects utilised refund	-	-	3,55,53,205	1,28,69,352	-	36,56,130	-	-	-	-	-	-	-	-	5,20,78,687	16,71,45,384
iv. Advance for purchase Utilised	-	25,26,56,533	41,41,68,813	69,12,687	21,00,000	5,67,77,219	4,60,48,845	-	13,03,07,196	4,02,51,157	-	-	45,95,683	-	95,38,18,133	5,99,61,040
v. Margin Money Reversed	-	-	-	-	-	1,18,00,000	-	-	-	-	-	-	-	-	1,18,00,000	3,89,10,000
vi. Deposit Advance Utilized/refund	-	10,68,548	-	-	1,95,75,663	-	-	-	-	-	-	-	-	-	2,06,44,211	72,53,876
vii. Mobilization Advance Reversed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
viii. Other Revenue	-	-	10,44,118	-	3,60,064	41,56,269	-	-	-	-	-	-	-	-	55,60,451	-
TOTAL (a+b) - A	3,76,342	33,52,40,526	52,31,57,110	18,01,59,172	9,83,85,207	9,04,64,780	5,54,71,442	11,46,704	15,34,03,613	4,93,51,221	5,82,437	39,91,305	52,15,817	4,23,61,933	1,53,93,07,610	94,84,03,580
c) Utilisation/Expenditure																
i. Capital Expenditure																
W.I.P	-	10,68,548	-	-	3,76,98,422	-	-	-	-	-	-	-	-	-	3,87,66,970	3,77,11,675
Architect fee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equipments	-	11,56,05,950	18,17,99,637	1,76,69,862	44,31,971	-	4,13,43,011	-	12,68,97,200	1,11,61,426	-	-	-	-	49,89,09,057	5,96,66,266
Computers / Software	-	11,12,39,651	-	-	58,76,886	4,30,59,134	-	-	27,07,327	-	-	-	13,73,259	-	16,42,56,257	2,70,37,664
Other Assets	-	5,33,718	-	-	-	-	-	-	-	-	-	-	-	-	5,33,718	3,90,75,150.00
															-	-
Total	-	22,84,47,867	18,17,99,637	1,76,69,862	4,80,07,279	4,30,59,134	4,13,43,011	-	12,96,04,527	1,11,61,426	-	-	13,73,259	-	70,24,66,002	16,34,90,756
ii. Revenue Expenditure																
Technical support	-	2,61,54,474	15,20,90,072	54,29,693	45,85,995	20,19,646	27,44,763	1,80,000	13,92,618	37,44,463	-	-	32,22,424	-	20,15,64,147	17,44,02,163
Adminisrtrative expenses	-	5,27,34,215	4,00,32,180	63,28,756	24,48,824	97,89,483	11,120	-	6,000	-	-	-	-	18,56,827	11,32,07,406	11,66,84,501
Travel	-	18,21,825	11,25,551	5,10,932	99,895	5,73,374	-	-	-	-	-	-	-	-	41,31,577	1,76,24,991
Consumable Materials / Data	-	4,04,04,340	15,48,15,708	47,70,990	8,56,014	3,67,74,676	19,49,951	-	-	5,60,096	-	-	-	-	24,01,31,775	2,10,58,878
															-	-
Total	-	12,11,14,854	34,80,63,511	1,70,40,371	79,90,728	4,91,57,179	47,05,834	1,80,000	13,98,618	43,04,559	-	-	32,22,424	18,56,827	55,90,34,905	32,97,70,533
iii. Others																
Advance against subprojects	-	3,68,84,696	-	-	-	-	-	-	-	2,86,83,857	-	-	-	-	6,55,68,553	86,10,172
Advance for Purchase	-	-	-	-	1,94,99,270	-	-	-	-	-	-	-	-	2,91,80,844	4,86,80,114	17,98,06,669
Deposit Works (APWD & RITES)	-	-	-	-	85,00,000	-	-	-	-	-	-	-	-	-	85,00,000	1,50,12,349
Margin Money against LC	-	1,94,00,000	-	-	-	-	-	-	-	-	-	-	-	-	1,94,00,000	1,39,00,000
Total	-	5,62,84,696	-	-	2,79,99,270	-	-	-	-	2,86,83,857	-	-	-	2,91,80,844	14,21,48,667	21,73,29,190
TOTAL (i+ii+iii) - B	-	40,58,47,417	52,98,63,148	3,47,10,232	8,39,97,277	9,22,16,313	4,60,48,845	1,80,000	13,10,03,145	4,41,49,843	-	-	45,95,683	3,10,37,671	1,40,36,49,575	71,05,90,478
Amount Refunded- C (Interest/Unspent Bal)	-	61,370	72,709	85,40,303	54,81,740	24,49,570	94,22,597	-	-	6,93,500	5,82,437	-	6,20,134	8,05,003	2,87,29,363	1,15,36,200
NET BALANCE AS AT THE PERIOD END {A -(B+C)}	3,76,342	-7,06,68,261	-67,78,747	13,69,08,636	89,06,189	-42,01,103	0	9,66,704	2,24,00,468	45,07,878	0	39,91,305	0	1,05,19,259	10,69,28,671	22,62,76,901

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE - 3 CURRENT LIABILITIES & PROVISIONS

Particulars	Current Year (2020-21) ₹	Previous Year (2019-20) ₹
A. CURRENT LIABILITIES		
Earnest Money Deposit	30,65,860	54,48,113
Security Deposit	72,16,243	1,26,70,347
Outstanding Expenses	2,03,53,274	1,97,13,842
Sundry Creditors	3,07,07,253	2,91,72,375
INSPIRE/DISHA/RTF-DCS Fellowship	10,32,645	15,92,595
Other bank Liability	8,49,79,897	2,16,03,837
Total – A	**14,73,55,172**	**9,02,01,109**
B. PROVISIONS		
Gratuity	4,43,24,793	3,96,24,585
Accumulated Leave Encashment	4,58,49,150	3,96,09,610
Total – B	**9,01,73,943**	**7,92,34,195**
Total (A+B)	**23,75,29,115**	**16,94,35,304**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE – 4 FIXED ASSETS **(Amount in ₹)**

Description (% of Depreciation)	Gross Block			Depreciation			Net Block	
	As at 31.03.2020	Additions During The Year	As at 31.03.2021	As at 31.03.2020	For the Year 2020-21	As at 31.03.2021	As at 31.03.2021	As at 31.03.2020
1. Land (0%)	1,000	-	1,000	-	-	-	1,000	1,000
2. Plant, Machinery & Equipment (15%)	4,61,99,557	23,998	4,62,23,555	**4,50,34,931**	1,76,494	**4,52,11,425**	10,12,130	11,64,627
3. Furniture & Fixtures (10%)	1,72,67,084	-	1,72,67,084	**1,30,33,329**	4,23,376	**1,34,56,704**	38,10,380	42,33,755
4. Office Equipment (15%)	34,52,865	31,860	34,84,725	**28,90,404**	86,759	**29,77,163**	5,07,562	5,62,461
5. Computer / Peripheral (40%)	12,90,17,761	2,03,055	12,92,20,816	**12,37,69,896**	21,80,368	**12,59,50,264**	32,70,552	52,47,865
6. Electric Installations (10%)	20,98,406	-	20,98,406	**14,90,944**	60,746	**15,51,690**	5,46,716	6,07,462
7. Library Books (40%)	8,38,71,234	36,909	8,39,08,143	**7,22,86,772**	46,45,559	**7,69,32,332**	69,75,811	1,15,84,462
8. Other Fixed Assets (15%)	70,47,041	-	70,47,041	**46,39,449**	3,61,139	**50,00,588**	20,46,453	24,07,592
9. Vehicles (existing) (15%)	22,23,774	-	22,23,774	**4,95,682**	2,59,214	**7,54,896**	14,68,878	17,28,092
Total	**29,11,78,722**	**2,95,822**	**29,14,74,544**	**26,36,41,406**	**81,93,655**	**27,18,35,061**	**1,96,39,483**	**2,75,37,316**
Previous Year	29,09,81,424	20,47,133	29,26,18,883	25,24,63,528	1,27,64,697	26,52,28,225	2,75,37,316	3,85,17,896

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE -4A -EARMARKED FIXED ASEETS

(Amount in ₹)

	Description of the Assets	Gross Block				Depreciation					Net Block	
Sl. No	Name of the Fund/Project	As on 01-04-2020	Additions 2020-21	Grant Utilized/ Received till 31-03-2021 (G/A -Gen/Capital)	Total Amount as on 31-03-2021	As on 31.03.2020	For the Year 2020-21	Diff. of Previous Years Dep.	Total Depreciation for the year	As at 31.03.2021	As at 31.03.2021	As at 31.03.2020
i)	Building Fund	63,25,08,439	-	-63,25,08,439	-	-	-	-	-	-	-	-
ii)	MDC & Equipment Fund	6,59,21,618	-	-6,59,21,618	-	-	-	-	-	-	-	-
iii)	Ocean Information and Advisory Services (OASIS)	1,76,83,39,705	22,84,47,867	-1,99,67,87,572	-	-	-	-	-	-	-	-
iv)	Computational Facilities	15,28,06,467	-	-15,28,06,467	-	-	-	-	-	-	-	-
v)	INDOMOD & SATCORE Projects	42,72,64,846	-	-42,72,64,846	-	-	-	-	-	-	-	-
vi)	Ocean Observation Networks	63,68,47,955	18,17,99,637	-81,86,47,592	-	-	-	-	-	-	-	-
vii)	International Training Center-ITCOocean	60,46,19,915	4,80,07,279	-65,26,27,194	-	-	-	-	-	-	-	-
viii)	O-MASCOT (HROOFS)	2,04,70,117	4,30,59,134	-6,35,29,251	-	-	-	-	-	-	-	-
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	13,31,28,616	4,13,43,011	-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	3,63,58,018	12,96,04,527	-16,59,62,545	-	-	-	-	-	-	-	-
xvii)	RIMES	3,73,75,525	1,11,61,426	-4,85,36,951	-	-	-	-	-	-	-	-
xviii)	Coastal Monitoring (CMI/SATCORE)	3,90,259	1,76,69,862	-1,80,60,121	-	-	-	-	-	-	-	-
xix)	NCS	-	13,73,259	-13,73,259	-	-	-	-	-	-	-	-
	Total	5,92,76,17,351	70,24,66,002	-6,63,00,83,353	-	-	-	-	-	-	-	-
	Previous year	5,76,41,26,595	16,34,90,756	5,92,76,17,351	11,73,46,91,200	-	-	-	-	-	-	-
	GRAND TOTAL	6,21,87,96,073	70,27,61,824	-6,33,86,08,809	-60,746	-26,36,41,406	-81,93,654	-27,18,35,061	-	-1,96,39,483	-2,75,37,316	-
	GRAND TOTAL (PREVIOUS YEAR)	6,05,51,08,019	16,55,37,889	5,92,71,97,677	11,44,20,82,317	-25,24,63,528	-1,27,64,697	-26,52,28,225	-1,56,658	-2,75,37,316	-3,85,17,896	-

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE - 5 CURRENT ASSETS, LOANS & ADVANCES **(Amount in ₹)**

Particulars	Current Year (2020 - 21) ₹		Previous Year (2019 - 20) ₹	
A. CURRENT ASSETS				
1. Inventories (Valued at cost)	7,78,348	7,78,348	23,30,633	23,30,633
2. Cash & Bank Balance :				
a) With Scheduled Banks – Current Account				
State Bank of India HAL CAMPUS A/c	2,65,84,224		3,67,23,541	
Union Bank Pragathinagar SAVINGS A/c	1,21,21,630		62,83,365	
Union Bank Pragathinagar - Consultancy A/c	97,46,703		55,17,551	
Union Bank Savings PORSEC - A/c	-		-	
State Bank of India - CPF A/c	1,48,40,399		75,41,216	
State Bank of India - ISPRS A/c	-		-	
State Bank of India - IDBPS 4095 A/c	1,18,676	6,34,11,632	1,10,655	5,61,76,328
b) Short Term Deposits with SBI	35,64,00,000		41,58,00,000	
c) Short Term Deposits with CPF	-		1,10,00,000	
d) Short Term Deposits with PORSEC	-		-	
e) Short Term Deposits with UB	-		-	
		35,64,00,000		42,68,00,000
TOTAL A:		**42,05,89,979**		**48,53,06,962**
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		13,100	
d) Petrol/Diesel	1,01,400	73,04,060	1,01,400	73,04,060
2. Advances & other amounts recoverable in cash or in kind or for value to be received				

a) Vehicle Advance to Employees		-		72,668	
b) Interest Accrued		43,25,504		2,59,69,555	
c) Other Advances		62,668		31,280	
d) Advance for Purchase		-		-	
e) Sundry Debtors		-		21,41,894	
f) Tour Advance		9,000		1,78,369	
g) LTC Advance		1,56,400		-	
h) TDS					
Opening Balance -	Rs.1,07,10,819				
Less: Refund received during the year	Rs.50,27,152				
Add: Current year accumulation	Rs.10,84,552				
Add: TDS Adjustment Entry	Rs.5,86,850	73,55,069		1,07,10,819	
i) Margin Money against Bank Guarantee		34,13,165	1,19,08,641	34,13,165	4,25,17,750
TOTAL B: (1+2)			**2,26,25,866**		**4,98,21,810**
GRAND TOTAL (A + B)			**44,32,15,845**		**53,51,28,772**

INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 6 - INCOME FROM SALES / OTHER INCOME

Particulars	Current Year (2020- 21) ₹	Previous Year (2019- 20) ₹
a) Other Receipts	17,44,269	33,10,936
b) Consultancy Services	35,09,497	38,08,473
c) Income from staff quarters	88,300	12,29,647
TOTAL	**53,42,066**	**83,49,056**
SCHEDULE 7 - INTEREST EARNED		
a) Interest on Short Term Deposits & Others	18,01,301	19,65,271
b) Bank Accounts	8,08,124	11,71,035
c) Staff Advances	29,000	93,000
d) Interest on Vehicle Advance	-	-
TOTAL	**26,38,425**	**32,29,306**
SCHEDULE 8 - IRRECOVERABLE GRANTS & SUBSIDIES RECEIVED		
a) Central Government (Recurring Grant received from MoES)	22,60,00,000	21,80,00,000
TOTAL	**22,60,00,000**	**21,80,00,000**
SCHEDULE 9 - ESTABLISHMENT EXPENDITURE		
a) Salaries, Wages & Allowances	14,75,28,432	12,02,35,508
b) Staff Welfare Expenses	8,75,680	17,43,220
c) Contributory Provident Fund	2,72,668	17,40,768
d) New Pension Scheme	78,32,148	62,44,708
e) Leave Travel Concession	29,85,563	17,46,617
TOTAL	**15,94,94,491**	**13,17,10,821**

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SCHEDULE 10 - OTHER ADMINISTRATIVE EXPENSES

Sl No.	Particulars	Current Year (2020 - 21) ₹	Previous Year (2019 - 20) ₹
1.	Electricity & Power Expenses	2,26,48,610	2,84,08,501
2.	Water Charges	32,98,309	42,85,120
3.	Operation & Maintenance expenses	1,20,40,791	1,94,26,408
4.	Garden Expenses	38,65,445	13,88,030
5.	Vehicle Hiring Expenses	4,06,668	17,52,333
6.	Postage, Fax & ISDN Charges	5,04,939	5,82,178
7.	Printing & Stationery	9,20,148	9,50,555
8.	Travelling Expenses :		
	Inland	-	4,26,080
	Foreign	-	10,60,420
	Others	46,710	20,651
9.	Seminar/Workshops Expenses	-	2,71,060
10.	General Expenses	1,53,85,002	87,43,651
11.	Audit Fee	23,600	23,600
12.	House Keeping & Plumbing	2,89,90,142	88,49,279
13.	Security Expenses	2,35,48,911	2,34,68,375
14.	Advertisement & Publicity	3,81,001	18,74,055
15.	Emoluments to Consultants	-	7,67,643
16.	Internet Expenses	4,45,182	31,16,273
17.	Legal Expenses	56,850	92,440
18.	Papers & Periodicals	4,331	15,986
19.	Conveyance Expenses	-	0.00
20.	Material /Consumable	20,81,808	3,90,892
21.	International Interface	88,240	15,35,557
22.	Others	1,12,000	84,000
	TOTAL	**11,48,48,687**	**10,75,33,088**

SCHEDULE NO.11

NOTES FORMING PART OF ACCOUNTS:

1. Significant Accounting Policies:

a) Basis of Accounting:

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

b) Income Recognition:

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

The Grant-in-aid received from Ministry of Earth Sciences for the purpose of meeting revenue expenditure is treated as Income to the Society and to the extent utilized for capital expenditure is added to the Corpus Fund. During the year 2020-21, the Society received Rs.22.60 Crores towards Recurring Grant as shown in the Schedule-8.

The remaining Grant-in-aid of Rs.25.00 Crores received from Ministry of Earth Sciences is being utilized for specific purposes for which they were intended and are disclosed under the Earmarked Funds- Schedule-2.

c) Fixed Assets and Depreciation:

i. Fixed Assets register was maintained by the Society.

ii. The management verified the assets physically by appointing a sub-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 rates 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) Building:

As per the guidelines provided to the Central Autonomous Bodies, the Funds inflow and outflow relating to the building are initially to be shown under Building Fund in the Earmarked Funds under Schedule–2 and on completion of the building; the value of building is to be transferred to the Fixed Assets schedule 4A upon obtaining the necessary approvals in this regard. The approval process is under finalization at Ministry and the necessary action will be taken during the next financial year.

f) 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 at the year end.

ii) Pension:

a) The IDBPS (INCOIS Defined Benefit Pension Scheme) is managed by a separate trust and employers contributions towards pension for the employees joined prior to 01-01-2004, was transferred by INCOIS to LIC of India Ltd up to August 31, 2015 only.

b) Based on the MoES letters, INCOIS requested all the 11 employees, who are under INCOIS-IDBPS, to exercise the option either to continue in the Contributory Provident

Fund or to join the New Pension Scheme as the IDBPS is being discontinued in INCOIS. The funds transfer to LIC of India Limited towards contribution of INCOIS for the IDBPS is deferred with effect from September, 2015 onwards

c) As per the directives of the GC, INCOIS has sent a letter dated March 19, 2015 to Joint Secretary (Establishment), MoES requesting for post-facto approval for the Defined Benefit Pension Scheme (DBPS) which has been implemented since May 2010 for its employees joined service prior to 1.1.2004.

d) MoES vide its reply letter dated August 13, 2015 informed that the issue has been examined in consultation with IFD, MoES and it has not been found possible to accede to consider INCOIS proposal for ex-post-facto approval for the Defined Benefit Pension Scheme (DBPS) which has been implemented since May 2010 for its employees joined service prior to 1.1.2004.

e) The letter further informs that the demand for pension in respect of INCOIS employees who joined prior to 1.1.2004 may please be regulated in terms of guidelines issued vide letter No.MoES/01/Dir(F)/2015 dated May 26, 2015.

f) All 11 employees in the scheme contested the exercising the option given by the INCOIS and filed a legal case with Central Administrative Tribunal, Hyderabad on November 12, 2015. The hearings are going on. The court has issued status-quo orders on February 24, 2016.

g) Subsequently, all the 11 employees sought permission of the Central Administrative Tribunal (CAT) to withdraw the O.A. Now the CAT, Hyderabad Bench vide order dated 21.5.2020 has dismissed the OA No.21/1525/2015. The Trust has also resolved and requested the LIC for closure of the Master Policy of Defined Benefit Pension Scheme, LIC considered the request and close the Master Policy and refunded an amount of Rs.6,70,76,877/-. Management initiated the process for obtaining necessary approvals for rejoining as well as the accounting treatment of the funds received from LIC of India Limited.

h) Periodical contributions to IDBPS are charged to revenue up to August 31, 2015 only. Management decided to initiate necessary action and make provisions/transfers in accounts based on the approvals.

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

iv) **Leave encashment:**

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

g) **Interest on Deposits:**

The Society invested surplus funds from time to time in Short Term Deposits in Nationalized Banks. For the year 2020-21, an amount of Rs.1,61,96,190/- was earned as interest on the Short Term Deposits in the bank. Since, the interest received on Short Term Deposits, relate to the grants accruing to the various projects and recurring grants received by INCOIS, the management decided to spread the interest on Short Term Deposits to such projects and INCOIS Society.

a.	Interest transferred to Ear-marked Funds	-	Rs.1,45,08,407.00
b.	Interest transferred to various other funds (Such as DST-DPWS, DST-NPDF, PORSEC, ISPRS, IDBPS - LIC AMOUNT, SERB)	-	Rs.16,14,610.00
c.	Interest transferred to Society	-	Rs.1,86,691.00
		Total	**Rs.1,63,09,708.00**

In addition to the apportioned interest amount of Rs.1,45,08,407/- for various earmarked funds in Schedule 2, the funds earned interest directly also credited to the relevant funds and such amount is worked out to Rs.46,20,819/-. Accordingly, the total interest earned for the earmarked funds shown in the schedule-2 is of Rs.1,91,29,226/-

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

The details are furnished below:-

(Amount in Rs.)

a.	Interest earned on closed STDRs	1,55,77,771.00
b.	Less: Transfer of outstanding Accrued Interest for the FY 2019-20	61,53,521.00
c.	Add: Net Accrued Interest for the current FY 2020-21 on SBI	56,87,388.00
d.	Add: TDS on closed and accrued TDRs on SBI	10,84,552.00
e.	Add: Net Interest of AB Savings for the current FY 2020-21	1,13,518.00
f.	Total Interest earned for the FY 2020-21	1,63,09,708.00

2. Notes on Accounts:

a) **EARMARKED FUNDS**:

The Society during the year 2020-21, received Rs.25,00,00,000/- Crores 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 funds positions in the Ear-marked funds for OASIS, OON and O-MASCOT programmes are negative. The funds were temporarily used by Management from other projects and will be replenished upon receipt of funds from the Ministry to avoid delay in smooth execution of the projects.

In this regard, the 15th ESSO council meeting held on 30th September 2014 under point no.12 of page-3 of the minutes delegated the powers to the centre Directors and the same is re-produced below for your reference:-

"In order to carry out the activities without any hindrance and achieve the objectives as highlighted in the administrative order, the available funds may be utilized from the different heads with the approval of Institute Director subject to the condition that the overall estimated cost of the programme indicated in the Administrative Order should not exceed due to shortage of funds under the relevant programme (Action: Directors/Heads of Organization)". Accordingly, upon such approval, the Management utilized the available funds to meet the expenditure of the projects.

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.65.38Cr of advances was adjusted and the value of "Advance for Purchase" as on 31-03-2021 was only Rs.14.59 Crores.

The accumulated value of the capital expenditure as on 31-03-2021 (excluding advances to sub-projects and advances for purchases), incurred in each year and specified in the Earmarked Funds under Schedule - 2, are stated below. A separate schedule has been added at Schedule 4A.

Sl No.	**Name of the Fund/ Project**	**As on 01-04-2020** ₹	**Additions 2020-21** ₹	**Total Amount as on 31-03-2021** ₹
i)	Building Fund	63,25,08,439		63,25,08,439
ii)	MDC & Equipment Fund	6,59,21,618		6,59,21,618
iii)	Ocean Information and Advisory Services (OASIS)	1,76,83,39,705	22,84,47,867	1,99,67,87,572
iv)	Computational Facilities	15,28,06,467		15,28,06,467
v)	INDOMOD & SATCORE Projects	42,72,64,846		42,72,64,846
vi)	Ocean Observation Networks	63,68,47,955	18,17,99,637	81,86,47,592
vii)	International Training Center-ITCOocean	60,46,19,915	4,80,07,279	65,26,27,194
viii)	O-MASCOT (HROOFS)	2,04,70,117	4,30,59,134	6,35,29,251
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	13,31,28,616	4,13,43,011	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	3,63,58,018	12,96,04,527	16,59,62,545
xvii)	RIMES	3,73,75,525	1,11,61,426	4,85,36,951
xviii)	Coastal Monitoring (CMI/SATCORE)	3,90,259	1,76,69,862	1,80,60,121
xix)	NCS	0	13,73,259	13,73,259
	TOTAL	**5,92,76,17,351**	**70,24,66,002**	**6,63,00,83,353**

b) **PROJECTS AND UTILISATION CERTIFICATES:**

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

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

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

c) **Contingent Liabilities:**

i. Contingent liabilities not provided for :

a. In view of the non-fulfillment of the contractual obligations the following Bank Guarantees were encashed. Depending upon the satisfactory fulfillment amount will be refunded in future and the amount was shown in Current Liabilities.

1.	M/s Gaian (FY2018-19)	Rs.9,50,000/-
2.	M/s Fujitsu India Private Limited (FY2020-21)	Rs.35,10,802/-

b. Periodical contributions to IDBPS are charged to revenue up to August 31, 2015 only. Management decided to initiate required action and make provisions/transfers in accounts based on the approvals.

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

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

d) I. 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.

II. 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.

III. 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.

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

e) 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.

f) Figures have been regrouped/rearranged where ever necessary.

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

As per our report of even date
For PPKG & Co.
Chartered Accountants

(Giridhari Toshniwal)
Partner
M. No. 205140
FRN No: 009655S

Place: Hyderabad
Date: 19.08.2021

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

(S. Nageswara Rao)
Sr. Accounts Officer

S. Nageswara Rao
Senior Accounts Officer

(T.Srinivasa Kumar)
Director

Dr. T. Srinivasa Kumar
Director, INCOIS

Indian National Centre for Ocean Information Services

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