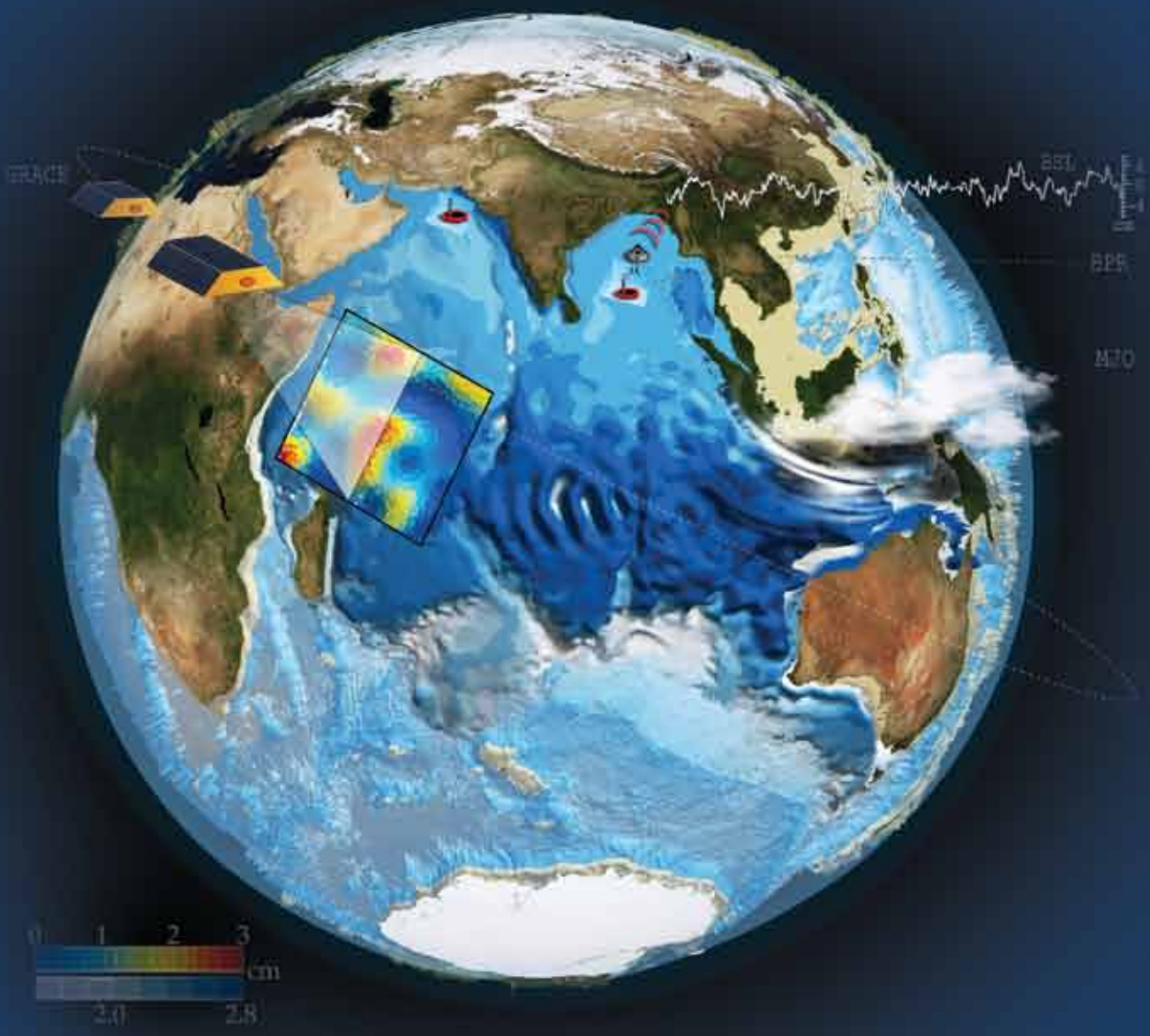
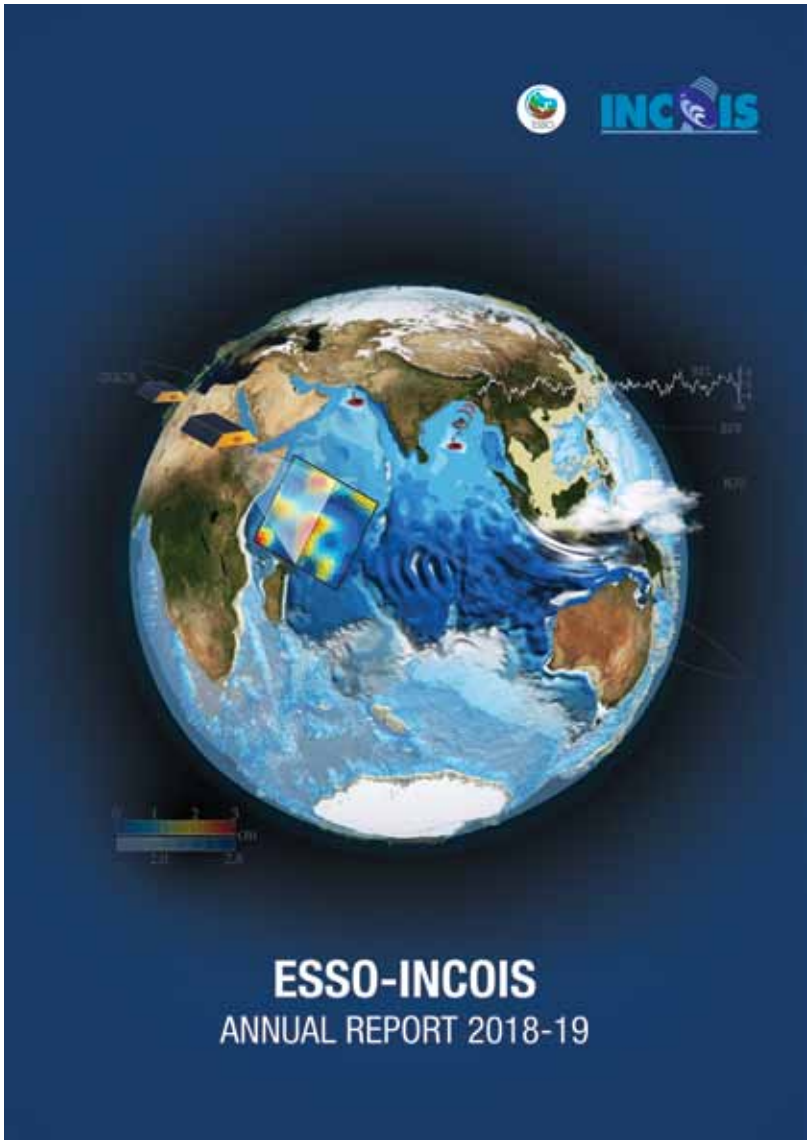


ESSO-INCOIS

ANNUAL REPORT 2018-19

Front Cover



In an important INCOIS study, barotropic sea level variability in the tropical Indian Ocean during December–April has been linked to a small patch of wind over the Eastern Indian Ocean, associated with boreal winter Madden–Julian Oscillations (MJO). The study used BPRs, Gravity Recovery and Climate Experiment(GRACE) and an OGCM.

Back Cover

Entrance to ESSO-INCOIS' Main Building

Photo Courtesy- Knowledge Resource Centre, ESSO-INCOIS

Annual Report 2018-19

ESSO-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

On 3 February 2019, INCOIS completed 20 years of service to society. The last two decades were eventful and saw the rapid growth of INCOIS. Over the past 20 years, INCOIS has become an international leader in operational oceanography, capacity building & training and ocean observations. This success has stemmed from balanced emphasis on focused research and its application for socially relevant issues. INCOIS has brought together 18 partner institutions from the Indian marine science community to build on ocean observations and disseminate advisories, early warnings and ocean state forecasts to various types of users.

Our scientists and engineers continued to carry out research focused on improving ocean forecasts, warnings etc. and enhancing our knowledge about Indian Ocean processes that shape the behaviour of the monsoon and fisheries. I am delighted to present a summary on our activities and achievements during 2018-19 in the form of *Annual Report*. The quality of our research in the form of peer-reviewed publications in journals of high impact and the feedback that we received from various users testify the usefulness of our advisories, forecasts, early warnings, ocean data and data products. INCOIS is not only committed to scientific excellence, but also to the needs of the users of ocean space.

In the pursuit of building longer time-series of ocean data, we 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. The profiles of turbulent kinetic energy dissipation rates collected using vertical micro-structure profilers during two cruises in the Bay of Bengal adds to our data archives and will aid the research to understand the mixing process in the seas around us. We have also conducted two cruises in the coastal waters of the Bay of Bengal to collect in situ data on optical and biogeochemical parameters to assess the quality of coastal waters. Also developed *Digital Ocean* (a web-based application) to provide a dynamic framework to integrate heterogeneous ocean data and its online viewing and analysis.

While continuing to provide the PFZ advisories and ocean state forecasts, we have also increased the direct information reception user-base of fishermen in India to 6.76 lakhs. All those fishermen are now regularly receiving PFZ advisories on their mobiles through SMS every day except during the fishing ban period or high sea conditions, when fishermen are advised not to venture out for fishing. Fishermen also receive daily updates of ocean state forecasts on their mobiles through SMS. In addition to issuing joint INCOIS-IMD bulletins that include forecasts of waves, swell and currents, we have also provided timely predictions on storm surges, including the level and extent of inundation on the coast, to IMD for public dissemination during the tropical cyclones Daye, Titli, Luban, Gaja and Pabuk.

Our tsunami early warning service continued to function, detecting every earthquake that occurred on the ocean bottom anywhere in the world. Two earthquakes in the Indian Ocean necessitated issuing of NO THREAT tsunami bulletins during 2018-19. They were issued promptly as per SOP.

In our efforts to make a tsunami resilient community in India, we, together with Odisha State Disaster Management Authority, implemented the Indian Ocean Tsunami Ready programme of IOC/ICG/IOTWMS in 6 villages in Odisha.

The implementation and operationalization of Local Ensemble Transform Kalman Filter (LETKF)-based data assimilation scheme in the 9.0 km resolution ROMS model for the Indian Ocean is the first of its kind. The system named RAIN (Reanalysis of Indian OceaN), is now being used to produce ocean reanalysis since its operationalisation on 4 February 2019. INCOIS has also coupled the HYCOM (ocean) with HWRF (atmospheric) model to provide real-time forecasts of tropical cyclones in the north Indian Ocean. India Meteorological Department uses the coupled model for forecasting the cyclones with greater accuracy.

The International Training Centre for Operational Oceanography (ITCOocean), the newly established UNESCO Category 2 Centre, continued to attract huge response from trainees for the training courses in operational oceanography. ITCOocean conducted 10 courses for 215 trainees from 29 countries including India. Ocean Teacher Global Academy of IODE/IOC/UNESCO funded the international participation in 3 courses. Dr. Harsh Vardhan, Hon'ble Minister for Earth Sciences, Science and Technology, Environment and Forests & Climate Change inaugurated the academic (Atal Bhavan) and guest house (Atal Athiti Griha) buildings for ITCOocean on 22 December 2018 in the presence of Dr. M. Rajeevan, Secretary, MoES and other dignitaries. During the year, INCOIS was honoured by the visit of Hon'ble Vice President of India, Shri M. Venkaiah Naidu on 13 July 2018. He also addressed the scientists and staff of INCOIS.

Though the number of publications remained more or less the same as last year, their quality has increased as evidenced by the higher impact factor journals in which they were published. INCOIS scientists published 36 research papers in reputed national and international journals with a cumulative impact factor of 88.77. Dr. B. Praveen Kumar was awarded the *Young Researcher Award-2018* in the field of Earth System Science by Ministry of Earth Sciences and Dr. Kunal Chakraborty was selected as a member of *Indian National Young Academy of Science (INYAS)* for five years with effect from 1 January 2019. Dr. P.A. Francis was elected as Fellow of Telangana Academy of Sciences and Dr. P.G. Remya was selected for *Young Scientist Award* by Telangana Academy of Sciences for the year 2018. Dr. Kunal Chakraborty and Dr. M.S. Girish Kumar were elected as *Associate Fellows* of Telangana Academy of Sciences. Ms. Jayashree Gosh, JRF, INCOIS was selected for *'Anni Talwani Memorial Grant for Women Researchers for the year 2018 by Indian Geophysical Union (IGU)*. I was awarded with the *National Award for Excellence in Ocean Science & Technology* – 2018 by Ministry of Earth Sciences.

Padma Bhushan Dr. K. Radhakrishnan, Former Chairman, ISRO, delivered the foundation day lecture on 4 February 2019. Over 4280 students and the members of the public visited our facilities during the *'Open House'* programmes conducted on the occasions of MoES Foundation Day, India International Science Festival 2018, Tsunami Awareness Day and INCOIS Foundation Day and during student visits-on-request. Five hundred and twenty government officers also made field visits to INCOIS as part of various training programmes.

The Official Language Implementation Committee of INCOIS organised 3 seminars during April 2018 to March 2019. INCOIS celebrated 'Hindi Pakhwara' during 1-14 September 2018.

As part of the Swachh Bharat activities, INCOIS celebrated Swachchta Pakhwara during 1-15 July 2018 and Swachchta Hi Seva drive on 28 September 2018.

Seventeen Project Scientists, 5 Project Assistants and 11 Administrative Assistants were recruited on contract-basis during the year. Five Project Scientists, 1 Project Assistant, 4 Administrative Assistants and 1 Scientific Assistant (regular) resigned/completed the term during the year. Shri. K. K. V. Chary, Deputy Chief Administrative Officer, INCOIS, superannuated on 30 June 2018. His services and administrative support that he provided since the formative years of INCOIS are acknowledged gratefully.

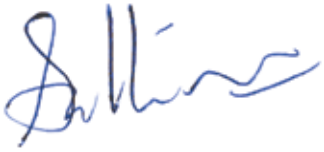
INCOIS continued its association with the Indian Ocean Global Ocean Observing System (IOGOOS), Regional Co-ordination of Argo Programme, Partnership for Observation of Global Ocean (POGO), Regional Integrated Multi-hazard Early warning System (RIMES) and the Intergovernmental Coordination Group (ICG) of Indian Ocean Tsunami and other hazards Warning System (IOTWS) of the Intergovernmental Oceanographic Commission (IOC)/UNESCO. INCOIS continued hosting the secretariats of IOGOOS, Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) and Ocean Bio-Informatics System (OBIS). In addition, the Indian node of Joint Programme Office (JPO) for IIOE-2 has been hosted at ESSO-INCOIS to coordinate the IIOE-2 project (2016-2020) jointly sponsored by IOC, SCOR and IOGOOS.

Untiring efforts of our scientists, scientific and administrative support staff ensured that INCOIS remained active and productive. However, I would be remiss if I do not acknowledge the unflinching support and guidance of Dr. M. Rajeevan, Chairman of INCOIS GC and the members of GC. Their continued guidance will be crucial as we embark on a future, filled with challenges and opportunities. I also thank the Chairs and members of Finance Committee and Research Advisory Committee for their advice and support in conducting the financial and scientific affairs of ESSO-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 were always there to support and resolve the issues. I thank them all.

The Annual Report was prepared by the Editorial Committee chaired by Francis with the support of its members Hari, Kiran, Praveen, Ajay, Nimit, Celsa, Sidhartha, Greeshma. I thank them for doing a wonderful job.

Thank you

Jai Hind



S. S. C. Shenoi

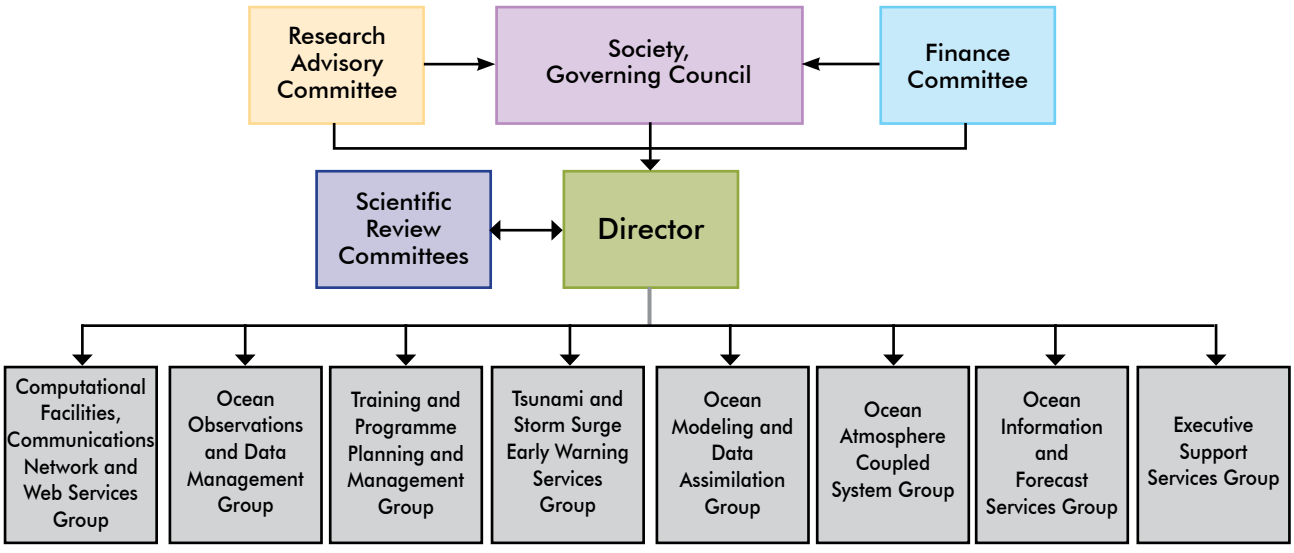
2. ESSO-INCOIS Organizational Structure

ESSO-INCOIS is an autonomous institute under the administrative control of Ministry of Earth Sciences (MoES), Government of India and a member of the Earth System Science Organization (ESSO).

ESSO-INCOIS was registered as a society under the Andhra Pradesh (Telangana) Public Societies Registration Act (1350, Falsi), at Hyderabad on 3 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 ESSO-INCOIS Society

Secretary to Government of India, Ministry of Earth Sciences	President
Director, National Remote Sensing Centre, Hyderabad	Vice President
Joint Secretary, Ministry of Earth Sciences	Member
Advisor, Ministry of Earth Sciences	Member
Director, National Institute of Oceanography, Goa	Member
Director, National Institute of Ocean Technology, Chennai	Member
Director, National Centre for Polar and Ocean Research, Goa	Member
Director, Indian National Centre for Ocean Information Services	General Secretary



Organisation Structure of ESSO-INCOIS

2.2 ESSO-INCOIS Governing Council

1.	Secretary to Government of India, Ministry of Earth Sciences	(Chairman)
2.	Additional Secretary & Financial Advisor/ Joint Secretary & Financial Advisor, MoES	(Member)
3.	Additional Secretary/ Joint Secretary, MoES,	(Member)
4.	Prof. G.S. Bhat, IISc Bangalore & Chairman, INCOIS-RAC	(Member)
5.	Dr. R.R. Navalgund, ISRO, Bangalore	(Member)
6.	Director, National Remote Sensing Centre	(Member)
7.	Director, Indian Institute of Tropical Meteorology	(Member)
8.	Director, National Institute of Oceanography	(Member)
9.	Head, National Centre for Medium Range Weather Forecasting	(Member)
10.	Programme Head (INCOIS), MoES	(Permanent Invitee)
11.	Representative, NITI Aayog	(Invitee)
12.	Director, Indian National Centre for Ocean Information Services	(Member Secretary)

2.3 ESSO-INCOIS Research Advisory Committee

1. Prof. G.S. Bhat, Indian Institute of Science (Chairman)
2. Dr. M. Dileep Kumar (Rtd.,), NIO (Member)
3. Dr. Prakash Chauhan, SAC (Member)
4. Dr. N.L. Sarda, IIT, Mumbai (Member)
5. Dr. Kusala Rajendran, IISc (Member)
6. Dr. M. Mohapatra, IMD (Member)
7. Dr. T.M. Balakrishnan Nair, INCOIS (Member-Secretary)

2.4 ESSO-INCOIS Finance Committee

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

2.5 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 ESSO-INCOIS are:

1. To establish, maintain and manage systems for data acquisition, analysis, interpretation and archival for ocean information and related services.
2. To undertake, aid, promote, guide and co-ordinate research in the field of ocean information and related services including satellite oceanography.
3. To carry out surveys and acquire information using satellite technology, ships, buoys, boats or any other platforms to generate information on fisheries, minerals, oil, biology, hydrology, bathymetry, geology, meteorology, coastal zone management and associated resources.
4. To generate and provide data along with value added data products to user communities.
5. To cooperate and collaborate with other national and international institutions in the field of ocean remote sensing, oceanography, atmospheric sciences/meteorology and coastal zone management.
6. To establish 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 ESSO-INCOIS.

2.6 Quality Policy

The ESSO-Indian National Centre for Ocean Information Services (ESSO-INCOIS), Earth System Sciences Organization (ESSO), 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

3.1 Discovery of basin-wide sea level coherency in the tropical Indian Ocean

Scientists of INCOIS in collaboration with some scientists from France discovered basin-wide coherent barotropic sea level oscillations in the tropical Indian Ocean at intraseasonal time scales. It has been shown that the sea level changes at intraseasonal timescale are forced by the winds associated with Madden Julian Oscillations in the eastern Indian Ocean.

3.2 New Buildings for ITCOocean

Completed the construction of buildings for ITCOocean on the northern end of INCOIS campus. Dr. Harsh Vardhan, Hon. Minister for Earth Sciences, Science and Technology, Environment and Forests & Climate Change inaugurated the academic and guest house buildings on 22 December 2018 in the presence of Dr. M. Rajeevan, Secretary, MoES.

3.3 Regional Analysis for the Indian Ocean

Local Ensemble Transform Kalman Filter (LETKF)-based data assimilation scheme developed to work with Modular Ocean Model has been implemented in a 9 km resolution ROMS model for the Indian Ocean for the first time. The system named RAIN (Reanalysis of Indian OceaN), is being used to produce ocean reanalysis since its operationalisation during the 20th foundation day of INCOIS on 4 February 2019.

3.4 HYCOM-HWRF coupled model for tropical cyclones

INCOIS successfully coupled HYCOM with the HWRF model to provide real-time forecasts of tropical cyclones in the north Indian Ocean.

3.5 Implementation of Indian Ocean Tsunami Ready programme

The Indian Ocean Tsunami Ready programme is an initiative of IOC/ICG/IOTWMS to make the local communities tsunami resilient. The National Committee lead by INCOIS worked with Odisha State Disaster Management Authority and implemented tsunami readiness in 6 tsunami-prone villages in the state of Odisha.

3.6 Release of Scientific Documentary films of INCOIS services

Dr. M. Rajeevan, Secretary MoES and Chairman INCOIS Governing Council released scientific documentary films on INCOIS services on 26 April 2018.

3.7 Development of Digital Ocean

Developed a web application, Digital Ocean, which provides a dynamic framework to integrate heterogeneous ocean data and its online analysis.

3.8 Process specific observations

In order to study small-scale turbulent mixing processes in the Bay of Bengal, INCOIS conducted two research cruises. Profiles of turbulent kinetic energy dissipation rates were collected using vertical micro-structure profilers during the two cruises in the Bay of Bengal.

3.9 Coastal water quality monitoring

Conducted two cruises in the coastal waters of the Bay of Bengal to collect in situ data on optical and biogeochemical parameters to assess the quality of coastal waters.

3.10 MoES Awards

Dr. S. S. C. Shenoi, Director, INCOIS was awarded with the prestigious National Award for Excellence in Ocean Science and Technology for his outstanding contributions in this field. Dr. B Praveen Kumar, Scientist-D, ODG, INCOIS was awarded with the Young Researcher award of MoES.

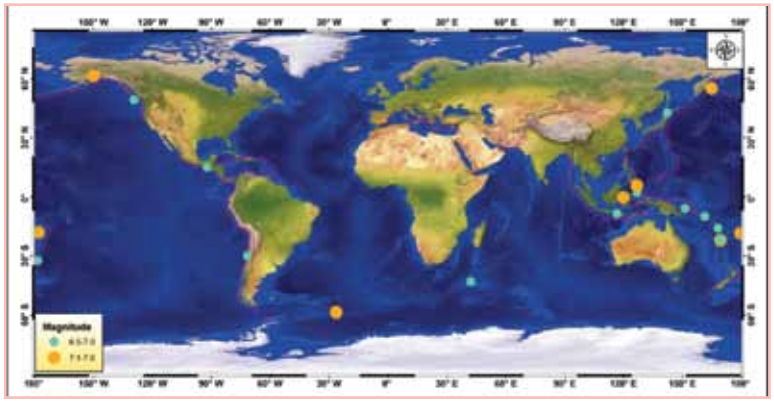
3.11 Telangana Academy of Sciences award/fellowships

Dr. P. G. Remya, Scientist-C, ISG, INCOIS received the prestigious Young Scientist Award instituted by the Telangana Academy of Sciences. Dr. P. A. Francis, Scientist-E & Head, MDG, INCOIS has been elected as the Fellow of Telangana Academy of Sciences. Dr. Kunal Chakraborty, Scientist-D, MDG, INCOIS and Dr. M. S. Girish Kumar, Scientist-D, ODG, INCOIS have been elected as associate fellows of the Telangana Academy of Sciences.

4. Services

4.1 Tsunami and Storm Surge Early Warning System

The Indian Tsunami Early Warning Centre (ITEWC) had monitored 28 earthquakes (in the ocean floor and near the coastal regions) of magnitude 6.5 M and above during the period April 2018 to March 2019. Out of these 28 earthquakes, only one earthquake had occurred in the Indian Ocean region. For all these earthquakes, ITEWC had disseminated the bulletins to all regional and national stake holders through email, fax, GTS and SMS.



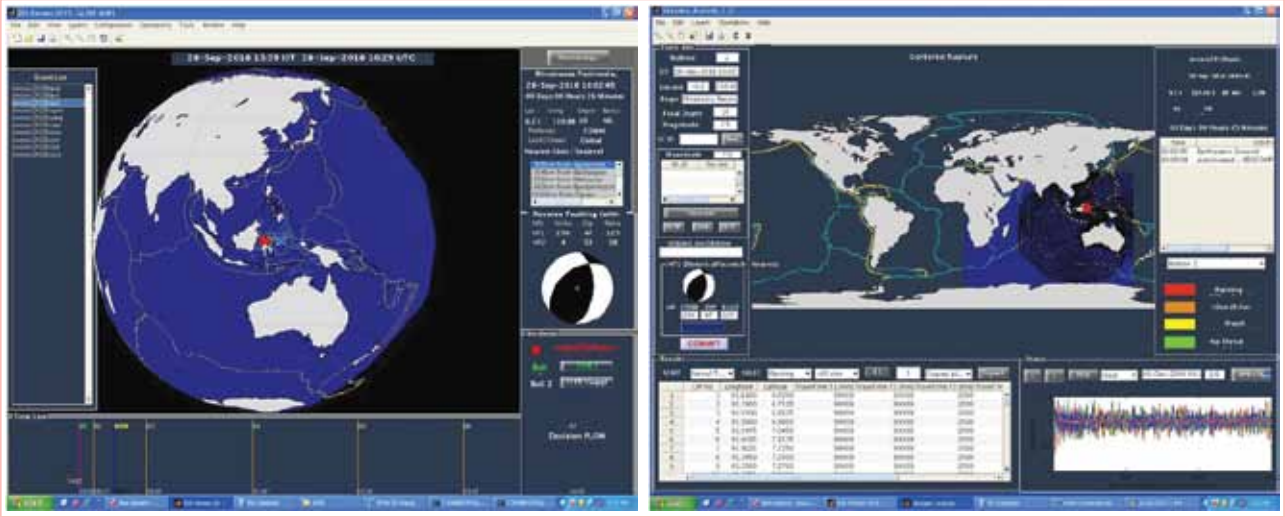
Location map of earthquakes of magnitude ≥6.5 monitored at ITEWC during 2018-19.

Epicentre (shown in inset) and threat maps of the Prince Edward Islands earthquake that occurred on 22 January 2019.

An earthquake with a magnitude of 6.6 M occurred near Prince Edward Islands Region (43.03°S, 42.26°E) in the southwestern Indian Ocean at 19:01 UTC on 22 January 2019. Based on pre-run model scenarios, ITWEC issued a 'NO THREAT' bulletin for the coastline of India and the Indian Ocean Region.

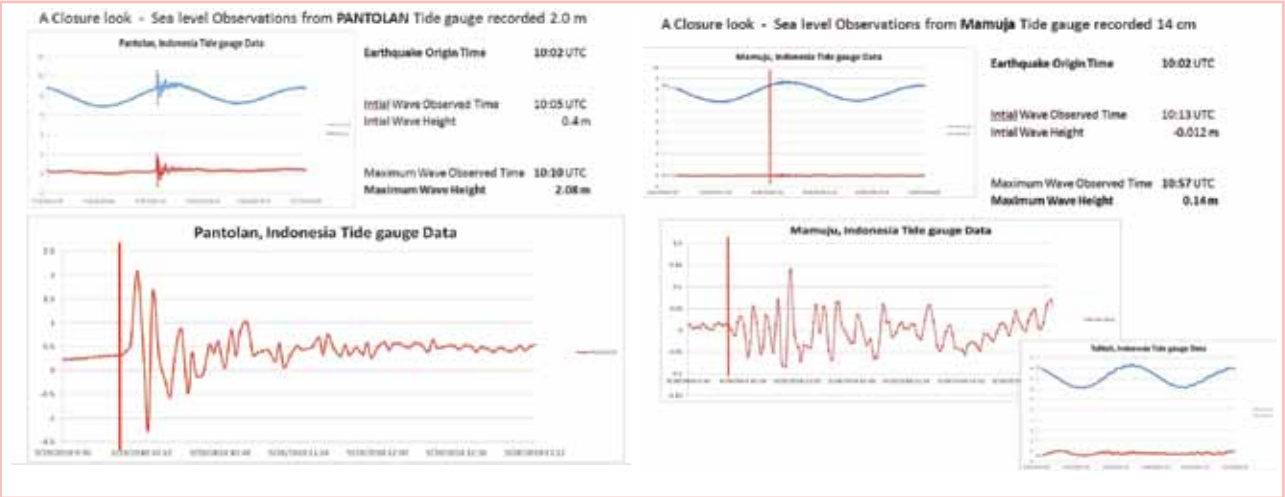
ITEWC monitored a 7.5 M earthquake that occurred at the Minahassa Peninsula, Sulawesi, Indonesia on 28 September 2018 10:02 UTC with epicentre at 0.19°S, 119.89°E at a focal depth of 10 km and issued a No Threat bulletin for India and other countries on the Indian Ocean Rim. Even though the earthquake happened on land with strike-slip faulting, it generated a major tsunami locally. This local tsunami was generated due to multiple landslides triggered by the earthquake and it caused the death of over 4300 people in Palu and the surrounding region. This was not predicted by the current tsunami warning systems, which focus only on tsunamis generated by earthquakes. Hence, early warning systems need to be further improved to predict tsunamis generated by atypical sources such as submarine landslides, volcanic eruptions and meteoric impacts.

Bulletin timelines for the Minahassa Peninsula, Sulawesi earthquake on 28th September 2018



Operational model forecasts during major event on 28th September 2018

Time (UTC)	Event	Elapsed Time from EQ Origin Time (min)
1002	Earthquake Occurrence	0
1006	Earthquake Detection by SEISCOMP	4
1010	Type - I NOTHREAT Bulletin Issue (FINAL)	8



Tsunami waves of 2m high recorded by nearby tide gauge Pantolan, Indonesia

4.1.1 Key Performance Indicators (KPI) of ITEWC

Sr. No.	Performance Indicator	Target	ITEWC Performance
KPI 1	Elapsed time from earthquake to issuance of first Earthquake Bulletin	10 Min	11.3
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	0.17

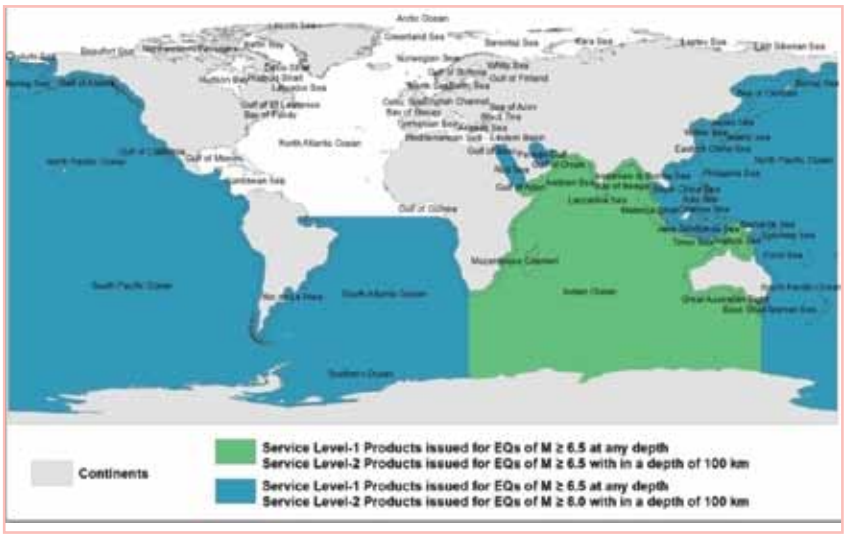
KPI 4	Accuracy of earthquake hypocenter depth in comparison with Final USGS parameters	30 Km	19.1
KPI 5	Accuracy of earthquake hypocenter location in comparison with Final USGS parameters	30 Km	16.5
KPI 6	Elapsed time from earthquake to issuance of first Threat Assessment Bulletin	20 Min	35

4.1.2 Operational Tsunami Forecast

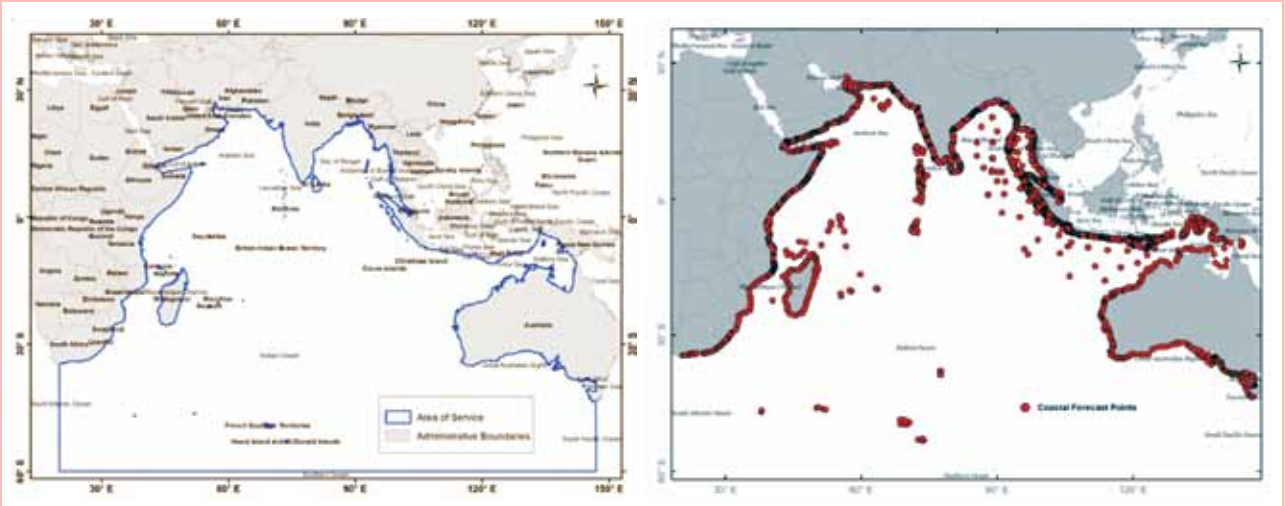
The Open Ocean Propagation Scenario Database (OOPSDB), which is the backbone of tsunami early warning centre operations, has been updated by incorporating source parameters representing the actual subduction zone geometries and unit source scaling with finite number of scenarios. The Application of Basic geophysical equations for Calculations and generation of Open Ocean Propagation Scenario DataBase (ABC of OOPSDB), which facilitates finite number of base-unit source scenarios generated by TUNAMI-FF model (source: https://github.com/tunamiff2011cuda/tunamiff2011) and scaling to different magnitudes "on-the-fly", has been adopted and validated for different historical tsunami events. The global geophysical relations for seismic moment and fault parameters in global subduction zones were used to define rupture geometries with uniform slip models and the theory of seismic moment and moment magnitude definition was used for scaling of the unit sources.

4.1.3 Enhancements in operational Decision Support System

INCOIS, is the first Tsunami Service Provider to achieve complete capability for providing Operational Service Level II prescribed by ICG-IOTWMS with a new decision support system, DSS2016. The new DSS harmonized procedures of other global tsunami warning centres along with operationalisation and integration of spatial layers such as Area of Service (AoS), Earthquake Source Zones (ESZ), Coastal Forecast Zones (CFZ) and Points (CFP) to the latest versions (Version-2018Mar14) as per TSP service definition.



Earthquake Source Zone (ESZ) and criteria for commencement of TSP Services for Indian Ocean Rim countries under IOTWMS Framework



Operational Area of Service (AoS) and Coastal Forecast Points and Zones (Version-2018Mar14) for harmonization of TSP Products under IOTWMS frame work as per service definition

4.1.4 Standby Inundation Model for Coastal Inundation Mapping

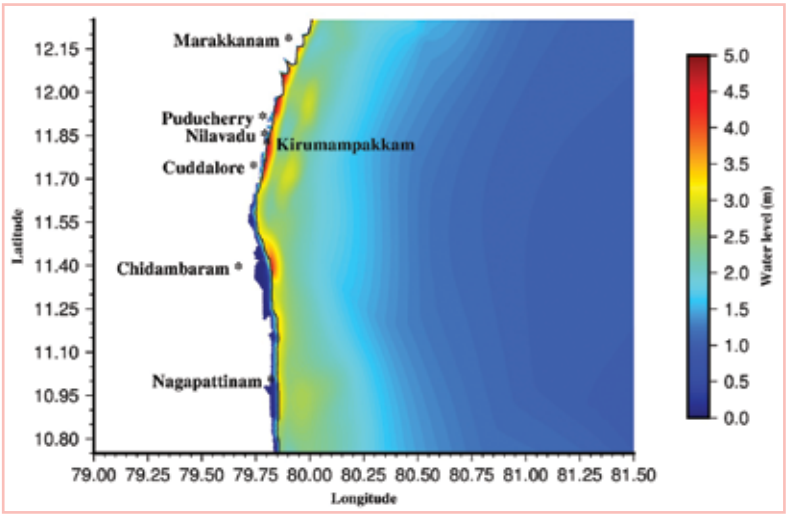
In order to assess the coastal inundation associated with major tsunamigenic earthquakes, a Standby Inundation Model For Coastal Inundation Mapping (SFC) tool was developed by INCOIS. SFC is a software tool that can be used at all stages of tsunami modelling and inundation mapping. Major applications of SFC are i) setting up of source parameters, ii) computation of initial deformation Uniform Slip Model (USM) and Variable Slip Model (VSM), iii) generation of bathymetry grids, iv) simulations of open ocean propagation and coastal inundation, v) exporting inundation data to be utilized in QGIS software, vi) integration of TUNAMI models for real-time model launch, and vii) access to OOPSDB through OPENDAP server configuration.

SIM for CIM Tool

4.1.5 Real-time Tsunami Inundation simulations using ADCIRC model

The Tsunami model currently in use to issue forecasts simulates only open ocean propagation characteristics. In order to include coastal inundation associated with tsunamis, the ADCIRC model, which is widely used for storm surge forecasts, has been configured for the Indian Ocean. This model configuration is capable of computing tsunami characteristics such as its propagation, the extent of inundation and inundation depth along the Indian coast. This setup was tested with 2004 Indian Ocean tsunami event data and results were validated with all available

observations. This is the first ever approach to model tsunami propagation and inundation using the ADCIRC model. As the model is fully parallelized, simulating 12-hr tsunami propagation characteristics takes around 51 sec only. For the prediction of inundation characteristics, the model takes around 5 min. With this setup, it will be possible to issue inundation warnings in real time.



Computed tsunami heights and associated inland extent of inundation along part of Tamil Nadu coast

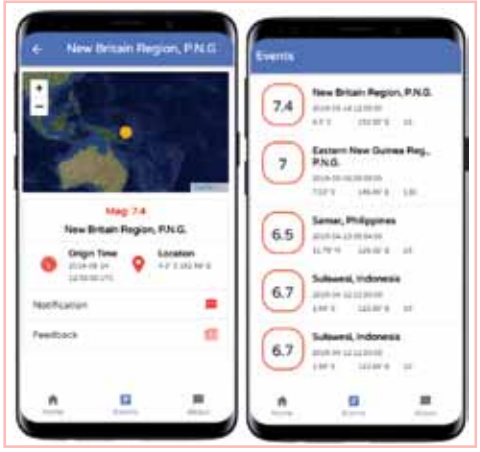
4.1.6 Web application for the assessment of Key Performance Indicators (KPI)

A web application was developed by INCOIS to support the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) for evaluating the performance of Tsunami Service Providers (TSP) in the Indian Ocean region against the stipulated Key Performance Indicators (KPI) in a common format.

Web application for the assessment of Key Performance Indicators

4.1.7 TSP India Mobile Application

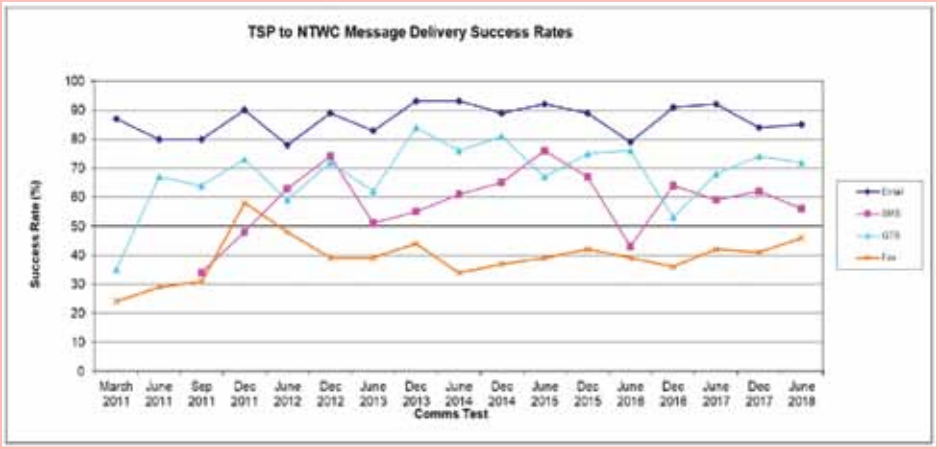
In the capacity of Tsunami Service Provider-India, ITEWC has developed a user-friendly mobile application to provide tsunami early warning notifications to National Tsunami Warning Centres (NTWCs) of Indian Ocean member countries in real time from TSP India.



4.1.8 Communication Tests (COMMs Test)

Two Communications (COMMs) tests, one on 13 June 2018 and another on 12 December 2018, were conducted to validate the dissemination processes of Tsunami Service Providers (TSPs) to National Tsunami Warning Centres (NTWCs). During the COMMs tests, ITEWC disseminated notification messages through email, fax, GTS, SMS as well as the website to 25 NTWCs and two other TSPs (Australia &

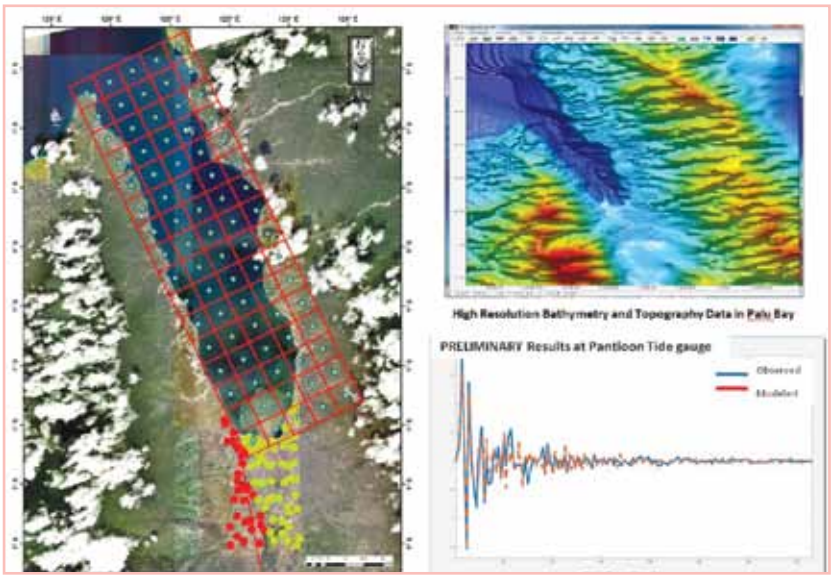
Indonesia) in the Indian Ocean region. It is found that the most effective mode of communication is through email, which had a success rate of 80-90%.



Message delivery success rate during COMMs Tests

4.1.9 Sea level Data Inversion Modeling

The real-time data from Bottom Pressure Recorders (BPRs) and tide gauges deployed in the Indian Ocean, which are being used to assess the severity of a tsunami-in-progress based on significant water level changes near the source, were utilised to predict the tsunami waveforms away from the source using inverse method. In addition to characterising tsunamis caused by typical sources such as seismic earthquakes, this technique is also useful to detect tsunamis caused by atypical sources such as volcanic eruptions, land based strike-slip earthquakes, etc. To test the sea level data inversion method, the recent tsunami that occurred near Palu, Indonesia on 28 September 2018, which was triggered by an "atypical" source (land-based earthquake) was studied. A database of unit source scenarios was generated using the ADCIRC model to set up sea level inversion. The sea level records from near-source sea level stations, Pantloon and Mamuju were used in this study. The high-resolution bathymetry and topography data obtained from the Badan Informasi Geospasial, Geospatial Agency of Indonesia was used to generate a finite element mesh. The estimates based on this inversion model clearly indicate that the main source of this tsunami was within Palu Bay, which generated the local tsunami and severely impacted Palu.

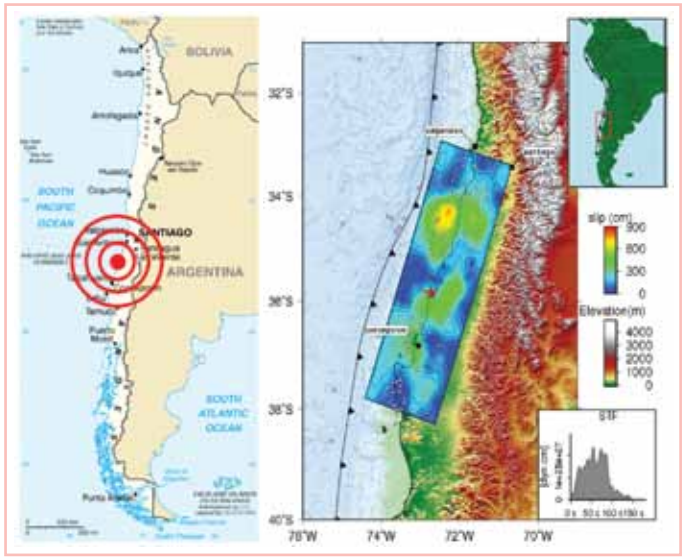


Tsunami Source Constraints – Sea level inversion for Tsunamigenic Source in Palu Bay

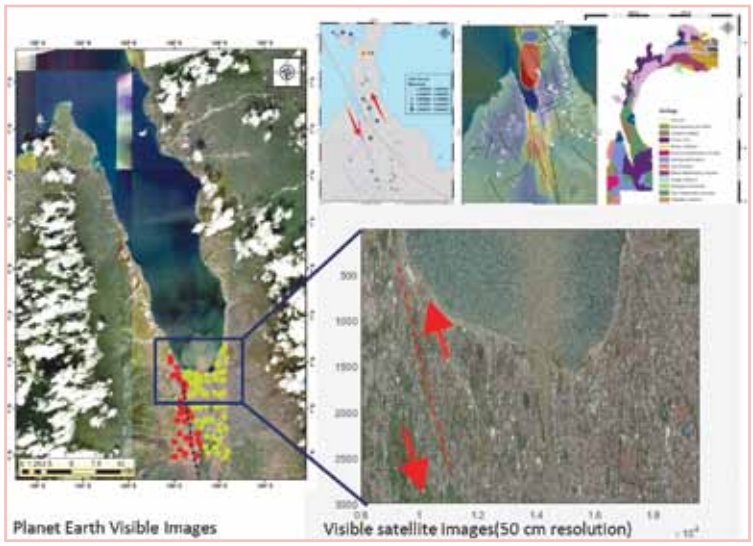
4.1.10 GNSS data inversion for near real-time estimation of tsunamigenic potential of an earthquake

Although early detection of an earthquake is possible from seismic data, the characterization of seismic ground motion, the rupture direction and area are not available quick enough to estimate tsunamigenic potential of an earthquake. The moment magnitude Mw is the critical indicator of tsunamigenic potential of an earthquake. However, its estimate requires seismic waveform

data for a longer period, which limits its use in tsunami warning. To overcome this drawback a new approach based on near-field GNSS measurements as well as strong motion sensors was initiated. The GNSS and strong motion data are used for source characterization and determination of earthquake magnitude. With the establishment of GNSS receivers along with atmospheric sensors and strong motion sensors, it is now possible to process GNSS & Strong motion data in real time and ascertain the potential of tsunami genesis at the earliest. The real-time GNSS data processing system estimates coordinate time series for every second for each station. The estimated coordinates are processed through the STA/LTA algorithm to detect the event. Once an earthquake event is detected, the earthquake parameters are estimated through an iterative method. This method has been tested for the devastating 8.8 Mw earthquake that occurred at Maule on 27 February 2010, which struck the coastal region of central Chile. The earthquake generated a damaging tsunami, with 29 metre maximum run-up water height reported at constitution. Inversion of high-rate GNSS data, yielded a kinematic rupture model with improved resolution of significant slip at shallow depth in two major rupture patches.



Fault plane slip distribution using GNSS data



Tsunami Source Constraints - Seismo-Geological and Fault displacement observations of Tsunami in Palu Bay on 28 September 2018

4.1.11 Tsunami Workshops ICG/IOTWMS 2nd Integrated Intersessional Meetings

INCOIS organised the 2nd Integrated Intersessional Meetings of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) of UNESCO during 26 June-14 July 2018 at INCOIS. Dr. M. Rajeevan, Secretary to Govt. of India, Ministry of Earth Science, inaugurated the meetings. The meetings included the following back-to-back events, i) training on Tsunami Emergency Maps, Plans and Procedures (TEMPP-2), ii) working group 1& 2, sub-regional working group, and task team meetings, and iii) training on tsunami warning centre operations and standard operating procedures for tsunami warning and emergency response. Sixty-six participants from 16 countries (Australia, Bangladesh, Comoros, Germany, India, Indonesia, Iran, Kenya, Madagascar, Myanmar, Oman, South Africa, Sri Lanka, Tanzania, Thailand and United Kingdom) and 1 UN agency attended the trainings/meetings.

Participants and experts at the 2nd Integrated Intersessional Meetings of the ICG/IOTWMS

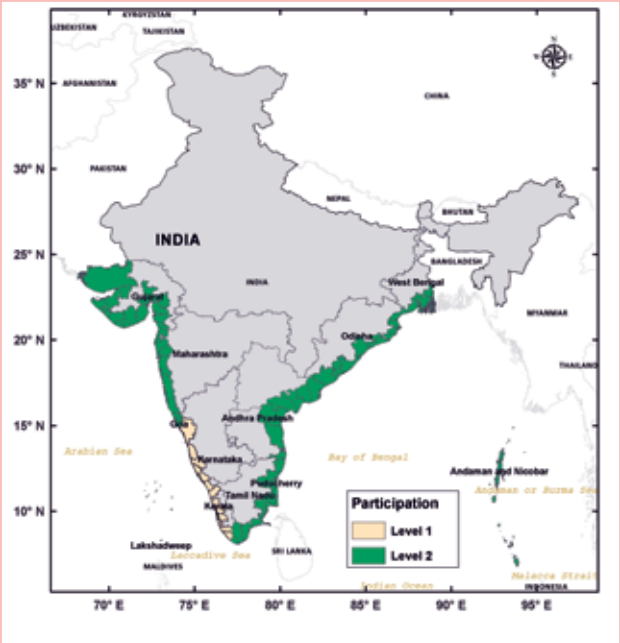
4.1.12 Tsunami SOP and Sensitization Workshops

INCOIS organized the National Tsunami Standard Operating Procedure (SOP) workshop on 10 August 2018 at INCOIS in connection with the IOWave18 Exercise held during 4-5 September 2018. A table-top exercise was also conducted on this occasion. Eighty participants from coastal States/UTs, Navy, Coast Guard, NDRF, Army and Port & Harbours attended the workshop. In preparation for the IOWave18 exercise, INCOIS and Andhra Pradesh State Disaster Management Authority jointly conducted a sensitisation workshop on 30 August 2018 at Vijayawada, Andhra Pradesh.

Participants of National tsunami SOP workshop on 10 August 2018

4.1.13 IOWave18 Tsunami Mock Exercise

ICG/IOTWMS of UNESCO conducted the IOWave18 Tsunami Mock exercise during 4-5 September 2018. INCOIS participated in this exercise in its capacity as National Tsunami Warning Centre (NTWC) for India as well as one of the Tsunami Service Providers (TSPs) for the Indian Ocean region. The exercise comprised two scenarios, one in the north-western Indian Ocean and the other in eastern Indian Ocean. The first scenario was an earthquake simulation



Level of participation by the coastal states in the IOWave18 exercise. [Level 1: Only administrative departments participated; Level 2: Public evacuation was carried out]

with a magnitude of 9.0 M off the coast of Iran on September 4 (0600 UTC). States along the west coast of India (Gujarat, Maharashtra and Goa) participated in this exercise. The second scenario was an earthquake simulation with a magnitude of 9.3 M in northern Sumatra, Indonesia on 5 September (0300 UTC).

Community evacuations and related activities during IOWave18 Exercise

States along the east coast of India (West Bengal, Odisha, Andhra Pradesh, Puducherry, Tamil Nadu and Andaman & Nicobar) participated in this exercise. ITEWC generated and disseminated 15 tsunami bulletins on both days to its national and regional contacts. Around 375 villages from 44 districts of 8 coastal States/UTs were involved in the whole exercise. More than 1,04,000 people were evacuated to shelters/safe places. It was observed that the average response time, notifying the public, was less than 30 minutes. Different modes of communication, viz., telephone, SMS, whatsapp, twitter, public radio, TV, website, siren, public alert system, police, door-to-door campaigns, mega phone, VHF, etc. were used to disseminate the information.

4.1.14 World Tsunami Awareness Day

World Tsunami Awareness Day activities during 3-5 November 2018

As part of the celebrations of the 3rd World Tsunami Awareness Day (5 November) a Tsunami Awareness lecture was delivered by Prof. C.P. Rajendran, JNCASR, Bangalore. An exhibition of Tsunami Science models by school students was held during this event and prizes were distributed to the winners. Additionally, a 2-day open house was organised for school children and the public on 3 & 5 November 2018.

4.1.15 Indian Ocean Tsunami Ready (IOTR) implementation

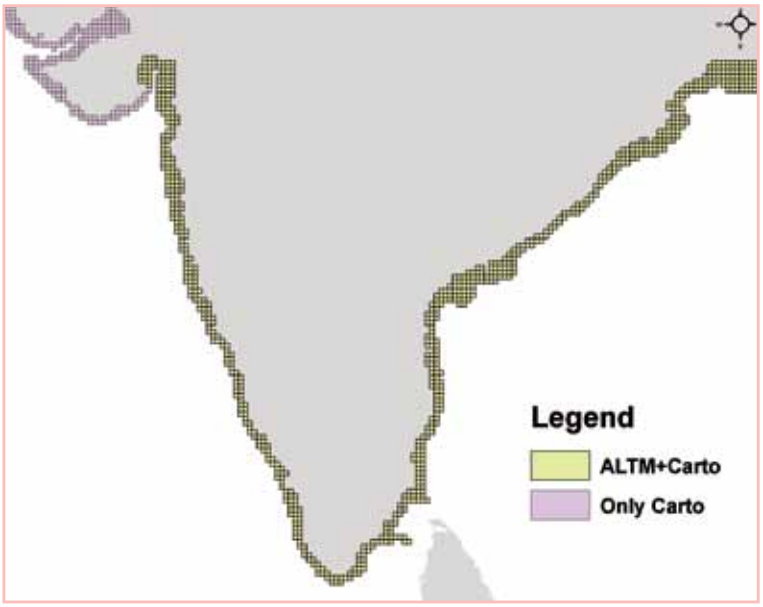
Indian Ocean Tsunami Ready (IOTR) programme is a community performance-based initiative of ICG/IOTWMS, which aims at facilitating tsunami preparedness among the coastal communities with active collaboration from the public and local/national emergency management agencies through a structural and systematic approach based on a few best-practice indicators. In India, the IOTR has been implemented in 6 tsunami-prone villages in the state of Odisha. The IOTR indicators were evaluated in these villages during the IOWave18 exercise. A National Board has been formed to implement and monitor this programme. The first meeting of this board was held on 10 August 2018.

Villages in Odisha, India in which the IOTR programme has been implemented

S No	District	Block (Sub-Dist)	Village
1	Balasore	BalasoreSadar	JayadevkasabaPahi
2	Bhadrak	Basudevpur	Podhuan
3	Kendrapara	Mahakalpada	TantiapalSasan
4	Jagatsinghpur	Ersama	Noliasahi
5	Puri	Astaranga	Keutajanga
6	Ganjam	Rangeilunda	Venkatraipur

4.1.16 Multi-Hazard Vulnerability Mapping

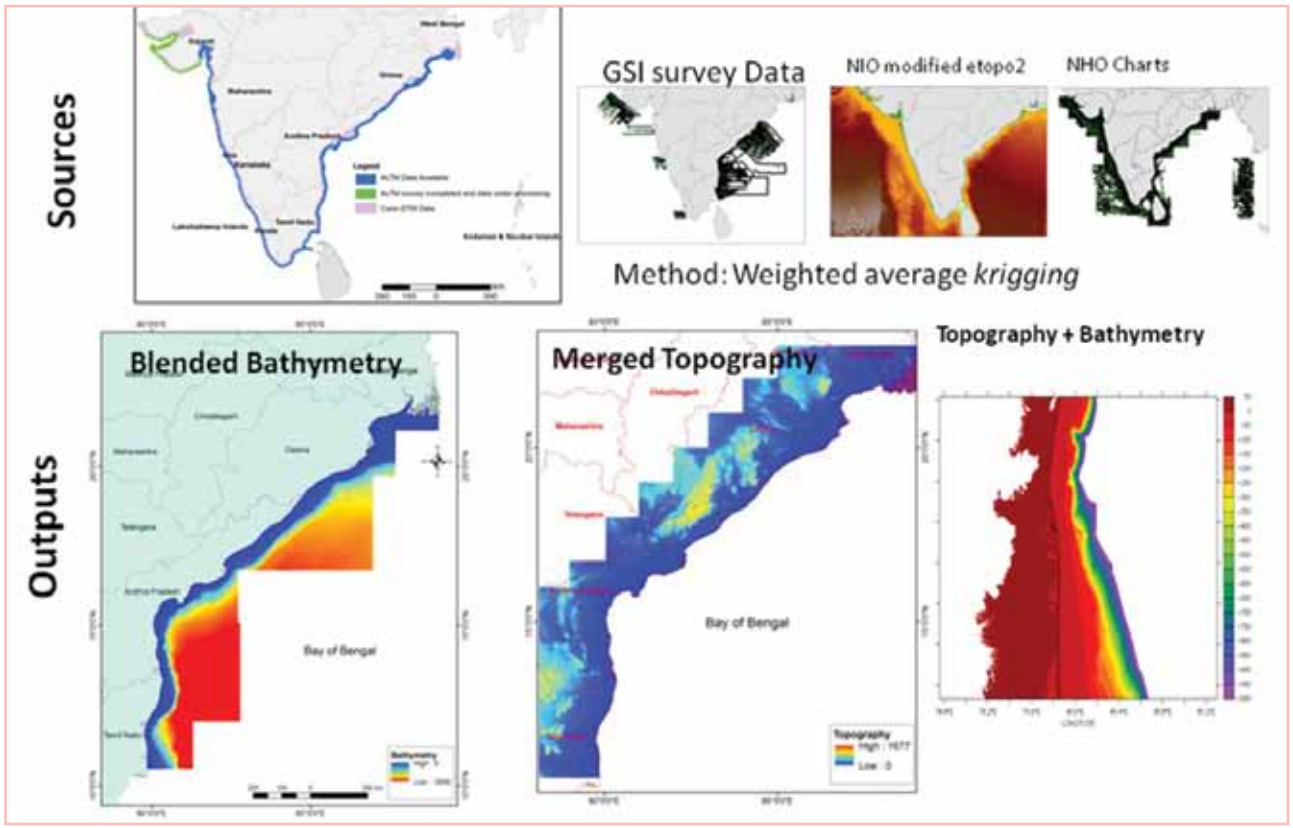
A total of 249 multi-hazard vulnerability maps at 1:25000 scale, covering the coastal stretch between Kochi and Bhavnagar, were revised with ALTM and Carto-DTM. Some of the low-lying coastal areas, which were not picked up earlier, are now recorded as multi hazard vulnerable areas based on ALTM data. With this, MHVM has been generated from Sundarbans to Bhavnagar using ALTM + Carto-DTM data. Rest of the areas along the Gujarat coast were mapped using only Carto-DTM.



Spatial coverage of multi-hazard vulnerability mapping

4.1.17 Blended bathymetry and topographic data

Bathymetry data obtained from ICMAM (Cuddalore-Nagapatnam), GSI (Andhra Pradesh and Tamil Nadu, Odisha) and NHO charts were merged with NIO modified ETOPO-2 data and a seamless bathymetric dataset for east coast of India with 200 m grid spacing up to 500 m water depth was prepared. The data were blended using weighted optimal interpolation technique. The RMSE of the blended bathymetric data is found to be 1.42 m. This data is now being used for configuring Tsunami, Storm Surge and Wave models. The data from ALTM, Carto-DTM and SRTM were merged to prepare a high-resolution topographic dataset up to 40 m elevation or the maximum extent of Carto-DTM. This topographic data was blended with the new bathymetric data prepared for the east coast. This data is being used for prediction of inundation using tsunami and storm surge models.



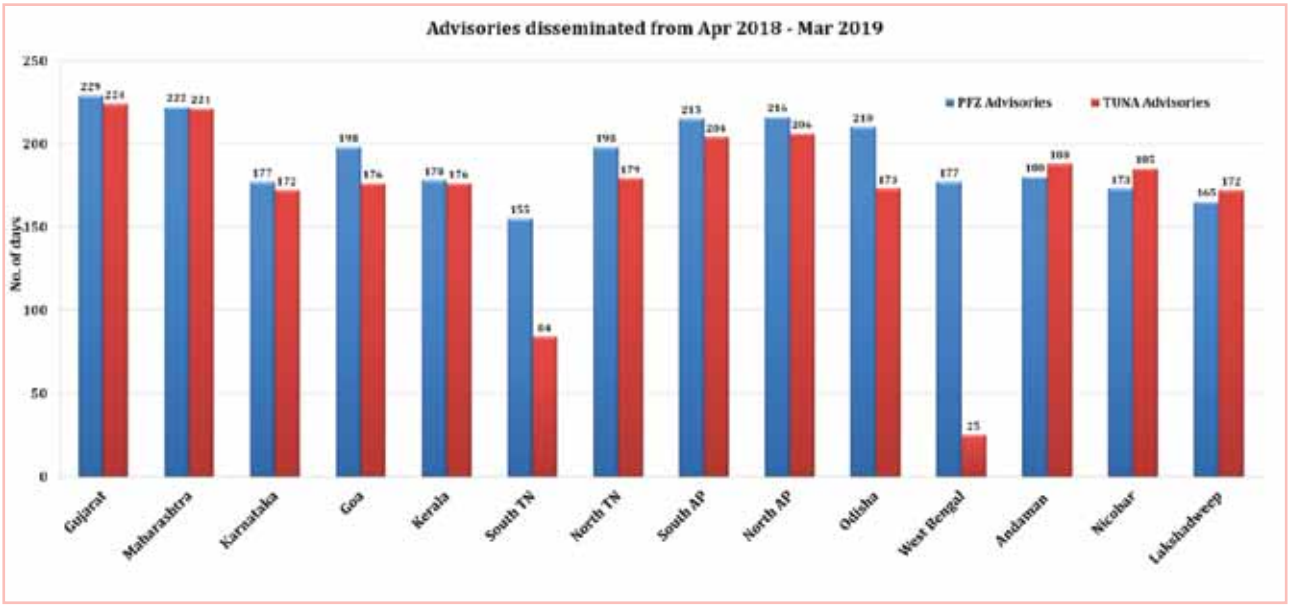
Merged bathymetric and topographic data

4.2 Marine Fisheries Advisory Services (MFAS)

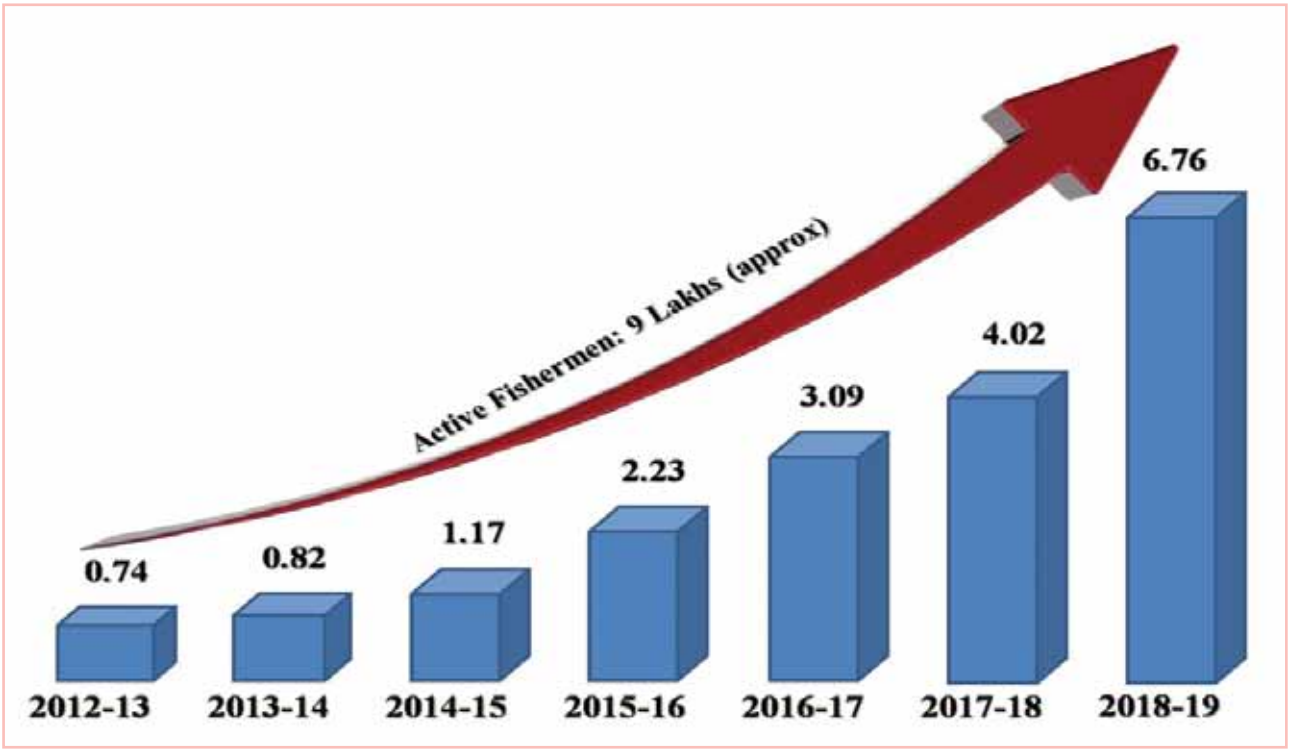
4.2.1 Potential Fishing Zones (PFZ) and Tuna PFZ Advisories

INCOIS continued its flagship service, Potential Fishing Zone (PFZ) advisories, which provides information on the fish aggregation regions at sea. These advisories are generated using the satellite data on Sea Surface Temperature (SST), chlorophyll concentration, water clarity and the sea surface height anomaly. The advisories are disseminated in smart map and text form on a daily basis, except during fishing-ban period and during adverse sea-state. During the period April 2018 to March 2019, multilingual Potential Fishing Zone (PFZ) advisories were disseminated on 299 days. During the same period, INCOIS provided Yellowfin Tuna advisories, which also

included the maximum fishing depth information, on 290 days. The catch patterns of Yellowfin Tuna are being analysed with reference to the related environmental variables for developing a Habitat Suitability Index (HSI).



Number of PFZ and Tuna PFZ advisories issued during April 2018-March 2019



Growth of INCOIS MFAS user-base over the years (numbers in Lakhs).

4.2.2 Experimental Hilsa Shad advisories

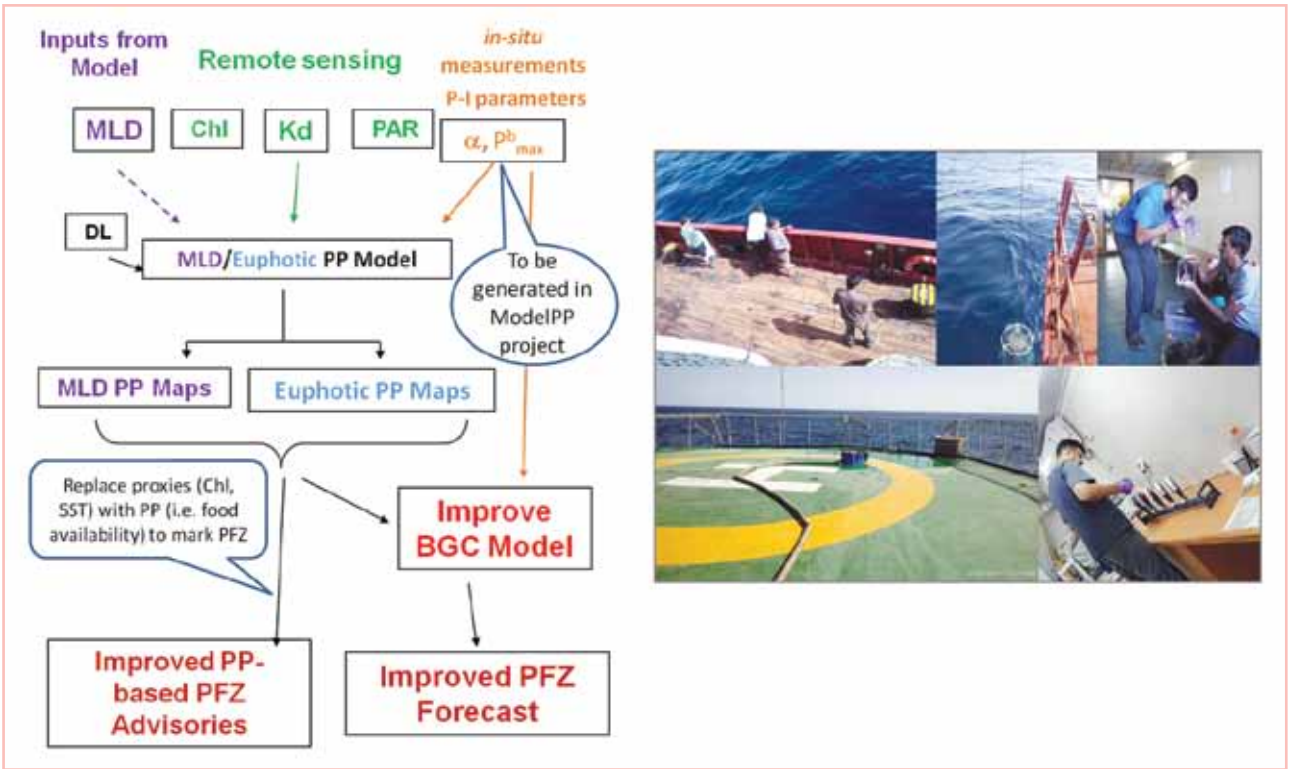
INCOIS continued to provide experimental Hilsa Shad advisories during FY 2018-19. It has now been planned to make these advisories operational by 2020. Additionally, for facilitating the collection and analysis of in situ data of ecosystem parameters and promoting outreach activities, INCOIS has initiated the process to establish a coastal laboratory facility at Digha with civil infrastructure support from the Fisheries Department, Govt. of W.B.

Sample collection (left) and user interaction (right) under the Hilsa-Shad initiative.

4.2.3 Ecosystem-based Fishery Advisory Services (EFAS)

Modelling Marine Primary Productivity

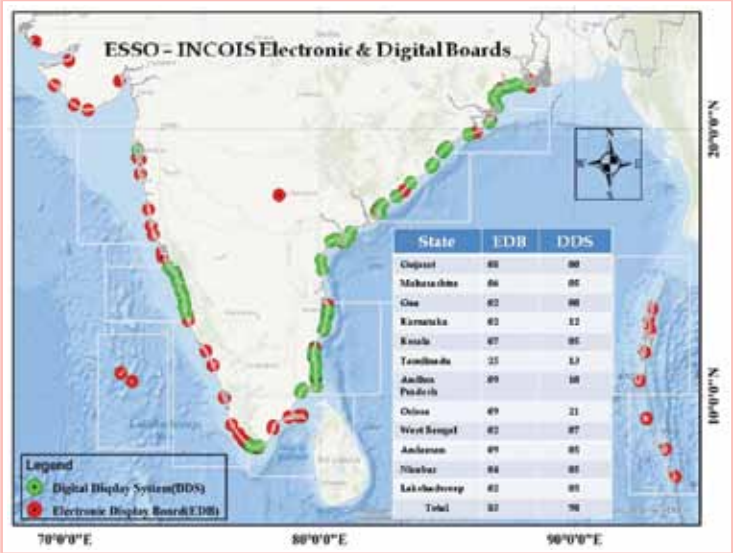
At present, the zones of fish aggregation are being identified from satellite data on Sea Surface Temperature (SST) and chlorophyll concentration. While these are good indicators of food-availability, they do not provide any information on the light harvesting (i.e. food-generating) capacity of the phytoplankton community (also known as primary productivity) in specific regions. Further improvement of PFZ advisories can be achieved by integrating Primary Productivity (PP) information into the PFZ identification process. This can also improve our understanding on the biogeochemical cycles – especially the nutrient and carbon cycles in the Indian seas, which will be very useful in modeling the ecosystem parameters. A pilot cruise was organized during February, 2019 to set the SOP and conduct primary productivity estimates. Future cruises are proposed to expand the observations, including photosynthesis and irradiance parameters.



Schematic workflow of PFZ generations after incorporating primary productivity information (Left).
Sample collection during the Primary-Productivity experiments (Right).

4.2.4 Digital Display Systems: The new-generation of Electronic Display Boards

The Electronic Display Boards (EDBs) installed at several fishing harbours along the coast has been proved to be very useful for timely dissemination of ocean information/advisories/forecasts from INCOIS to the users. INCOIS started installing a new generation of EDBs viz. Digital Display Systems (DDS) in January 2018. The DDS have solar panels for power and are run with in-house developed software. Presently, a total of 98 DDS are installed along the Indian coast, in addition to the 85 existing EDBs.

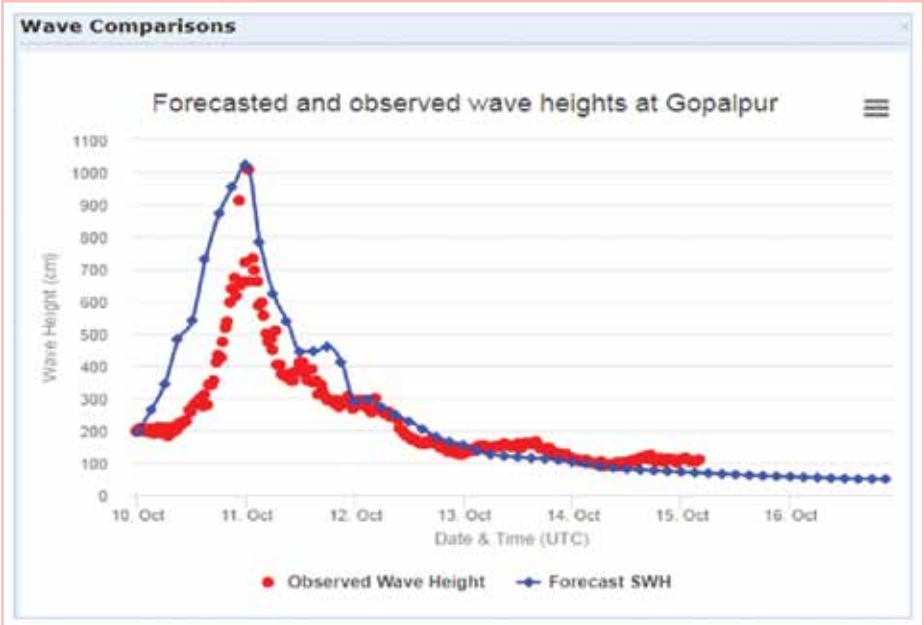


Map showing installed DDS along with existing EDBs at various coastal locations.

4.3 Ocean State Forecast Services

4.3.1 Ocean State Forecasting during Cyclones

INCOIS continued its regular ocean state forecast services and provided suitable advisories/ forecasts during the occurrence of tropical cyclones in the northern Indian Ocean. Warnings were issued for the impending high waves off the coasts of Odisha and Andhra Pradesh during the occurrence of cyclone Titli during 7-13 October 2018. INCOIS issued 20 Joint Bulletins with IMD, during this period. The wave rider buoy deployed by INCOIS off the coast of Gopalpur recorded maximum wave height of 7.46 m at 0530 hrs on 11 October 2018, while the maximum wave height predicted by INCOIS was 7.85 m.



Predicted and Observed wave heights (cm) during Cyclone Titli (7-13, October 2018) at Gopalpur.

INCOIS also issued 23 Joint Bulletins with IMD including information on associated wave parameters during the passage of cyclone Liban, which was formed in the central Arabian Sea

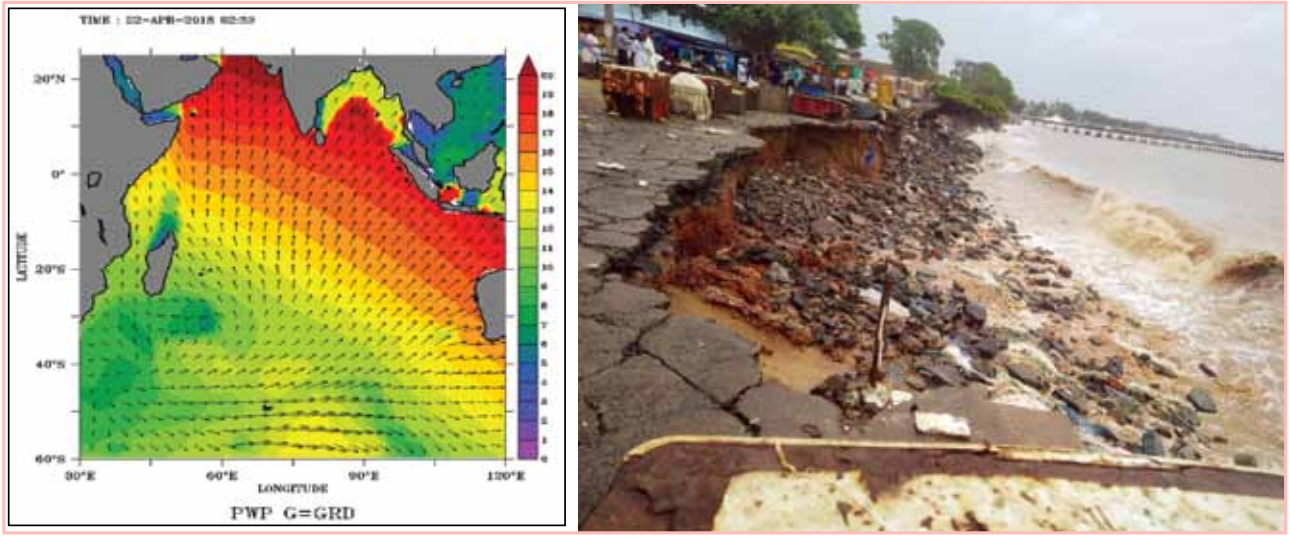
on 6 October 2018 and moved northwestward to make landfall in eastern Yemen on 14 October 2018. Observations from the wave-height meters installed in open ocean moored buoys (AD06, AD07 and AD09) as well as the wave rider buoy at Ratnagiri were used to validate the ocean state forecasts issued by INCOIS.

Predicted and Observed wave heights (m) during Cyclone Luban (7-14, October 2018).

INCOIS issued forecasts of ocean state and warnings/alerts associated with the passage of cyclone Gaja for the coastal waters of Tamil Nadu, Puducherry, Kerala and Lakshadweep during the period 10-20 November 2018. Maximum significant wave height recorded by the wave rider buoy deployed off the coast of Puducherry was 2.9 m, which matched well with the predicted wave height of 2.8 m. The total number of Joint INCOIS-IMD Bulletins issued for this system was 34. INCOIS also issued 15 INCOIS-IMD Joint Bulletins for the cyclone Pabuk during 3-6 January 2019.

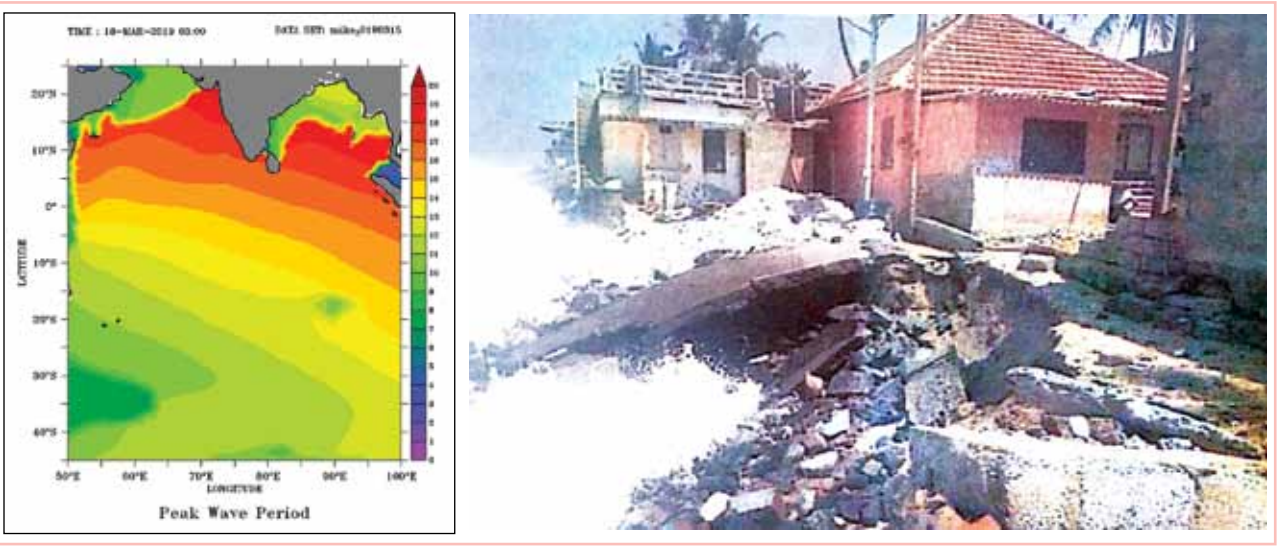
4.3.2 Forecast on high period swell and rough sea conditions & perigean spring tide events

INCOIS issued early warnings on swell surges and rough sea conditions during 20-24 April 2018 and 17-22 March 2019 for the coastal waters, especially for the west coast and island territories. These swell surges were caused by the arrival of long period swells that originated from



Peak wave period (in seconds) during 22 April 2018 and a photograph showing the damage that occurred at Kozhikode coast in Kerala.

the distant Southern Indian Ocean. The early warnings issued by INCOIS helped to secure life and livelihoods of the people residing along the coastline.



Peak wave period (in seconds) during 18 March, 2019, and a photograph showing the damage at Thiruvananthapuram coast in Kerala.

4.3.3 Ocean State Forecast dissemination through All India Radio

On 18 June 2018, Mr. R. Siva, Member of Legislative Assembly, Puducherry inaugurated the dissemination of ocean state forecasts through All India Radio stations in Tamil Nadu and Puducherry. Daily ocean state forecasts issued by INCOIS are now being broadcasted by AIR stations at Chennai, Tiruchirapalli, Karaikal, Puducherry, Nagarcoil, Tirunelveli, Tuticorin.

Shri. R. Siva, the Member of Legislative Assembly, Puducherry inaugurates the dissemination of Ocean state forecast through All India Radio stations at Puducherry by on 18 June 2018.

4.3.4 Small vessel advisory services

A special service named "Small vessel advisory service" was developed by INCOIS to issue warnings indicating potential zones where the sea state is adverse for voyages. The warnings are issued for different categories of vessels based on the Boat Safety Index (BSI), which is a function of steepness index, crossing sea index and an index for rapid development of sea.

4.3.5 User Interaction workshops and Trainings

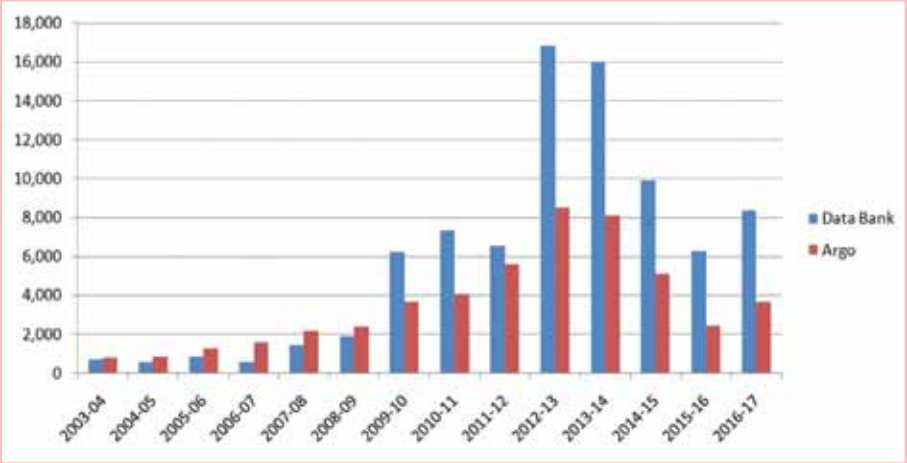
- INCOIS organised a one-day user interaction/awareness meeting and training for trainers at Thiruvananthapuram in collaboration with the Thiruvananthapuram Social Service Society

(TSSS) on 8 May 2018. Ninety representatives of the fisherfolk from south Tamil Nadu, Thiruvananthapuram and Kollam districts of Kerala attended the user interaction/awareness meeting and 30 trainers attended the training for trainers session.

- INCOIS, in collaboration with a risk communication & anthropology research team from Sussex University, UK, organized another one-day training for trainers of Ocean State Forecast, Information and Advisory services from INCOIS at St. Xavier's College, Thumba, Thiruvananthapuram on 23 September 2018. Sixty-five trainers/fishers from various villages in Thiruvananthapuram attended the training workshop.
- INCOIS imparted training on the Search And Rescue Aid Tool (SAR) and impact-based ocean state forecast, advisory and information services during the 'Maritime search and rescue workshop' conducted by the Coast GuardMaritime Rescue Coordination Centre (MRCC), Port Blair, under the aegis of National Maritime Search and Rescue Board (NMSRB) on 8 October 2018. Fifty officers from the Coast Guard, fishery departments and other stake holders attended this training.
- INCOIS provided training on the Search And Rescue Aid Tool (SAR) and impact-based ocean state forecast, advisory and information services during the "Search And Rescue Seminar on Efficacy of Maritime search and rescue in India: A relook" and participated in a meeting conducted by the Coast Guard Region (North East) Head Quarters at Kolkata on 13 November 2018. Twenty officers from the Coast Guard attended this training.

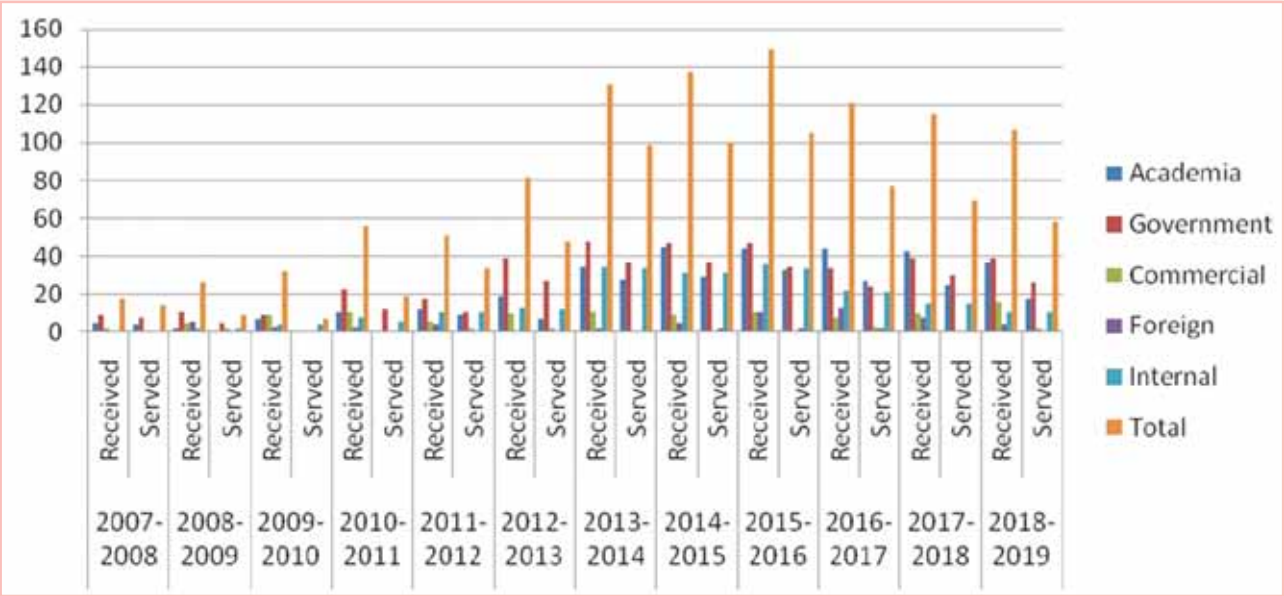
4.4 Data Services

INCOIS, being the central repository for the oceanographic data in the country, sustained and strengthened real-time data reception, processing and quality control of oceanographic/surface meteorological data from a wide range of ocean observing systems such as Argo floats, moored buoys, drifting buoys, wave rider buoys, tide gauges, wave height meters, ship-mounted autonomous weather stations and HF radars. Further, surface met-ocean data were regularly disseminated to various operational agencies in the country through email/web-site/ FTP in near-real time. The data centre also supports several R&D efforts of the ocean science community by providing tailor-made data and products based on their requests. The data centre also obtained and archived delayed mode data from various observing systems such as XBT/XCTD observations, Met observations (Indian Navy), OSCAT data (SAC), IMD marine meteorological data, ADCP data, high-resolution OMNI buoy data etc. and



Number of online data users for both the Argo and Data Bank over the past few years.

made significant progress in rescuing historical Met-Ocean data sets. Several valuable historical datasets available in hard copy such as cruise reports or handwritten notes, were digitized and archived. Digitization of such physical records of historical cruises from FORV Sagar Sampada is in progress.



Number of customised offline data requests served over the past few years.

Table: Details of data received from April 2018 to March 2019

Institute/ Programme	Parameters	Period of observations	No. of platforms/ stations reported	Status
Indian Navy	Surface met parameters	April 2018- December 2018	3 Quarterly data	Archived
Indian Navy (XBT)	Temperature profiles	2015-16	3353 profiles	Archived
NIOT (NDBP)	Met Ocean Parameters	April 2018-March 2019	17 buoys	Added to database
NIO (Drifting buoys)	Met Ocean Parameters	April 2018-March 2019	8 buoys	Added to database
INCOIS (Ship AWS)	Met parameters	April 2018-March 2019	32 ships	Added to database
INCOIS/NIO (coastal AWS)	Met parameters	April 2018-March 2019	3 stations	Added to database
INCOIS (WRB)	Wave	April 2018-March 2019	17 stations	Added to database
NIOT (HFRADAR)	Currents	April 2018-March 2019	5 pair stations	Added to database
INCOIS (Argo CTD)	Temperature/Salinity	April 2018-March 2019	26818 profiles	Added to database

4.4.1 Ocean Remote sensing data products

Remote sensing data from the sensors flown on board Oceansat-2, NOAA series of satellites, METOP, Terra and Aqua, and Suomi-NPP satellites were received in real time at ground stations

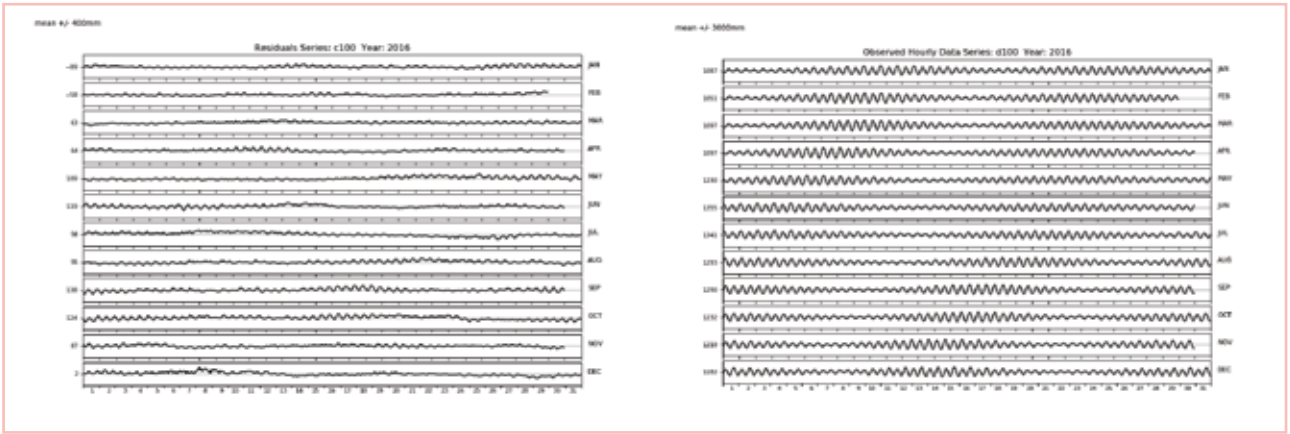
established at INCOIS. The data were processed and made available for in-house operational activities as well as for other operational agencies in the country in near-real time. INCOIS also provided data to many research organizations based on specific requests. Satellite data archived at INCOIS are listed below.

Table: Details of remote sensing data holdings till date.

Satellite	Sensor	Products	Period of data availability
MetOp - A&B NOAA-18&19	AVHRR	• L1b • Sea Surface Temperature • FOG • Cloud top Temp • Normalized Difference Vegetation Index (NDVI)	Sep 2006 to till date
Oceansat-2	OCM	• L1b • Chlorophyll-a • Total Suspended Sediments • Diffuse Attenuation Coefficient (Kd490) • Aerosol Optical Depth (AOD)	Feb 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

4.4.2 Quality control of sea level data

INCOIS has been receiving real time sea-level data from a network of 36 stations for operational tsunami warning services. The sea level data are archived in the servers for operational and research use. The archived data from 2010-2018 has been processed and quality controlled. Quality control includes removal of spikes, gap filling, if the gap is less than 24 hours, and correcting time shift errors.

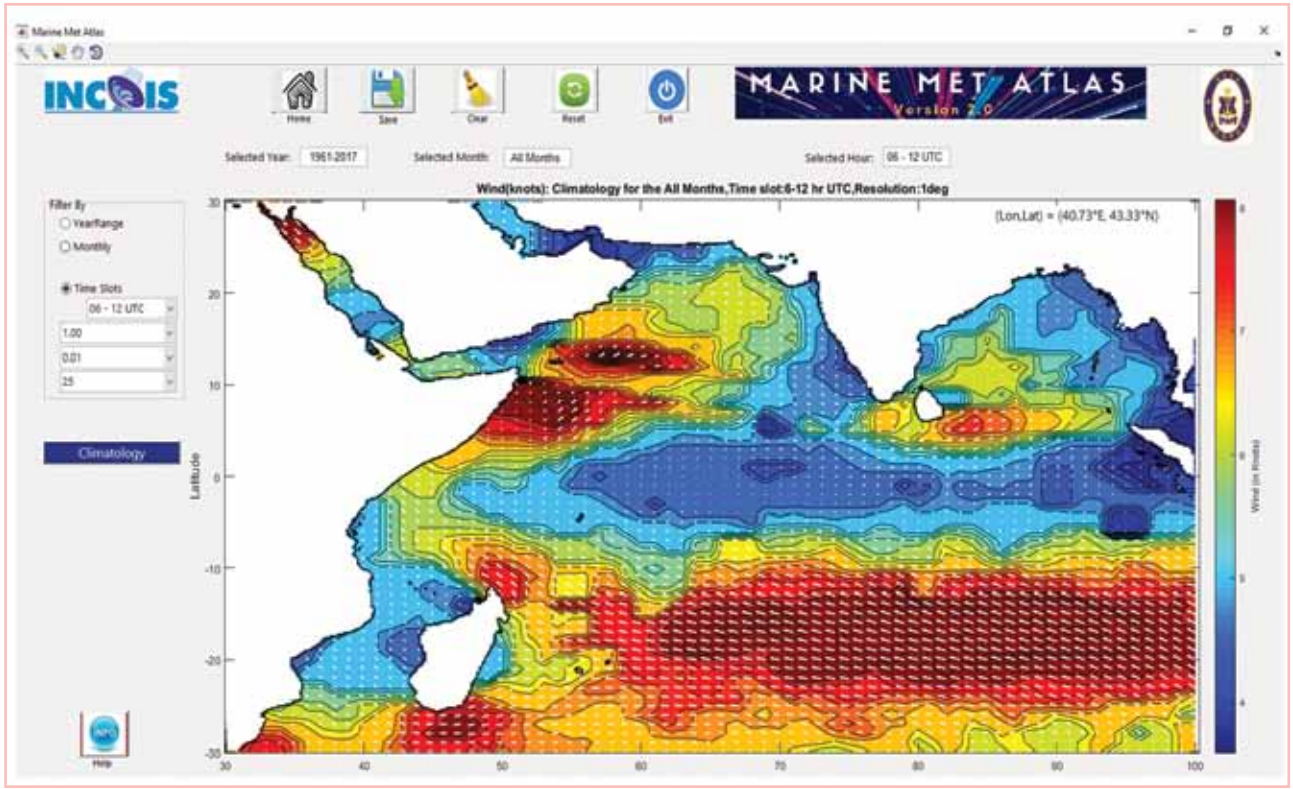


Aerial Bay tide data residual and observed plots after the QC process

4.4.3 Marine Meteorological Atlas (MaMeAT)

INCOIS data centre continued to support the Indian Navy by providing oceanographic data and related software. A scientific visualization software tool (MaMeAT), developed for the visualization and analysis of met-ocean data, was handed over to the Naval Operations Data Processing and Analysis Centre (Indian Navy) in the presence of Vice Admiral S.N. Ghormade, NM, DG of Naval Operations and other naval officers. One of the important objectives of MaMeAT is to display climatological data (e.g., Evaporation Duct Height (EVD), Wind, Dry Bulb Temperature, Sea Surface Temperature, Sea Surface Salinity, Relative humidity, Sea Level Pressure) at each grid point or along-the-track location on board naval vessels.

Dr S.S.C Shenoi, Director INCOIS, handing over the atlas to the Vice Admiral S.N.Ghormade, NM, Director General of Naval Operations

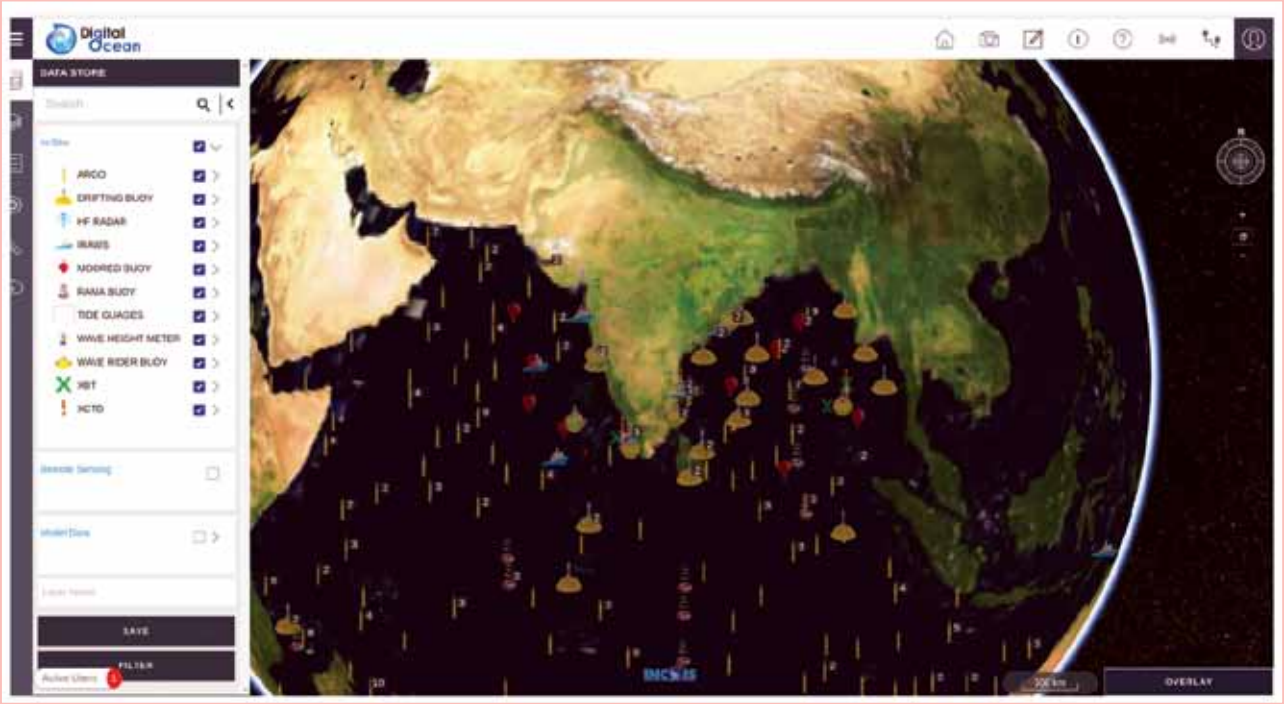


Wind climatology (in knots) over Indian Ocean (a snapshot from MaMeAT)

4.4.4 Development of Digital Ocean

The Digital Ocean (DO) is a web application developed by INCOIS to manage ocean data by providing a dynamic framework to efficiently integrate and manage heterogeneous ocean data. Digital ocean also provides advanced visualization and analysis tools. It has been designed as a one-stop solution for all data related services such as archiving, visualising and dissemination

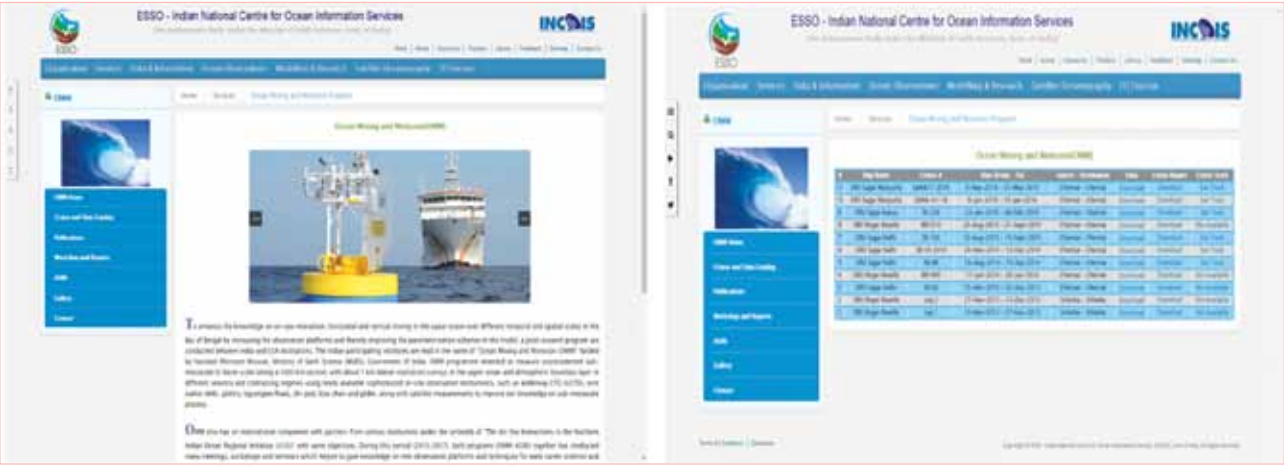
for various data products at the INCOIS data centre. It has also advanced capabilities for multi-dimensional data visualisation and fusion of heterogeneous data to derive insights. The Digital Ocean application has been deployed at the INCOIS data centre and its stability and performance are being tested to make it operational.



The Digital Ocean web application: a snapshot of available in situ platforms in the Indian Ocean

4.4.5 OMM Data

The marine meteorological and oceanographic data collected as part of the Ocean Mixing and Monsoons under the National Monsoon Mission has been archived and a web interface was developed to host the data on INCOIS website to provide this data to the scientific community with login credentials.



Web-interface for the OMM data

4.4.6 Other Significant achievements

- Sustained and enhanced the reception and processing of data from insitu observing systems (viz., Argo Floats, Moored Buoys, Drifting Buoys, XBT/XCTD, Current Meter Moorings, AWS, Wave Rider Buoys, Wave Height Meters) and dissemination to the users for INCOIS operational

and research activities in real time as well as disseminated the data to the users on request through Ocean Data and Information System (ODIS).

- Implemented two-step quality control procedure, which include both real time and delayed mode processing, to provide value-added high quality datasets in user friendly formats such as NetCDF.
- Added new observing systems (AWS, ADCP, WRB, Tide Gauge, Wave Height Meter, Moored Buoys, Drifters) to the reception and processing chain.
- Generated updated NetCDF files for the OMNI buoys data, Current Meter moorings, HF Radar data for use in validation of OGCM operationally run at INCOIS. Also generated flux data utilizing the parameters from buoys.
- Argo data and products pertaining to IO dissemination through FTP (UCSD and INCOIS web sites).
- Destriped ocean colour products viz., Chl, kd490, TSM , AOD from OCM-2 and AVHRR products viz., Cloud Top Temperatures, Fog products, SST operationally generated and supplied to IMD, Indian Air Force and researchers at universities and institutes.
- IRAWS hourly data has been processed and quality controlled.
- Rescued and archived CTD, XBT data from Ministry funded cruises from ships ORV Sagar Kanya, ORV Sagar Nidhi and FRV Sagar Sampada. Set up QC methods and visualization tools for processing, Quality Checking, visualization and dissemination. Matlab-based tools were developed for processing, performing quality control and visualization of the data.
- Maintained meta data portal for MoES, IIOE-2 and populating them with the metadata generated by programs funded by MoES.
- Generated and distributed remote sensing products to project specific cruise by NIO and MoES in real time and to AP and TS state governments.
- Developed online inventory for the Cruise Summary Reports for monitoring the use of equipment onboard MoES Vessels and generation of metadata.
- Sustained the supply of in situ data sets to Indian Navy on Quarterly basis through CDs and secured FTP.
- New formats were developed for data transmission on GTS as well as new data sets are added to GTS. New Quality Control methods were developed for improving the quality of the data.
- Continued to update data in INCOIS Live Access Server.
- Generated value-added products from in situ and remote sensing data (OCM-2, OSCAT global winds etc.) made available to users in INCOIS.
- Written cruise records from FORV Sagar Sampada 01–100 were obtained from CMFRI and CMLRE and are being digitized. Till now more than 75 records have been digitized. All cruise summary reports are first scanned and soft copies of the same are generated. These are digitized using OCR software with some manual intervention. Some very specialized hand-written words related to marine fisheries in particular, were found hard to digitize. Information pertaining to fisheries, physical oceanography etc. are being extracted from digitized records.

4.5 Computational Facilities and Web Based Services

4.5.1 Computing Infrastructure

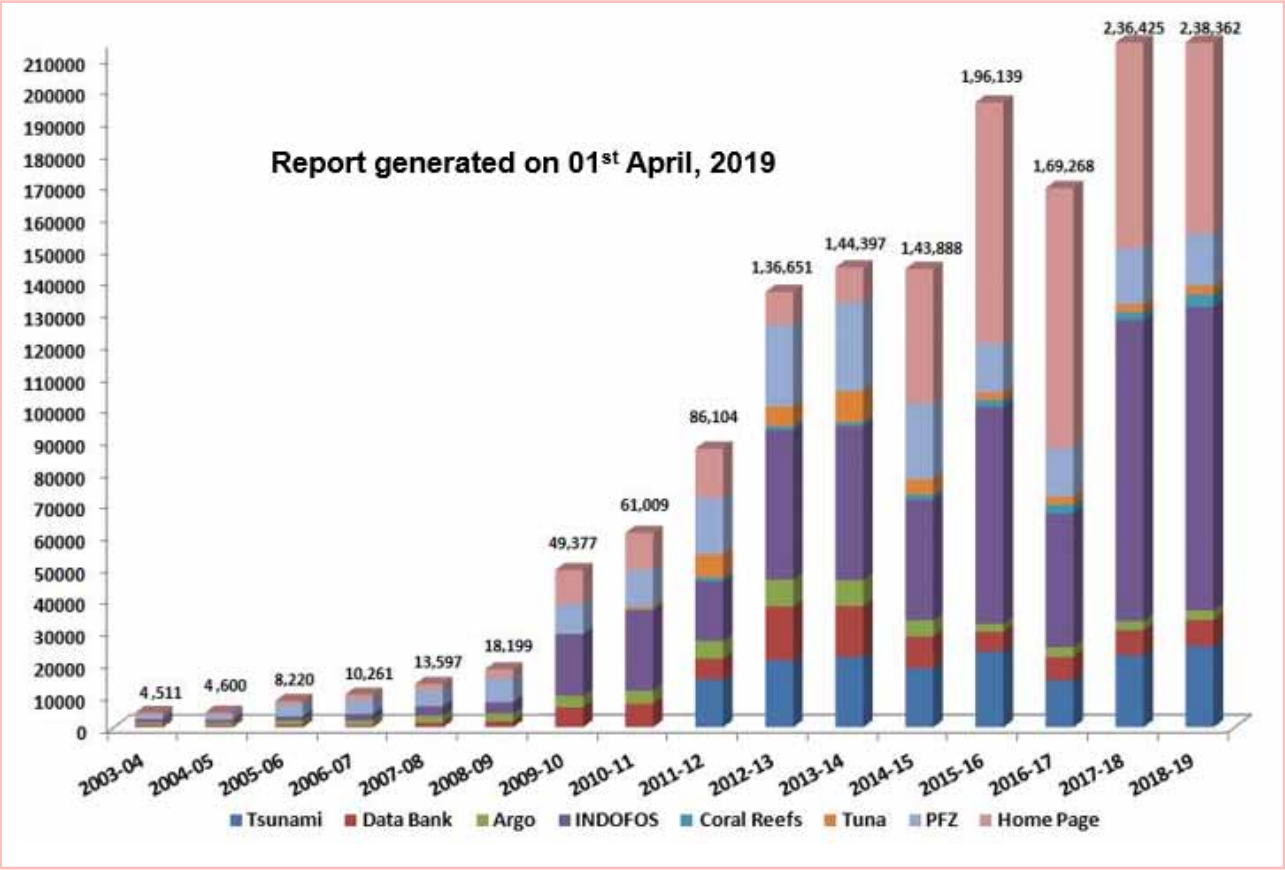
INCOIS maintained state-of-the-art computational facilities, which include a high-performance computer of 33TF capacity and its allied infrastructure, 415 TB storage, ERP servers, FTP server, web and application servers, Live Access Server, workstations, desktops, laptops, link load balancers, application load balancers, firewalls, core switches, edge switches and campus-wide networking. The network and the infrastructure have been set up in such a manner that no single point of failure can affect operational services. INCOIS continued to maintain the computing and network infrastructure with an uptime of 99% to support the operational and R & D projects. Office automation has been successfully implemented based on SAP. In addition to the computational resources available at INCOIS, the MoES HPC facility at IITM (125TF) and NCMRWF (949 TF) were also used by INCOIS for the integration of numerical models used for operational forecasts and R&D purposes.

4.5.2 Web services

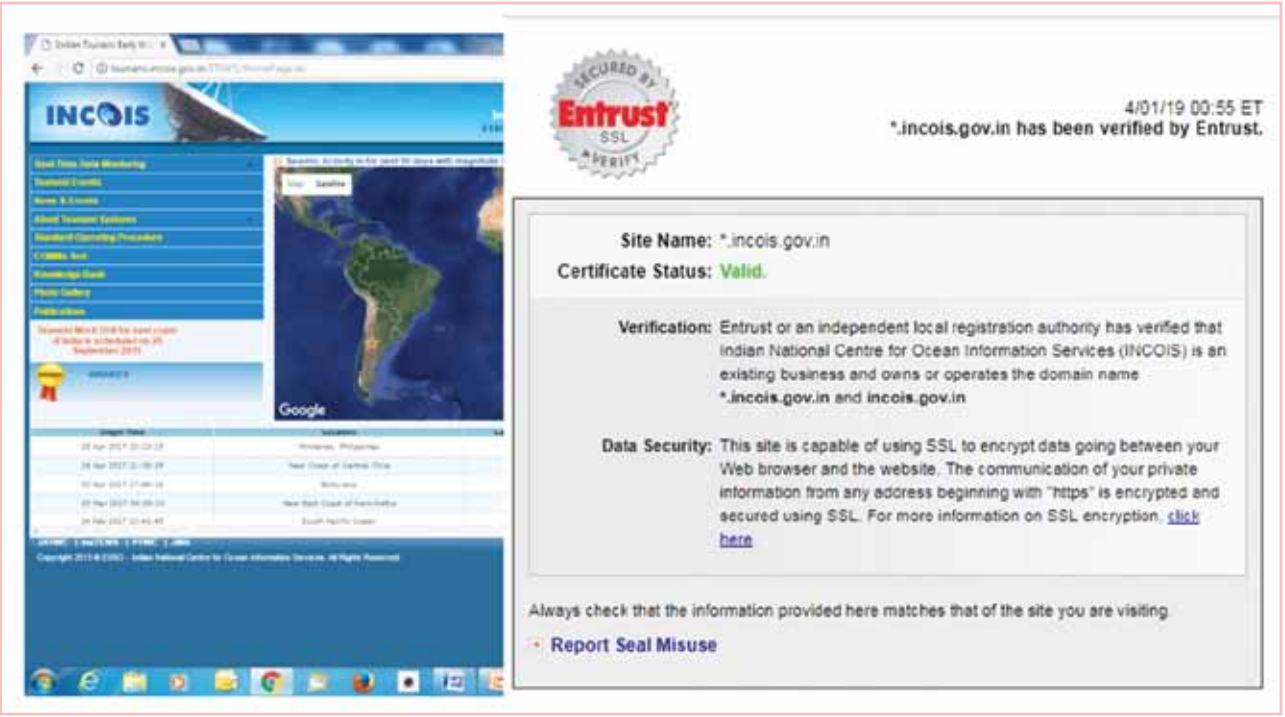
During 2018-19, INCOIS continued to manage the various web-based services besides developing web applications for specific requirements. Some of the other notable activities during this period are as below:

- Online Recruitment Portal for various posts at INCOIS, MoES, NCPOR, NCESS & IMD.
- Wildcard Secured Socket Layer (SSL) Certificate (*.incois.gov.in) for INCOIS domain & its sub domains.
- Website for Regional Analysis of Indian OceaN (RAIN).
- Web application for Ocean State Forecast - Tropical Cyclone Heat Potential and Value-added Services for Andhra Pradesh Maritime Board.
- Enhancements to NTWC Warning Status Reporting Form and implementation of the GeoJSON mechanism for exchange of information with TSP-Australia.
- Login-based web application for Online Reports Generation of ITCOocean Training Courses.

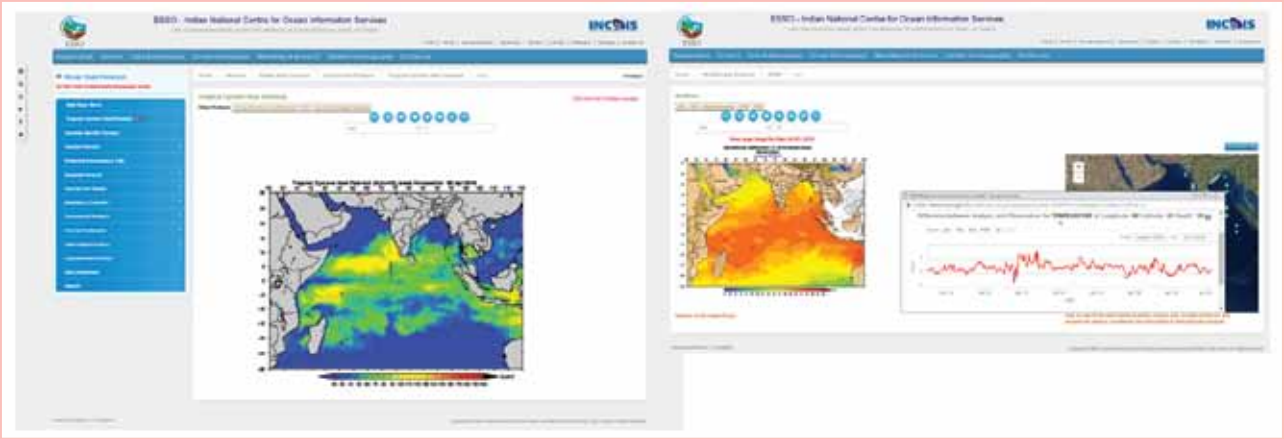
- Website for INCOIS Contributory Medical Scheme-2018.
- Website for INCOIS Scientific Documentary Films.
- Streamlined the In-house INCOIS Intranet Application.
- Enhanced and restructured Human Resources Web Application.



Year-wise number of visitors in INCOIS homepage and the webpages of different operational services



Wildcard Secured Socket Layer (SSL) Certificate (.incois.gov.in)*



Web pages developed to disseminate Tropical Cyclone Heat Potential (TCHP) information and Regional Analysis for Indian Ocean (RAIN)

4.6 Consultancy Projects

Following consultancy projects and services were taken up by INCIOS during the period April 2018–March 2019

Sl. No	Agency	Project (Deliverable)	Amount (in Lakhs INR)
Project Completed			
1	Department of Ports, Andhra Pradesh	Project on IVL & Subscription of Dynamic IVL (Project Report)	11.80
2	JNPT, Mumbai	Oil spill trajectory prediction at the proposed Vadhavan Port, Maharashtra and assessing the probable spread towards Tarapur Atmoic Power Station (Project Report)	14.23
Project being executed			
3	ONGC	Data Delivery on currents/ eddies for wells (daily forecast mode/ Project Report)	101.60*
4	Port Management Board, Andaman & Nicobar Islands	Project on IVL & Subscription of Dynamic IVL (Project Report)	27.00
5	Maharashtra Maritime Board	Project on IVL & Subscription of Dynamic IVL (Project Report)	30.00

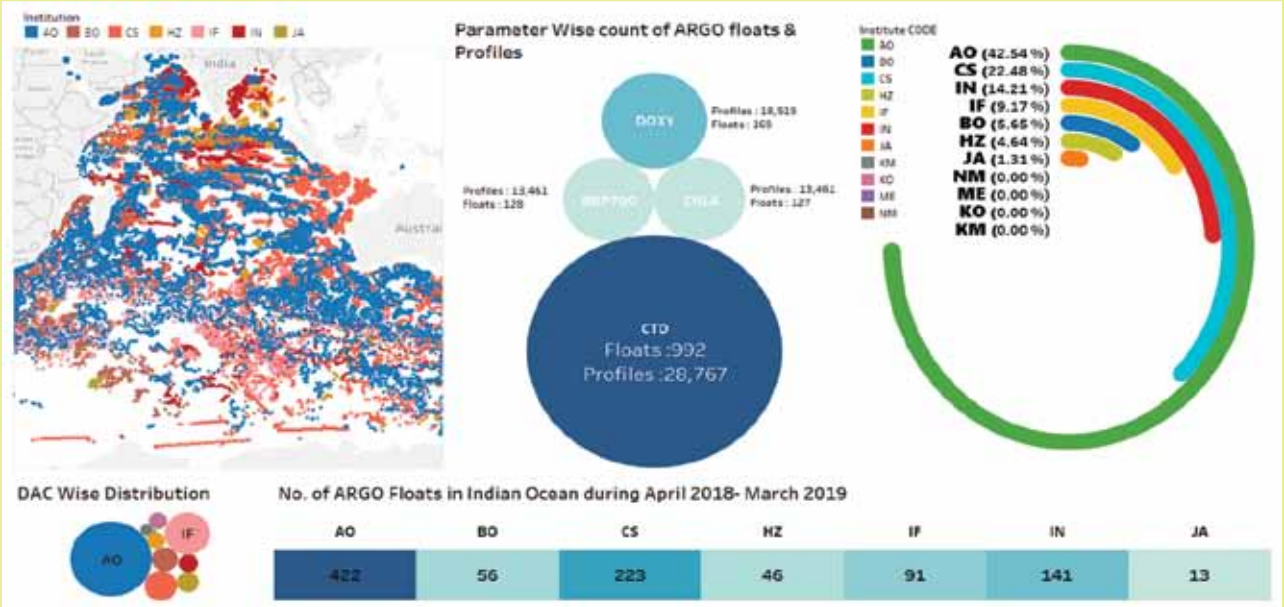
** Total consultancy project cost for 3 years*

5. Ocean Observation Network

INCOIS maintained an array of in situ ocean observing platforms and collected high quality observations from the Indian Ocean. Data from most of these platforms get assimilated into the numerical ocean models run at INCOIS, in addition to their use for basic research and improvements in ocean models.

5.1 The Argo programme

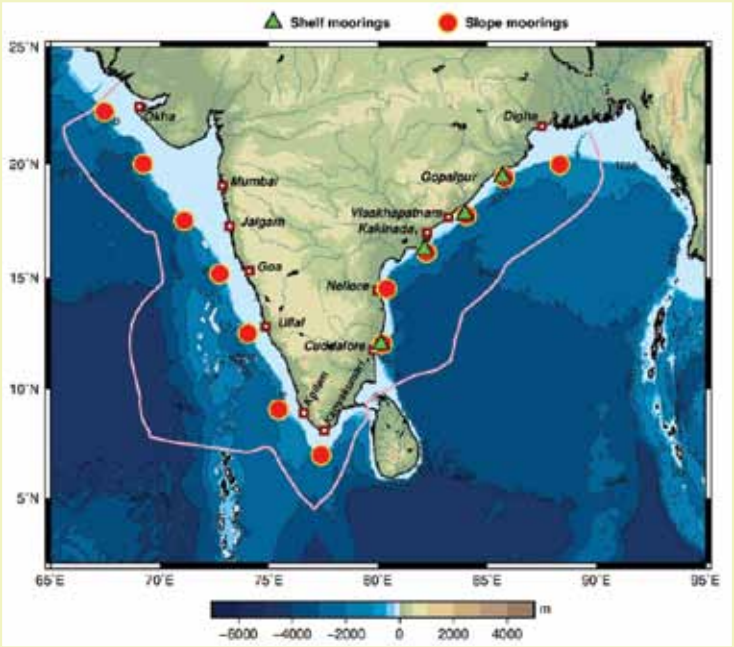
The Argo network is a major collaborative programme under the Global Ocean Observing System (GOOS). During the FY 2018-19, INCOIS deployed 5 core Argo floats (temperature and salinity sensors only) and 1 Bio-Argo float (temperature, salinity, dissolved oxygen, chlorophyll and backscatter sensors) in the Indian Ocean. As on 31 March 2019, there are 992 active Argo floats in the Indian Ocean, of which 138 are deployed by India. During FY 2018-19, INCOIS received 28,767 temperature and salinity profiles from Argo floats. In the 19th Argo Data Management meeting held during 2-7 December 2018 at Scripps Institute of Oceanography, La Jolla, California, the issues related to the sensors and the software used for Delayed Mode Quality Control were extensively discussed. All the recommendations related to data processing and quality checks were implemented by INCOIS. India is part of the international Argo Steering Team (AST) which provides scientific leadership and oversees the development and implementation of the Argo global array operated by various regional and national Argo projects. India's national report on the Argo programme was submitted for the 20th AST Meeting (AST-20) held in Hangzhou, China during 13-15 March 2019. One of the recommendations made during this meeting was to increase the number of biogeochemical floats in the Argo network to ~22%. Towards achieving this goal and also to support in-house biogeochemical research activities, INCOIS purchased totally 40 floats of which 14 are BGC floats (35%) for deployment in the Indian Ocean during 2018-19 and their deployment is under progress.



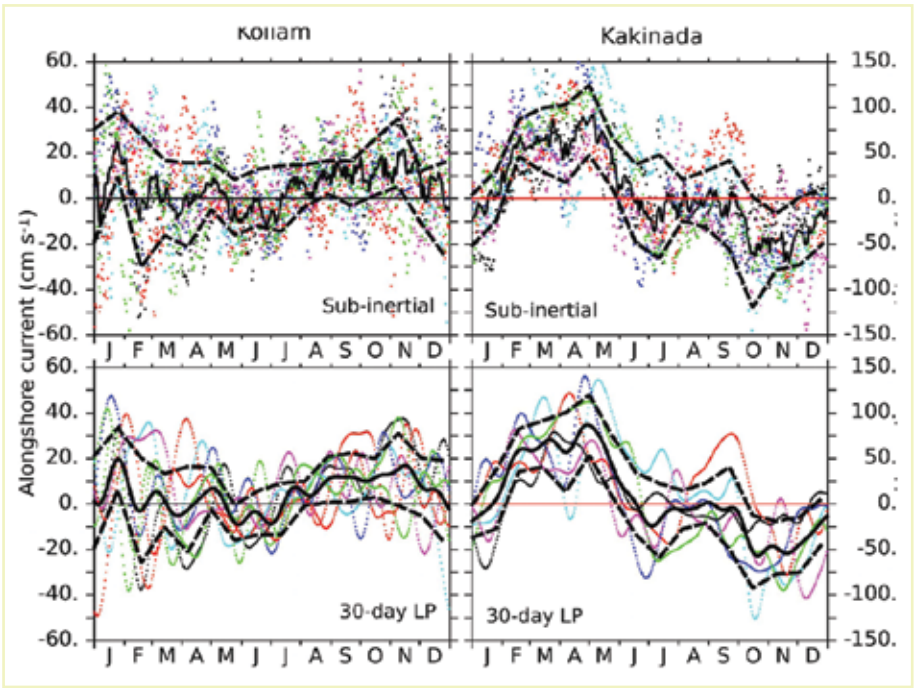
Statistics of Argo floats and profiles in the Indian Ocean for the period April 2018 to March 2019

5.2 Coastal ADCP network

INCOIS, in collaboration with National Institute of Oceanography, Goa, maintained 17 ADCP moorings along Indian coastal regions during the FY 2018-19, out of which 4 moorings are in the shelf regions of the east coast of India. A new mooring has been deployed in the slope off Okha. With this, there are 7 slope moorings on the west coast and 6 slope moorings on the east coast. In addition, 4 moorings are maintained on the shelf off the east coast. At present, there is at least one slope mooring off every coastal state, maintaining an inter-mooring spacing of around 2.5-3 degrees.



Locations of ADCP moorings in the Indian coastal waters



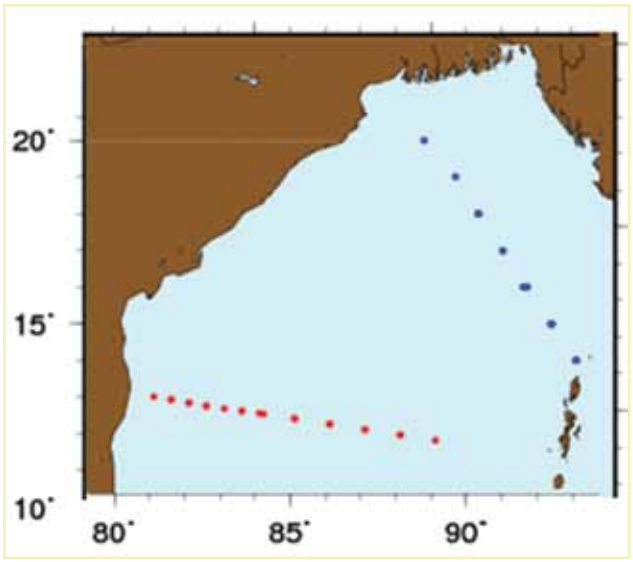
The top panels show the alongshore, sub-inertial WICC off Kollam (left) and EICC off Kakinada at 48~m; the unit is cm/s. The solid black curve is the mean for the available data during 2008–2018 for Kollam and 2009–2018 for Kakinada and each colour represents the current during a particular year. The dashed black curves mark one standard deviation about the mean. The bottom panels show the 30-day low-passed (LP) current; a Lanczos filter was used for filtering and the solid and dashed black curves and the coloured dots are as in the top panels. Note that in spite of the scatter of the coloured dots about the mean, the canonical poleward (equatorward) direction of the EICC is evident even in the sub-inertial current in the top panels. It is only during summer, when the near-surface EICC is weak, that the scatter about the zero line is significant, indicating the possibility that the EICC may flow in either direction during a given year. In contrast, the WICC shows a much higher scatter and it can flow in either direction on a given day.

Data from the coastal ADCP network have covered more than a decade and have led to the better understanding of the variability in the boundary currents off the Indian coasts over a range of periodicities. ADCP data analysis showed that the seasonal cycle dominates off the east coast, but intraseasonal variability is stronger off the west coast. The decade-long ADCP record allows us to confirm the dominance of seasonality in the East Indian Coastal Current (EICC) regime in a robust fashion. It was shown that the direction of sub-inertial flow in spring (winter) is poleward

(equatorward) on most of the events off Kakinada on the east coast. It is only during the summer monsoon that the direction of the EICC is ambiguous. The ADCP data have also confirmed that coastally-trapped waves have an impact on the currents even at periods as short as 4 days and even in the nearshore shallow waters. This inference is drawn on the basis of data from these ADCPs and the correspondence between the ADCP currents at the shelf-edge and the short-term measurements of nearshore currents using a set of current-meter moorings. So far 4 PhDs and 15 research articles have been published using data from the ADCP network.

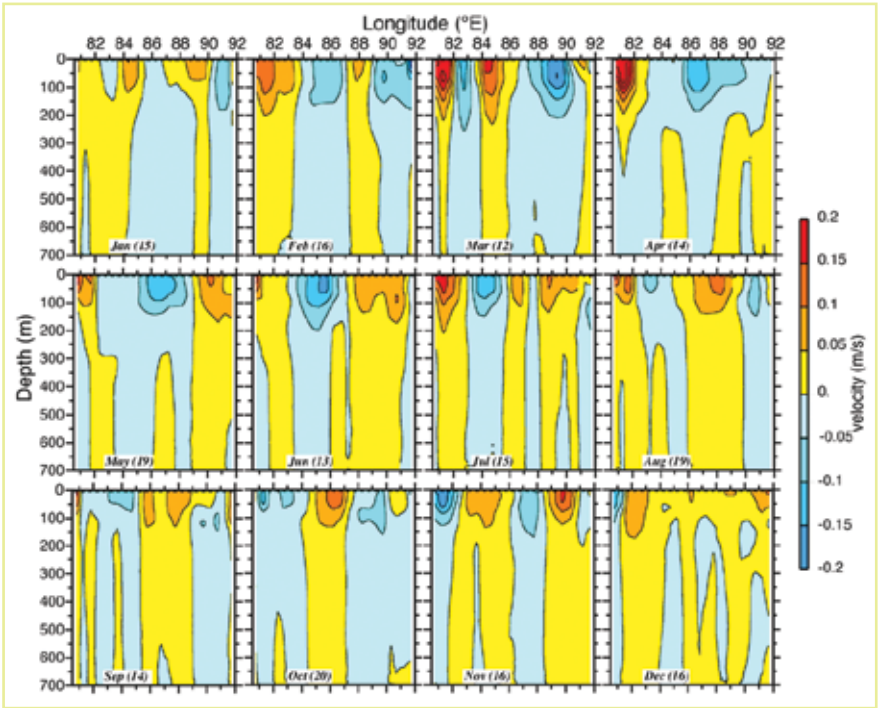
5.3 XBT Programme

During the reporting period, 4 XBT transects were covered (two along Chennai-Port Blair and two along Port Blair-Kolkata), and 24 XBT profiles, 12 XCTD profiles were collected in addition to 82 samples of sea water. In addition to these regular transects, 137 XBT profiles, 42 XCTD profiles as well as 511 samples of sea water were also collected utilizing opportunities during research cruises.



XBT/XCTD transects in the Bay of Bengal. Red dots (XBTs) line is CP transect, blue dots (XCTDs) line is Port Blair-Kolkata transect.

Climatology of geostrophic currents along the Chennai-Port Blair section was estimated using XBT data collected over 27 years and it has been observed that it matches well with estimates from satellite and other past observations. Analysis of geostrophic currents suggests that the strongest and most variable flow is seen along the western boundary in the Bay of Bengal (typically between 81°E and 83°E). This boundary current (referred to as EICC) flows northward from February and further intensifies in March–April. It remains northward (though of lesser magnitude) until August. By September, the boundary flow almost disintegrates, giving way to an equatorward flow in October, which peaks during November and decays in December. The core of the

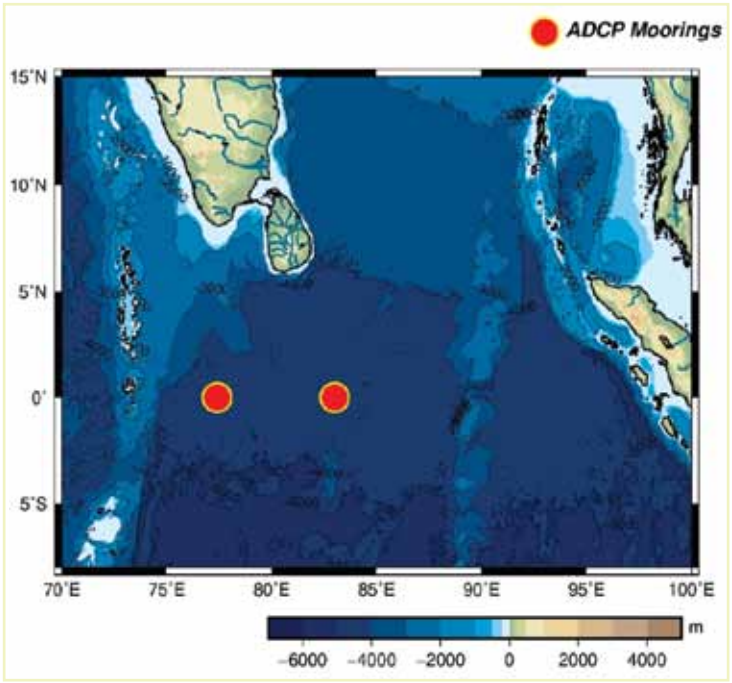


Monthly climatology of observed cross-track geostrophic currents along the Chennai-Port Blair route (Data collected during several cruises)

boundary current spans the upper 200 m when it flows poleward, whereas it appears shallower (down to 100 m or so) during its equatorward phase in November.

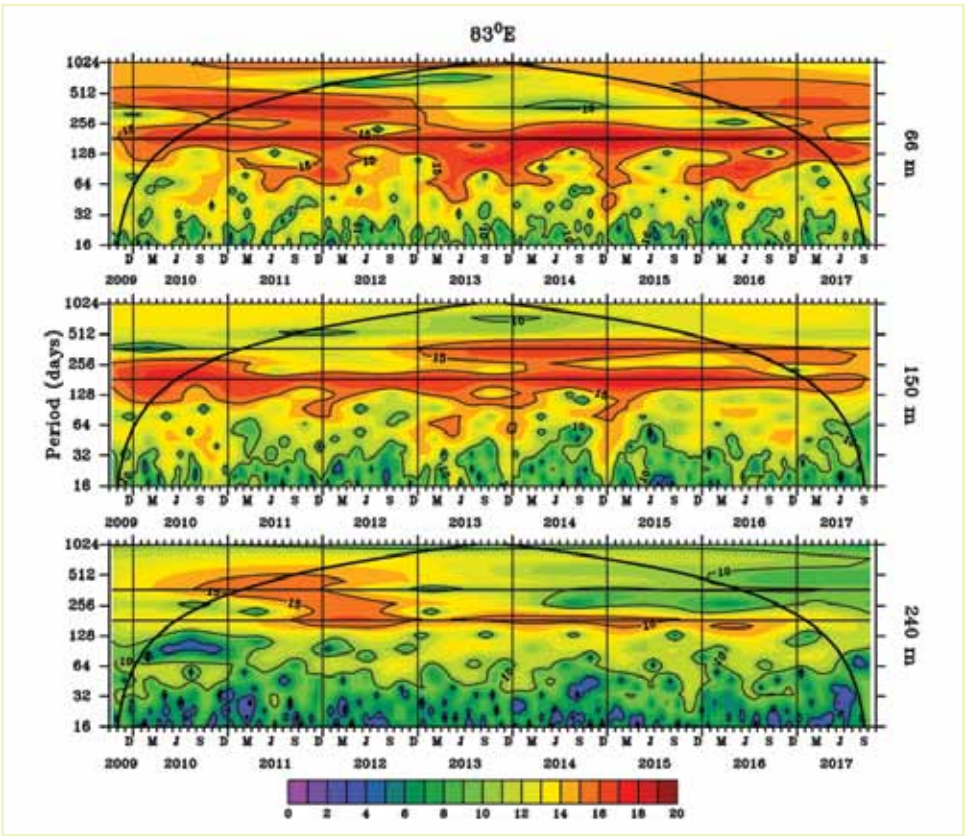
5.4 Equatorial current meter moorings

During the period April 2018 to March 2019, two equatorial ADCP moorings were maintained at 77.4° E, 0° N and 83° E, 0° N. Each of these moorings were equipped with two 75 kHz ADCPs to measure the currents from 50-850 m depth levels. Additional current meters were equipped at ~1000 and ~4000 meters to measure the currents at those levels.



Locations of equatorial ADCP moorings

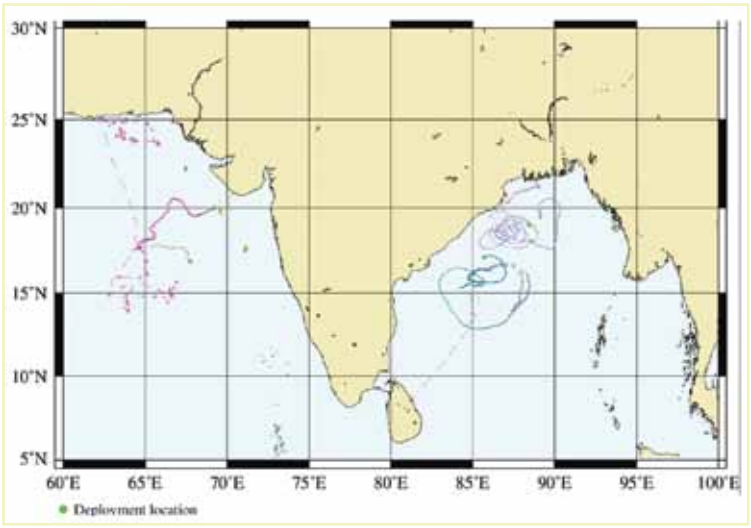
Undercurrents are evident in raw currents from the equatorial moorings at 120–180 m. Upward phase propagations, which are primarily semi-annual, are also seen. It is found that the semi-annual cycle is present in the undercurrents throughout the year with only slight variations in the amplitude. However, the annual cycle in the undercurrents shows strong interannual variability. The data also show the existence of biweekly oscillation and intraseasonal oscillations. The biweekly-oscillation signals extended till 4000 m depth whereas the signals of intraseasonal oscillations were seen only till 200 m depth.



Wavelets for zonal currents at three different depths: (a) 66 m, (b) 150 m (c) 240 m. The wavelets are shown for 83°E. The black curve in the dome shape is the cone of influence.

5.5 The drifter programme

With funding from INCOIS, CSIR-National Institute of Oceanography continued the deployment of drifters in the Indian Ocean. During 2018-19, 11 drifters were deployed and 9 of them are active at present.

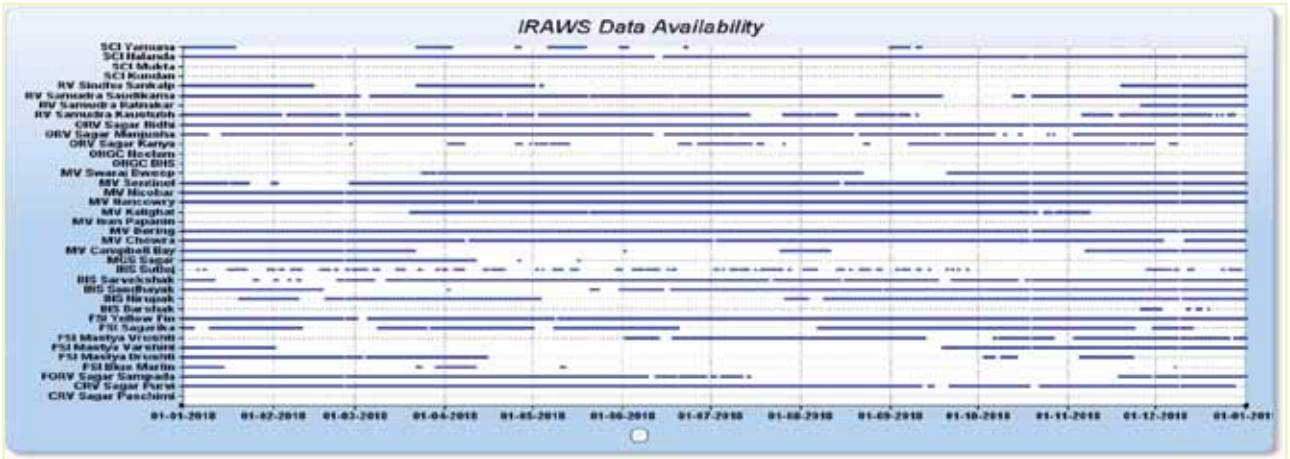


Tracks of drifters deployed during the period April 2018- March 2019.

5.6 Automated Weather Stations (AWS)

INCOIS maintained a network of 31 AWSs onboard research and survey vessels under different departments/agencies/ministries of Government of India, such as SCI, NHO, GSI, FSI and MoES. Two new AWS were installed onboard RV Ratnakar belonging to GSI and MFV Blue Fin owned by Directorate of Fisheries, Lakshadweep in 2018-19. During 2018-19, INCOIS carried out 88 preventive maintenances, 20 breakdown maintenances and 12 calibrations on AWS systems to ensure continuous availability of quality data from these platforms.

AWSs installed onboard MFV Blue Fin (Directorate of Fisheries, Lakshadweep; left panel) and RV Ratnakar(GSI).

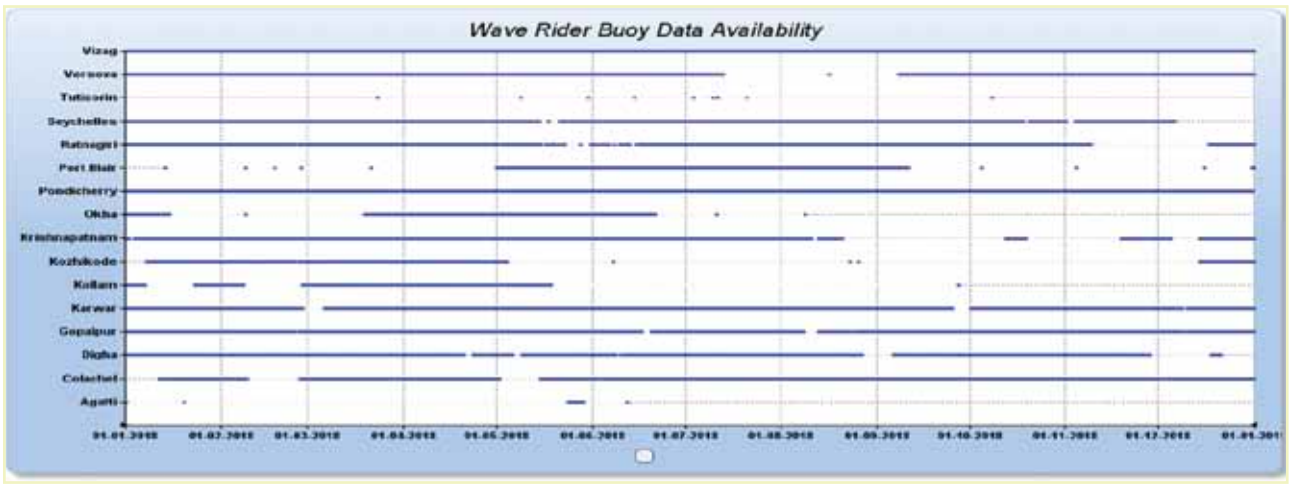


Data availability from AWSs installed onboard research vessels

5.7 Wave Rider Buoy Network (WRB)

Locations of Wave Rider Buoys around India and Seychelles.

In the FY 2018-19, INCOIS maintained a network of 16 wave rider buoys to monitor ocean state and to perform real-time and delayed-mode validations of ocean state forecasts. Regular calibrations of the WRBs at recommended intervals were performed to maintain the quality of data from these insitu observatories. INCOIS redeployed 5 re-calibrated buoys during 2018-19. The buoys drifted away from the locations of their initial deployment were retrieved on 16 occasions during April 2018-2019. Location and detection of these buoys, that drifted away from the initial locations, became possible only because they were equipped with INSAT transmitters. Integration of INSAT transmitter with the wave rider buoy was developed indigenously by INCOIS in collaboration with the manufacturer of wave rider buoy and INSAT transmitter. The buoys, thus retrieved, were later redeployed at respective locations. INCOIS established a new WRB station off Veraval to measure wave parameters off Gujarat coast. A second-generation wave rider buoy (MK-IV), which is capable of measuring currents and wave parameters was integrated with INSAT communication system. Sea trials of this unit were successfully completed during the reporting period.

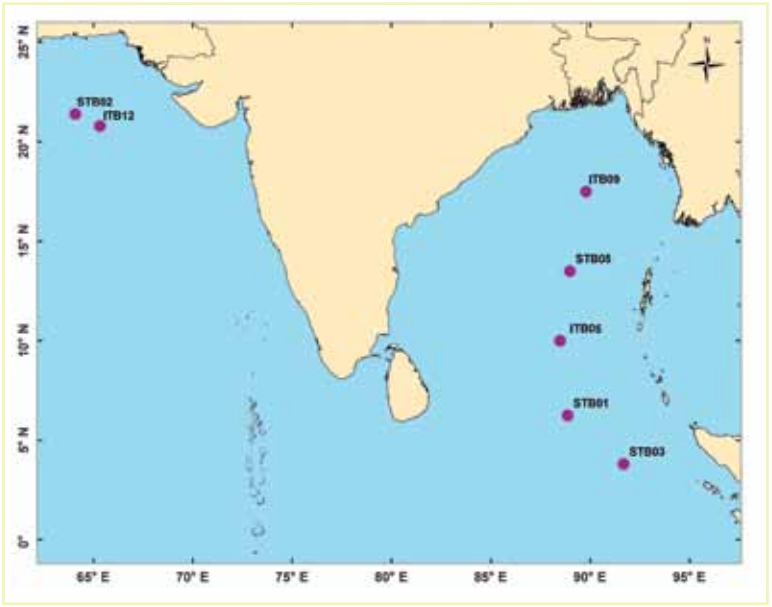


Availability of data from Wave Rider Buoys around India and Seychelles.

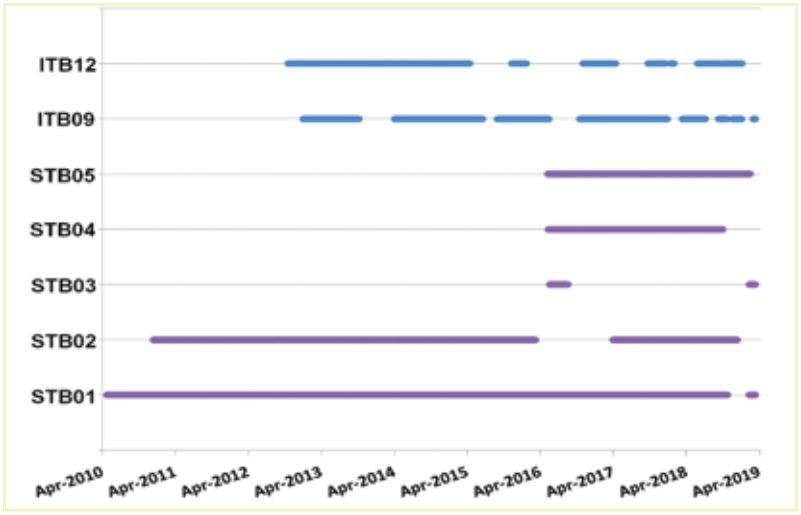
5.8 Tsunami Buoys

INCOIS maintained a network of 4 tsunami buoys deployed close to the tsunamigenic source regions in the Bay of Bengal and Arabian Sea. Data from these buoys were received at the Indian Tsunami Early Warning Centre (ITEWC) in real time through satellite communication. INCOIS

also continued to receive real-time data from 3 Indian Tsunami Buoys (ITBs) deployed and maintained by National Institute of Ocean Technology, Chennai. In addition to these buoys, real-time data from about 50 tsunami buoys operated by other countries in the Indian and Pacific Oceans were also received at ITEWC and the data was published on the tsunami website. INCOIS shared real-time data of all tsunami buoys to NDBC-NOAA for global users. Tsunami buoys deployed at 6.2° N, 88.8° E (STB01) and



Locations of the sea level network of Tsunami buoys



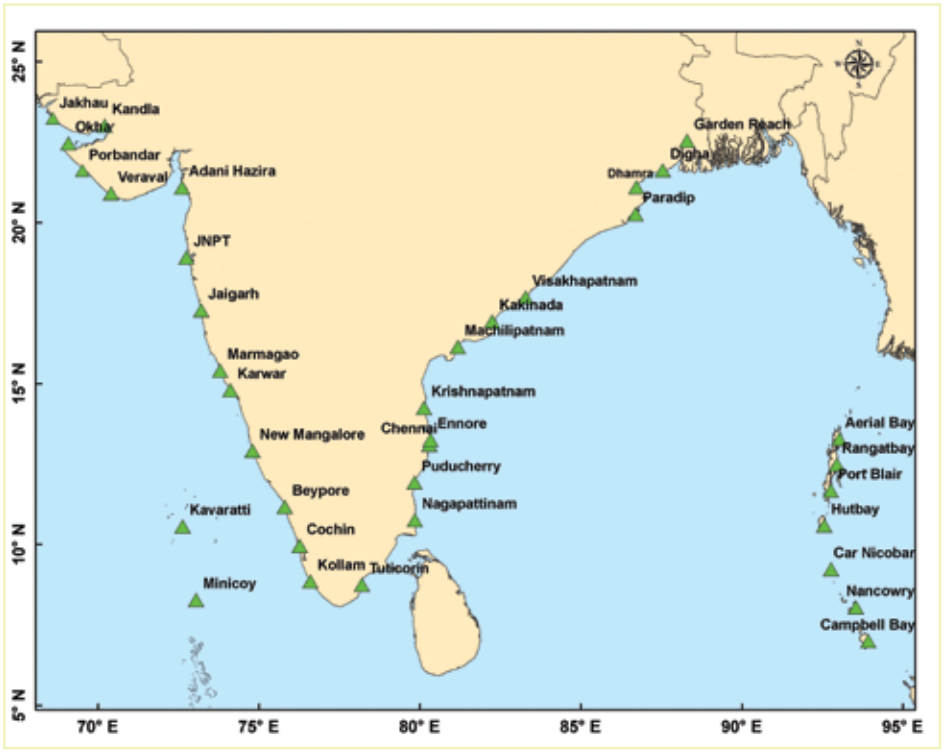
Availability of data from tsunami buoys in the period April 2010 - March 2019 (Purple: INCOIS STBs; Blue: NIOT ITBs)

3.8° N, 91.7° E (STB05) were retrieved for maintenance and replaced with refurbished spare systems. Surface buoy part of STB04, deployed at 10.0° N, 88.5°E drifted on 9 October 2018, but was recovered by the Indian Navy on 25 October 2018. However, the attempt to retrieve the bottom pressure recorder of this tsunami buoy was not successful due to communication failure with ORE acoustic release.


Deployment of SAIC Tsunami Buoy onboard Sagar Nidhi cruise in February 2019

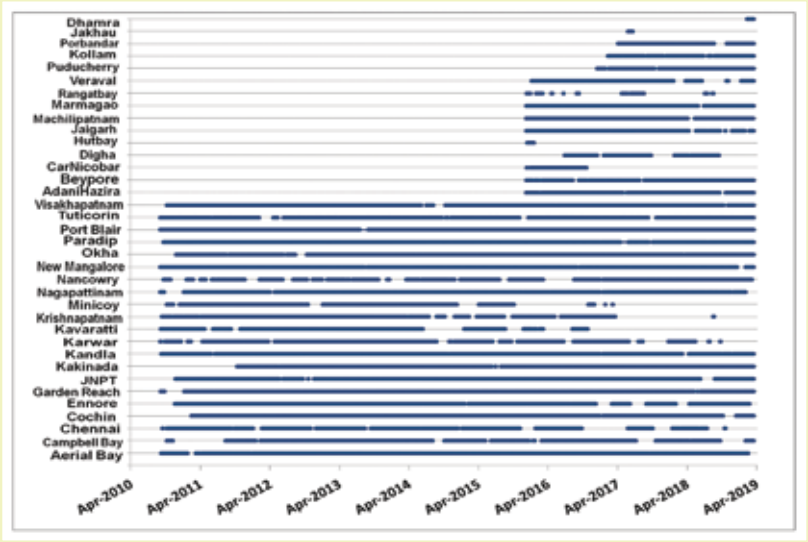
5.9 Tide gauges

INCOIS continued to maintain the network of 36 tide gauges installed at predetermined locations along the coasts of the Indian mainland and islands to monitor the sea level, especially, the progress



Locations of the Sea level network of Tide Gauges

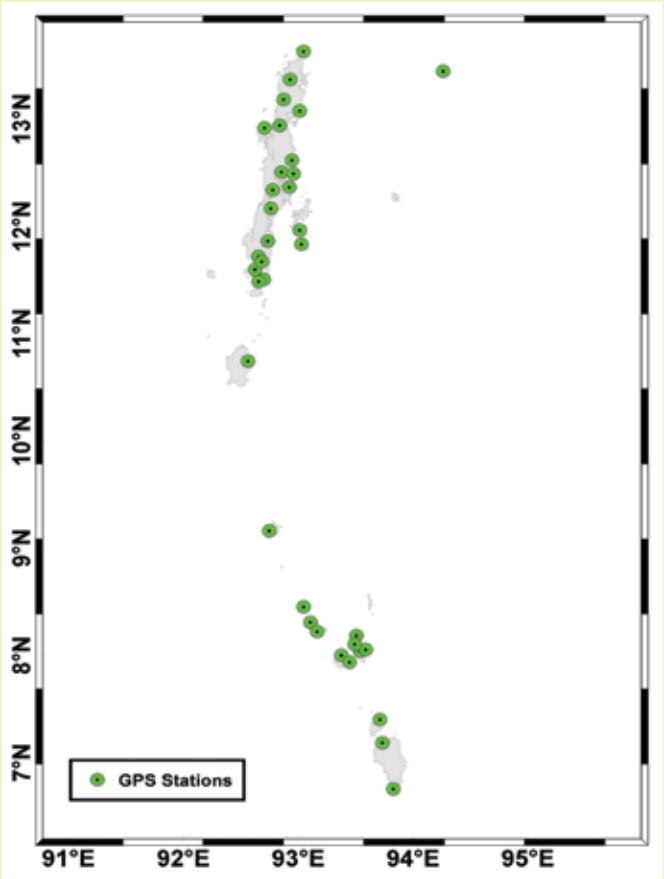
of tsunami waves and to validate model simulations. The 36th Radar-based tide gauge was set up at Dhamra, Odisha in February 2019. Continuous real-time data from the tide gauges are being received at ITWEC through INSAT and GPRS communications. In addition, INCOIS also received data from around 350 international tide gauges in near-real time which are operated by other countries. INCOIS shared real-time data from 8 tide gauges (Chennai, Kochi, Nancowry, Port Blair, Visakhapatnam, Minicoy, Marmagao and Veraval) with IOC Sea level stations monitoring facility. Process to upgrade 21 tide gauges (established in 2010-11) with new data logger, RADAR sensors (at 5 locations), INSAT transmitters and GPRS is in progress.



Data availability from Tide gauge network during April 2010-March 2019

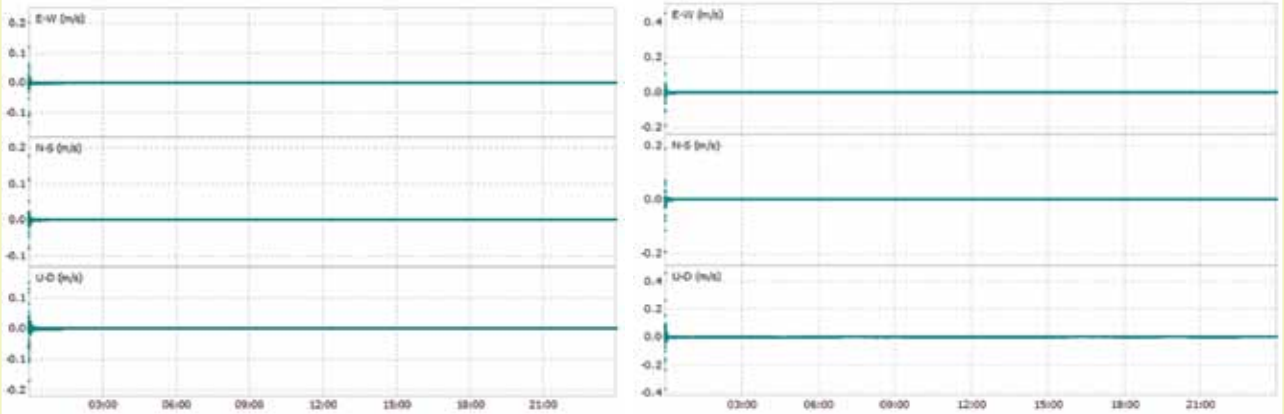
5.10 GNSS & Strong Motion network in A&N Islands

The installation of co-located strong motion sensors, GNSS receivers and meteorological sensors with real-time VSAT connectivity in the Andaman & Nicobar (A&N) Islands has been completed at 30 locations. VSAT connectivity has been provided to all these stations. Ministry of Environment and Forest and Climate Change issued the NOC for 3 ecologically sensitive locations (Interview Island, East Island and Narcondum) on the submission of necessary Environment Impact Assessment reports. The EIA was carried out by Andaman and Nicobar Centre for Ocean Science and Technology (ANCOST), Port Blair, which is a field unit of NIOT, Chennai. Subsequently, Andaman Public Works Department (APWD) has initiated construction of observatories at those locations as well.



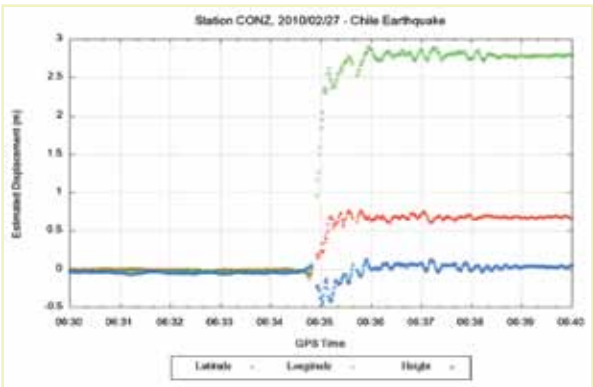
Locations Map of GNSS and SMA stations at A&N Islands

The real-time high-rate GNSS data together with precise satellite orbit and clock information are used to develop real-time Precise Point Positioning (PPP) technique as that can be used to construct the displacement waveforms due to earthquake and invert those to derive the source parameters of earthquakes in real time. The spatial distributions of fault slip derived using the permanent coseismic displacements obtained from the real-time PPP float solution for an event occurred in Chile on 27 February 2010 is shown in the figure. The parameters are estimated using the broadband seismic data after a time lapse of 30-45 minutes and the same derived using real-time GNSS receivers within 10-15 minutes.



Car-Nicobar and Mayabunder GNSS stations data after post processing

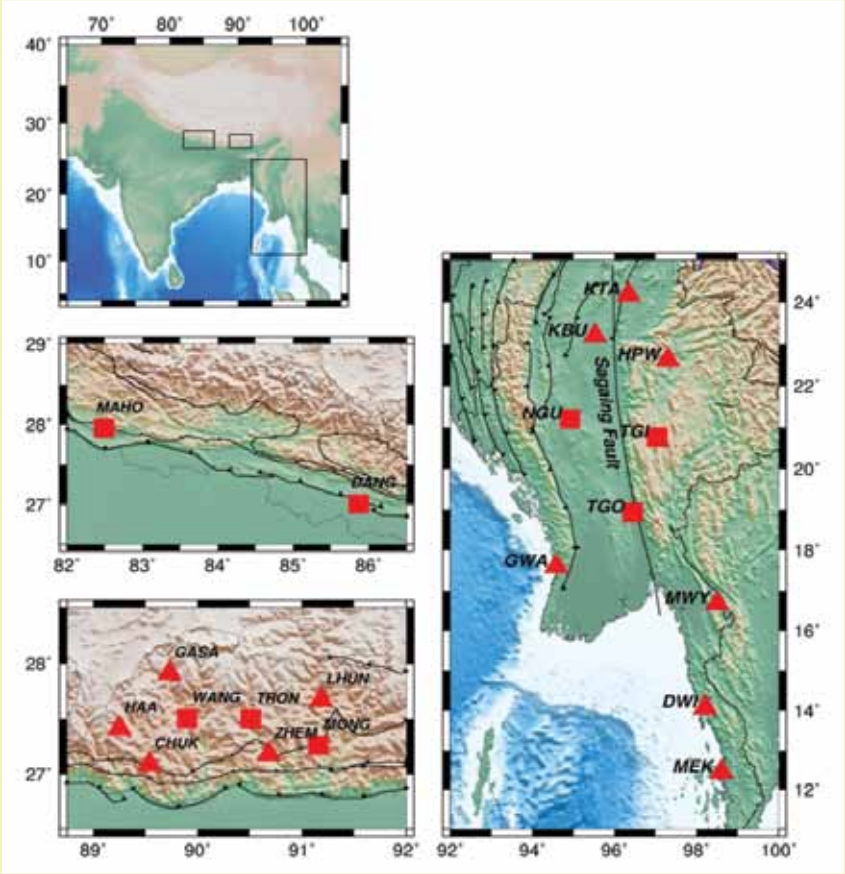
Co-located SMA and GNSS stations in Kadamtala, Andaman & Nicobar Islands



Co-seismic displacement of Concepcion (CONZ), Chile GNSS station for the 2010 Chile Earthquake occurred off the coast of central Chile on 27 February 2010 at 06:34 UTC

5.11 Deployment of Broad Band Seismometers, GNSS, Strong Motion sensors in neighbouring countries: RIMES Crustal deformation project

To understand the crustal deformation associated with the earthquakes in North-East India, 20 real-time broadband seismometers, 8 accelerographs and 8 GNSS were established in Nepal, Bhutan and Myanmar. The deployment was facilitated through a project sanctioned by Regional Integrated Multi-hazard Early Warning System for Africa and Asia (RIMES). The title of the project was "Implementation of prioritized technical capacity development projects in RIMES for Afro Asian Region". INCOIS procured and despatched the equipment for their installation at the predetermined locations in those countries. The real-time data from these stations along with other seismic stations from the Indian shield are used to monitor the seismicity in the region. Apart from using the data for locating earthquake position in real time, data from these stations are also used to study the crustal structure of the Myanmar region with receiver function method utilizing broadband seismic stations data.

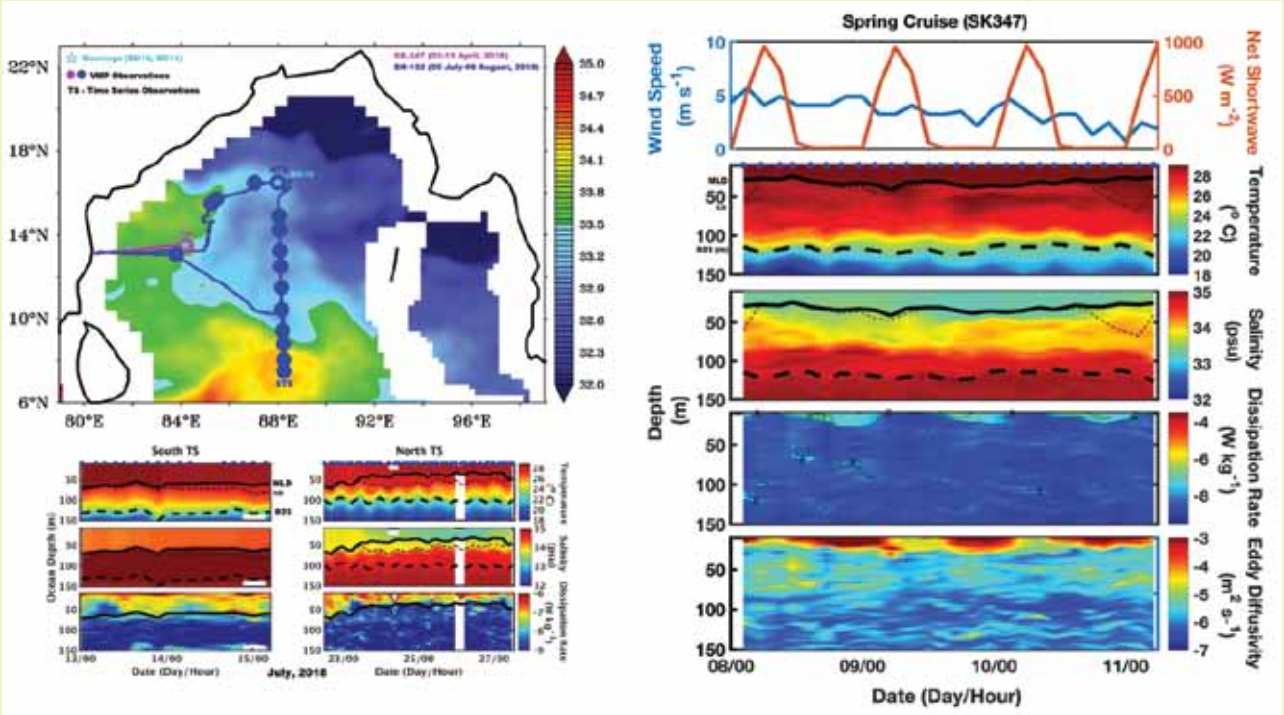


Location of the network of Seismic and GNSS stations. Red triangles represent station with only seismic broadband sensor while red squares represent stations where broadband sensors, accelerometers and GNSS sensors are installed together.

5.12 Process specific observations

In order to study the microscale turbulent mixing processes in the Bay of Bengal, INCOIS conducted two research cruises on board ORV Sagar Kanya (SK-347; 3-13 April 2018) and ORV Sagar Nidhi (SN-132; 5 July-6 August 2018). During these cruises, profiles of turbulence kinetic energy (TKE) dissipation rates were measured at the regions of different stratification and forcing (wind and buoyancy) in the Bay of Bengal using vertical microstructure profiler (VMP-250). During the spring cruise, 228 turbulence profile measurements were collected from a location near BD-11 (NDBP-NIOT) mooring (13.41°N, 84.01°E). The mixed layer depth in this location varied between 30-40 m, and thermocline was around 120 m deep. Time series of TKE during spring showed clear diurnal cycle with high value of TKE (> 10-8 W Kg-1) restricted to very shallow depth (<10 m) during morning hours and penetrated deeper at night hours (~25m). During summer, time series of turbulence measurements were made at two different locations (southern Bay of

Bengal: 7.499°N, 88.25°E and central Bay of Bengal: 16.51°N, 87.98°E) and 401 profiles of turbulence measurements were collected throughout the cruise. At the southern Bay of Bengal location, mixed layer depth varied between 60-70 m and thermocline was at around 130 m. In the central Bay of Bengal location, mixed layer was around 40 m deep and thermocline was observed between 100-110 m. During the period of observations, central Bay of Bengal location had strong salinity stratification compared to the southern Bay of Bengal location. High values of TKE (> 10^{-8} W Kg^{-1}) extended to much deeper layers in the southern Bay of Bengal than in the central Bay of Bengal. Apart from these measurements, INCOIS also collected data on different oceanographic parameters using underway CTD, ADCP, ship CTD and meteorological measurements using ship-based AWS as well as water samples. INCOIS also deployed the Seaglider (SG627) on 28 July 2018 during this cruise in the Bay of Bengal, which was later recovered on 24 November 2018 during a cruise on board ORV Sagar Manjusha.



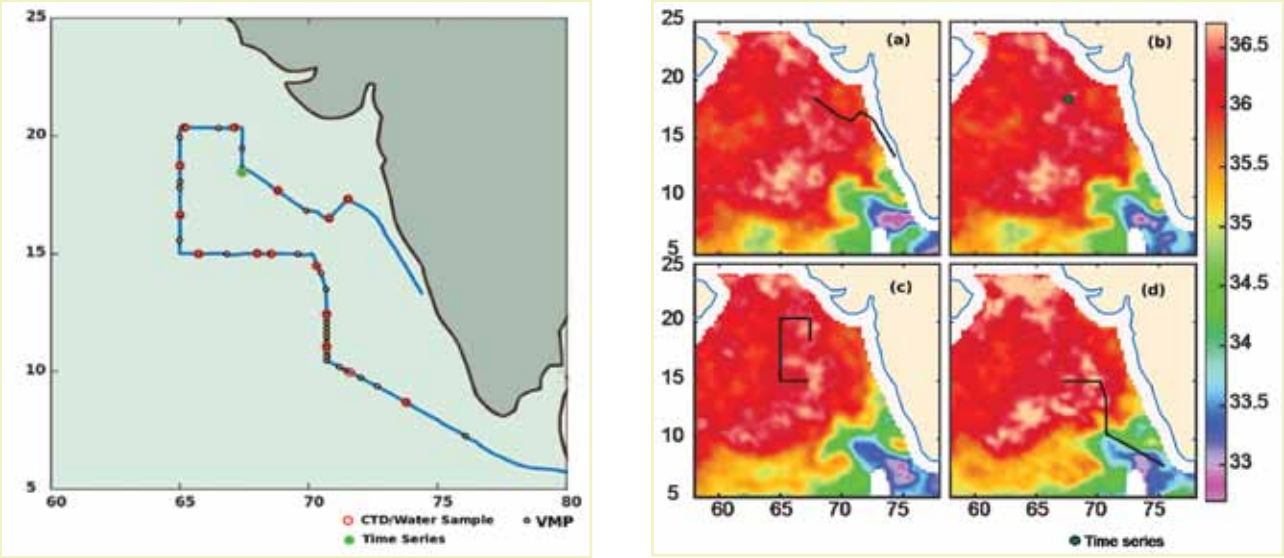
Left top panel: Sea Surface Salinity for July, 2018. Spring (SK-347; 03-13 April, 2018) and summer (SN-132; 05 July-06 August, 2018) cruises track along with VMP measurements locations.

Left bottom: Observations using Vertical Microstructure Profiler (VMP) during Spring cruise (SN-132) at Southern and central BoB. Thick black line represents MLD, thin dashed represents ILD and thick dashed line represents depth of 23^{0}C isotherm.

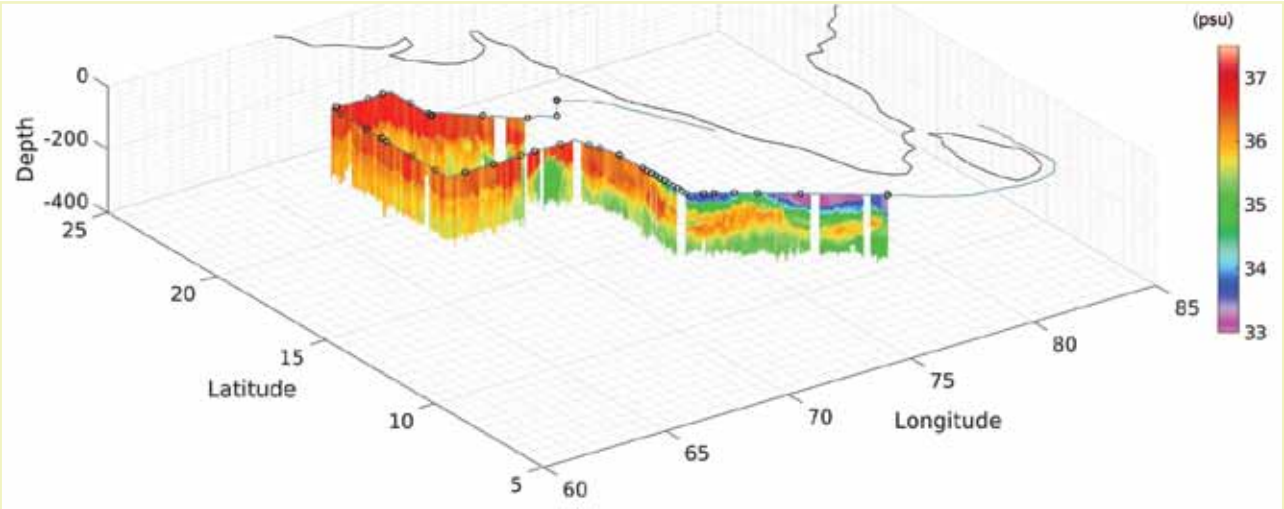
Right: Observations using Vertical Microstructure Profiler (VMP) during Spring cruise (SK-347).

INCOIS also conducted a cruise in the Northeastern Arabian Sea during winter 2019 on board Sagar Nidhi (SN-137) during 5 January to 5 February, 2019. An 8-day long continuous time series (10 January-17 January, 2019) measurement of the microstructure of temperature, conductivity and shear using Vertical Microstructure Profiler (VMP-250) at every 3 hour intervalin the upper 350 m was conducted in the northern Arabian Sea (18.5°N, 67°E) close to the NIOT mooring AD06. Additionally, in order to estimate the horizontal temperature and salinity gradient in the study region, 20 km long zonal and meridional underway CTD data were also collected surrounding the time-series location. The data is being analysed to estimate the temperature and salinity budget

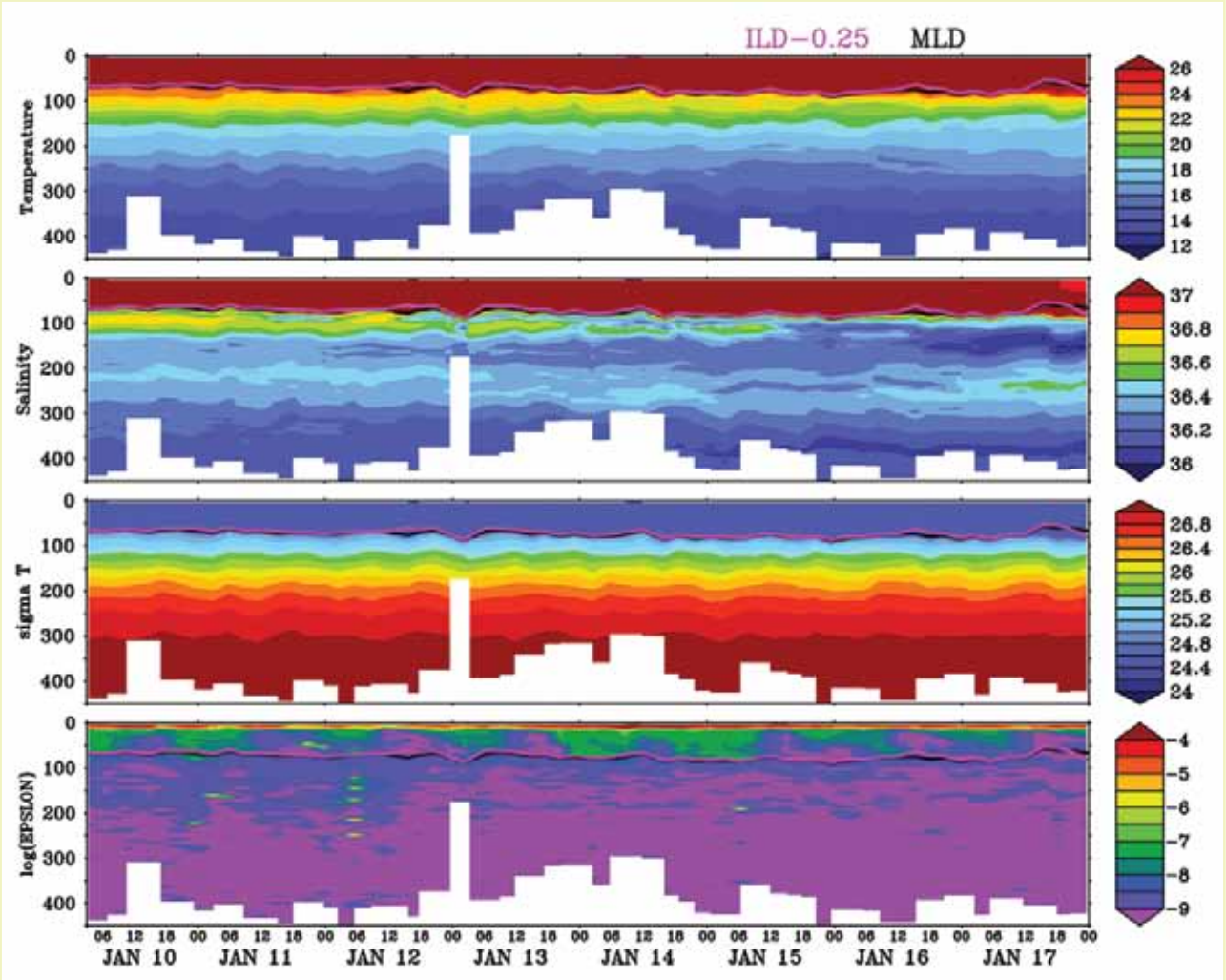
in the mixed layer and the diapycnal heat and salt flux at the base of mixed layer. Other data collected during the cruise are ship-based/portable CTD data and water samples for measuring dissolved oxygen, nutrients and chlorophyll. VMP data were also collected twice a day (1100hrs and 2300hrs) along the cruise transects. Preliminary analysis of the data collected during this cruise shows the presence of double diffusion between 90 and 100 m depth (below the mixed layer), which is conceding with presence of salinity interleaving structure.



(left panel) The blue line represents the cruise track of SN-137. The green circle represents time-series station. The red open circle represents the CTD/water sample measurements locations. The grey closed circle represents VMP observation. (Right panel) The SMAP sea surface salinity and SN-137 cruise track.



The salinity data collected through uCTD during SN-137. The open circle represents the VMP observation.

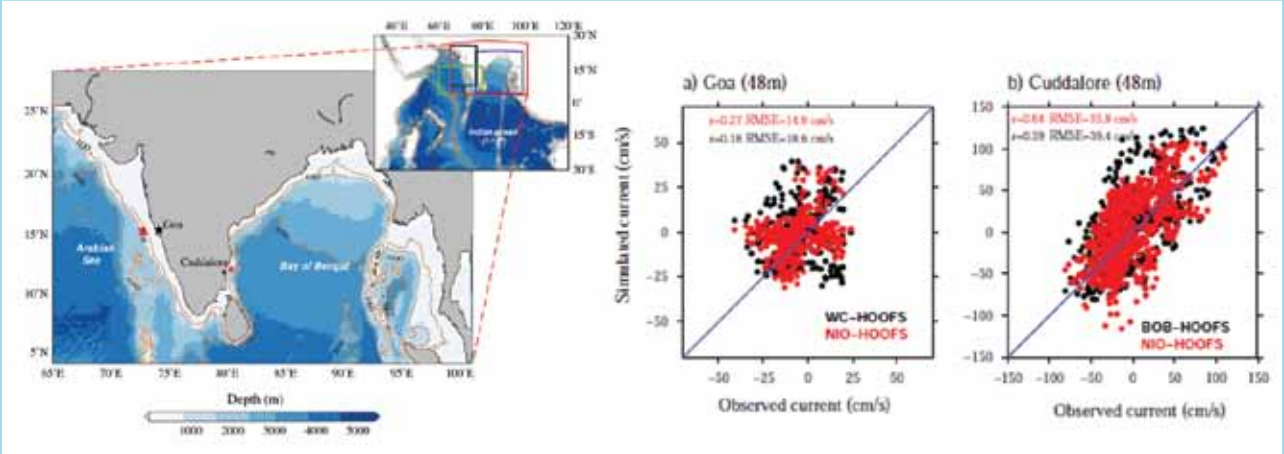


Time series of (top to bottom) temperature (°C), salinity (psu), sigma-t (Kg m^{-3}) and rate of dissipation of turbulent kinetic energy (log (ε); W kg^{-1})

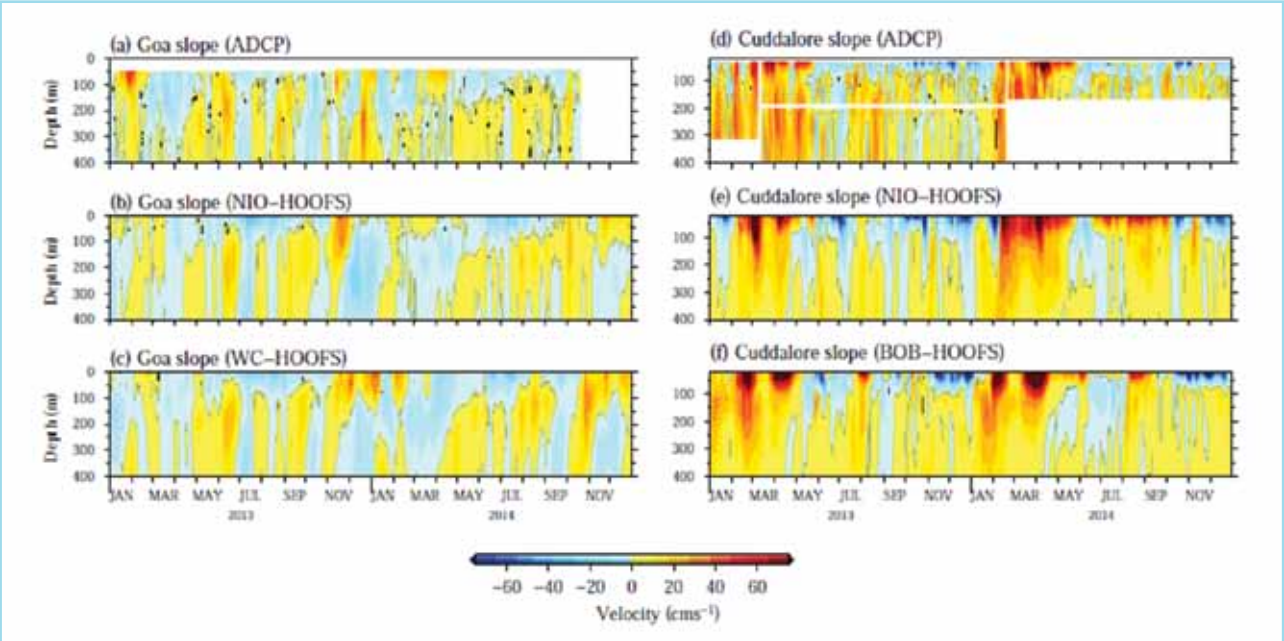
6. Ocean Modeling and Data Assimilation

6.1 High-resolution model for the North Indian Ocean

INCOIS is providing forecasts on various oceanographic parameters using a series of high-resolution (2.2 km) models configured based on Regional Ocean modelling System (ROMS). Due to the limitations in computational resources, these models were configured for smaller domains, such as the west coast of India (WC-HOOFS), south eastern Arabian Sea (SEAS-HOOFS) and the Bay of Bengal (BB_HOOFS). With the availability of computational resources with higher capacity, it has now become possible to combine these configurations into a single setup. Accordingly, INCOIS has now set up a single high-resolution (2.2 km) configuration of ROMS for the entire northern Indian Ocean domain ranging from 65° E-99.5° E and 3.5° N-26.5° N called NIO-HOOFS. This model is being forced with six-hourly wind and other atmospheric fluxes from the



Domain of the NIO-HOOFS configuration and comparison of alongshore currents simulated by NIO-HOOFS and WC-HOOFS (BB-HOOFS) off Goa (Cudallore)

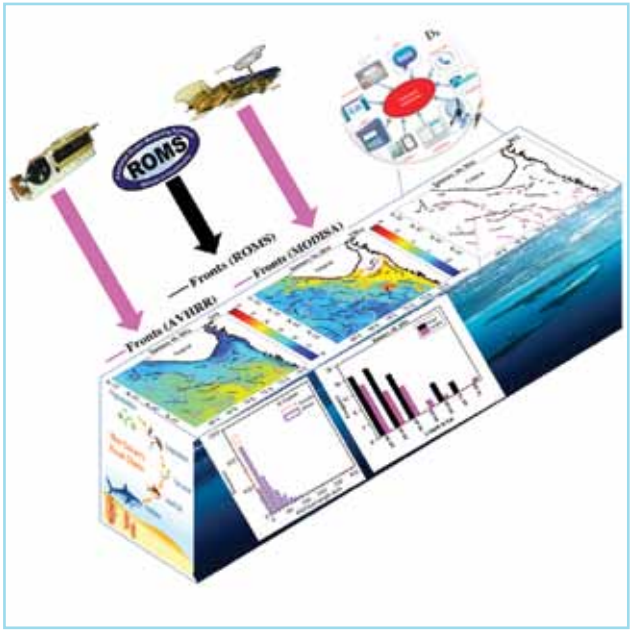


Time-depth sections of alongshore currents simulated by NIO-HOOFS, WC-HOOFS (BB-HOOFS) are compared with ADCP observations on the slope off Goa (Cudallore).

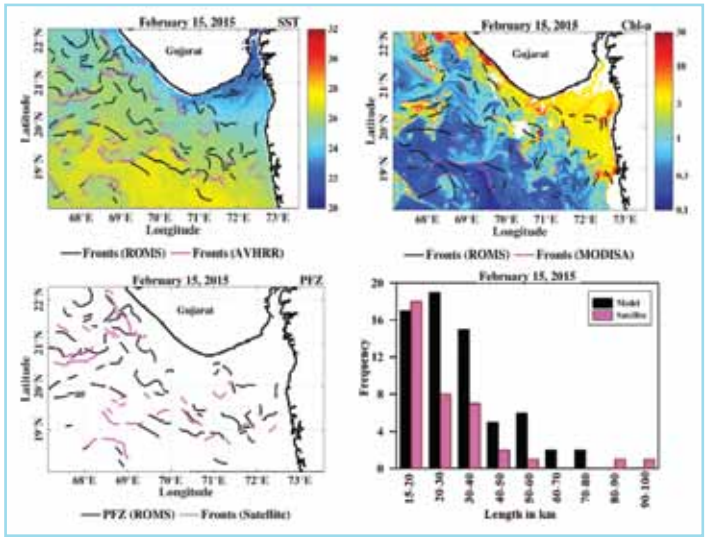
Global Forecast System (GFS) model run by National Centre for Medium Range Weather forecast (NCMRWF) at a horizontal resolution of ~ 12 km. The initial and boundary conditions for this model are being derived from Regional Analysis for Indian Ocean (RAIN). It is observed that the NIO-HOOFS has better skills to simulate coastal circulation compared to the individual configurations of HOOFS. In addition, this combined setup eliminates the requirement of multiple model runs to issue ocean state forecasts. Experimental runs of this system are now in progress.

6.2 Ecosystem Modeling

The operational Potential Fishing Zone (PFZ) advisories generated and disseminated by INCOIS rely on remotely-sensed sea surface temperature (SST) and chlorophyll-a (Chl-a) data from NOAA-AVHRR and MODIS-AQUA and/or Oceansat-2 satellites, respectively. During situations of cloud cover, it becomes difficult to retrieve SST/Chl-a data from satellite images. Further, the present PFZ advisories are valid only for that day or at the best for the next 24 hours. As resources are depleting in nearshore regions, it is essential to encourage fishermen to carry out pelagic fishing activities in deep seas, which involve multi-day fishing. Therefore, accurate forecasting of the regions of fish availability for next 3 to 5 days has become a necessity. To overcome the operational difficulties in generating PFZ advisories due to non-availability of data and to transform the PFZ advisories into PFZ forecasts, a coupled physical-biogeochemical model in the regional scale has been developed. This modeling framework involves an online coupling of the Regional Ocean Modeling System (ROMS) physics/dynamics with an ecosystem component at a very high spatial resolution (1/48°; approximately 2.25 km spatially averaged). This system will be made operational very soon.



Schematic representation of PFZ forecast system

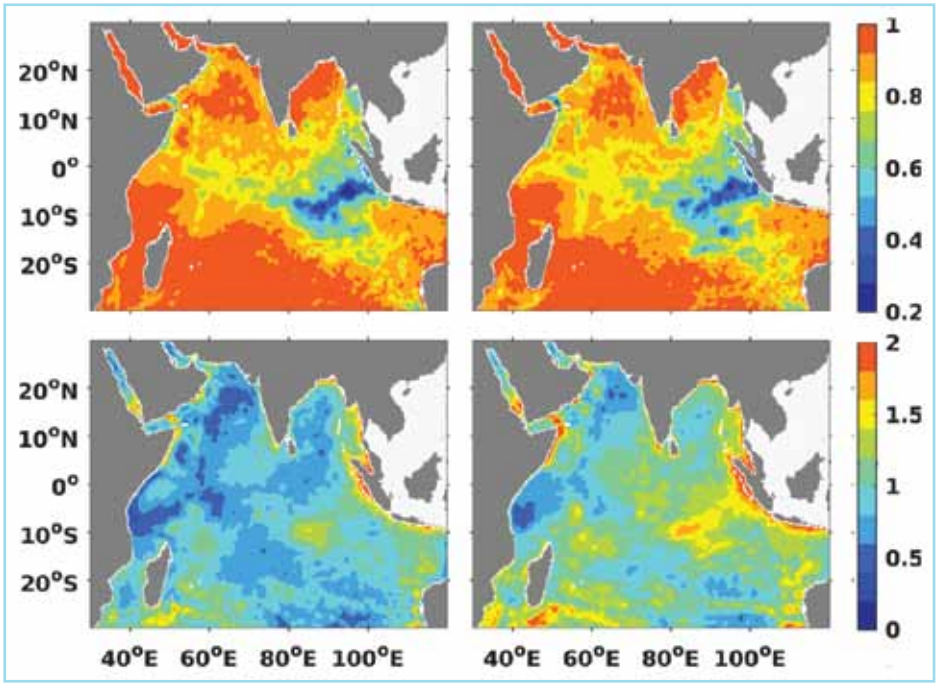


Comparison of PFZ advisories generated using model simulations and the satellite observations

6.3 Data Assimilation in ROMS

The Local Ensemble Transform Kalman Filter (LETKF) data assimilation scheme demonstrated

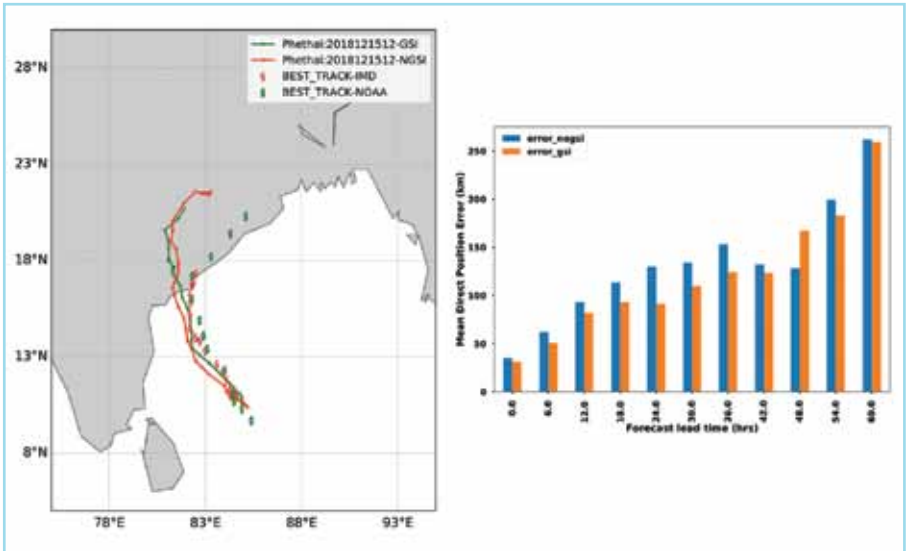
in MOM has been implemented for the first time in the Regional Ocean Modeling System (ROMS) model. The ROMS with LETKF has been set up as Regional Analysis of Indian OceaN (RAIN) to produce the daily regional ocean analysis. RAIN assimilates in situ temperature and salinity profiles and satellite track data of sea surface temperature (SST) into a 9 km resolution basin-wide ROMS using LETKF assimilation scheme. It has been made operational during the INCOIS 19th foundation day celebration on 4 February 2019. The novelty of this assimilation system is that it employs two different mixing schemes across the 80-member ensemble in order to arrest filter divergence. The assimilation cycle is kept at 5 days after multiple sensitivity tests. This system provides analysis of the Indian Ocean from Aug 2016 onwards till date and the analyses are regularly updated at https://incois.gov.in/portal/rain/rain_about.jsp. The website also provides information about the observations that has gone into assimilation for a particular analysis and validation results of its performance to instill added confidence among the users.



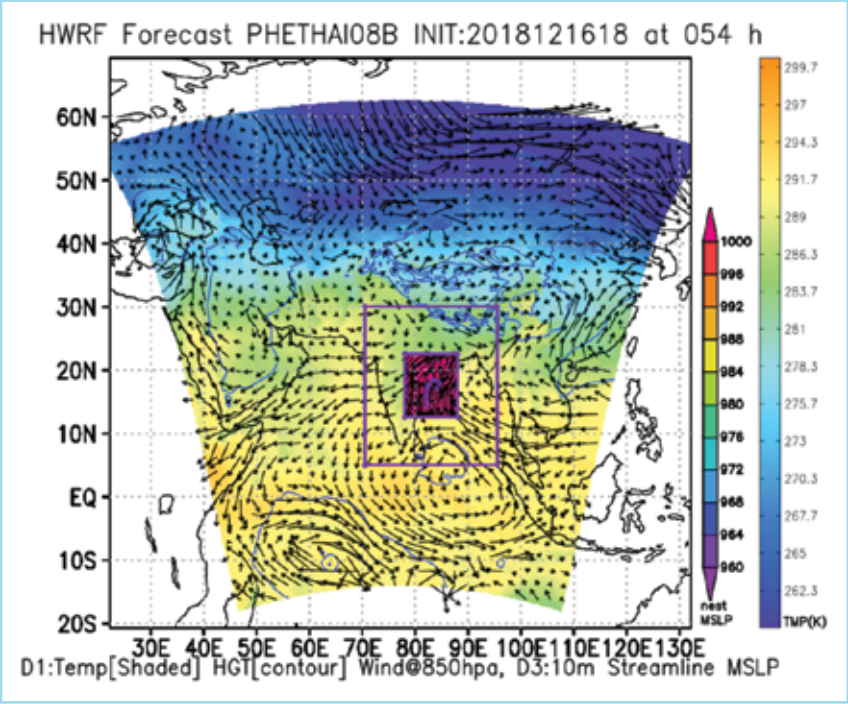
Maps of correlation (top) and root mean squared error (bottom) between AVHRR SST and SST of RAIN (left) and free model (right)

6.4 HYCOM-HWRF coupled model for Tropical Cyclone Prediction

HWRF-HYCOM coupled system with moving nest has been set up at with oceanic initial and boundary conditions obtained from high resolution (1/16°) Operational Indian Ocean HYCOM nested to a 1/4th degree Global HYCOM. Major components of the system are (a) HWRF atmospheric model, (b) HYCOM ocean model and (c) the coupler. The



Track of Phethei cyclone predicted by HYCOM-HWRF system and direct position error in the track simulations

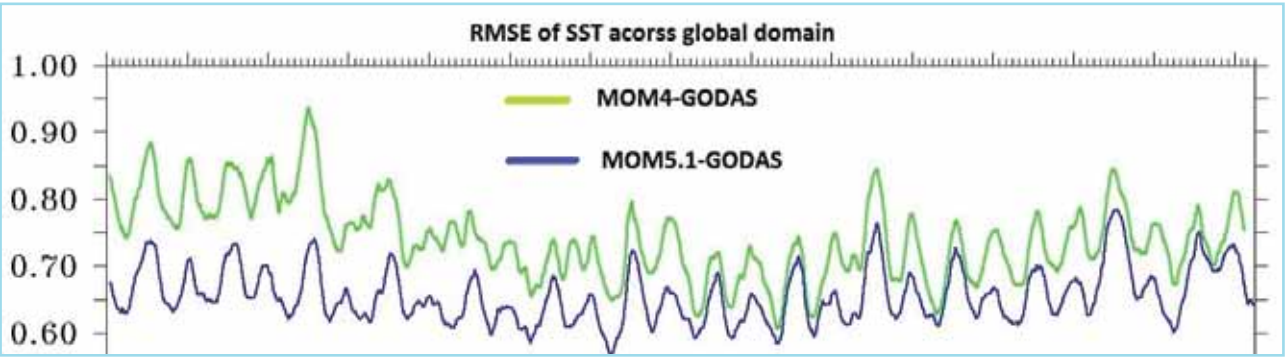


Representation of model grids in the HWRF-HYCOM configuration for the prediction of cyclone Phethai

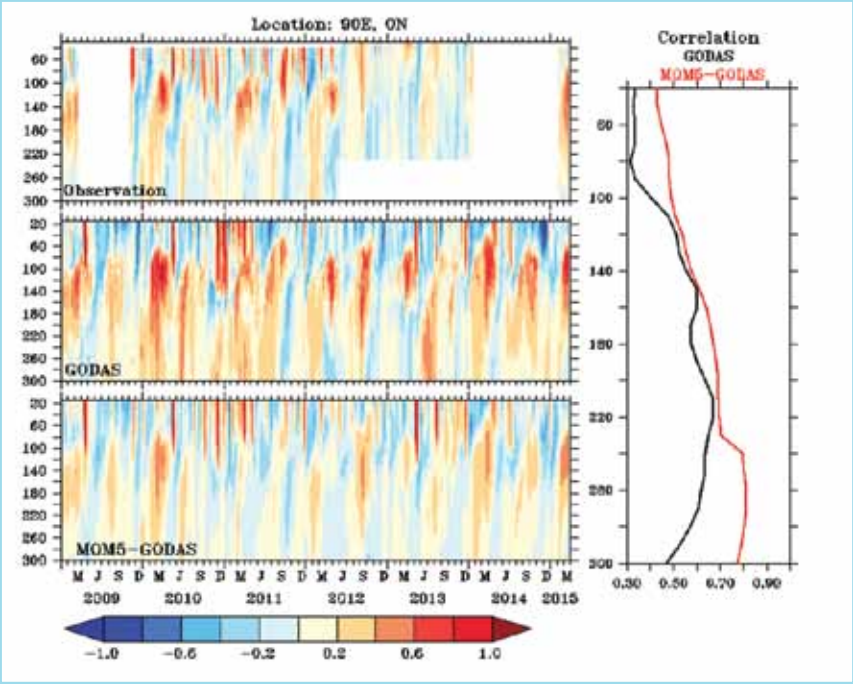
coupler exchanges SST and atmospheric forcing between and atmospheric and ocean model at each integration time step (360 sec). HWRF has been configured for the north Indian Ocean with a parent domain having a dimension of approximately 80°x80° with a horizontal resolution of 18 km on a rotated latitude/ longitude grid. The dimension of the middle nested domain is about 24°x24° with a horizontal resolution of 6 km and inner most nested domain of about 7°x7° with horizontal resolution of 2 km. The parent and child models are nested 2-way and the inner domains move along with the storm with its evolution. HWRF gets initialized by both vortex improvement procedure and data assimilation. The NCEP Global Forecast System (GFS) analysis has been used to generate the initial conditions (ICs) for the HWRF parent domain. The ocean component is one way nested to the INCOIS-HYCOM. Experimental simulation of the tropical cyclone Phethai was carried out using this coupled model setup.

6.5 Global Ocean Analysis

INCOIS continued to provide global ocean analysis products based on the Global Ocean Data Analysis System (GODAS) system. The ocean model of the GODAS has been upgraded from version 4.0 of Modular Ocean Model (MOM4.0) to version 5.1 (MOM5.1). It is found that the upgradation of the model has improved ocean analysis considerably.



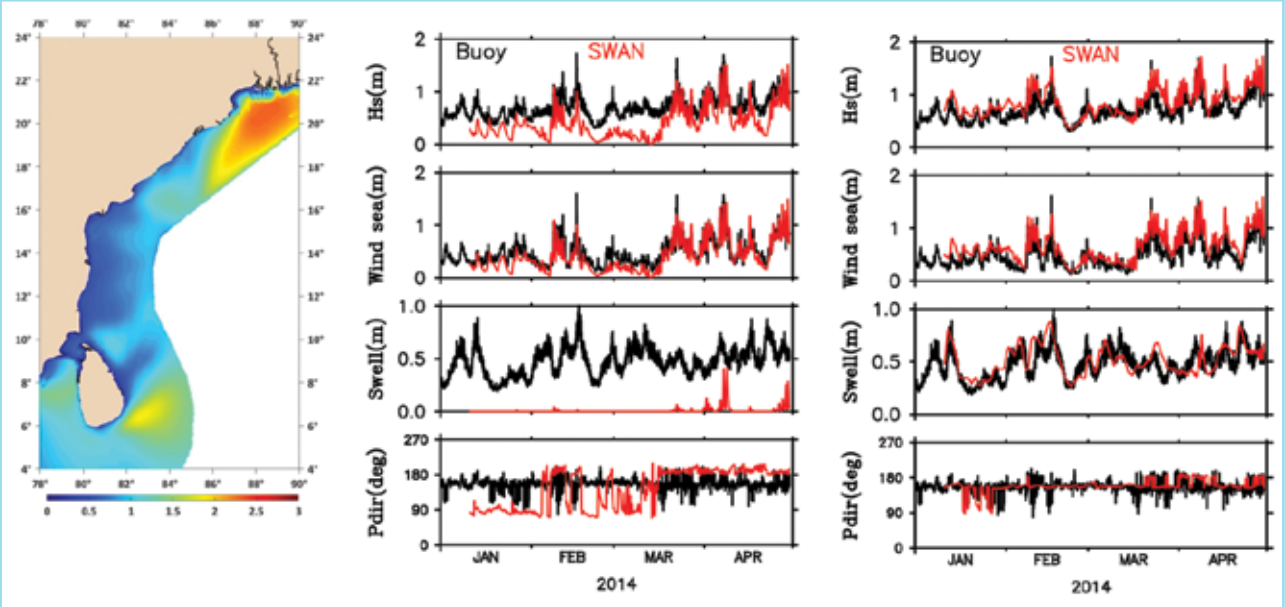
RMSE of global SST simulated by MOM4-GODAS and the improved MOM5.1-GODAS.



Comparison of time-depth section of currents simulated by MOM4-GODAS and MOM5.1-GODAS at 90°E, Equator with ADCP observations

6.6 Unstructured SWAN model for east-coast of India

Unstructured SWAN model with resolution varying from 300 m to 5 km and forced with boundary conditions derived from WAVEWATCH III model has been configured for the east coast of India. The model domain extends approximately 2-3 degrees offshore. Preliminary analysis suggests significant improvements in the simulation of significant wave height, swell wave height and peak wave direction compared to the simulations without boundary conditions.



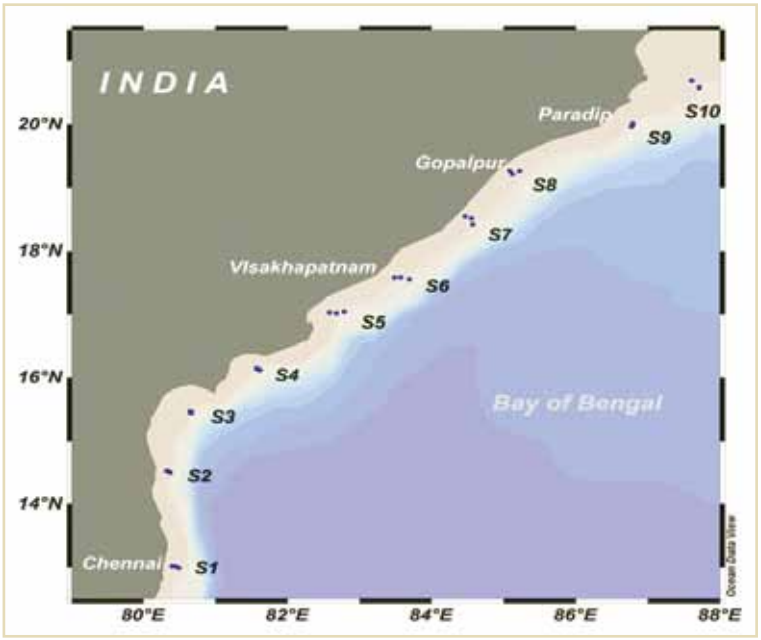
Unstructured SWAN model for east-coast of India

Domain of the unstructured SWAN configuration and the comparison of wave parameters simulated by the model with and without boundary conditions

7. Marine Observation System Along the Indian Coast (MOSAIC)

7.1 Coastal water quality monitoring

The ever-increasing coastal population and rapid economic growth along the coastal corridor have made the Indian coastal waters vulnerable to human-induced pollutions and associated changes. Though limited sampling to measure water quality parameters in the coastal waters around India were conducted earlier, a sustained effort has been missing to understand and quantify anthropogenic perturbations on the coastal waters. The MOSAIC (Marine Observation System Along the Indian Coast) programme aims to fill this gap by establishing a buoy-based automated monitoring system along the Indian coast to monitor the coastal waters in real time and assess the health of coastal ecosystem. The data collected over a period of time will also help differentiate human-induced changes from natural variabilities. To start with, INCOIS conducted five cruises in the coastal Bay of Bengal during the past two years, of which two were during 2018-19. ORV Sagar Manjusha was used for these cruises during monsoon and post-monsoon seasons to understand the effect of the monsoon on the coastal water quality and ecosystem.



Track and sampling locations of cruises conducted under the MOSAIC programme

List of cruises conducted under MOSAIC programme in the FY 2018-19

Sl. No	Cruise No.	Period
1	SM 09/2018	27 June-12 July 2018
2.	SM 18/2018	4 November-16 November 2018

In situ optical and biogeochemical data together with physical data were collected from the coastal waters in the Bay of Bengal to understand physical-biological variability and interactions in the coastal waters and to assess the impact of river water discharge on coastal ecosystem and to develop algorithms to derive geophysical parameters from satellite-based sensor data for coastal waters. The data on various physical, chemical and biological parameters were collected at ten transects at 30-100 m water depth. The samples are being analysed in the laboratory at INCOIS. The preliminary analysis of the nutrient data suggests the evidence of silicate stress in the coastal bay.

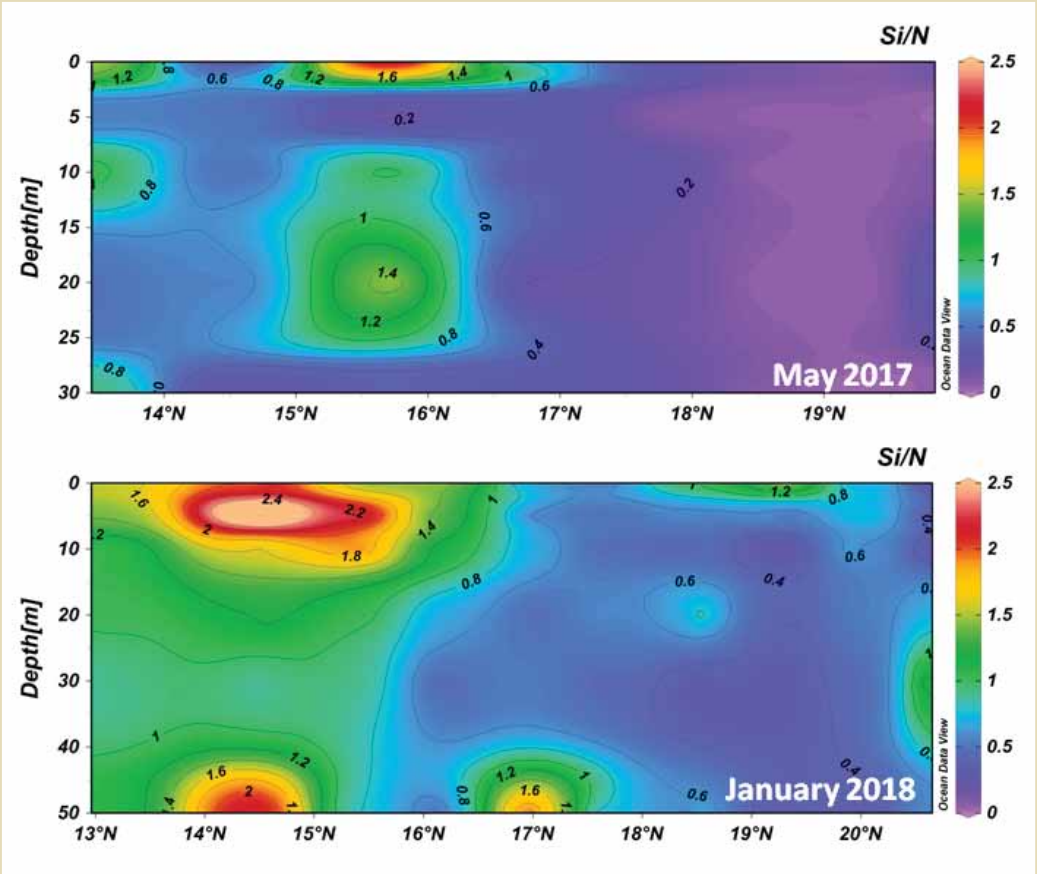


Fig: Latitudinal section of Si/N ratio during May 2017 (top panel) and January 2018 (bottom panel). The Si/N ratio in coastal waters of northern Bay of Bengal is silicate stressed (Si/N < 1).

The phytoplankton community is usually dominated by diatoms (silicate-based). Diatoms are expected to thrive in high silicate and nitrate conditions. The observed low Si/N ratio indicates a possible species shift from diatoms to dinoflagellates (57-62%) and cyanobacteria (88-100%).

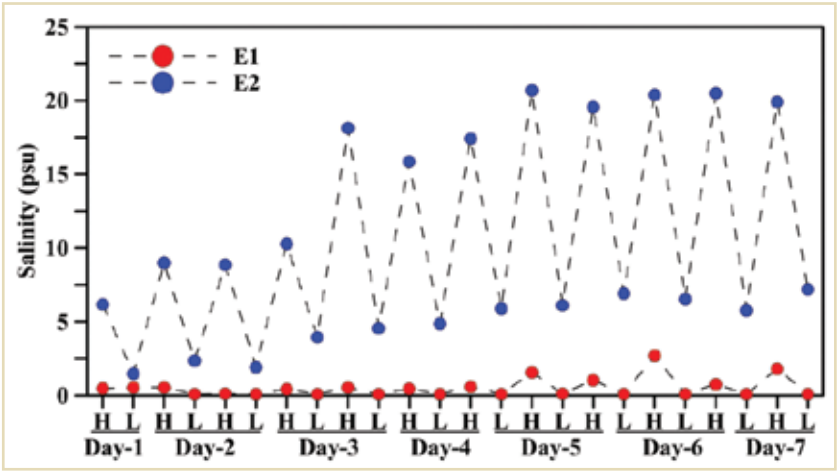
Onboard sampling activities during the MOSAIC cruises

7.2 Field Campaign in Mahanadi Estuary

Mahanadi river system, which is the third largest river in peninsular India, receives effluents from different industrial and urban centres. The fishing jetty close to the estuarine mouth also adds pollutants to the near-coastal area. It also receives a large amount of agricultural runoff along its course. The water quality of the Mahanadi Estuarine system is largely controlled by tide and hence a pilot field campaign was conducted in the estuary to understand the dynamics of biogeochemical-optical parameters in response to the tides during post south-west monsoon of 2018.

Sampling Locations during field campaign in Mahanadi Estiary. Inset shows the time of sampling with respect to tidal height.

During the field campaign, two stations, one in the upstream area and another in the downstream area were sampled at high and low tide regimes. Different environmental parameters such as salinity, temperature, phytoplankton pigment, phytoplankton and detritus absorption, Chromophoric Dissolved Organic Matter, pH, Total Alkalinity, Dissolved Inorganic Carbon, Total Suspended Matter, Turbidity, Dissolved Oxygen, macronutrients (nitrite, nitrate, phosphate, silicate, ammonium) Biochemical Oxygen Demand, concentration of *Escherichia coli* and Apparent Optical Properties were recorded/analysed.



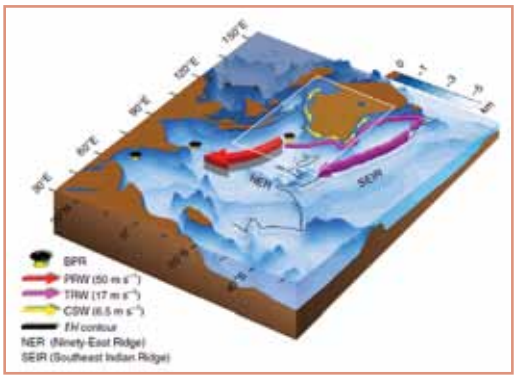
Salinity variation in Mahanadi estuary at different tidal levels

The preliminary analysis of data suggests strong tidal influence not only on the physical properties but also on the dissolved oxygen and nitrate concentrations. Concentration of *E.Coli* bacteria (385 CFU/ml), which is an indicator of water quality, was also high and was beyond the permissible limit.

8. Research Highlights

8.1 Basin-wide sea level coherency in the tropical Indian Ocean driven by Madden–Julian Oscillation

It has been widely accepted that barotropic sea level changes in the tropics are insignificant at intraseasonal time scales (periods of 30–80 days). Bottom pressure records were used to show the evidence for significant basin-wide barotropic sea level variability in the tropical Indian Ocean during December–April with standard deviations amounting to ~30–60% of the standard deviation in total intraseasonal sea level variability. It was found that the origin of this variability is linked to a small patch of wind over the Eastern Indian Ocean, associated with boreal winter Madden–Julian Oscillations (MJO). These large fluctuations are likely to play a prominent role in the intraseasonal sea level and mass budgets. Because of their much faster propagation than baroclinic processes, they allow the basin to adjust to climatic perturbations much more rapidly than was previously thought. These results suggests that the prevalence of large barotropic variability over vast parts of the tropical oceans at intraseasonal time scales and the importance of baroclinic physics in their generation should be accounted for while interpreting the signals obtained by space-borne altimetry and gravimetry. The findings of this paper assumes particular importance as the intensity of MJOs is expected to strengthen in a changing climate.



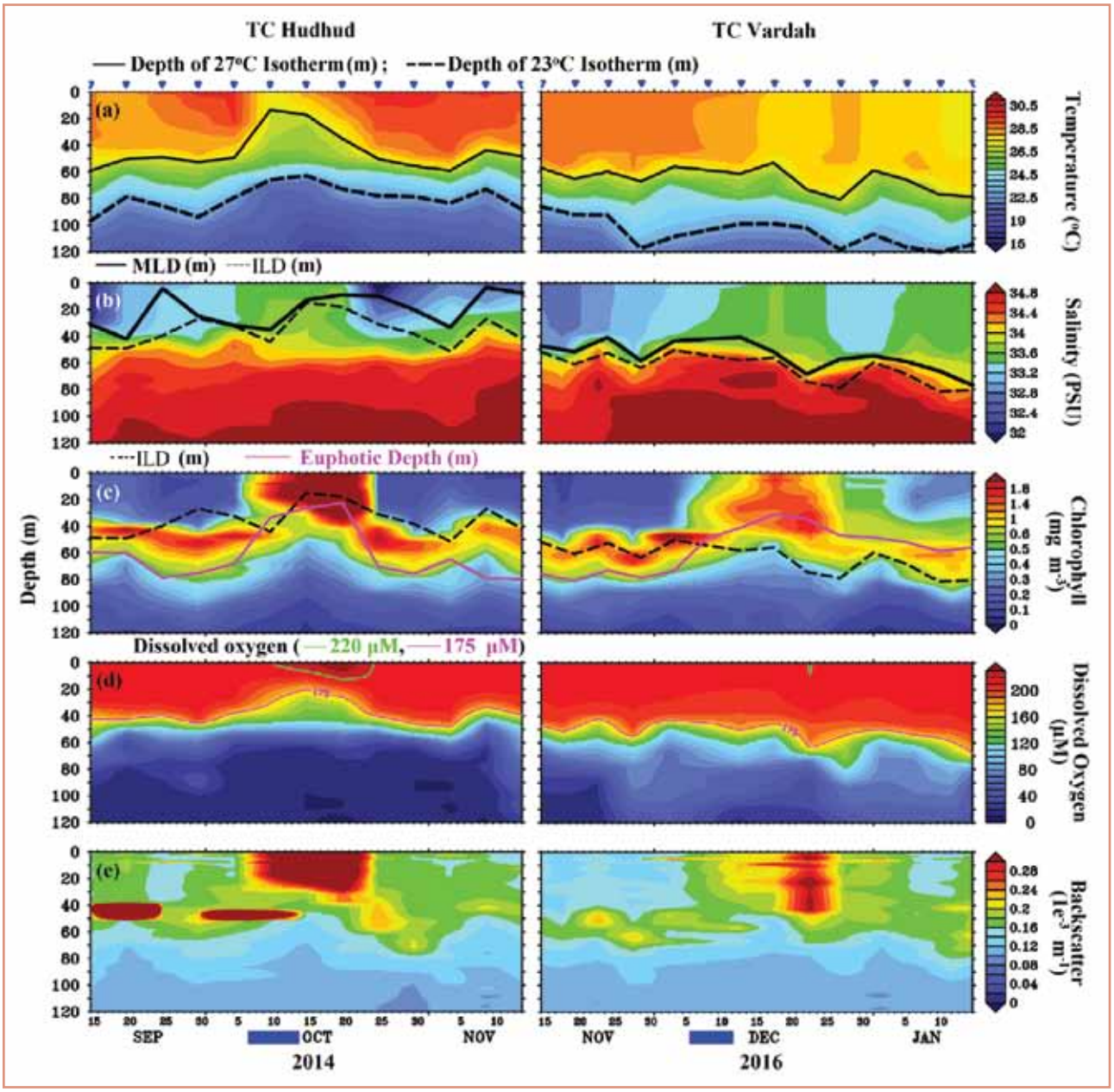
Schematic diagram of the propagation of barotropic waves forced by winds over the NWAB (white box). The arrows represent the pathways of barotropic waves.

Ref: Rohit, B., Paul, A., Durand, F., Testut, L., Prerna, S., Afroosa, M., Ramakrishnaa, S.S.V.S., Shenoi, S.S.C., Basin-wide sea level coherency in the tropical Indian Ocean driven by Madden–Julian Oscillation (2019) Nature Communications 10. p. 125.

8.2 Quantifying tropical cyclone's effect on the biogeochemical processes using profiling float observations in the Bay of Bengal

Physical and biogeochemical observations from an autonomous profiling Argo float in the Bay of Bengal show significant changes in upper ocean structure during the passage of Tropical Cyclone (TC) *Hudhud* (7–14 October 2014). TC *Hudhud* mixed water from a depth of about 50 m into the surface layers through a combination of upwelling and turbulent mixing. Mixing was extended into the depth of nutricline, the oxycline and the subsurface-chlorophyll-maximum; thus there was a strong impact on the biogeochemistry of the upper ocean. Before the storm, the near-surface layer was nutrient depleted and was thus oligotrophic with the chlorophyll-a concentration of less than 0.15 mg m^{-3}. Storm mixing initially increased the chlorophyll by 1.4 mg m^{-3}, increased the surface nitrate concentration to about 6.6 μM kg^{-1}, and decreased the sub-surface dissolved oxygen (30–35 m) to 31 % of saturation (140 μM). These conditions were favorable for phytoplankton growth resulting in an estimated increase in primary productivity averaging 1.5 g Cm^{-2} day^{-1}

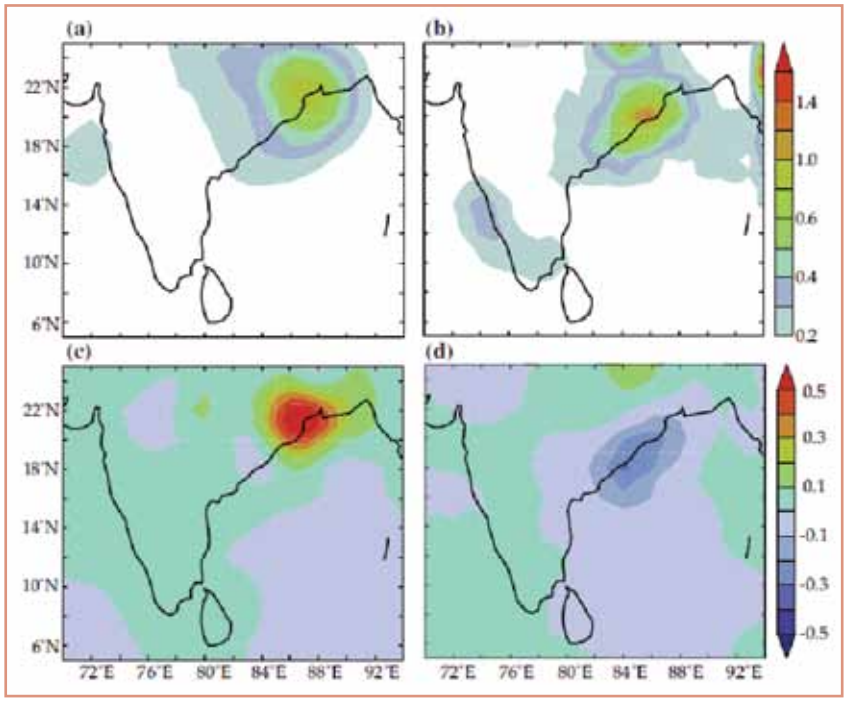
over 15 days. During this bloom, chlorophyll-a increased by 3.6 mg m^{-3}, and dissolved oxygen increased from 111 % to 123 % of saturation. Similar observations during TC *Vardah* (6–12 December 2016) showed much less mixing. Analysis suggests that relatively small (high) translation speed and presence of cold (warm) core eddy leads to strong (weak) oceanic response during TC *Hudhud* (TC *Vardah*). Thus, although cyclones can cause strong biogeochemical responses in the Bay of Bengal, the strength of response depends on the properties of the storm and the prevailing upper ocean structure such as presence of mesoscale eddies.



Temporal evolution of depth-time section of (a) temperature (°C), (b) salinity, (c) Chlorophyll (mg m^{-3}), (d) Dissolved Oxygen (µM) and (e) optical backscatter (1e^{-3} m^{-1}) from C-Float (WMO ID 2902114) during 15 September, 2014 to 15 November, 2014 (left panels; TC Hudhud) and 15 November 2016 to 15 January 2017 (right panels; TC Vardah) in the south-western BoB. In panel (a), thick dashed line: depth of 23°C isotherm (m) and thin black line: depth of 27°C isotherm. In panel (b), thick black line: MLD (m), and thin black dash line: ILD (m). In panel (c), thick pink line: euphotic depth, and thin black dash line: ILD (m). In panel (d), thin pink (green) line: depth of 175 (220) µM dissolved oxygen (m). Blue thick line in the bottom of the figure indicates TC Hudhud period (7–14 October, 2014; left panel) and TC Vardah (6-12 December, 2016). The blue inverted triangle on top of the panel (a) indicates the surfaced date of C-Float profiling measurements.

Ref: Girishkumar, M. S., Thangaprakash, V. P., Udaya Bhaskar, T. V. S., Suprit, K., Sureshkumar, N., Baliarsingh, S. K., et al. (2019). Quantifying tropical cyclone's effect on the biogeochemical processes using profiling float observations in the Bay of Bengal. Journal of Geophysical Research: Oceans, 124, 1945– 1963. https://doi.org/10.1029/2017JC013629

8.3 Relationship between the Indian summer monsoon rainfall and the EQUINOO in the CFSv2



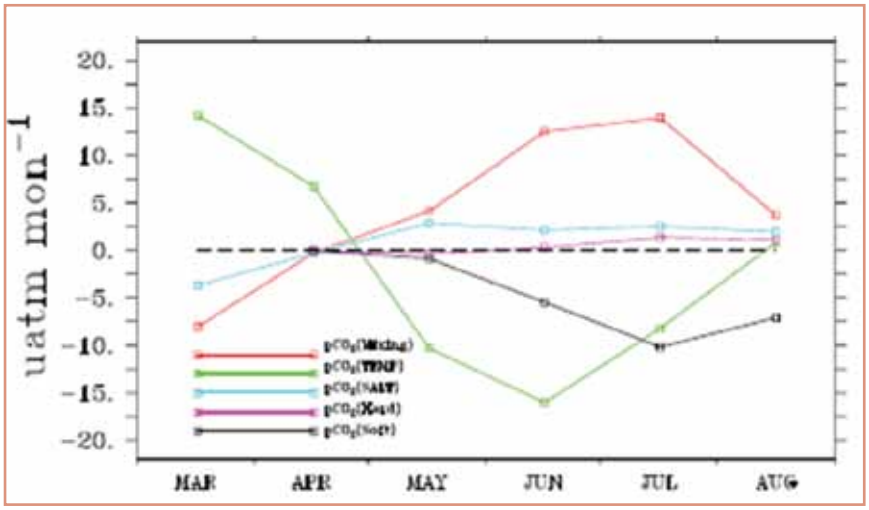
Track density of low-pressure systems (LPS) during summer monsoon season in (a) the observation and (b) the model. The composite of difference in the track density between positive EQUINOO years and negative EQUINOO years in the (c) observation and (d) the model. The colour scheme represents number of LPS passed over a 1°x1° resolution grid point in a monsoon season (June–September) for the period 1982–2010.

Ref: Vishnu, S., Francis, P.A., Ramakrishna, S.S.V.S., Shenoi, S.S.C., On the relationship between the Indian summer monsoon rainfall and the EQUINOO in the CFSv2 (2018) Climate Dynamics, 19(7), e825.

Several recent studies have shown that positive (negative) phase of Equatorial Indian Ocean Oscillation (EQUINOO) is favourable (unfavourable) to the Indian summer monsoon. However, many ocean–atmosphere global coupled models, including the state-of-the-art Climate Forecast System (CFS) version 2 have difficulty in reproducing this link realistically. The retrospective forecasts by the CFS model for the period 1982–2010 were analysed in this study with an objective to identify the reasons behind the failure of the model to simulate the observed links between Indian summer monsoon and EQUINOO. It was found that, in the model hindcasts, the rainfall in the core monsoon region was mainly due to westward propagating synoptic scale systems, that originated from the vicinity of the tropical convergence zone (TCZ). The analysis further showed that unlike in observations, in the CFS, majority of positive (negative) EQUINOO events are associated with El Niño (La Niña) events in the Pacific. In addition to this, there has been a strong link between EQUINOO and Indian Ocean Dipole (IOD) in the model. It was shown that, during the negative phase of EQUINOO/IOD, northward propagating TCZs remained stationary over the Bay of Bengal for longer period compared to the positive phase of EQUINOO/IOD. As a result, compared to the positive phase of EQUINOO/IOD, during a negative phase of EQUINOO/IOD, more westward propagating synoptic scale systems originated from the vicinity of TCZ and moved on to the core monsoon region, which resulted in higher rainfall over this region in the CFS. It was further shown that frequent, though short-lived, westward propagating systems, generated near the vicinity of TCZ over the Bay moved onto the mainland were responsible for less number of break monsoon spells during the negative phase of EQUINOO/IOD in the model hindcasts. This study underlines the necessity for improving the skill of the coupled models, particularly CFS model, to simulate the links between EQUINOO/IOD and the Indian summer monsoon for reliable predictions of seasonal and intraseasonal variation of Indian summer monsoon rainfall.

8.4 Dominant Biological Control Over Upwelling on pCO_2 in Sea East of Sri Lanka

Upwelling enhances pCO_2 levels due to injection of carbon-rich water to the surface despite the removal of carbon due to increase in primary production supported by enhanced nutrients. It was hypothesized that in the Bay of Bengal, upwelling may decrease pCO_2 due to existence of low saline and pCO_2- poor waters in the subsurface layer. In order to test this hypothesis, a high-resolution state-of-the-art ocean biogeochemical model (Regional Ocean Modeling System) runs were examined at the sea east of Sri Lanka (SESL) where intense upwelling occurs during summer monsoon (May to August). Upwelling enhances pCO_2 by 34 μatm, whereas decrease in surface temperature and increase in surface salinity reduce pCO_2 by 24 μatm. The estimated net effect of upwelling was an increase in pCO_2 by 10 μatm. In contrast, soft and hard tissues together contributed to a decrease in pCO_2 by 21 μatm suggesting that the biological effect dominates over upwelling, resulting in a net decrease of pCO_2 by 11 μatm in the SESL. This striking contrast between the increase in pCO_2 due to physical dynamics (upwelling) and the removal of pCO_2 due to biological processes was caused by shallow (deep) nitracline (dissolved inorganic carbon-isoline) in the SESL.



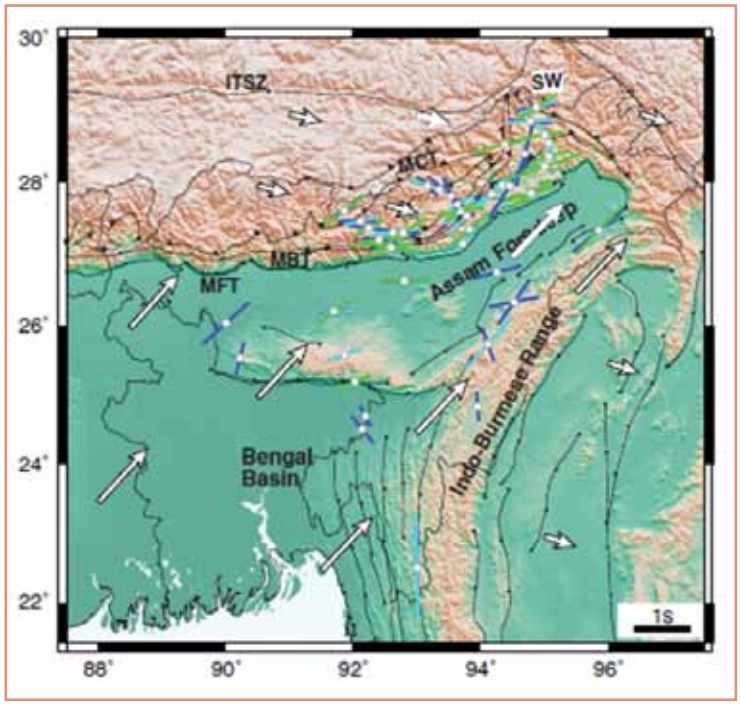
The contribution of the individual components (dissolved inorganic carbon [vertical mixing], sea surface temperature, sea surface salinity, and total biology [soft tissue and hard tissue]) on net pCO_2 variability during March to August in the sea east of Sri Lanka region. Black dotted line represents the control run, red line represents the contribution of dissolved inorganic carbon (vertical mixing), green line represents the contribution of sea surface temperature, cyan line represents the contribution of sea surface salinity, black line represents the contribution of biological soft tissue, and magenta line represents the contribution of biological hard tissue.

Ref: Chakraborty, K., Valsala, V., Gupta, G.V.M., Sarma, V.V.S.S., Dominant Biological Control Over Upwelling on pCO_2 in Sea East of Sri Lanka (2018) Journal of Geophysical Research: Biogeosciences, 123(10), pp.3250-3261.

8.5 Mantle Deformation in the Eastern Himalaya, Burmese Arc and Adjoining Regions

This study presented new results of shear wave splitting at 56 broadband stations installed in the Eastern Himalaya, Burmese Arc, and adjoining regions. The fast polarization directions (FPDs) within the Himalaya, Burmese Arc and the foredeep are parallel to the strike of the orogens, suggesting a coherently deformed lithospheric mantle under compression. The FPDs follow the Main Boundary Thrust and the Main Central Thrust in the central segment of the Arunachal Himalaya. Smaller delay times (~0.7 s) can be best explained by multiple layers of anisotropy, where combined effects of the anisotropic fabric of a coherently deformed lithosphere of the Arunachal Himalaya and plate motion related strain are playing a role. Null measurements in the Siang window may be due to the Indian plate interaction with Eurasia and Burma plates, causing different layers of anisotropy.

Another possibility is the coincidence of source polarization direction with the fast axis. In the Bengal Basin, the nulls could be due to annihilation of frozen anisotropy in the downwelling Indian lithosphere and the APM-related strain, or a highly heterogeneous mantle affected by the Kereguelen plume magmatism, at ~116 Ma.

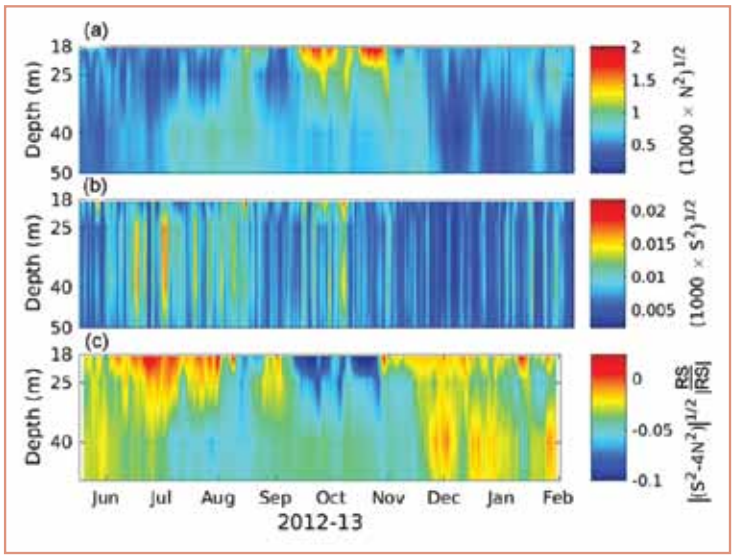


Composite splitting parameters for different phases plotted at the station locations. Blue bars represent measurements from the SKS phase, green bars represent measurements from SKKS, and cyan bars represent measurements from PKS phases. The lengths of the bars are proportional to the delay times, and their orientations are along the fast-axis directions. The absolute plate motion directions are shown as arrows in a no-net rotation frame

Ref: Saikia, D., Kumar, M.R., Singh, A., Roy, S.K., Raju, P.S., Lyngdoh, A.C., Mantle Deformation in the Eastern Himalaya, Burmese Arc and Adjoining Regions (2018) Geochemistry, Geophysics, Geosystems, 19(11), pp. 4420-4432.

8.6 Shear flow instabilities and unstable events over the northern Bay of Bengal

A year-long mooring data were used to study the upper ocean unstable events and instabilities at 18°N 89°E, which is a climatologically important region in the North Bay of Bengal. Near-surface stability was studied from the context of the buoyancy frequency normalized shear (Vz/N) and reduced shear (S^2-4N^2) which are convenient measures to quantify flow stability, compared to the more widely used Richardson number (Ri). The analysis was carried out across three contrasting time periods, the monsoon, postmonsoon, and the winter of year 2012. Although it is well known that the flow stability changes from stable to unstable at Ri = Ricr=0.25, the relative importance of the perturbations of shear and buoyancy frequency in driving the unstable events is not well studied over the open oceans and more particularly over the Bay of Bengal. At 18°N, 89°E both higher than average shear and lower than average buoyancy frequency perturbations are crucial in driving the unstable events during the summer and



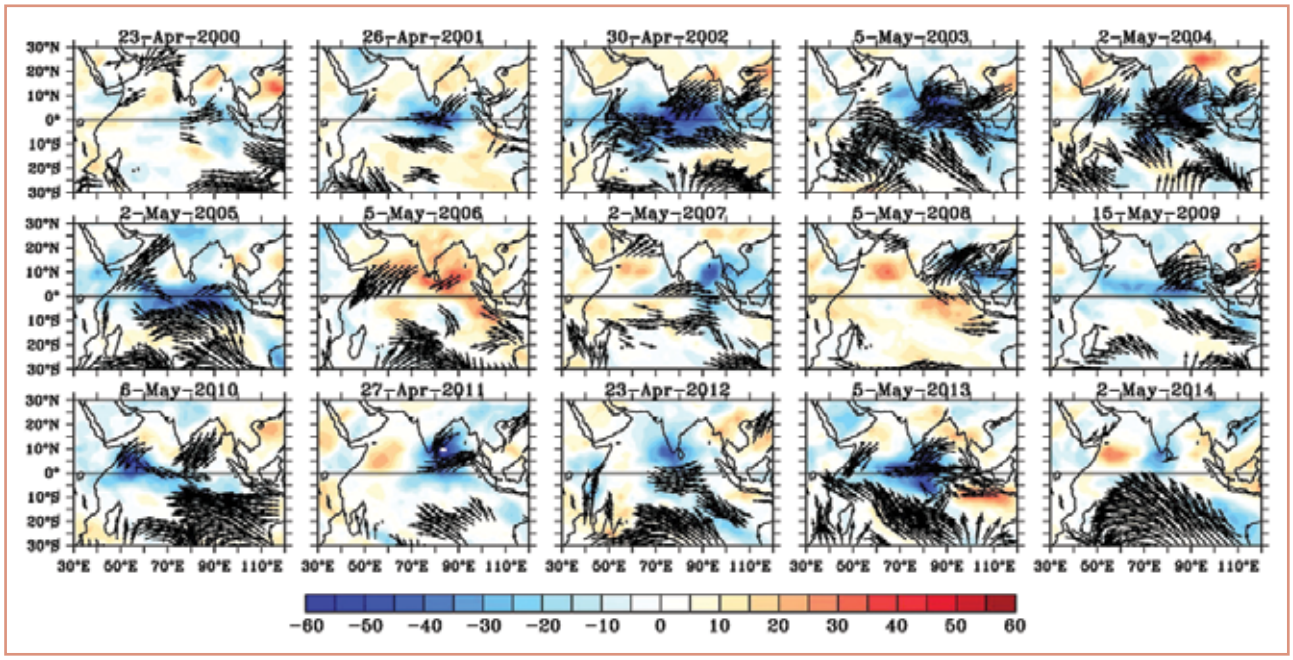
Panel (a) shows the variation of $N^2(z)$ during May 2012 to February 2013. $N^2(z)$ is scaled for better visualization of the features of the flow. The near-surface layers are stably stratified from late September to end of October. Near-surface shear (Vz) from May 2012 to February 2013 is shown in panel (b). High shear is observed across the upper 50 m during the months of June to August. Reduced shear $S^2 - 4N^2|1/2RS/|RS|$ where RS is $(S^2 - 4N^2))$ is shown in panel (c). The near-surface layers across 25–30 m are stable to shear during September–October.

Ref: Jampana, V., Ravichandran, M., Sengupta, D., DAsaro, E. A., Rahaman, H., Joseph, S., Chaudhuri, D., Shear flow instabilities and unstable events over the north bay of Bengal (2018) Journal of Geophysical Research: Oceans, 123(12), pp. 8958-8969.

premonsoon period. However, at increasing depths, the influence of shear perturbations becomes more dominant. Invoking the Miles-Howard criteria for flow instability, it was seen that during the postmonsoon period, the buoyancy frequency perturbations were more critical than shear perturbations in driving the unstable events. In winter, the unstable events were influenced by both the buoyancy frequency and shear perturbations.

8.7 Wyrtki Jets: Role of intraseasonal forcing

Direct current measurements observed from the acoustic Doppler current profilers in the equatorial Indian Ocean (EIO) and solutions from an ocean general circulation model were investigated to understand the dynamics of the Wyrtki jet. These jets are usually described as semiannual direct wind forced zonal currents along the central and eastern EIO. In this paper, it was shown that both, spring and fall, Wyrtki jets show predominant semiannual spectral peaks, but significant intraseasonal energy is evident during spring in the central and eastern EIO. It was also shown that for the semiannual band, there is a strong spectral coherence between the overlying winds and the currents in the central EIO, but no coherency was observed in the eastern part of the EIO. Moreover, for the intraseasonal band, strong coherency between the winds and currents is evident. During spring, intraseasonal currents induced by the Madden–Julian oscillation (MJO) superimpose constructively with semiannual currents and thus intensify the strength of the spring Wyrtki jet. Also, the atmospheric intraseasonal variability accounts for the interannual variabilities observed in spring Wyrtki jets.

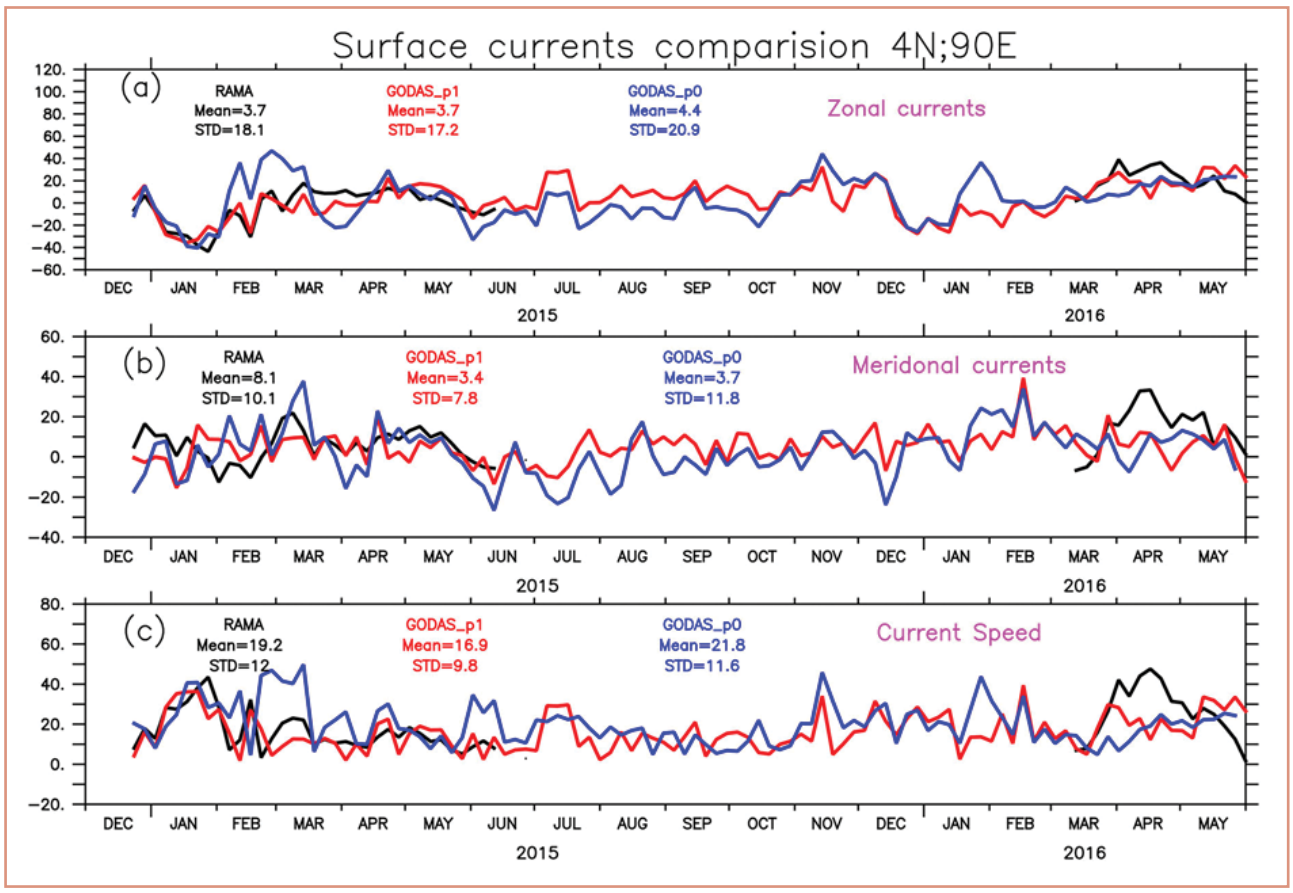


Snapshots of the 30–90-day filtered OLR (shaded, W/m^2) and wind stress with magnitude more than 0.02 dyn cm^{-2} (vector; every 4th vector is plotted) for the day when the strength of the convection and associated wind field is maximum and strong WJs are seen along the EIO.

Ref: Prerna, S., Chatterjee, A., Mukherjee, A., Ravichandran, M., Shenoi, S.S.C., Wyrtki Jets: Role of intraseasonal forcing (2019) Journal of Earth System Science, 128 (1), art. no. 21.

8.8 Improved ocean analysis for the Indian Ocean

The National Centers for Environmental Prediction (NCEP) and the Indian National Centre for Ocean Information Services (INCOIS) produce global ocean analyses based on the Global Ocean Data Assimilation System (GODAS). This system uses a state-of-the-art ocean general circulation model named modular ocean model (MOM) and the 3D-Variational (3DVar) data assimilation technique. INCOIS-GODAS operational analysis products with an upgrade of the physical model from MOM4p0d to MOM4p1 were evaluated in this paper. Two experiments were performed with same atmospheric forcing fields:(i) using MOM4p0d (GODAS_p0), and (ii) using MOM4p1 (GODAS_p1). Observed temperature and salinity profiles were assimilated in both experiments. Validation with independent observations show improvement of sea surface temperature (SST), sea surface salinity (SSS) and surface currents in the new analysis GODAS_p1 as compared to the old analysis GODAS_p0.



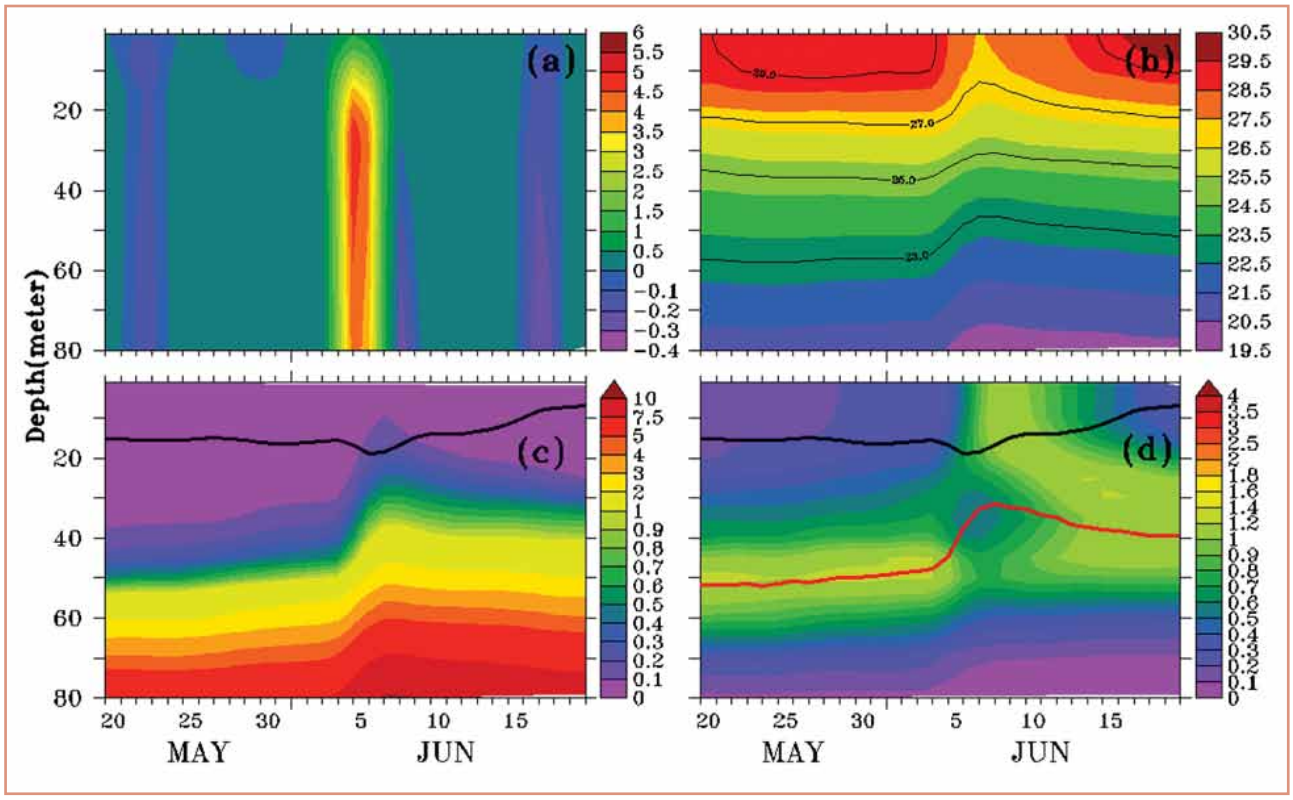
Time series of surface current (cm/s) comparisons in the eastern equatorial Indian Ocean at 90°E,4°N (a) zonal current (b) meridional current (c) current speed. Mean and Standard deviations are also mentioned in each panel for the buoy and respective analysis products.

Ref: Rahaman, H., Venugopal, T., Penny, S. G., Behringer, D. W., Ravichandran, M., Raju, J. V. S., Sengupta, D., Improved ocean analysis for the Indian ocean (2019) Journal of Operational Oceanography, 12(1), pp. 16-33.

8.9 Modeling the enhancement of sea surface chlorophyll concentration during the cyclonic events in the Arabian Sea

The response of a marine system to a tropical cyclone is often less studied due to lack of direct observations of such events. The multifold benefits of using a fully coupled physical-biogeochemical model, configured using Regional Ocean Modeling System (ROMS), in investigating the

biogeochemical response of the upper ocean to a tropical cyclone in the semi-landlocked basin of Arabian Sea in the north Indian Ocean was demonstrated in this paper. It was shown that the model manages to capture the spatio-temporal variability of the biological state variables during and after the passage of cyclones. It was also found that Ekman pumping leads to the shoaling of thermocline depth – which in turn, triggers productivity in the upper ocean by means of nutrient entrainment. The sea surface chlorophyll concentration reaches its peak approximately with the time-lag of a week after the increase in the nitrate concentration of the surface waters. The chlorophyll enhancement followed by phytoplankton bloom is dependent on the intensity of the cyclone and is inversely dependent on the translational speed of the cyclone.



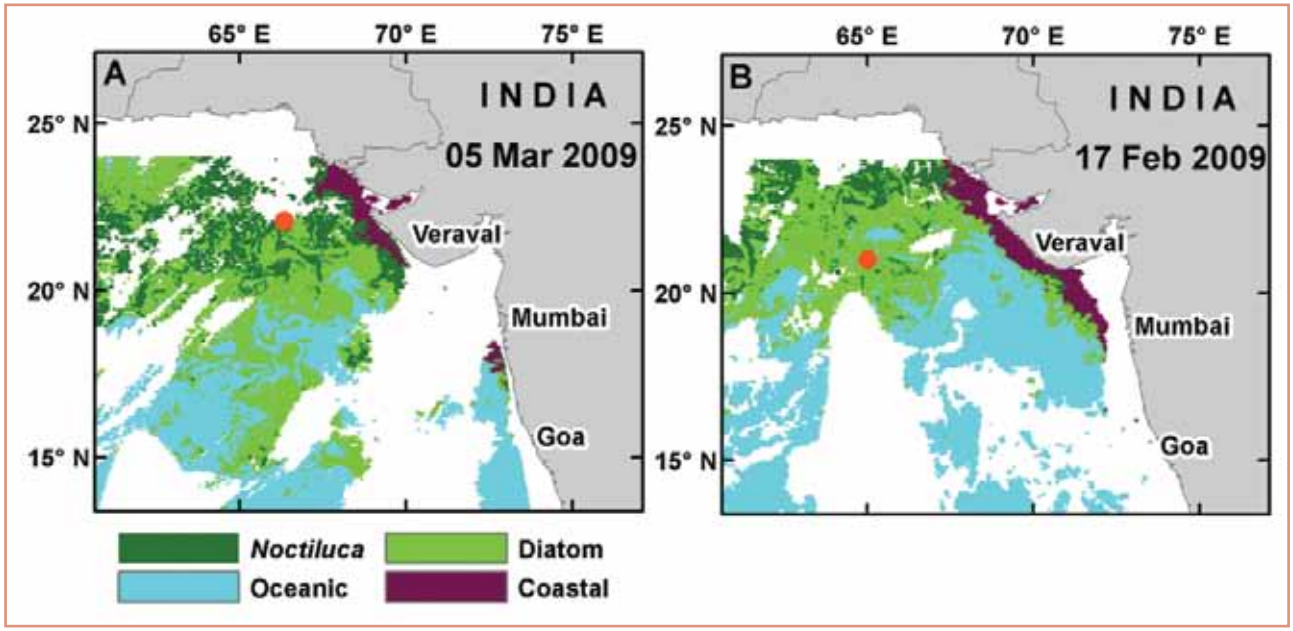
ROMS model simulated (a) Vertical current velocity (meter d^{-1}) (b) Temperature (°C) overlaid with temperature contours (c) Nitrate concentration (mMm^{-3}), and (d) Chlorophyll concentration (mgm^{-3}) concentrations, along the track of event SCS Gonu. Black line in (c) and (d) is Mixed Layer Depth (MLD). Red line in (d) is mean-depth of DCM (Deep Chlorophyll Maxima).

Ref: Chakraborty, K., Nimit, K., Akhand, A., Prakash, S., Paul, A., Ghosh, J., Udaya Bhaskar, T.V.S., Chanda, A. Modeling the enhancement of sea surface chlorophyll concentration during the cyclonic events in the Arabian Sea (2018) Journal of Sea Research, 140, pp. 22-31.

8.10 Oceanic Noctiluca blooms not associated with hypoxia in the Northeastern Arabian Sea

Intense blooms of the heterotrophic dinoflagellate, green *'Noctiluca scintillans'*, have been reported annually in the Northern Arabian Sea since the early 2000s. Although not known to produce organic toxins, these blooms are still categorized as a harmful due to their association with massive fish mortalities. Recent work has attributed these blooms to the vertical expansion of the oxygen minimum zone, driven by cultural eutrophication from major coastal cities in western India. As diatoms are preferred prey of green *'Noctiluca scintillans'*, more frequent blooms of this mixotroph will likely impact the productivity of important fisheries in the region. Shipboard measurements and data from biogeochemical-Argo floats were used to assess the relationship

between oxygen concentrations and green *Noctiluca* blooms in the Northeastern Arabian Sea and shown that regardless of the presence of a *Noctiluca* bloom, the dissolved oxygen in the photic zone was always >70% saturated, with an average oxygen saturation >90%. The variability in the relative abundance of diatoms and green *Noctiluca* is not correlated with changes in oxygen concentration. These findings provide no evidence that cultural eutrophication has contributed to the decadal scale shifts in plankton composition in the Northeastern Arabian Sea oceanic waters. Conversely, the climatic warming of surface waters would have intensified stratification, thereby reducing net nutrient flux to the photic zone and decreasing silicate to nitrate ratios (Si:N); both factors that could increase the competitive advantage of the mixotroph, green *Noctiluca*, over diatoms. If so, the decadal-scale trajectory of phytoplankton community composition in the Northeastern Arabian Sea may be a harbinger of future climate-driven change in other productive oceanic systems.

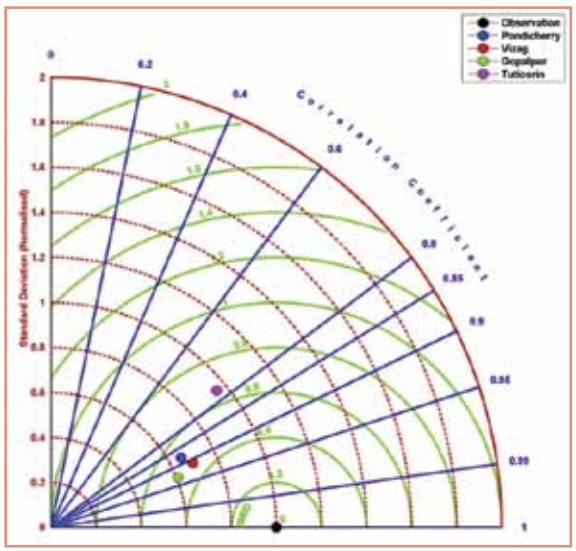


Spatial distribution of green Noctiluca, diatom, non-bloom oceanic and coastal waters derived from MODISA data on 17 February 2009 and 05 March 2009. Red solid circles denote the confirmation of a (A) green Noctiluca bloom and (B) diatom bloom using in situ data.

Ref: Lotliker, A.A., Baliarsingh, S.K., Vera L. Trainer, Mark L. Wells, Cara Wilson, Udaya Bhaskar, T.V.S., Samanta, A., Shahimol, S.R., Characterization of oceanic Noctiluca blooms not associated with hypoxia in the Northeastern Arabian Sea (2018) Harmful Algae, 74, pp. 46-57.

8.11 An operational wave forecasting system for the east coast of India

An operational wave forecasting system for the east coast of India based on Unstructured Simulating WAves Nearshore model (UNSWAN) has been described in this paper. This modelling system uses very high-resolution mesh near the Indian east coast and coarse resolution offshore, and thus avoids the necessity of nesting with a global wave model. The model was forced with European Centre for Medium-Range Weather Forecasts (ECMWF) winds and simulates wave parameters and wave spectra for the next 3 days. The spatial pictures of satellite data overlaid on simulated wave height show that the model is capable of simulating the significant wave heights and their gradients realistically. Spectral validation has been done using the available data to prove the reliability of the model. To further evaluate the model performance, the wave forecast for the entire year 2014 was evaluated against buoy measurements at 4 wave rider buoy locations. It was found that the model simulated significant wave height (Hs) are better correlated during post-monsoon



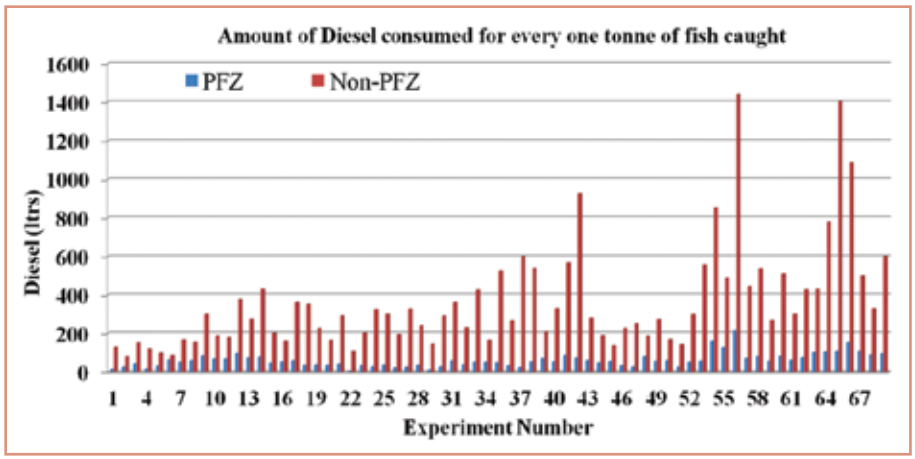
Taylor diagram of Hs (in meters) for Gopalpur, Visakhapatnam, Pondicherry and Tuticorin locations. The red colour semi-circles represent isolines of normalised standard deviation while the green colour semi circles represent those of centered root mean square difference. Blue lines represent correlation coefficient.

Ref: Sandhya, K.G., Murty, P.L.N., Deshmukh, A., Balakrishnan Nair, T.M., Shenoi, S.S.C., An operational wave forecasting system for the east coast of India (2018) Estuarine, Coastal and Shelf Science, 202, pp. 114-124.

season compared to other seasons. The variability of Hs was also the highest during this season at all locations. The wind sea component showed higher variability compared to the corresponding swell component in all locations and for all seasons. The variability was picked by the model to a reasonable level in most of the cases. The results of statistical analysis show that the modelling system is suitable for use in the operational scenario.

8.12 Environmental Benefits due to Adoption of Satellite-based Fishery Advisories

Fishing operations in India consume large amount of fuel mostly for scouting operations by vessels. The satellite based Potential Fishing Zone (PFZ) advisories have provided an effective solution for making the fishing operations more profitable by reducing search time and hence reducing fuel consumption, which in turn reduces the CO_2 emission to the atmosphere. In order to quantify the amount of reduction in the CO_2 emission, the data collected from the 69 ring seine operations off Kerala coast have been utilized. The average CO_2 emission within PFZ and outside PFZ advisories are found to be 0.161 t and 0.959 t respectively, resulting in reduction of 0.8 t. The total reduction in CO_2 emission due to usage of PFZ advisories by these 69 experiments is found to be 55.052 t. The quantification of these results clearly showed that the PFZ advisories are helpful in reducing the CO_2 emission to the atmosphere and making it environment friendly.



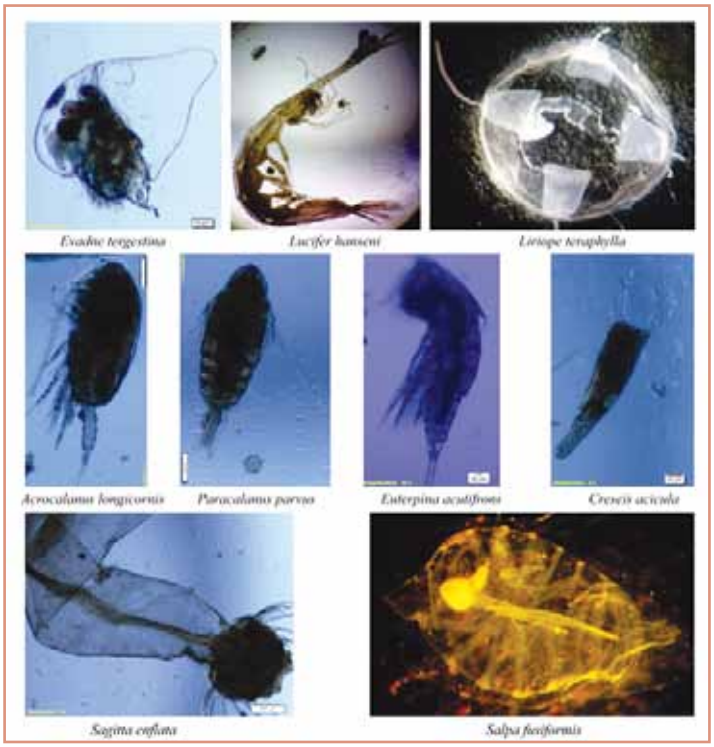
Comparison of the diesel consumed between the vessels which used PFZ and which fished randomly without using PFZ

Ref: Nagaraja Kumar, M., Nair Preetha, Pillai, V.N., Srinivasa Kumar, T., Environmental Benefits due to Adoption of Satellite-based Fishery Advisories (2018) Fishery Technology, 55, pp. 100-103.

8.13 Zooplankton Distribution in Coastal Water off Gopalpur

An interannual study on zooplankton abundance, biomass, and species composition was carried out during different seasons in two local coastal water types off Gopalpur, north-western Bay of Bengal. Although, Type-1 was observed with higher zooplankton abundance in comparison

to Type-2, pattern of variation followed similar seasonal trends in both water types during individual years. Well pronounced seasonality was observed in zooplankton distribution. Zooplankton community was composed of 217 holoplankton and 22 meroplankton. The holoplankton community was predominated by copepods in terms of species diversity and abundance followed by hydrozoa, tintinnida, malacostraca, gastropoda, chaetognatha and chordata. The meroplankton were represented by larval forms viz. bivalve veliger, brachyuran zoea larvae, caridean larvae, copepod nauplii, fish egg and gastropod veliger. Dominance of copepod species viz. *Acrocalanus longicornis, Paracalanus aculeatus and Paracalanus parvus* were observed frequently in both water types. The species richness was higher in Type-1 in comparison to Type-2 during both the years. Salinity regimes and availability of phytoplankton prey influenced the distribution and species composition of zooplankton assemblage.

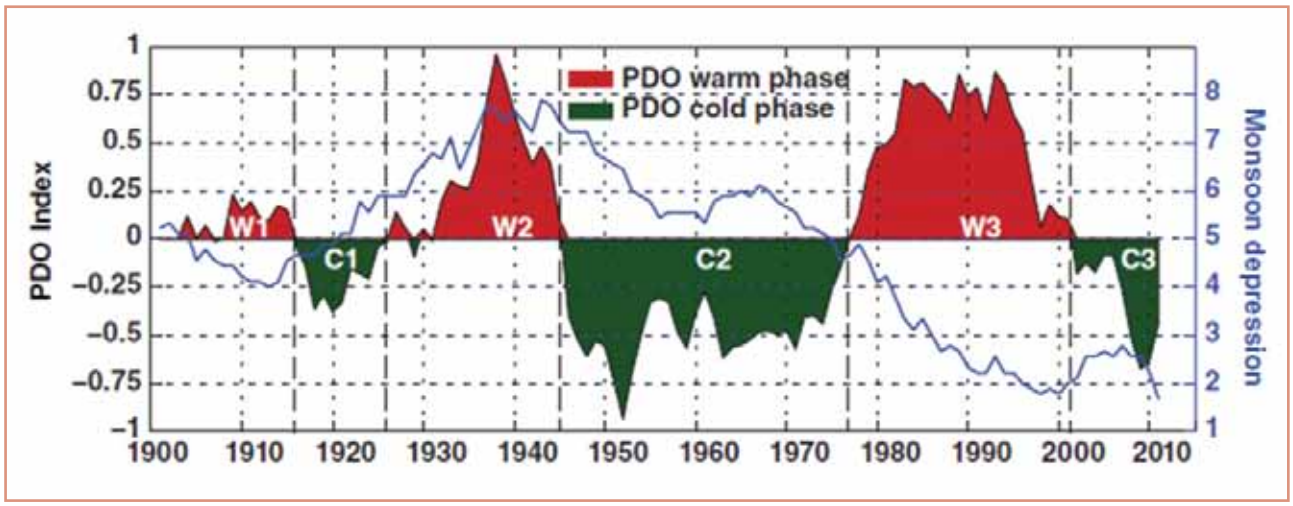


Under-microscope photographs of dominant species in coastal water off Gopalpur.

Ref: Baliarsingh, S.K., Srichandan, S., Lotliker, A.A., Kumar, T.S., Sahu, K.C., Zooplankton Distribution in Coastal Water off Gopalpur, North-Western Bay of Bengal, (2018) Journal of Ocean University of China, 17(4), pp. 879-889.

8.14 Relationship between the Pacific Decadal Oscillation and monsoon depressions

This study investigated the relationship between inter-decadal variation in the number of monsoon



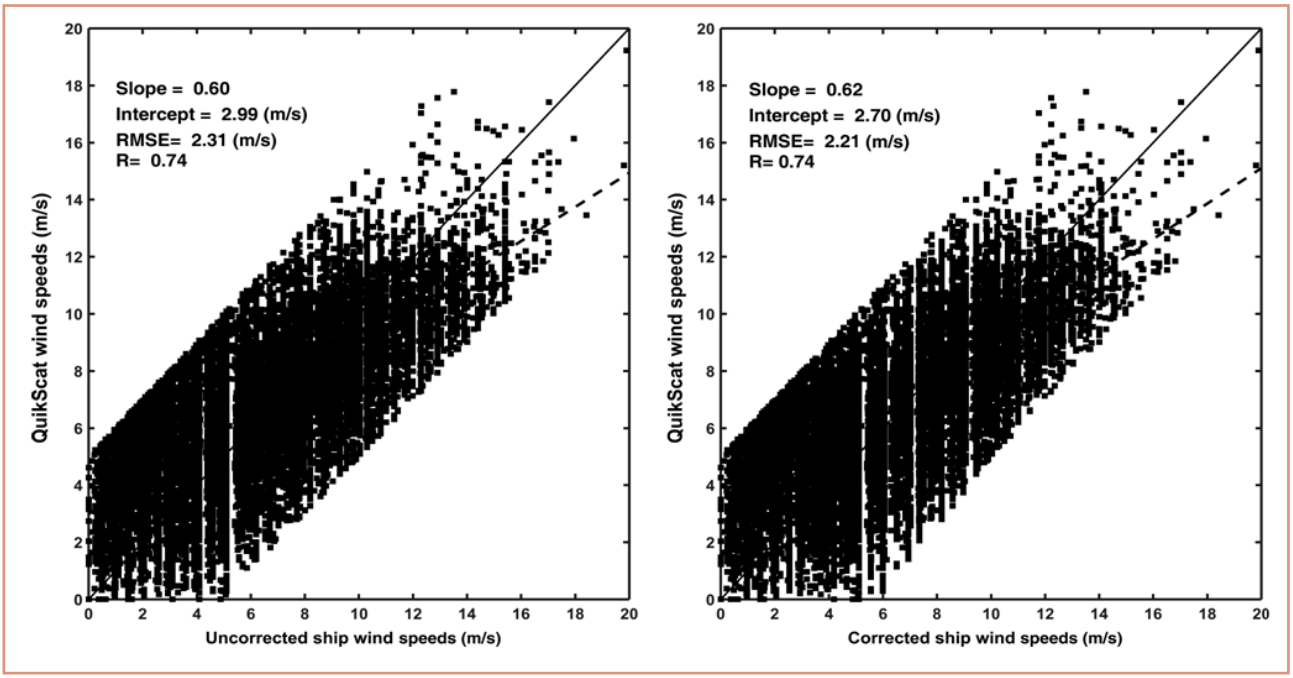
Time series of the PDO (C) index obtained from JISAO (filled). Red (green) represents the warm (cold) period of the PDO. Number of monsoon depression during the summer monsoon season is plotted (blue line; right axis). A 9-year running average is performed to extract the decadal variability.

Ref: Vishnu, S., Francis, P.A., Shenoi, S.S.C., Ramakrishna, S.S.V.S. On the relationship between the Pacific Decadal Oscillation and monsoon depressions over the Bay of Bengal (2018) Atmospheric Science Letters, 19 (7), art. no. e825.

depressions (MDs) over the Bay of Bengal (BoB) and the Pacific Decadal Oscillation (PDO). It was shown that there is an out-of-phase variation in the number of MDs over the BoB and the PDO, except during 1927–1945. Quantitative estimates of the relative contributions of individual environmental parameters showed that the variation in the mid-tropospheric relative humidity over the BoB is the primary reason for the observed variation in the number of MDs. It was further postulated that the variation in the sea surface temperature in the western equatorial Indian Ocean associated with the PDO could be one of the reasons for the changes in the moisture advection over to the BoB and hence the variation in the number of MDs in inter-decadal timescale.

8.15 Correction to Beaufort-estimated wind speeds over the Tropical Indian Ocean

The Beaufort Scale was used to estimate wind speeds (WSs) over oceans before the introduction of ship-mounted anemometers. Beaufort-estimated WSs form a major component of most historical data sets such as those of the International Comprehensive Ocean-Atmosphere Dataset (ICOADS) and data obtained from the Indian Meteorological Department (IMD). The Beaufort-estimated WSs in the individual records of the ICOADS and IMD data are based on the World Meteorological Organization (WMO) 1100 scale, which gives biased WS equivalents. Corrections to this scale have been formulated to give better estimates of the WS. In this paper, the corrections were derived explicitly for the Tropical Indian Ocean (30-100° E, 30° S-30° N) using individual records from the ICOADS and IMD unique data for the period 1985-2005. There is significant improvement in the agreement between Beaufort estimates and the anemometer-measured WSs based on these corrections. The regression coefficients for the new scale are derived using annual and monthly data. The correction scale derived, which is based on the regression coefficients for July (July scale), gives less bias compared with the scales of other months. The slope differs by almost 17% when the new July scale is applied to the annual data when compared with the Da Silva scale; the bias showed a reduction from 0.52 to 0.08 m/s.

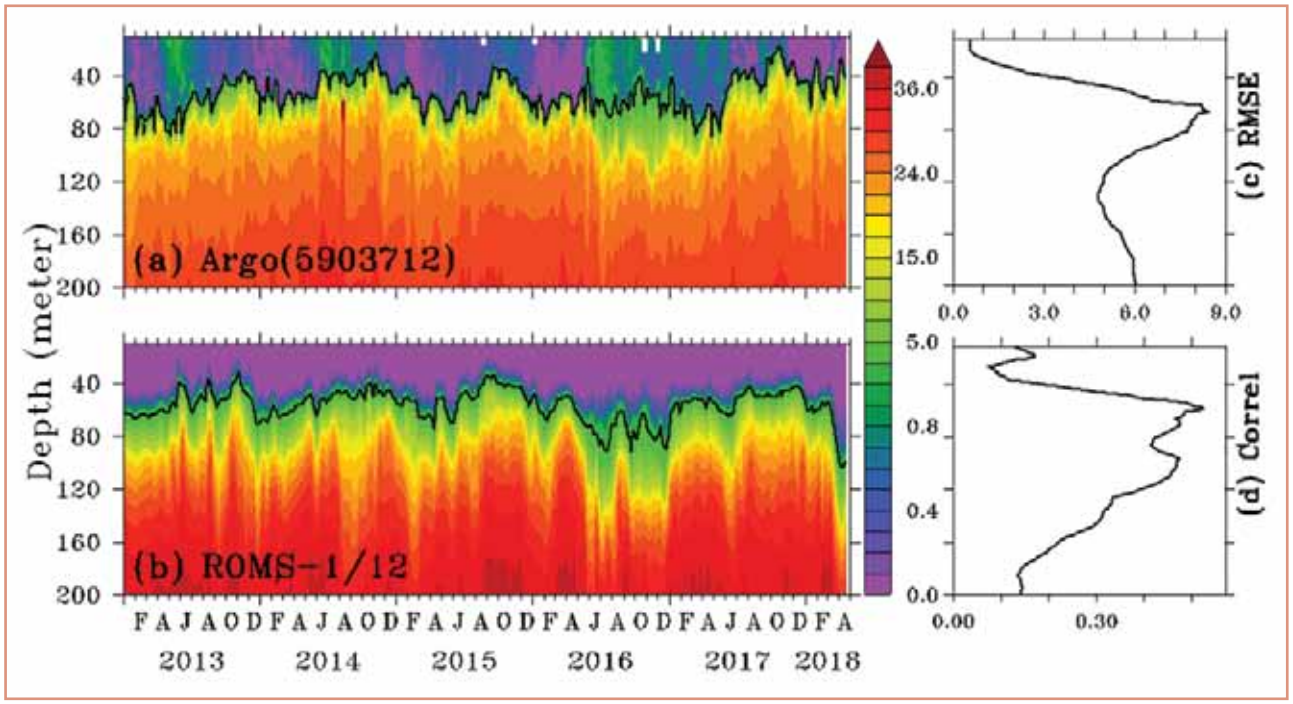


Comparison between QuikSCAT and ship-based wind speeds (m/s)

Ref: Kameshwari, N., Udaya Bhaskar, T.V.S., Pattabhi, R.R.E., Jampana, V. Correction to Beaufort-estimated wind speeds over the Tropical Indian Ocean (2018) Meteorological Applications, 25 (4), pp. 642-654.

8.16 Assessment of model-simulated upper ocean biogeochemical dynamics of the Bay of Bengal

The capability of a physical-biogeochemical model configured using Regional Ocean Modeling System (ROMS) in simulating upper ocean biogeochemical dynamics of the Bay of Bengal (BoB) was evaluated with available remote sensing and in situ observations for the period March 2008 to November 2015. Model-simulated chl-a showed better correlation (R^2 = 0.80) with the in situ observations as compared to that retrieved from satellite (R^2 = 0.72). Although, the model underestimates chl-a (slope = 0.84), significant correlation proves its capability to reproduce the in situ trend. The root mean square error (RMSE) between model simulated and satellite retrieved chl-*a* against measured chl-a are 0.33 and 0.36, respectively. Additionally, a comparison with remote sensing time series data indicated that the model realistically simulated the seasonal variability of chl-a. Further, temperature, salinity, nitrate, chl-a and dissolved oxygen (DO) profiles obtained from two biogeochemical Argo floats deployed in the central BoB, were also compared with model-simulated profiles. In comparison, the model adequately simulated the observed subsurface variability of chl-a as well as persistent Deep Chlorophyll Maximum (DCM) at depths between 20 and 90 m having concentration 0.75–1.0 mg-m^{-3}. The undulations in the subsurface spatial variability of chl-a were appreciably well captured by the model and comparable with the observations albeit the magnitude is overestimated in the model.



Time-series of nitrate (mM/m^3) profiles obtained from (a) bio-Argo float (5903712) and (b) ROMS-1/12°. In the panel (a) to (b) black line represents depth of nitracline (m) characterized as<2 mM/m^3 nitrate concentration. Depth-wise statistics of nitrate at bio-Argo float locations

Ref: Chakraborty, K., Lotliker, A.A., Majumder, S., Samanta, A., Baliarsingh, S.K., Ghosh, J., Madhuri, P.P., Saravanakumar, A., Sarma, N.S., Rao, B.S., Shanmugam, P. Assessment of model-simulated upper ocean biogeochemical dynamics of the Bay of Bengal (2019) Journal of Sea Research, 146, pp. 63-76.

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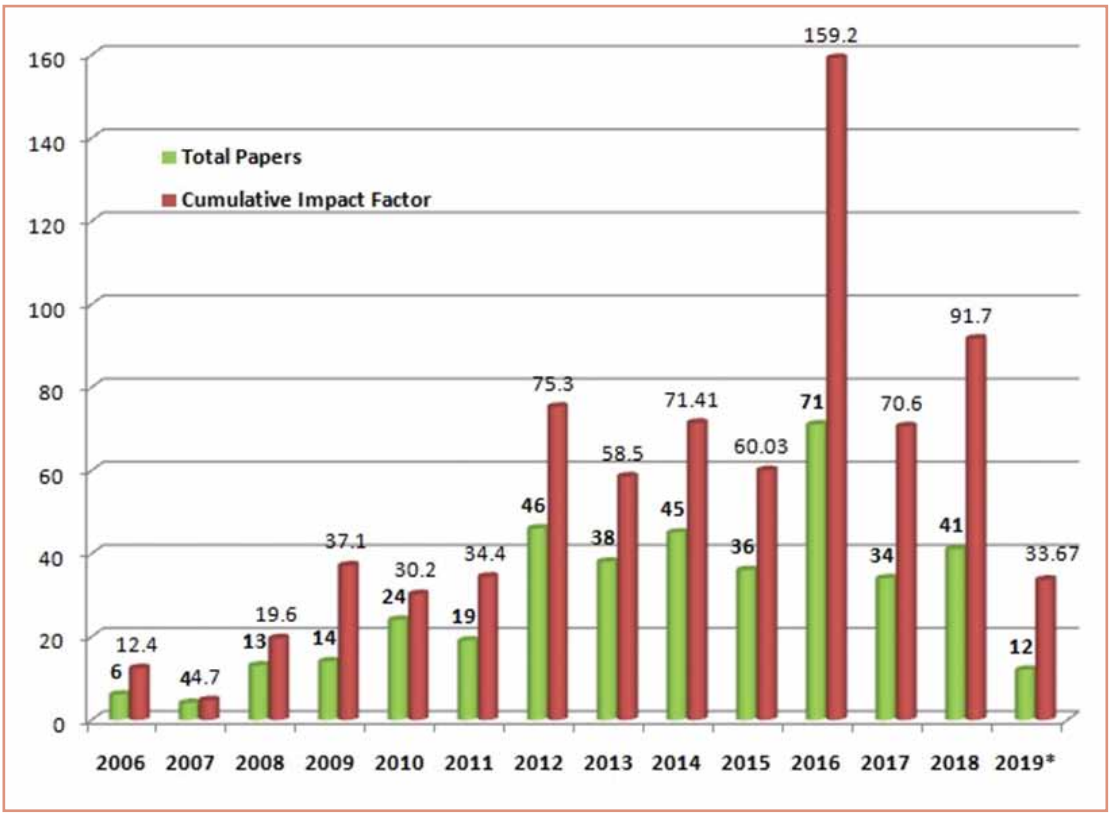

Growth of publications in SCI journals from INCOIS and their cumulative impact factor.

9. Capacity Building and Training

9.1. Inauguration of ITCOocean Building

In order to cater to increased infrastructure requirements the International Training Centre for Operational Oceanography (ITCOocean), which was upgraded as a Category 2 Centre of UNESCO in November 2017, a full-fledged facility consisting of an academic building and international guest house was constructed on the INCOIS campus. Dr. Harsh Vardhan, Hon'ble Minister for Science & Technology, Earth Sciences, Environment and Forests & Climate Change, inaugurated the newly constructed ITCOocean Complex on 22 December, 2018 and dedicated it to the memory of Former Prime Minister Shri Atal Bihari Vajpayee who contributed significantly to the growth of science and technology in the country. On the occasion, the academic building was named as Atal Bhavan and the Guest House as Atal Atithi Griha.

9.2. Training programmes conducted by ITCOocean

During the past year, ITCOocean conducted 10 training courses of duration 1 to 2 weeks. Two hundred and fifteen (215) trainees from 29 countries including India attended the courses. The number of courses conducted by ITCOocean since its inception in mid-2013 till the end of 31 March 2019 stands at 36 and the total number of trainees at 922 drawn from 48 countries including India. All trainees were issued with certificates of participation and course completion.

- The ITCOocean, INCOIS-Ocean Teacher Global Academy (Intergovernmental Oceanographic Commission) Training Course on "Discovery and Use of Operational Ocean Data Products & Services" was held during 18-22 June 2018, at INCOIS. Twenty-five trainees from India, Maldives, Malaysia, Indonesia, Kenya, Sri Lanka, Bangladesh, Philippines, China Indonesia, Tanzania, Vietnam, Mauritius attended the course. Seven of them joined the course online utilizing the capabilities of the e-class room at INCOIS.
- A course on" Operational Ocean Services, Data and Data Products" specifically for the Indian Coast Guard Officers was conducted during 18-19 September 2018. Eighteen officers from Indian Coast Guard attended the course.
- International training course on "Data Visualisation of Marine Met data (using FERRET)"

was conducted in collaboration of OTGA-IOC during 27-31 August 2018. Twenty-five participants attended this course from Malaysia, India, Mauritius, Vietnam, Bangladesh, Sri Lanka, Philippines, Iran, Thailand and Fiji.

- A training course on "Fish-catch Time-Series Forecasting with R" was held during 24-28 September 2018. This training course focused on forecasting fisheries catch time-series and documentation with R statistical software, creating codes to enable the participants to create their own products. Twenty-eight participants from various national institutes attended the course. Dr. Elizabeth Holmes from National Oceanic and Atmospheric Administration (NOAA), USA was the main tutor for this training programme. Other faculty members were scientists from Centre for Marine Living Resources and Ecology, Kochi and INCOIS.
- International training course on "Geospatial Techniques for Coastal Mapping and Monitoring (Using QGIS)" in collaboration with OTGA-IOC during 26-30 November 2018. There were 37 participants from India, Iran, Egypt, Oman, Indonesia, Philippines, Kenya, Vietnam, Saudi Arabia, Sri Lanka, Bangladesh, Singapore, Tanzania and Thailand. The faculty members for this course were drawn from INCOIS.
- "Training for International Seabed Authority Trainers" was held during 10-21 December 2018. Faculty members for this course were drawn from INCOIS, NGRI, NRSC and University of Hyderabad. Five participants were from Brazil, Sri Lanka, Mauritius, Somalia and Cameroon.
- INCOIS Operational Services Training for Indian Navy Officers (SNOM-Advanced Oceanography Course) was conducted during 21-23 February 2019 to provide exposure to

Indian Navy officers about various products and services provided by INCOIS for operational requirements. One Commander and 4 Lieutenant Commanders from School of Naval Oceanology and Meteorology (SNOM), Kochi attended the training. Faculty members were from INCOIS.

- Training course on "Marine Phytoplankton-optics, pigment and taxonomy" was conducted during 25-29 March 2019. Eighteen participants from various national institutes and universities across India participated in this course.
- A two-day training organised on the use of Ocean State Forecast products and PFZ advisories for NGO Trainers (who cater mainly to the fishing community) in collaboration with MS Swaminathan Research Foundation (MSSRF) during 4-5 October 2018.
- Training on "the Utilization of Services from INCOIS" was conducted for Indian Air Force Trainee Officers on 10 October 2018. Five Met-trainee officers along with their Trainer from Air Force Academy, Dundigal and two Sri Lankan Air Force personnel attended the training.

9.3. Lectures and Symposia

- Dr. M.R.K Prabhakar Rao, Former Scientist 'G', National Geophysical Research Institute (NGRI) delivered a lecture on "Maths and Physics in Indian Classical Music" on 25 March, 2019.
- Prof. Raghu Murtugudde, Professor, CMNS-Atmospheric & Oceanic Science, University of Maryland made a presentation on "Water quality monitoring and forecasting: Need and Challenges" on 22 March 2019.
- Prof. Eric D'Asaro, Professor, School of Oceanography, Washington University delivered two lectures on "Measuring Mixing in the Ocean-Part 1- Microstructure" & "Part 2- Internal Waves" during 27-28 February 2019.
- Dr. Manita Chouksey, Post Doctoral Research Fellow, University of Hamburg delivered a lecture on 'Disentangling gravity waves from balanced flow' on 8 January 2019.
- Dr. Atmaram, Assistant Professor, Hindi Department, University of Hyderabad delivered a lecture on "How to Work in Hindi on Computer" on 18 December 2018.
- Prof. Craig Lee, University of Washington delivered a lecture on "Air-Sea Interaction, Circulation and Upper Ocean Dynamics in the Arabian Sea" on 22 November 2018.
- Prof. Debasis Sengupta, Chairman, Centre for Atmospheric and Oceanic Sciences, Indian Institute of Science, Bengaluru delivered a lecture on "Space-time scales of Bay of Bengal Salinity" at INCOIS on 11 October 2018.

- Prof. Charitha Pattiaratchi, Professor, Oceans Graduate School & The Oceans Institute, The University of Western Australia delivered two lectures on "Sea level variability: from surface gravity waves to mean sea level" and "Sustained coastal ocean observations in south-west Australia" during 28-29 June 2018.
- Dr. Sunita H. Khurana, Director, Institute of Secretariat Training and Management, DoPT, Govt. of India, New Delhi delivered a lecture and also conducted a special interaction session on "Redressal of complaints from women under Sexual Harassment of Women at Workplace Act -2013" on 13 April 2018.

9.4. Workshops and conference

- The "National Oceanography Workshop (NOW) 2018" was organized during 14-16 November 2018. Major themes of the workshop were (1) Numerical modeling of Ocean circulation, waves and storm surges, (2) Oceans and Climate, (3) Ocean Data Assimilation, (4) Marine biogeochemistry and ecosystem modeling and (5) Ocean process studies. Over 130 participants from various institutions across the country participated and presented research papers. The conference had 54 invited talks by experts and 65 poster presentations by students and early career scientists.
- A 2- day national conference on "Integrating Biogeochemistry and Ecosystems in a Changing Oceanic Environment" was conducted at the KUFOS-INCOIS Joint Research Centre during 17-18 January 2019. Over 130 participants from various institutions across the country participated and presented the research papers. The conference had 13 invited talks by

experts, 8 oral presentations by researchers and 26 poster presentations by students and early career scientists. The invited talks covered various aspects of biogeochemistry, ocean modelling and fisheries.

- INCOIS hosted a 2-day NOAA-ONR-MoES workshop during 25-26 February 2019 to explore collaborative observations and research of the Arabian Sea. The workshop involved discussions on identification of scientific questions that require new observations, common areas of interest, implementation of joint oceanographic observation campaign in the Arabian Sea so that the ocean circulation and air-sea interaction processes that influence the Asian Monsoon can be understood better. Around 20 scientists from institutions under Ministry of Earth Sciences (MoES) and other Indian institutions (Indian Institute of Science, IIT-Bhubaneswar, IIT-Delhi, University of Hyderabad) attended the workshop and held discussions with 9 members from National Oceanographic Atmospheric Administration (NOAA), USA, Office of Naval Research (ONR), USA and other US institutions (Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, University of Washington, University of Massachusetts, Dartmouth).

- INCOIS, in association with Vidyasagar University, organized a two-day national workshop on "Operational oceanography to serve coastal community of West Bengal" at Digha, Purba Medinipur, West Bengal during 29-30 March 2019. The workshop focussed on increasing awareness among the stake holders of INCOIS services and to sensitize the scientific and

academic community on the necessity of Operational Oceanography for a sustainable future. The workshop was inaugurated by Prof. Ranjan Chakraborty, Vice-Chancellor of Vidyasagar University. Dr. T.M. Balakrishnan Nair, Scientist G and Head of ISG, INCOIS delivered the key note speech on INCOIS services and its uniqueness. A scientific session was also conducted during the workshop in which the invited speakers lectured on various aspects of Operational Oceanography for the betterment of seafarers in West Bengal.

10. International Interface

10.1 IOGOOS Secretariat

The Indian Ocean Global Ocean Observing System (IOGOOS) regional alliance provides a collaborative platform for sustained ocean observations as part of the Global Ocean Observing System (GOOS). It covers the aspects related to physical, biogeochemical, biological and climate related observations and modelling. Twenty-nine institutions from 17 countries are members of IOGOOS. Shri. M. Nagaraja Kumar, Scientist-E, ISG serves as Secretary of IOGOOS and INCOIS continues to host the Secretariat that coordinates related activities. Dr. S.S.C. Shenoi, Director, INCOIS having been elected as chair of IOGOOS in 2017, has been endorsed to continue till November 2020.

The 15th annual meeting of IOGOOS was held at Port Elizabeth, South Africa as part of the "International Indian Ocean Science Conference -2019" during 11-25 March 2019. The meeting was held in conjunction with the meetings of allied projects such as Indian Ocean Research Panel (IORP), Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER), Indian Ocean Observing System (IndOOS) Resources Forum (IRF) and International Indian Ocean Expedition (IIOE-2). Representatives from India, Thailand, Indonesia, IOC, Mauritius and USA participated in the meeting. IOGOOS Secretariat, through the sponsorship funds provided by IOC/UNESCO, facilitated the sponsorship of 3 delegates to participate in these integrated meetings.

10.2 International Oceanographic Data Exchange

The programme "International Oceanographic Data and Information Exchange" (IODE) of the Intergovernmental Oceanographic Commission (IOC) of UNESCO focuses on enhancing marine research, exploitation and development, by facilitating the exchange of oceanographic data and information between participating member states. INCOIS was designated in 2004 by IODE as the responsible National Oceanographic Data Centre (NODC) for India. Shri. E. Pattabhi Rama Rao Scientist-F, Head ODG and TWG is the National Coordinator from India for 'Data Management' under the IODE Programme. He additionally serves on the Steering Groups of Ocean Biogeographic Information System (SG-OBIS) and IODE Quality Management Framework (SG-IODE QMF).

10.3 OceanSITES

OceanSITES is a global time-series programme and a recognized component of the Global Ocean Observing System as well as part of the international JCOMM. INCOIS has been designated as OceanSITES Data Assembly Centre (DAC). Shri. E. Pattabhi Rama Rao, Scientist-F, Head ODG and TWG, represents INCOIS on the OceanSITES Data Management Team which has developed the data management system with appropriate standards, formats and quality controls related to the time-series data from oceans.

10.4 Partnership for Observation of the Global Oceans (POGO)

INCOIS continued to be a member of POGO which is a forum created in 1999 by the Directors and leaders of major oceanographic institutions around the world to promote global ocean observations and research. POGO particularly focuses on the implementation of an 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, non-profit registered with the United Nations, aiming to provide regional early warning services and to build the capacity of its Member States in end-to-end early warning of tsunamis and hydro-meteorological hazards. Heads and representatives of National Meteorological and Hydrological Services (NMHSs) and national scientific and technical agencies that generate early warning information for different hazards in Afghanistan, Bangladesh, Bhutan, Cambodia, Comoros, Djibouti, India, Kenya, Lao PDR, Madagascar, Maldives, Mongolia, Mozambique, Myanmar, Nepal, Papua New Guinea, Philippines, Seychelles, Sri Lanka, Sudan, Thailand, Timor-Leste, Tonga and Yemen, met from 13-14 November 2018 in Pathumthani, Thailand to update the portfolio of products and services available from RIMES and to receive feedback on the usefulness and benefits of these products and services for better managing resources in climate-sensitive sectors and in building hazard-resilient communities. They also discussed how these products and services could be scaled for other member states and collaborating states to meet specific user demands. The council appreciated the efforts of INCOIS along with those of IMD, NCMRWF and ECMWF for continuous support and for extending technical assistance to RIMES member and collaborating states, and in implementing Master Plan priorities to build national integrated multi-hazard early warning systems.

As per the MoU between MoES, Govt. of India and RIMES for provision of forecast services to RIMES member countries, INCOIS continues to extend the ocean forecasting services for Comoros, Madagascar, and Mozambique along with Seychelles, Sri Lanka and Maldives.

10.6 The Indian Ocean Observing System (IndOOS)

The Indian Ocean Observing System (IndOOS) was implemented to improve understanding of Indian Ocean processes with reference to the global climate change. India is a major contributor in the implementation of Indian Ocean observing systems. Other major contributors are US, Japan, Australia. The IndOOS Review Workshop was held at Port Elizabeth, South Africa during 11-15 March 2019 in conjunction with the "International Indian Ocean Science Conference – 2019". Dr. S.S.C. Shenoi, Director, INCOIS, Shri M. Nagaraja Kumar Scientist 'E' and Satya Prakash Scientist 'E' participated in this workshop.

10.7 SIBER International Programme Office

INCOIS has been hosting the Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) programme office since 2010. The office manages the organisation of annual Science Steering Committee (SSC) meetings and sharing of online updates along with management of the SIBER website. INCOIS is represented at SIBER by Dr. Satya Prakash, Scientist 'E', ISG, who also manages the programme office. The 9th annual meeting of SIBER was held at Port Elizabeth, South Africa during 11-15 March 2019.

10.8 International Indian Ocean Expedition-2 (IIOE-2)

The Second International Indian Ocean Expedition (IIOE-2) is a major global scientific initiative co-sponsored by Intergovernmental Oceanographic Commission (IOC), the Scientific Committee on Oceanic Research (SCOR) and the Indian Ocean Global Observing System (IOGOOS), with INCOIS serving as one of the two Joint Programme Offices (JPOs). Dr. Satheesh Shenoi, Director, INCOIS serves as one of three co-chairs of the IIOE-2 Steering Committee and Dr. Satya Prakash, Scientist 'E', ISG, serves the JPO-India coordinator. INCOIS continued to publish the half-yearly newsletter of IIOE-2, "The Indian Ocean Bubble-2". In addition, INCOIS also publishes the IIOE-2 monthly newsletter, which provides regular updates on the activities of IIOE-2. The 3rd meeting of the Steering Committee of IIOE-2 was held at Port Elizabeth, South Africa during 11-15 March 2019. Dr. Satheesh Shenoi, Director, INCOIS and Dr. Satya Prakash, Scientist-E, ISG and JPO-India coordinator, attended this meeting. An important outcome of the meeting was the unanimous agreement by the Steering Committee on the continuation of IIOE-2 at least up to 2025 to achieve its proposed goals.

10.9 GODAE Ocean View

GODAE Ocean View is a group of scientists representing agencies which provide operational ocean forecasts and manage in situ and remote sensing observation platforms. This forum provides an excellent platform for these scientists to exchange their experiences and collectively carry out inter-comparison exercises of various ocean forecast and analysis products. INCOIS has been part of this group since October 2010 as a member of the science team (GOVST). Dr. Abhisek Chatterjee, Scientist-D, MDG represents INCOIS in the GOVST. From July 2013 onwards, Director, INCOIS serves as a member of the Patrons' Group of GODAE Ocean View which is responsible for guiding the GODAE Ocean View Science Team to attain various targets and for supporting the project office established in the UK Met Office.

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

The Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) established by the Intergovernmental Oceanographic Commission (IOC) coordinates the implementation of the Indian Ocean Tsunami Warning and Mitigation System.

The Indian Tsunami Early Warning Centre (ITEWC) at INCOIS serves as one of the Regional Tsunami Service Providers for the Indian Ocean. The 12th Session of ICG/IOTWS was held during 9-12 March 2019 at Kish Island, Iran. Shri. E. Pattabhi Rama Rao Scientist-F, Head-ODG and TWG, and Shri. Ch. Patanjali Kumar, Scientist-E attended this meeting. Shri. E. Pattabhi Rama Rao was elected as the Vice-Chair for the ICG/IOTWMS while Shri. Ch. Patanjali Kumar was elected as Vice-Chair for the Working Group-2 (WG-2) on Tsunami Detection, Warning and Dissemination, and Smt. M.V. Sunanda was elected as Vice-Chair for Sub Regional Working Group for the North West Indian Ocean (WG-NWIO).

INCOIS scientists have also been nominated as members for various Working Groups (WG) and Task Teams (TT) of ICG/IOTWMS. Shri. R.S. Mahendra and Shri. B. Ajay Kumar are members in Working Group-1 (WG-1) on Tsunami Risk, Community Awareness and Preparedness while Shri. J. Padmanabham is a member in WG-2, and Dr. Dipankar Saikia is a member in WG-NWIO. Also, Shri. Ch. Patanjali Kumar is member in TT for Scientific Hazard Assessment of the Makran Subduction Zone, Ms. M.V. Sunanda is member in TT for Tsunami Preparedness for a Near-Field Tsunami Hazard, and Shri. B. Ajay Kumar is a member in TT for the Exercise Indian Ocean Wave 2020.

11. General Information

11. 1 Official Visit of Hon'ble Vice President of India

Shri. M. Venkaiah Naidu, Hon'ble Vice President of India, visited INCOIS campus facilities on 13 July 2018. Shri Md. Mohamood Ali, Deputy Chief Minister, Revenue, Relief & Rehabilitation, ULC, Stamps & Registration, Govt. of Telangana, Shri. Vipin Chandra, Joint Secretary, MoES, Govt. of India and Dr. M. V. Reddy, IAS, Collector, Medchal-Malkajgiri District accompanied him on the occasion. During the visit, Hon'ble Vice-President addressed the staff of INCOIS, delegates from 18 Indian Ocean Rim countries, who were attending the 2nd ICG/IOTWMS Integrated Intersessional Meetings at INCOIS and other guests from nearby institutions such as NGRI and Hyderabad Central University. He emphasized the need to further the country's progress by concentrating on 'Education, Scientific Development and Assistance to Agricultural Sector'. Hon'ble Vice President complimented INCOIS for making its services accessible for the benefit of society and mitigation of natural calamities and following the principle of information with confirmation.

11.2 Superannuation

Shri K.K.V. Chary, Dy. C.A.O. superannuated on 30 June 2018. He completed over 17 years of service at INCOIS having been a great support to the institute since its inception and formative years. He was fondly felicitated at a special farewell function in the presence of his family members. Staff members addressed him and shared their memories and experiences of working with him.

11.3 ESSO-INCOIS Foundation Day

On the occasion of the 20th foundation day celebrations of INCOIS, Padma Bhushan, Dr. K. Radhakrishnan, Honorary Distinguished Advisor, Department of Space/ISRO, Former Chairman, ISRO & Former Director, INCOIS delivered the Foundation Day Lecture on "Human Space Flight Emerging Scenario" on 4 February 2019. The Regional Analysis for the Indian Ocean (RAIN) and the upgraded Indian Ocean Forecast System were inaugurated on the occasion. Additionally, a school-level quiz on the theme 'Explore our Ocean' was organized in which 6 schools (7-9 Std teams) participated and over 465 school and college students attended the "Open House" organized on 4th & 8th February 2019 as part of the celebration.

11.4 Awards and Honours

11.4.1 Ministry of Earth Science Awards

- Dr. S.S.C. Shenoi, Director, ESSO-INCOIS was awarded the *National Award for Excellence in Ocean Science & Technology* – 2018 for his outstanding scientific contributions in the field of Ocean Science and Technology. The award was handed over on the MoES foundation day celebrations held at Vigyan Bhawan, New Delhi on July 27, 2018.
- Dr. B. Praveen Kumar, Scientist-D was awarded the *Young Researcher Award-2018* for his outstanding research contributions in the field of Earth System Science.
- Dr. M. S. Girish Kumar, Scientist-D was awarded the *Certificate of Merit* for his outstanding contributions in ocean science.
- Mr. Sidhartha Sahoo, Scientific Assistant-B, INCOIS was awarded the *Best Employee Award* for his outstanding contributions in the management of scientific information services.

11.4.2 Rajbhasha Pradip and Prayag Puraskar

- Dr. S.S.C. Shenoi, Director, INCOIS was honoured with Rajbhasha Pradip Puraskar and Shri. K. K. V. Chary, Dy. Chief Administrative Officer, INCOIS was honoured with Rajbhasha Parishad Puraskar, by Vigyan Parishad Prayag, Jodhpur Branch, for promoting the usage of Hindi in INCOIS.

11.4.3 Indian National Science Academy (INSA)

Dr. Kunal Chakraborty was selected as a member of *Indian National Young Academy of Science (INYAS)* for five years with effect from 1 January 2019.

11.4.4 Telangana Academy of Sciences Fellowship/Awards

- Dr. Francis P. A., Head & Scientist-E elected as *Fellow* of Telangana Academy of Sciences.
- Dr. Remya P.G, Scientist-C selected for *Young Scientist* Award by Telangana Academy of Sciences for the year 2018.

- Dr. Kunal Chakraborty, Scientist-D elected as *Associate Fellow* of Telangana Academy of Sciences.
- Dr. Girish Kumar MS, Scientist-D elected as *Associate Fellow* of Telangana Academy of Sciences.

11.4.5 IGU Grant

Ms. Jayashree Gosh, JRF, INCOIS was selected for *'Anni Talwani Memorial Grant for Women Researchers for the year 2018 of Indian Geophysical Union (IGU)'*. IGU provided her financial support to participate in the the 55th Annual Convention of IGU-2018 on "Changing Water Cycle and Water Resources" to be held RNTU, Bhopal during December 5-7, 2018.

11.5 INSA Remote Area Lecture

Dr. Kunal Chakraborty, Scientist-D, INCOIS and INSA Young Associate delivered lectures on "How Data & Technology Makes Our Life Easier at the Sea" as part of the Indian National Science Academy's programme of lectures in remote/rural areas at Ramnagar College and Khejuri College, Purba Medinipur district, West Bengal during 4-5 December, 2018. The Rural Eco-Development Centre (REDC) extended their help towards arranging the lectures in the remote colleges of West Bengal.

11.6 INCOIS Scientific Films

With an aim to popularise INCOIS services among the public and users, 8 scientific short films, showcasing INCOIS services and products, were produced. These documentaries were prepared for durations of 5 minutes and 1 minute. The themes of the films are (a) Tsunami Early Warning Services, (b) Ocean State Forecast Services (c) Potential Fishing Zone Services and (d) General Activities of INCOIS. All films are translated in 8 languages (Tamil, Telugu, Bengali, Odia, Malayalam, Kannada, Marathi and Gujarati) spoken in the Indian coastal states, in addition to English and Hindi versions.

The films were released by Dr. M. Rajeevan, Secretary, Ministry of Earth Sciences, Government of India on 26 April 2018 during the MoES mid-year review meeting held at Hyderabad. The films

were duly made accessible on the INCOIS website at https://incois.gov.in/hrd/isdf/index.jsp and on INCOIS social media accounts (YouTube, Facebook and Twitter) to facilitate easy viewing and downloading.

11.7 Visitors

More than 4800 persons including 520 national and international government officials visited INCOIS during 2018-19. To ensure awareness about INCOIS activities, products and services, special Open House Programmes were organized. These included 2-day programmes celebrating MoES Foundation Day (25 & 27 July 2018), India International Science Festival-IISF (18 & 20 September 2018), Tsunami World Awareness Day (3 & 5 November 2018) and INCOIS Foundation Day (4 & 8 February 2019). During these events, student competitions like model-making and quizzes were also conducted. On request, visits were also arranged for several groups of school and college students.

Additionally INCOIS participated in three prominent Expos (IISF Expo in Lucknow, India Science Congress-Pride of India Expo in Jalandhar, Punjab and World Ocean Science Congress Expo in Kochi) to showcase the services and products for visitors through posters, model displays and live interaction.

11.8 Promotion of Hindi

The Official Language Implementation Committee of INCOIS organized four meetings of the committee to review the progress and plan the activities, three seminars and a special programme

during the *Hindi Pakhwara* celebration during 1-14 September 2018. A Hindi Training Programme was also conducted during the year.

Hindi Seminars

- "Plastic Pollution and Our life" - Dr. D.D. Ozha, Senior Scientist and Member of Hindi Advisory Committee, MoES, Government of India on June 05, 2018.
- "How to Work in Hindi on Computer" - Dr. Atmaram, Assistant Professor, Department of Hindi, University of Hyderabad on December 18, 2018.
- "Maths and Physics of Music" - Dr. M.R.K Prabhakar Rao, Former Scientist 'G', NGRI, on March 25, 2019.

Hindi Pakhwara

A Hindi Pakhwara programme was conducted during 1-14 September 2018. The programme included competitions on essay writing, extempore speech, power point presentation, etc. for the staff. A special elocution competition was also conducted for the children of INCOIS staff. As a part of the celebration, a special event was also organized on 11 September 2018. Dr. Koshalya, Former Assistant Director and In-charge, Hindi Teaching Scheme, Hyderabad was the Chief Guest at the function. Winners of Hindi essay, elocution, extempore and the other competitions were felicitated at the event.

Department of Official Language, Ministry of Home Affairs, Hindi Teaching Scheme, Hyderabad conducted two training sessions for Hindi at INCOIS. Shri Shivanand Kalekar, Hindi Professor, Hindi Teaching Scheme, Hyderabad was the faculty for these sessions. The first session was during January- May 2018 and 44 regular employees attended the Hindi Pragya examination on

22 May 2018 in which 43 members passed with first class and one with second class. The second session (July-November) started in the first week of August 2018. Twenty-eight officials (including project staff) attended the Hindi Prabodh (18 November 2018), Pragya (25 November 2018) and Parangat exams (17 November 2018). Twenty-six attendees passed with first class while one passed with second class.

11.9 International Yoga Day

INCOIS celebrated the 4th International Yoga Day as per Ministry of Ayush Protocol 2018 at INCOIS campus on 21 June 2018. On this occasion, a Yoga camp was arranged at INCOIS Multi-Purpose Hall by Yoga Chaitanya Sadanam, a Branch of Yoga Consciousness Trust, Viginigiri. The three-hour long session (from 0930 hrs to 1230hrs) included lectures and practical sessions. A DVD and the soft copy of a book on Yoga published by Ministry of AYUSH (Ayurveda, Yoga & Naturopathy, Unani, Siddha and Homoeopathy) was circulated among INCOIS staff members.

11.10 Swachch Bharat Programme

INCOIS observed Swachh Bharat Pakhwara during 1-15 July, 2018 as a part of the Swachhtha Action Plan for the year 2018-19. Shri Subhash Reddy, Director, Smaran NGO, Guest of Honour delivered a lecture on "Rain Water Harvesting" and inaugurated a Portable Cabin for the use of housekeeping staff.

This was followed by a cleanliness drive by teams of employees that focused on campus areas as well as the areas on the outer periphery where additional trees were planted. A one-day awareness-cum-cleanup was also conducted at Zilla Parishad High School, Pragathi Nagar during which staff briefed the students on the best practices for health and cleanliness, while distributing flyers

highlighting these aspects in Telugu, Hindi and English. The team also joined the students in clearing the debris on the school grounds.

On 28 September 2018 under the umbrella of "Swachchta hi Seva", a "Shramdaan" drive was conducted for cleaning the campus and old / new clothes collected from the staff were distributed to the labourers and outsourced staff at INCOIS.

11.11 Vigilance and RTI Activities

Shri B.V. Satyanarayana, Scientist 'G' & Head, CWG continued to serve as Vigilance Officer at INCOIS. Twenty complaints have been received during April 2018 to March 2019. Upon verification, as per CVC guidelines, it was found that 15 complaints were pseudonymous and hence no further investigation was carried out. Four complaints were attended to and disposed of. The remaining one complaint is being processed. The same has been reported to CVO, MoES. “Vigilance Awareness Week” was observed at ESSO-INCOIS during 27-31 October 2018. INCOIS staff took the Vigilance Pledge on 30 October 2018.

In respect of the Right to Information Act (RTI) 2005, ESSO-INCOIS related queries were regularly updated on the ESSO-INCOIS website in prescribed format. E. Pattabhi Rama Rao, Scientist E & Head, DMG is the Public Information officer and S.S.C. Shenoi, Director, ESSO-INCOIS is the First Appelate authority. Under RTI, 32 requests were received and the required information was provided. Seven appeals were also received and disposed off under RTI act during this period.

11.12 Campus development activities

SITC of 50 KLD capacity STP plant: A 50 KLD capacity STP has been installed and is put to regular use from January 2019. On an average 25 KL of treated water is being generated and used for watering the plants. The use of recycled water reduced the usage of water from tankers.

Plantation of trees: Around 1200 avenue trees have been planted near the ITCOocean building. The plants were obtained free-of-cost from the Forest Department.

Installation of RO plant: Two 250 LPD capacity RO plants were installed for supplying drinking water in INCOIS.

Installation of LED lamps: All CFL lamps in INCOIS campus have been now replaced by LED lamps. With this change, the total lighting load has been reduced to 50%.

11.13 Academic Projects carried out by students at INCOIS

Seventy-eight students carried out short- and long-term projects at INCOIS during 2018-19. They are:

Sl. No	Name of Student	Institute	Project Guide
1.	Abid Hosen Sk.	Vidyasagar University	Sourav Maity
2.	Abheyraj M.	Jawaharlal Nehru Technological University (JNTU), Hyderabad	Venkat Shesu R
3.	Abhija Jagadeesh N P	University of Madras	Harikumar R
4.	Abhijith Raj	Cochin University of Science and Technology (CUSAT)	Girish Kumar MS
5.	Ahammed S M S	Cochin University of Science and Technology (CUSAT)	Kunal Chakraborty
6.	Ajay I.	VNR-VJIET, Hyderabad	Venugopala CH
7.	Akhilesh H G	Kuvempu University	Mahendra RS
8.	Akshay R	Kuvempu University	Prakash Chandra Mohanty
9.	Akshitha Putta	SNIST, Hyderabad	Venkat Shesu R
10.	Alok Kushwaha	Pune University	Prakash Chandra Mohanty
11.	Amba Sharma	Institute of Aeronautical Engineering	PLN Murty
12.	Amit Kumar jena	Berhampur University	Aneesh Lotliker
13.	Arpita Panda	University of Hyderabad	Arnab Mukharjee
14.	Ashin Kuriakose	Cochin University of Science and Technology (CUSAT)	Girishkumar MS
15.	Aswin K. Sasi	Kerala University of Fisheries and Ocean Studies (KUFOS)	Praveen Kumar B
16.	Athulya K	Cochin University of Science and Technology (CUSAT)	Suprit Kumar
17.	Bhavani Sankar Gottipati	Jawaharlal Nehru Technological University (JNTU), Kakinada	Srinivasa Rao N
18.	Bhavani T.	Andhra University	Patanjali Kumar CH
19.	Divya P	National Institute of Technology, Karnataka	Mahendra RS
20.	Gagan G Rao	Kuvempu University	Mahendra RS
21.	Gautham Varma	Lendi Institute of Engg and Technology	Venugopala CH
22.	Gowthami S. B.	National Institute of Technology, Karnataka	Prakash C Mohanty
23.	Greeshma Varghese	Kerala University of Fisheries and Ocean Studies (KUFOS)	Mahendra RS
24.	Hanumantha Rao	Central University of Gujarat	Murty PLN

25.	Hariprasad Reddy B.	VBIT, Hyderabad	PLN Murty
26.	Harshini Kaparthi	SNIST, Hyderabad	Venkat Shesu R
27.	Harshith C Prince	Mangalore University	Mahendra RS
28.	Hemanth P.	VNR-VJIET, Hyderabad	Arun Nerakkol
29.	Himaja Manamasa	Jawaharlal Nehru Technological University (JNTU), Hyderabad	Venkat Shesu R
30.	Hymavathi J.	Andhra University	Patanjali Kumar CH
31.	Indirapriyatharsini T.	Bharathidasan University	Aneesh Lotliker
32.	Jaya Kumar Y.	Andhra University	Patanjali Kumar CH
33.	Kinnera V.	SNIST, Hyderabad	Venkat Shesu R
34.	Kishore Kumar	Kuvempu University	Mahendra RS
35.	Kshitija Suryawanshi	CEPT University	Satya Prakash
36.	Lakshmi J.	R.V.R. & J.C. College of Engineering	Venkat Shesu R
37.	Madhuvani T.	SNIST, Hyderabad	Venkat Shesu R
38.	Manjunath T N	KSRSAC, Bengaluru	Mahendra RS
39.	Mariya Benny	University of Hyderabad	Francis PA
40.	Meera Nair M S	University of Madras	Harikumar R
41.	Merlin Jestice	Central University of Rajasthan	Francis PA
42.	Mohammed Munzil	Cochin University of Science and Technology (CUSAT)	Satya Prakash
43.	Mounika C.	R.V.R. & J.C. College of Engineering	Venkat Shesu R
44.	Nagendra J.	R.V.R. & J.C. College of Engineering	Venkat Shesu R
45.	Navya K.	R.V.R. & J.C. College of Engineering	Venkat Shesu R
46.	Nijad V P	Central University of Karnataka	Mahendra RS
47.	Nikhil Kumar K.	VNR-VJIET, Hyderabad	Venugopala CH
48.	Prabhandha G.	VBIT, Hyderabad	PLN Murty
49.	Preethi Konkathi	National Institute of Technology, Karnataka	PLN Murty
50.	Robiul Hassan	Vidyasagar University	Sourav Maity
51.	Revathy R.	National Institute of Technology, Karnataka	Prakash C Mohanty
52.	Sabana Sabu	Kerala University of Fisheries and Ocean Studies (KUFOS)	Prakash C Mohanty
53.	Sachidananda Sahoo	Berhampur University	Aneesh Lotliker
54.	Saicharan V.	VNR-VJIET, Hyderabad	Arun Nerakkol
55.	Sai Karthik	Somaiya College of Engineering	Venu Gopal CH
56.	Sai Lakshmi S.	Andhra University	Patanjali Kumar CH
57.	Sajidh C K	Cochin University of Science and Technology (CUSAT)	Abhisek Chatterjee
58.	Sandip Pal	CIFE Mumbai	Mahendra RS
59.	Shanika Poojary	Mangalore University	Mahendra RS
60.	Shantika G Bhat	Mangalore University	Mahendra RS

61.	Shrabana Chakraborty	Pune University	Srinivasa Rao N
62.	Shreeharsha M Hegde	Mangalore University	Mahendra RS
63.	Shwetha Shetty	Mangalore University	Mahendra RS
64.	Somen Das	Vidyasagar University	Sourav Maity
65.	Sourav Dutta	Vidyasagar University	Nagaraja Kumar M
66.	Sreedevi P V	Cochin University of Science and Technology (CUSAT)	Arya Paul
67.	Sreekanth Reddy N.	Symbiosis Institute of Geoinformatics, Pune	Srinivasa Rao N
68.	Srikanth Palleti	Jawaharlal Nehru Technological University (JNTU), Kakinada	Srinivasa Rao N
69.	Srinivasu Muniyya Ch.	Andhra University	Patanjali Kumar CH
70.	Suma T.	R.V.R. & J.C. College of Engineering	Venkat Shesu R
71.	Sumanta Kar	Vidyasagar University	Nagaraja Kumar M
72.	Swathi D.	R.V.R. & J.C. College of Engineering	Venkat Shesu R
73.	Uday Kiran B.	VNR-VJIET, Hyderabad	Venugopala CH
74.	Utthama Pandian	Annamalai University	Suresh Kumar
75.	Vaishnavi P. C.	National Institute of Technology, Karnataka	Mahendra R S
76.	Vamshij Joseph	Mangalore University	Mahendra RS
77.	Vishnu Varun	Lingaya's Vidyapeeth	Murali Krishna
78.	Vooha Challagulla	National Institute of Technology, Karnataka	PLN Murty

11.14 Deputation Abroad

Sl. No.	Name of the Official (Dr./Mr./Ms.)	Meeting/Conference/Training
1.	S.S.C Shenoi Director, INCOIS	To attend the meeting on collaboration on Marine fisheries and Harmful algal blooms between MoES and NOAA, USA held at La Jolla, San Diego & Seattle USA during 14-18 May 2018.
		To attend "Asia Weather and Climate Services Pathways for Regional Collaboration Forum held at Geneva, Switzerland during 18-20 September 2018.
		To attend meeting of the Steering Committee of IIOE-2 and the Annual Meetings of Indian Ocean Global Ocean Observing System (IOGOOS)-XIV, Indian Ocean Research Panel (IORP), Sustained Indian Ocean Biogeochemistry and Ecosystem Research (SIBER) and IndOOS Ocean Resource Forum (IRF) in Port Elizabeth, South Africa during 11-15 March 2019.
2.	T. M. Balakrishnan Nair, Scientist 'G', Head ISG	To participate in the COWCLIP meeting of the JCOMM in Paris, France During 21-25 May 2018.

3.	E. Pattabhi Rama Rao, Scientist 'F', Head-ODG & TWG	To participate in the 25th Session of the IOC Committee on International Oceanographic Data and Information Exchange (IODE- XXV) and Scientific Conference at Tokyo, Japan during 18-22 February 2019.
		To attend the (i) Planning meeting of Steering Group of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS), (ii) Expert Consultation on "Scientific Tsunami Hazard Assessment of the Makran Subduction Zone", and (iii) 12th Session of ICG/IOTWMS (ICG/IOTWMS-XII) at Kish Island, Islamic Republic of Iran during 7-12 March 2019.
4.	T.V.S Udaya Bhaskar, Scientist 'F' & Head TPG	To participate in workshop on Coordinated Quality Control System for the Historical Subsurface Ocean Temperature (and Salinity) Observations at Oostene, Belgium during 16-20 April 2018.
		To participate in Ocean Teacher Global Academy (OTGA) Steering Group IV Meeting organized by IOC/UNESCO Project Office for IODE at Brussels, Belgium during 14-17 May 2018.
		To participate in the 19th Meeting of Argo Data Management Team (ADMT-19) at Scripps Institute of Oceanography, California, USA during 2-7 December 2018.
5.	M. Nagaraja Kumar, Scientist 'E', ISG	To participate in the IOGOOS Workshop and 15th Annual meeting held in conjunction with the meetings of SIBER, IRF, IOP and IIOE- 2 meetings at Port Elizabeth, South Africa during 11-15 March 2019.
6.	Satya Prakash, Scientist 'E', ISG	To participate in the IOGOOS Workshop and 15th Annual meeting held in conjunction with the meetings of SIBER, IRF, IOP and IIOE- 2 meetings at Port Elizabeth, South Africa during 11-15 March 2019.
7.	R.S. Mahendra, Scientist 'E', TWG	To attend the Bilateral Consultative meeting cum Joint ZMT-MoES workshop on Marine Sciences' and Coastal Sustainability during 20-21 August 2018 in Bermen, Germany.
		To attend "Training of Trainers on Tsunami Evacuation Maps, Plans and Procedures (TEMPP3)" organized by Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) of IOC-UNESCO at Citeko, Indonesia during 25 November-1 December 2018.

8.	Ch. Patanjali Kumar, Scientist 'E', TWG	To attend the (i) Planning meeting of Steering Group of the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS), (ii) Expert Consultation on "Scientific Tsunami Hazard Assessment of the Makran Subduction Zone", and (iii) 12th Session of ICG/IOTWMS (ICG/IOTWMS-XII) at Kish Island, Islamic Republic of Iran during 7-12 March 2019.
9.	Kunal Chakraborty, Scientist 'D', MDG	To participate in the India - UK Frontiers of Science Symposium for young scientists during 15-18 May 2018 at Chicheley Hall (Milton Keynes, UK).
10.	N Suresh Kumar, Scientist 'D' ODG	To attend the training Session on the direct co-variance flux mooring being purchased from Woods Hole Oceanographic Institution (WHOI), Woods Hole, Massachusetts, USA during 29 October to 14 December 2018.
11.	Arun Nherakkol, Scientist 'C', ISG	To Seychelles for maintenance of Wave rider buoy to validate the Integrated Ocean Information System for Indian Ocean Countries through RIMES during 5-13 January 2019.
12	S Shiva Prasad, Scientist 'C', ODG	To attend the training Session on the direct co-variance flux mooring being purchased from Woods Hole Oceanographic Institution (WHOI), Woods Hole, Massachusetts, USA during 29 October to 14 December 2018.
13	B. Ajay Kumar, Scientist 'C', TWG	To participate (i) workshop on Lessons Learnt from IOWave18 Tsunami Mock Exercise during November 15-17, 2018 and (ii) the ICG/IOTWMS Steering Group Meeting during 19-21 November 2018 at Jakarta, Indonesia.
14.	C. Jeyakumar Chelliah, Scientific Assistant 'B', ISG	To Seychelles for maintenance of Wave rider buoy to validate the Integrated Ocean Information System for Indian Ocean Countries through RIMES during 11-17 July 2018.
		To Seychelles for maintenance of Wave rider buoy to validate the Integrated Ocean Information System for Indian Ocean Countries through RIMES during 5-13 January 2019.
15.	K. Siva Srinivas, Project Scientist 'B', TWG	To attend "Training of Trainers on Tsunami Evacuation Maps, Plans and Procedures (TEMPP3)" organized by Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) of IOC-UNESCO at Citeko, Indonesia during 25 November 25 2018 to 1 December 2018.
16.	M. Ramesh Kumar Murugan, Project Assistant, ISG	To Seychelles for maintenance of Wave rider buoy to validate the Integrated Ocean Information System for Indian Ocean Countries through RIMES during 11-17 July 2018.

11.15 INCOIS Human Capital

Category/Designation	Regular	Category/Designation	Project Mode
Scientific Staff			
Director	1	Project Sci - D	1
Scientist 'G'	4*	Project Sci - C	5
Scientist 'F'	3	Project Sci - B	34
Scientist 'E'	9	Project Assistant	38
Scientist 'D'	15	Admin Assistant/ Office Assistant/ Jr. Office Asst.	10
Scientist 'C'	12	Lab Attendants	9
Scientist 'B'	3	Driver-cum-Attendant	4
Scientific Support Staff		Consultants	1
Scientific Assistant B	16	Research Fellows	
		(Ph.D Programme/ Women Scientist/Post Doctoral Fellow)	13
Scientific Assistant A	2		
Administrative Support			
Manager	1		
Jt. Manager	2		
Asst. Manager	4		
Sr. Executive	3		
Total	**75**	**Total**	**115**

* Dr. M. Ravichandran, Scientist 'G' & Dr. T. Srinivasa Kumar, Scientist 'G' are on lien.

12. Acronyms

ABC	Application of Basic geophysical equations for Calculations
ADCIRC	Advanced Circulation (Storm surge model)
ADCP	Acoustic Doppler Current Profiler
ADMT	Argo Data Management Team
AIR	All India Radio
ALTM	Airborne Laser Terrain Mapping
ANCOST	Andaman and Nicobar Centre for Ocean Science and Technology
AOD	Aerosol Optical Depth
AoS	Area of Service
AP	Andhra Pradesh
APM	Absolute Plate Motion
APPMB	Andhra Pradesh Port Management Board
APWD	Andaman Public Works Department
ARGO/Argo	Array for Real-time Geotropic Oceanography
AST	Argo Steering Team
AVHRR	Advanced Very High-Resolution Radiometer
AWS	Automated Weather Stations
AYUSH	Ministry of Ayurveda, Yoga & Naturopathy, Unani, Siddha and Homoeopathy
BGC	Biogeochemical
BoB	Bay of Bengal
BPRs	Bottom Pressure Recorders
BSI	Boat Safety Index
CEPT	Centre for Environmental Planning and Technology
CFL	Compact Fluorescent Lamp
CFP	Coastal Forecast Points
CFS	Climate Forecast System
CFU	Colony-Forming Unit
CFZ	Coastal Forecast Zones
Chl-a	Chlorophyll-a
CIFE	Central Institute of Fisheries Education
CMFRI	Central Marine Fisheries Research Institute
CMIP	Coupled Model Intercomparison Project
CMLRE	Centre for Marine Living Resources & Ecology, Kochi

CMNS	College of Computer, Mathematical, and Natural Sciences, University of Maryland
COMMs	Communications Test
CONZ	Co-seismic displacement of Concepcion
COWCLIP	The Coordinated Ocean Wave Climate Project
CrIS	Central Receiving Stations
CSIR	Council of Scientific & Industrial Research
CTD	Conductivity-Temperature-Depth
CUSAT	Cochin University of Science and Technology
CVC	Central Vigilance Commission
CVO	Central Vigilance Officer
CWG	Computational Facilities, Communications Network and Web Services
DAC	Data Assembly Centre
DCM	Deep Chlorophyll Maxima
DDS	Digital Display Systems
DG	Director General
DINEOF	Data Interpolation Empirical Orthogonal Functions
DMG	Data Management Group
DO	Digital Ocean
DSS	Decision Support System
DTM	Digital Terrain Model
DVD	Digital Versatile Disc
Dy. CAO	Deputy Chief Administrative Officer
ECMWF	European Centre for Medium-Range Weather Forecasts
EDBs	Electronic Display Boards
EFAS	Ed Fishery Advisory Services
EIA	Environmental Impact Assessment
EICC	East Indian Coastal Current
EIO	Eastern Indian ocean
EQ	Earth Quake
EQUINOO	Equatorial Indian Ocean Oscillation
ERP	Enterprise Resource Planning
ESSO	Earth System Science Organisation
ESZ	Earthquake Source Zones
ETOPO	Earth Topographic
FF	Far Field
FORV	Fisheries Ocean Research Vessel

FRV	Fishery Research Vessel
FSI	Fishery Survey of India
FTP	File Transfer Protocol
FY	Financial Year
GC	Governing Council
GeoJSON	Geo JavaScript Object Notation
GFS	Global Forecast System
GNSS	Global Navigation Satellite System
GODAE	Global Ocean Data Assimilation Experiment
GODAS	Global Ocean Data Assimilation System
GOOS	Global Ocean Observation System
GOVST	GODAE Ocean View Science Team
GPRS	General Packet Radio Service
GSI	Geological Survey of India
GTS	Global Telecommunication System
HF	High Frequency
HF RADAR	High Frequency RAdio Detection And Ranging
HOOFS	High Resolution Operational Ocean Re-Analysis and Forecast System
HPC	High Performance Computer
HSI	Habitat Suitability Index
HWRF	Hurricane Weather Research and Forecast
HYCOM	Hybrid Coordinate Ocean Model
IAS	Indian Administrative Service
ICG	Intergovernmental Coordination Group
ICMAM	Integrated Coastal and Marine Area Management
ICOADS	International Comprehensive Ocean-Atmosphere dataset
IEEE	Institute of Electrical and Electronics Engineers
IGU	Indian Geophysical Union
IIOE	International Indian Ocean Expedition
IISF	India International Science Festival
IIT	Indian Institute of Technology
IITM	Indian Institute of Tropical Meteorology
ILD	isothermal layer depth
IMD	Indian Meteorological Department
INCOIS	Indian National Centre for Ocean Information Services
IndOOS	Indian Ocean Observing System
INSA	Indian National Science Academy

INSAT	Indian National Satellite System
INYAS	Indian National Young Academy of Science
IO	Indian Ocean
IOC	Intergovernmental Oceanographic Commission
IOD	Indian Ocean Dipole
IODE	International Oceanographic Data and Information Exchange
IOGOOS	Indian Ocean Global Ocean Observing System
IOP	Inherent Optical Properties
IORP	Indian Ocean Regional Panel
IOTR	Indian Ocean Tsunami Ready
IOTWMS	Indian Ocean Tsunami Warning and Mitigation System
IOTWS	Indian Ocean Tsunami Warning System
IOWave18	IOTWS Indian Ocean Tsunami Exercise 2018
IRAWS	INCOIS Real-time ship-mounted Automatic Weather Station
IRF	IndOOS Resources Forum
ISG	Ocean Information and Forecast Services Group, ESSO-INCOIS
ISPRS	International Society for Photogrammetry and Remote Sensing
ISRO	Indian Space Research Organisation
ITCOocean	International Training Centre for Operational Oceanography
ITEWC	Indian Tsunami Early Warning Centre
IVL	Inland Vessel Limits
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology
JISAO	Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
JNCASR	Jawaharlal Nehru Centre for Advanced Scientific Research
JNPT	Jawaharlal Nehru Port Trust
JNTU	Jawaharlal Nehru Technological University
JPO	Joint Programme Office
JRF	Junior Research Fellow
KLD	Kilolitres per Day
KPI	Key Performance Indicators
KSRSAC	Karnataka State Remote Sensing Application Center
KUFOS	Kerala University of Fisheries and Ocean Studies
LETKF	Local Ensemble Transform Kalman Filter
LPD	Litres per Day
LPS	Low Pressure System
LTA	long term average

LW	Long Wave
MaMeAT	Marine Meteorological Atlas
MDG	Ocean Modeling and Data Assimilation Group (MDG)
METOP	Meteorological OPerational
MFAS	Marine Fisheries Advisory Services
MFV	Motor Fishing Vessel
MHVM	Multi-Hazard Vulnerability Map
MJO	Madden-Julian Oscillation
MLD	Mixed Layer Depth
MODIS	Moderate Resolution Imaging Spectroradiometer
MODISA	Moderate Imaging Spectroradiometer-Aqua
MoES	Ministry of Earth Sciences
MOM	Modular Ocean Model
MRCC	Maritime Rescue Coordination Centre
MSSRF	M S Swaminathan Research Foundation
MTS	Marine Technology Society
MW	Medium Wave
NCCR	National Centre for Coastal Research
NCEP	National Centers for Environmental Prediction
NCESS	National Centre for Earth Science Studies
NCMRWF	National Centre for Medium Range Weather Forecasting
NCPOR	National Centre for Polar and Ocean Research
NCS	National Centre for Seismology
NDBC	National Data Buoy Center
NDBP	National Data Buoy Programme
NDRF	National Disaster Response Force
NDVI	Normalized Difference Vegetation Index
NetCDF	Network Common Data Form
NGO	Non-Governmental Organisation
NGRI	National Geophysical Research Institute, Hyderabad
NHO	National Hydrographic Office
NIO	National Institute of Oceanography, Panaji
NIOT	National Institute of Ocean Technology, Chennai
NMSRB	National Maritime Search and Rescue Board
NOAA	National Oceanic and Atmospheric Administration
NOC	No Objection Certificate
NODC	National Oceanographic Data Centre

NOW	National Oceanography Workshop
NPP	National Polar-orbiting Partnership
NRSC	National Remote Sensing Centre
NTWC	National Tsunami Warning Centre
NWAB	North West Australian Basin
NWIO	North West Indian Ocean
OBIS	Ocean Bio-Informatics System
OCM	Ocean Colour Monitor
OCR	Optical Character Recognition
ODG	Ocean Observations and Data Management Group
ODIS	Ocean Data Information system
OGCM	Oceanic General Circulation Model
OLR	outgoing longwave radiation
OMM	Ocean Mixing and Monsoon
ONGC	Oil and Natural Gas Corporation Limited
ONR	Office of Naval Research
OOPSDB	Open Ocean Propagation Scenario DataBase
OPENDAP	Open-source Project for a Network Data Access Protocol
ORV	Ocean Research Vessel
OSCAT	OceanSat Scatterometer
OTGA	Ocean Teacher Global Academy
PDO	Pacific Decadal Oscillation
PFZ	Potential Fishing Zones
POGO	Partnership for Observation of the Global Oceans
PP	Primary Productivity
PPP	Precise Point Positioning
QC	Quality Control
QMF	Quality Management Framework
R&D	Research & Development
RADAR	RAdio Detection And Ranging
RAIN	ReAnalysis of INdian Ocean
REDC	Rural Eco-Development Centre
RIMES	Regional Integrated Multi-Hazard Early Warning System
RMSE	Root Mean Square Error
RNTU	Rabindranath Tagore University
ROMS	Regional Ocean Modeling System
RTI	Right to Information Act

SAC	Space Applications Centre, Ahmedabad
SAIC	Science Applications International Corp.
SAP	Systems, Applications & Products in data processing
SARAT	Search And Rescue Aid Tool
SCI	Shipping Corporation of India
SCOR	Scientific Committee on Oceanic Research
SCS	Severe Cyclonic System
SEAS	South Eastern Arabian Sea
SESL	South East of Sri Lanka
SFC	Standby Inundation Model For Coastal Inundation Mapping
SIBER	Sustained Indian Ocean Biogeochemistry and Ecosystem Research
SITC	Standard International Trade Classification
SMA	Strong Motion Accelerograph
SMAP	Soil Moisture Active Passive
SMS	Short Messaging Service
SNIST	Sreenidhi Institute of Science and Technology
SNOM	School of Naval Oceanology and Meteorology
SOP	Standard Operating Procedure
SRTM	Shuttle Radar Topography Mission
SSC	Science Steering Committee
SSL	Secured Socket Layer
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
STA	Short Term Average
STP	Sewage Treatment Plant
SW	Short Wave
SWAN	Simulating WAves Nearshore
TB	Tera Bytes
TCHP	Tropical Cyclone Heat Potential
TCZ	Tropical Convergence Zone
TEMPP	Tsunami Evacuation Maps, Plans and Procedures
TF	Tera Flop
TKE	Turbulent Kinetic Energy
TPG	Training and Programme Planning and Management Group
TSM	Total Suspended Matter
TSP	Tsunami Service Providers
TSSS	Thiruvananthapuram Social Service Society

TV	Television
TWCs	Tsunami Warning Centres
TWG	Tsunami and Storm Surge Early Warning Services Group
UCSD	University of California San Diego
UK	United Kingdom
ULC	Urban Land Ceiling
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNSWAN	Unstructured SWAN
USA	United States of America
USGS	United States Geological Survey
USM	Uniform Slip Model
UTC	Coordinated Universal Time
UTs	Union Territories
VBIT	Vignana Bharathi Institute of Technology
VHF	Very High Frequency
VIIRS	Visible Infrared Imaging Radiometer Suite
VMP	Vertical Microstructure Profiler
VNR-VJIET	Vallurupalli Nageswara Rao Vignana Jyothi Institute of Engineering & Technology
VSAT	Very Small Aperture Terminal
VSM	Variable Slip Model
WAM	Wave Model
WHOI	Woods Hole Oceanographic Institute
WICC	West India Coastal Current
WMO	World Meteorological Organisation
WRB	Wave Rider Buoy
XBT	Expendable Bathy Thermograph
XCTD	Expendable CTD
ZMT	Leibniz Centre for Marine Tropical Ecology

13. Finance

Annexure-3

PPKG & Co
CHARTERED ACCOUNTANTS

#5-8-352, 7th Floor, Raghav Ratna Towers,
Chirag Ali Lane, Abids, Hyderabad-500 001.
Ph : +91-40-23205049, 66132176, 48517622
email : giri@ppkg.com www.batgach.com

AUDITORS' REPORT

To

The Chairman and Members,
Governing Council,
ESSO-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 ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES** as at 31st March 2019, 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 purposes 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 Sheet, Income & Expenditure Account, Receipts & Payments Account are in agreement with the Books of Account.
4. In our opinion and to the best of our information and according to the explanations given to us and subject to Notes to Accounts Schedule 11 points No 1 c(v), 1(f)(ii)-gf, 2(d)(iv), 2(e), 2(g) of schedule forming part of accounts, the Balance Sheet as at 31st March 2019, 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**
Chartered Accountants

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

Date: 02.08.2019
Place: Hyderabad

ESSO-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 2019

Particulars	Schedules	Current Year (2018-19) ₹	Previous Year (2017 - 18) ₹
CAPITAL & LIABILITIES			
Corpus fund	1	18,93,84,127	16,31,42,934
Earmarked funds	2	(4,59,66,254)	(2,22,49,991)
Current liabilities & Provisions	3	20,88,79,932	12,56,89,642
Total		**35,22,97,805**	**26,65,82,585**
ASSETS			
Fixed Assets	4	3,85,17,896	4,10,22,860
Current Assets, Loans & Advances	5	31,37,79,909	22,55,59,725
Total		**35,22,97,805**	**26,65,82,585**
Notes forming part of Accounts	11		

As per our report of even date

For PPKG & Co.

Chartered Accountants

Giridhari lal Toshniwal

Partner

M. No. 205140

FRN No: 009655S

For and on behalf of

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

(S. Nageswara Rao)

Sr. Accounts Officer

(S.S.C. Shenoi)

Director

Place: Hyderabad

Date: 02.08.2019

ESSO-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 2019

Particulars	Schedules	Current Year (2018-19) ₹	Previous Year (2017 - 18) ₹
INCOME			
Income from Sales / Other Income	6	58,37,681	56,90,624
Interest Earned on Investments	7	15,74,907	64,05,211
Recurring Grants	8	25,00,00,000	23,17,30,000
TOTAL - A		**25,74,12,588**	**24,38,25,835**
EXPENDITURE			
Establishment Expenditure	9	11,81,69,954	12,14,30,908
Other Administrative Expenses	10	10,30,29,511	12,77,11,604
Depreciation	4	99,71,931	1,83,03,041
TOTAL - B		**23,11,71,396**	**26,74,45,553**
Excess of Income over expenditure (A-B)	1	**2,62,41,192**	**(2,36,19,718)**
Add / Less: Prior Period Items			
Balance being net income / deficit transferred to Corpus Fund		**2,62,41,192**	**(2,36,19,718)**
Notes forming part of Accounts	11		

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

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

Place: Hyderabad
Date: 02.08.2019

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

(S. Nageswara Rao)
Sr. Accounts Officer

(S.S.C. Shenoi)
Director

ESSO-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 2019

RECEIPTS	CURRENT YEAR 2018-19		PAYMENTS	CURRENT YEAR 2018-19	
	₹	₹		₹	₹
Opening Balance			**Establishment Expenses**		
INCOIS Current A/c-SBI-HAL Campus Br.	11,03,47,172		Pay, Leave Salary Allowace	9,29,45,877	
INCOIS Savings A/c-AB-Pragathi Nagar Br.	31,54,175		NPS & CPF	56,54,008	
AB Consultancy A/c	3,82,809		Staff Welfare (Medical IP & OP)	20,57,745	
Short Term Deposits with Bank	6,93,00,000	**18,31,84,156**	Leave Travel Concession Expenses	33,61,419	**10,40,19,049**
INCOIS IGOOS Secretariat-Local	6,55,390		**Administrative Expenses**		
INCOIS IGOOS Secretariat-Foreign	12,49,333		EL encashment during LTC	6,62,217	
Andhra Bank PORSEC 2012 Savings Bank Account	33,668		Children Education Allowance	10,26,726	
INCOIS-CPF Account	43,97,251		Travel Expenses-Inland	20,88,100	
INCOIS-IDBPS Account	1,03,333		Foreign	11,65,702	
INCOIS-ISPRS	3,00,397		Others	1,89,725	
AB PORSEC-Deposit	27,00,000	**94,39,372**	Telephone & Fax Expenditure	5,39,003	
Additions:			Postage & Telegraphs	1,16,706	
CPF STDRs	1,10,00,000	**1,10,00,000**	Printing & Stationery	14,62,247	
			Honorarium to External Experts	2,12,000	
			Advertisement & Publicity	15,68,289	
			Subscription to Newspapers/Journals	41,785	
Earmarked Funds			Seminar, Conference & Workshop Expenses	1,97,874	
Ocean Information and Advisory Services(O-IAS)	24,53,00,000		Audit Fee	18,251	
Ocean Observation Systems (OOS)	14,10,00,000		Office Expenses	83,89,502	
International Training Centre for Operational Oceanography (ITCOOcean)	29,86,00,000		General Expenses	6,45,011	
Regional Integrated Multi-Hazard Early Warning System (RIMES)	3,18,84,000		International Interface (GODAE subscription)	5,21,640	**1,88,44,778**

Multi Hazard Vulnerability Mapping	16,78,90,000	**88,46,74,000**			
			Operation & Maintenance		
			Vehicle Hiring	8,26,435	
BG Encashment (GAIAN)	9,50,000	**9,50,000**	House Keeping, Plumbing & Garden Expenses	1,67,21,865	
			Security Expenses	1,54,09,362	
			Water Expenses	44,83,337	
Recurring Grants	25,00,00,000	**25,00,00,000**	Civil Services	2,62,954	
			Electricity Expenditure	2,77,16,975	
Other Receipts:			Pest Control Expenses	1,07,900	
Consultancy Projects:			Maintenance & Repairs	1,08,64,273	
ITD Cementation	54,000		Material Consumable	32,59,302	
ITD Cementation	10,800		Emoluments to Consultants	6,58,763	
RKEC Projects	38,880		Air & Electrical Expenses	28,75,450	
PINFRA Operating Company	7,080		Payment of GSLIS to Mr. KKV Chary	59,393	
Gujarat Environment Mgmt. Inst.	29,498		Amount sent to MoES for Sale of Scrap of HPC Buy back	3,45,000	
INTECH Insurance Surveyor Pvt. Ltd.	16,200		Expenditure of ICG/IOTWS	5,58,547	
HOWE Engineering Projects	3,88,800		Refund of unspent balance to ICG/IOTWS	2,96,056	
Jawaharlal Nehru Port Trust	6,51,374.50		Transfer to NIOT Reserve Fund	23,99,763	
Jawaharlal Nehru Port Trust	6,51,374.50		AB Consultancy Bank charges	246	
Maharashtra Maritime Board	2,81,960		Bank charges	926	
ONGC Kakinada	20,15,060		Sponsorship of TA/DA reimbursement	1,38,000	**8,69,84,547**
SECON Pvt Ltd	27,531	**41,72,558**			
Other Receipts:					
Interest on Short Term Deposits	1,32,14,787		PF transfer to Mr. KKV Chary	9,12,917	
Interest on IOGOOS Foreign A/c	70,492		PF transfer to Mr. M. Nagaraja Kumar	2,81,000	**11,93,917**
Interest on IOGOOS Local A/c	23,236				
Interest on AB Savings A/c	88,426				
Interest on AB Consultancy A/c	36,885		Amount spent towards WHOI training	7,80,824	
Interest on SBI CPF A/c	2,13,250		Unspent balance refunded to IISC	6,19,176	**14,00,000**
Interest on IDBPS	3,666				
Interest on ISPRS	10,652				
Interest earned on ACD-TSSPDCL	4,38,920		Airfare reimbursement to Mr. Peter	97273	

Interest received on AB-PORSEC Account	3,126		Bank Charges	1946	
Interest on Vehicle Advance	2,17,297		Paid to Bureau of Meterology	117306	
Interest Margin Money TDR's	7,04,747		Bank charges for Bureau of Meterology for Jakarta	1966	
Earnest Money Deposits	50,50,480		Paid to Mr. Venkat Seshu for Jakarta Meeting	899	
Security Deposits	50,000		Paid to Balmer Lawrie for Air tickets	274661	
Sale of Scrap for HPC Buy Back	3,45,000		Bank statement charges	480	**4,94,531**
Inspire /UGC Fellowship	16,07,009				
EM Other Receipts-ITCOO (MOB.Adv. Refund)	1,56,35,420				
Income from MP Hall	56,280		Expenditure towards UNESCO/OTGA/IOC	23,85,575	**23,85,575**
Income from Tender Sales	1,500				
Income from Guest House	4,34,400				
RTI Fee	350		**Payments Against Earmarked Funds**		
Vehicle Advance to Employees (Recovery)	21,000		**Construction of New Building (Phase II)**		
National Post Doctoral Fellow	9,10,000		Construction buildings	4,46,95,853	
Fee from training courses	1,14,040		Refund of Encashed BG of Unity	3,26,00,000	**7,72,95,853**
Proceeds of cancellation of TDR-PORSEC	30,21,714				
Funds received from IOGOOS Member Countries	4,02,524				
Funds received from IOGOOS	70,440	**4,27,45,641**	**OASIS**		
			Equipments	67,90,319	
Refund by NIOT Space Segment Charges	9,98,153	**9,98,153**	Hardware/Software	13,41,25,585	
			Technical Support	4,61,84,430	
Amount received from UNESCO/OTGA/IOC	42,22,441	**42,22,441**	Administrative Expenses	4,95,82,233	
			Travel	76,27,103	
			Consumable Material / Data	5,06,28,100	
Amount Received from UNESCO (ICG/IOTWS)	8,54,603		Advance against subprojects	2,24,23,950	
Amount Received from OTGA	56,75,945		Advance for Purchase	84,53,632	
Funds received from IISC	14,00,000		Depository Work (APWD)	32,00,737	**32,90,16,089**
Funds received from MEA for Tsunami Training	25,90,283	**1,05,20,831**			
			Ocean Observation Networks - OON		
Contribution received to CPF A/c	38,27,639		Technical Support	98,41,999	

CPF contribution received from Dr. M. Ravichandran	5,18,172		Administrative Expenses	96,34,016	
CPF contribution received from Dr. T. Srinivasa Kumar	1,50,577	**44,96,388**	Equipment	1,65,389	
			Travel	22,67,345	
			Consumable Material / Data	2,04,20,431	
Received from LIC-GSLIS of Mr. G. Suresh	31,840.00		Advance for Purchase	14,31,45,767	
Received fromLIC-GSLIS of Mr. KKV Chary	59,393.00	**91,233**	Margin Money against LC	26,00,000	**18,80,74,947**
Unspent Balances received from Sub Projects:			**Satellite Coastal and Oceanographic Research**		
Potential Fishing Zone	812		Administrative Expenses	7,86,811	**7,86,811**
Ocean State Forecast	2,04,750				
HROOF	32,448				
PALEO Tsunami	41,932		**International Training Centre (ITCOocean)**		
SATCORE	1,72,506	**4,52,448**	Technical support	39,47,933	
			Administrative Expenses	41,95,228	
			Travel	34,02,416	
			Consumable Materials / Data	1,56,875	
			Depository Work (RITES)	12,00,00,000	**13,17,02,452**
			O-MASCOT		
			Technical support	23,59,528	
			Adminisrtrative expenses	41,23,478	
			Travel	8,28,180	
			Consumable Materials / Data	4,24,859	
			Advance against subprojects	1,37,39,061	
			Advance for Purchase	95,19,227	**3,09,94,333**
			IT & E Governance Fund		
			Hardware/Software	12,13,300	**12,13,300**
			V Sat Terrestrial Link		

			Technical support	87,12,309	
			Adminisrtrative expenses	16,29,871	
			Travel	4,557	**1,03,46,737**
			Multi Hazard Vulnerability		
			Technical support	2,65,500	**2,65,500**
			Monsoon Mission		
			Administrative Expenses	10,64,499	
			Advance for Purchase	9,19,95,793	
			Margin Money against LC	13,10,000	**9,43,70,292**
			RIMES Afro Asian Region		
			Equipments	41,87,302	
			Advance against subprojects	77,42,762	
			Advance for Purchase	2,43,36,249	**3,62,66,313**
			CSS		
			Equipments	15,750	
			Consumable Materials / Data	33,030	**48,780**
			IIOE2		
			Adminisrtrative expenses	1,33,425	
			Travel	1,56,594	**2,90,019**
			Expenditure on Fixed Assets		
			Plant & Machinery	1,02,896	
			Office Equipment	40,946	
			Library Books	68,51,125	
			Other Fixed Assets	4,72,000	**74,66,967**
			Other Payments		
			Refund of Earnest Money Deposit	69,96,540	

			Security Deposits	16,20,713	
			Inspire Fellowship (Regn. Fee, travel etc.)	61,133	
			LTC Advance	23,99,620	**1,10,78,006**
			Closing Balance		
			INCOIS Current A/c-SBI-HAL Campus Br.	9,41,50,483	
			AB Savings A/c	29,61,504	
			AB Consultancy A/c	23,06,178	
			Short Term Deposits with Bank	14,85,00,000	
			Andhra Bank PORSEC 2012 Savings Bank Account	19,942	
			INCOIS IGOOS Secretariat-Local	7,48,706	
			INCOIS IGOOS Secretariat-Foreign	21,59,341	
			INCOIS-CPF Account	72,44,223	
			INCOIS-IDBPS Account	1,06,999	
			INCOIS-ISPRS	3,11,049	
			AB PORSEC-Deposit	29,00,000	
			CPF STDRs	1,10,00,000	**27,24,08,425**
Total	**1,40,69,47,221**	**1,40,69,47,221**	**Total**	**1,40,69,47,221**	**1,40,69,47,221**

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

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

Place: Hyderabad
Date: 02.08.2019

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

(S. Nageswara Rao)
Sr. Accounts Officer

(S.S.C. Shenoi)
Director

ESSO - 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 2019

SCHEDULE 1 – CORPUS FUND

Particulars	Current Year (2018-19) ₹	Previous Year (2017 - 18) ₹
Corpus Fund at the beginning of the year	16,31,42,934	18,67,62,652
Add: Net income transferred from Income & Expenditure Account	2,62,41,193	(2,36,19,718)
BALANCE AS AT THE YEAR END	**18,93,84,127**	**16,31,42,934**

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

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

Place: Hyderabad
Date: 02.08.2019

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

(S. Nageswara Rao)
Sr. Accounts Officer

(S.S.C. Shenoi)
Director

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 2 - EARMARKED FUNDS

(Amount in Rs.)

Particulars	FUND-WISE BREAK UP														TOTALS	
	Building Fund	OASIS	Ocean Observation Networks	SATCORE	ITCOO	O-MASCOT	IT & E Governance Fund	V SAT Node	MH Vulnerability	Monsoon Mission	RIMES	CSS	IIOE2	NCS	Current Year 2018-19	Previous Year 2017-18
a) Opening balance of the funds	2,98,45,623	-7,20,95,405	-2,53,43,420	41,10,305	-7,81,34,256	11,33,45,926	30,32,872	1,63,32,119	-16,67,70,931	13,40,68,610	1,64,16,711	5,78,571	17,98,321	5,64,963	-2,22,49,991	22,16,21,362
b) Additions to the Funds:																
i. Grants	-	24,53,00,000	14,10,00,000	-	29,86,00,000	-	-	-	16,78,90,000	-	3,18,84,000	-	-	-	88,46,74,000	59,53,00,000
ii. Interest if any	16,38,829	14,43,803	9,87,712	1,29,134	32,70,036	34,94,442	1,02,705	2,70,457	12,463	39,11,864	2,19,640	19,483	56,693	19,860	1,55,77,121	2,00,35,405
iii. Advance for sub projects utilised/refund	-	2,47,494	-	1,72,506	-	32,448	-	-	-	-	-	-	-	-	4,52,448	18,42,18,592
iv. Advance for purchase Utilised	-	1,04,93,455	-	-	-	-	-	-	-	-	-	-	-	-	1,04,93,455	52,46,098
v. Margin Money Reversed	-	-	13,66,000	-	-	45,70,000	-	-	-	-	-	-	-	-	59,36,000	11,44,64,000
vi. Deposit Advance Utilized/refund	-		-	-	1,62,40,699	-	-	-	-	-	-	-	-	-	1,62,40,699	19,78,62,344
vii. Mobilization Advance Reversed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
viii. Other Revenue	-	-	-	-	1,56,35,420	-	-	-	-	-	-	-	-	-	1,56,35,420	4,54,92,887
ix. BG encashment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,26,00,000
TOTAL (a+b) - A	**3,14,84,452**	**18,53,89,347**	**11,80,10,292**	**44,11,945**	**25,56,11,899**	**12,14,42,816**	**31,35,577**	**1,66,02,576**	**11,31,532**	**13,79,80,474**	**4,85,20,351**	**5,98,054**	**18,55,014**	**5,84,823**	**92,67,59,152**	**1,41,68,40,688**
c) Utilisation/Expenditure																
i. Capital Expenditure																
W.I.P	4,46,95,853		-	-	15,24,83,982	-	-	-	-	-	-	-	-	-	19,71,79,835	25,81,64,662
Architect fee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Equipments	-	67,90,319	1,65,389	-	-	-	-	-	-	-	41,87,302	15,750	-	-	1,11,58,760	5,82,67,851
Computers / Software	-	13,41,25,585		-	-	-	12,13,300	-	-	-	-	-	-	-	13,53,38,885	43,92,203
Other Assets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	**4,46,95,853**	**14,09,15,904**	**1,65,389**	**-**	**15,24,83,982**	**-**	**12,13,300**	**-**	**-**	**-**	**41,87,302**	**15,750**	**-**	**-**	**34,36,77,480**	**32,08,24,717**
ii. Revenue Expenditure																
Technical support	-	4,61,84,430	98,41,999	-	39,47,933	23,59,528	-	87,12,309	2,65,500	-	-	-	-	-	7,13,11,699	32,73,24,979
Adminisrtrative expenses	-	4,95,82,232	96,34,016	7,86,811	41,95,228	41,23,478	-	16,29,871		10,64,499	-	-	1,33,425	-	7,11,49,560	11,50,95,109
Travel	-	76,27,104	22,67,345	-	34,02,416	8,28,180	-	4,557		-	-	-	1,56,594	-	1,42,86,196	1,34,99,396
Consumable Materials / Data	-	5,06,28,100	2,04,20,431	-	1,56,875	4,24,859	-	-		-	-	33,030		-	7,16,63,295	14,19,24,508
Total	**-**	**15,40,21,866**	**4,21,63,791**	**7,86,811**	**1,17,02,452**	**77,36,045**	**-**	**1,03,46,737**	**2,65,500**	**10,64,499**	**-**	**33,030**	**2,90,019**	**-**	**22,84,10,749**	**59,78,43,993**
iii. Others																
Advance against subprojects	-	2,24,23,950		-	-	1,37,39,061	-	-	-	-	77,42,762	-	-	-	4,39,05,773	14,47,06,769
Advance for Purchase	-	84,53,632	14,31,45,766	-	-	95,19,227	-	-	-	9,19,95,793	2,43,36,249	-	-	-	27,74,50,667	16,47,18,200
Deposit Works (APWD & RITES)	-	32,00,737	-	-	-	-	-	-	-	-	-	-	-	-	32,00,737	14,50,00,000
Margin Money against LC	-	-	26,00,000	-	-	3,95,70,000	-	-	-	13,10,000	-	-	-	-	4,34,80,000	6,59,97,000
Refund of Encashed BG of Unity	3,26,00,000														3,26,00,000	-
Total	**3,26,00,000**	**3,40,78,319**	**14,57,45,766**	**-**	**-**	**6,28,28,288**	**-**	**-**	**-**	**9,33,05,793**	**3,20,79,011**	**-**	**-**	**-**	**40,06,37,177**	**52,04,21,969**
TOTAL (i+ii+iii) - B	**7,72,95,853**	**32,90,16,089**	**18,80,74,946**	**7,86,811**	**16,41,86,434**	**7,05,64,333**	**12,13,300**	**1,03,46,737**	**2,65,500**	**9,43,70,292**	**3,62,66,313**	**48,780**	**2,90,019**	**-**	**97,27,25,406**	**1,43,90,90,679**
Amount Refunded-C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NET BALANCE AS AT THE PERIOD END {A -(B+C)}	**-4,58,11,401**	**-14,36,26,742**	**-7,00,64,654**	**36,25,134**	**9,14,25,465**	**5,08,78,483**	**19,22,277**	**62,55,839**	**8,66,032**	**4,36,10,182**	**1,22,54,038**	**5,49,274**	**15,64,995**	**5,84,823**	**-4,59,66,254**	**-2,22,49,991**

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE - 3 CURRENT LIABILITIES & PROVISIONS

Particulars	Current Year (2018-19) ₹	Previous Year 2017 - 18) ₹
A. CURRENT LIABILITIES		
Earnest Money Deposit	62,83,733	82,29,793
Security Deposit	1,06,95,909	93,71,163
Outstanding Expenses	1,95,04,058	1,20,54,239
Sundry Creditors	8,85,60,182	3,08,87,131
INSPIRE/DISHA/RTF-DCS Fellowship	(9,13,506)	(4,80,578)
Other bank Liability	2,15,82,223	0.00
Total – A	**14,57,12,599**	**6,00,61,747**
B. PROVISIONS		
Gratuity	3,13,65,335	2,88,15,430
Accumulated Leave Encashment	3,18,01,998	3,68,12,465
Total – B	**6,31,67,333**	**6,56,57,895**
Total (A+B)	**20,88,79,932**	**12,56,89,642**

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE – 4 FIXED ASSETS **(Amount in Rs.)**

DESCRIPTION (% of Depreciation)	GROSS BLOCK			DEPRECIATION					NET BLOCK	
	As at 31.03.2018	Additions during the year	As at 31.03.2019	As at 31.03.2018	For the year 2018-19	Diff of Previous Years Dep	Total Depreciation for the year 2018-19	As at 31.03.2019	As at 31.03.2019	As at 31.03.2018
1. Land (0%)	1,000	-	1000	-	-	-	-	-	1000	1,000
2. Plant, Machinery & Equipments (15%)	4,54,24,724	1,02,896	4,55,27,620	4,46,30,913	1,37,147	90,722	2,27,869	4,48,58,782	6,68,838	7,93,811
3. Furniture & Fixtures (10%)	1,72,67,084	-	1,72,67,084	1,17,49,257	5,55,048	2,58,606	8,13,654	1,25,62,911	47,04,173	55,17,827
4. Office Equipment (15%)	34,11,919	40,946	34,52,865	26,14,697	1,23,327	53,122	1,76,449	27,91,146	6,61,719	7,97,222
5. Computer / Peripherals (40%)	12,90,17,761	-	12,90,17,761	10,77,48,443	1,03,58,045	21,64,831	1,25,22,876	12,02,71,319	87,46,442	2,12,69,318
6. Electric Installations (10%)	20,98,406	-	20,98,406	12,90,978	81,748	50,722	1,32,470	14,23,448	6,74,958	8,07,428
7. Library Books (40%)	7,69,76,410	68,51,125	8,38,27,535	6,95,85,693	54,32,129	-1,04,54,024	-50,21,895	6,45,63,798	1,92,63,737	73,90,717
8. Other Fixed Assets (15%)	65,75,041	4,72,000	70,47,041	33,18,537	5,59,468	3,36,575	8,96,043	42,14,580	28,32,460	32,56,504
9. Vehicles (15%)	27,42,112	-	27,42,112	15,53,079	1,79,660	44,805	2,24,465	17,77,543	9,64,569	11,89,033
Total	**28,35,14,457**	**74,66,967**	**29,09,81,424**	**24,24,91,597**	**1,74,26,572**	**-74,54,641**	**99,71,931**	**25,24,63,527**	**3,85,17,896**	**4,10,22,860**
Previous Year	27,48,84,173	86,30,284	28,35,14,457	22,41,88,556	1,83,03,041	-	-	24,24,91,597	4,10,22,860	5,06,95,617

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

Schedule 4A - Earmarked Fixed Assets

	Description of the Assets	Gross Block					Depreciation					NetBlock	
Sl.No	Name of the Fund/Project	Rate	As on 01-04-2018	Additions 2018-19	Grant Utilized/ Received till 31-3-19 (G/A -Gen/ Capital)	Total Amount as on 31-03-2019	As on 31.03.2018	For the Year 2018-19	Diff. of Previous Years Dep.	Total Depreciation for the year	As at 31.03.2019	As at 31.03.2019	As at 31.03.2018
i)	Building Fund		589,683,874	44,695,853	-634,379,727	-	-	-	-	-	-	-	-
ii)	MDC & Equipment Fund		65,921,618	-	-65,921,618	-	-	-	-	-	-	-	-
iii)	Ocean Information and Advisory Services (OASIS)	-	1,588,972,051	140,915,904	-1,729,887,955	-	-	-	-	-	-	-	-
iv)	Computational Facilities	-	152,806,467	-	-152,806,467	-	-	-	-	-	-	-	-
v)	INDOMOD & STACORE Project	-	427,264,846	-	-427,264,846	-	-	-	-	-	-	-	-
vi)	Ocean Observation Networks	-	597,736,214	165,389	-597,901,603	-	-	-	-	-	-	-	-
vii)	International Training Center - ITCO ocean	-	396,219,380	152,483,982	-548,703,362	-	-	-	-	-	-	-	-
viii)	O-MASCOT (HROOF)	-	19,942,324	-	-19,942,324	-	-	-	-	-	-	-	-
ix)	HPC System-INCOIS *	-	136,414,440	-	0	-	-	-	-	-	-	-	-
x)	IT & E Governance Fund	-	57,621,080	1,213,300	-58,834,380	-	-	-	-	-	-	-	-
xi)	HPC System-Others	-	1,336,157,396	-	-1,336,157,396	-	-	-	-	-	-	-	-
xii)	CSS	-	1,421,621	15,750	-1,437,371	-	-	-	-	-	-	-	-
xiii)	V SAT Node	-	133,128,616	-	-133,128,616	-	-	-	-	-	-	-	-
xiv)	Ernet India		7,200,000	-	-7,200,000	-	-	-	-	-	-	-	-
xv)	IOAS		5,125,986	-	-5,125,986	-	-	-	-	-	-	-	-
xvi)	MH Vulnerability		2,830,738	-	-2,830,738	-	-	-	-	-	-	-	-
xvii)	Monsoon Mission		36,358,018	-	-36,358,018	-	-	-	-	-	-	-	-
xviii)	RIMES		2,058,886	4,187,302	-6,246,188	-	-	-	-	-	-	-	-
	Total		**5,556,863,555**	**343,677,480**	**-5,764,126,595**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
	Previous year		**5,236,038,838**	**320,824,717**	**-5,556,863,555**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
	GRAND TOTAL (Sch. 4 + 4A)		**5,840,378,012**	**351,144,447**	**-5,764,126,595**	**290,981,424**	**242,491,597**	**17,426,572**	**-7,454,641**	**9,971,931**	**252,463,528**	**38,517,896**	**41,022,860**
	GRAND TOTAL (PREVIOUS YEAR)		**5,510,923,011**	**329,455,001**	**-5,556,863,555**	**283,514,457**	**224,188,556**	**18,303,041**	**-**	**18,303,041**	**242,491,597**	**41,022,860**	**50,695,617**

* For the S.No ix, after obtaining the necessary approvals the HPC system was Disposed off for a value of rupees 3,45,000 and the amount was remitted back to MoES. Hence, the value at the end of financial year 2018-19 was shown as Zero.

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE - 5 CURRENT ASSETS, LOANS & ADVANCES

Particulars	Current Year (2018 - 19) ₹		Previous Year (2017-18) ₹	
A. CURRENT ASSETS				
1. Inventories (Valued at cost)	5,65,132	5,65,132	4,52,241	4,52,241
2. Cash & Bank Balance:				
a) With Scheduled Banks – Current Account				
State Bank of India HAL CAMPUS A/c	9,14,99,176		11,03,47,172	
Andhra Bank Pragathinagar SAVINGS A/c	29,63,131		31,54,175	
Andhra Bank Pragathinagar - Consultancy A/c	23,06,529		3,82,809	
Andhra Bank Savings PORSEC - A/c	19,942		-	
State Bank of India - CPF A/c	72,44,233		-	
State Bank of India - ISPRS A/c	3,11,049		-	
State Bank of India - IDBPS 4095 A/c	1,06,999	10,44,51,059	-	11,38,84,156
b) Short Term Deposits with SBI	14,85,00,000			
c) Short Term Deposits with CPF	1,10,00,000		6,93,00,000	
d) Short Term Deposits with PORSEC	29,00,000			
e) Short Term Deposits with AB	-	16,24,00,000		6,93,00,000
TOTAL A:		**26,74,16,191**		**18,36,36,398**
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	84,668		1,04,042	
b) Interest Accrued	1,58,14,255		1,27,20,142	

c) Other Advances		-		-	
d) Advance for Purchase		21,44,317		21,44,317	
e) Sundry Debtors		7,32,813		-	
f) Tour Advance		29,56,981		16,36,174	
g) LTC Advance		4,74,000		5,58,727	
h) TDS					
Opening Balance -	Rs.1,40,42,701				
Less: Refund received during the year	Rs.0.00				
Add: Current year accumulation	Rs.22,27,428				
Less: TDS Adjustment Entry	Rs.28,30,670	1,34,39,459		1,40,42,701	
i) Margin Money against Bank Guarantee		34,13,165	3,90,59,658	34,13,165	3,46,19,238
TOTAL B: (1+2)			**4,63,63,718**		**4,19,23,328**
GRAND TOTAL (A + B)			**31,37,79,909**		**22,55,59,725**

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 6 - INCOME FROM SALES / OTHER INCOME

Particulars	Current Year (2018- 19) ₹	Previous Year (2017 - 18) ₹
a) Sale of Tender Forms	1,500	17,900
b) Other Receipts	16,58,189	19,54,678
c) Consultancy Services	34,94,835	31,60,860
d) Income from staff quarters	6,83,157	5,57,186
TOTAL	**58,37,681**	**56,90,624**

SCHEDULE 7 - INTEREST EARNED		
a) Interest on Short Term Deposits & Others	14,39,227	62,51,352
b) Bank Accounts	1,25,311	1,29,433
c) Staff Advances	10,369	24,426
TOTAL	**15,74,907**	**64,05,211**

SCHEDULE 8 - IRRECOVERABLE GRANTS & SUBSIDIES RECEIVED		
a) Central Government (Recurring Grant received from MoES)	25,00,00,000	23,17,30,000
TOTAL	**25,00,00,000**	**23,17,30,000**

SCHEDULE 9 - ESTABLISHMENT EXPENDITURE		
a) Salaries, Wages & Allowances	10,67,82,368	10,89,28,438
b) Staff Welfare Expenses	20,57,745	18,39,320
c) Contributory Provident Fund	3,14,414	8,83,882
d) New Pension Scheme	56,54,008	60,91,157
e) IDBPS Trust	-	23,33,615
f) Leave Travel Concession	33,61,419	13,54,496
TOTAL	**11,81,69,954**	**12,14,30,908**

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 10 - OTHER ADMINISTRATIVE EXPENSES

Sl No.	Particulars	Current Year (2018-19) ₹	Previous Year (2017-18) ₹
1.	Electricity & Power Expenses	2,98,03,776	2,96,86,666
2.	Water Charges	45,46,205	45,42,676
3.	Operation & Maintenance expenses	1,64,99,333	3,60,61,813
4.	Garden Expenses	11,29,035	12,53,395
5.	Vehicle Hiring Expenses	8,26,435	7,56,872
6.	Postage, Fax & ISDN Charges	6,55,709	6,17,314
7.	Printing & Stationery	14,62,248	14,75,278
8.	Travelling Expenses:		
	Inland	20,88,100	22,72,166
	Foreign	11,65,702	17,25,531
	Others	1,89,725	75,721
9.	Seminar/Workshops Expenses	1,97,874	12,67,211
10.	General Expenses	90,26,430	1,11,40,960
11.	Audit Fee	25,651	16,666
12.	House Keeping & Plumbing	1,34,65,247	1,35,92,320
13.	Security Expenses	1,54,09,362	1,74,66,721
14.	Advertisement & Publicity	15,68,289	27,82,481
15.	Emoluments to Consultants	7,22,763	7,23,704
16.	Internet Expenses	0.00	8,67,727
17.	Legal Expenses	2,12,900	56,147
18.	Papers & Periodicals	41,785	42,561
19.	Conveyance Expenses	0.00	1,912
20.	Material /Consumable	32,59,302	4,68,951
21.	International Interface	5,21,640	6,52,811
22.	Others	2,12,000	1,64,000
	TOTAL	**10,30,29,511**	**12,77,11,604**

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 2018-19, the Society received Rs.25.00 Crores towards Recurring Grant as shown in the Schedule-8.

The remaining Grant-in-aid of Rs.88.47 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.
v. The necessary correction entries were passed for the SAP error occurred during the financial year 2015-16 while calculating the depreciation. Such difference amount was shown separately under "Difference of previous years Depreciation" in the schedule-4 of the financial statements. The impact of this is Rs. (-) 74,54,641 been taken to Income & Expenditure Account along with Current year Depreciation. Because of this the Income has been under stated and Assets are over stated after of effecting the correction entries.

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.

f) **Employee Benefits:**

i) **Gratuity:**

The present value of the INCOIS obligations under Gratuity is recognized on the basis of an actuarial valuation made by 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 for the year 2018-19 towards pension for the employees joined prior to 01-01-2004, was transferred by INCOIS to LIC of India Ltd.

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) Periodical contributions to IDBPS are charged to revenue up to August 31, 2015 only. Management decided to initiate required action and make provisions in accounts based on the Judgment from the Hon'ble Central Administrative Tribunal.

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 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 2018-19, an amount of Rs.1,63,18,256/- 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.

Accordingly, out of total interest of Rs.1,63,18,256/-, the management had transferred an interest of Rs.1,53,01,469/- to various projects classified in Earmarked Funds under Schedule-2, and other funds received from INSPIRE Fellowship, DST-DPWS, DST-NPDF and the balance interest of Rs.10,16,787/- was considered as income of the Society.

However interest is not being charged on excess funds (funds that are in negative balance) used for the Earmarked funds to the respective grants.

The details are furnished below:-

(Amount in Rs.)

a.	Interest earned on regular STDRs	1,32,14,787.00
b.	Less: Transfer of outstanding Accrued Interest for the FY 2017-18	11,90,090.00
c.	Add: Net Accrued Interest for the current FY 2018-19 on SBI	27,69,532.00
d.	Add: TDS on accrued interest on Electricity Deposit	43,892.00
e.	Add: TDS on closed and accrued TDRs on SBI	14,80,135.00
f.	Total Interest earned for the FY 2018-19	1,63,18,256.00

2. Notes on Accounts:

a) EARMARKED FUNDS:

The Society during the year 2018-19, received Rs.88.47 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 overall funds positions in the Ear-marked funds 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 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, the total value of equipment is transferred to equipments under the same Schedule. The total value of "Advance for Purchase" as on 31-03-2019 was Rs. 27.75 Crores.

The accumulated value of the capital expenditure as on 31-03-2019 (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 01-04-2018 ₹	Additions 2018-19 ₹	Total Amount as on 31-03-2019 ₹
i)	Building Fund	58,96,83,874	4,46,95,853	63,43,79,727
ii)	MDC & Equipment Fund	6,59,21,618	-	6,59,21,618
iii)	Ocean Information and Advisory Services (OASIS)	1,58,89,72,051	14,09,15,904	1,72,98,87,955
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	59,77,36,214	1,65,389	59,79,01,603
vii)	International Training Centre-ITCOocean	39,62,19,380	15,24,83,982	54,87,03,362
viii)	O-MASCOT (HROOFS)	1,99,42,324	-	1,99,42,324
ix)	HPC System – INCOIS*	13,64,14,440	-	0.00
x)	IT & E Governance Fund	5,76,21,080	12,13,300	5,88,34,380
xi)	HPC Systems – Others	1,33,61,57,396	-	1,33,61,57,396
xii)	CSS	14,21,621	15,750	14,37,371
xiii)	V SAT Node	13,31,28,616	-	13,31,28,616
xiv)	Ernet India	72,00,000	-	72,00,000
xv)	IOAS	51,25,986	-	51,25,986
xvi)	MH Vulnerability	28,30,738	-	28,30,738
xvii)	Monsoon Mission	3,63,58,018	-	3,63,58,018
xviii)	RIMES	20,58,886	41,87,302	62,46,188
	TOTAL	**5,55,68,63,555**	**34,36,77,480**	**5,76,41,26,595**

*For the S.No.ix, after obtaining the necessary approvals the HPC system was disposed off for a value of Rs.3,45,000/- and the amount was remitted back to MoES. Hence, the value at the end of Financial Year 2018-19 was shown as ZERO.

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. There is a legal dispute going on with M/s Gaian and the firm's Bank Guarantee was encashed amounting to Rs.9,50,000/-. Depending upon the judgment of the case, the action will be taken in future and the amount was shown in current liabilities.

b. Periodical contributions to IDBPS are charged to revenue up to August 31, 2015 only. Management decided to initiate required action and make provisions in accounts based on the Judgment from the Hon'ble Central Administrative Tribunal, the amount is to be ascertained subject to the approval of Governing Council.

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 Ms. 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) **Deduction of TDS and reconciliation of accumulated TDS**

During the Financial Year 2017-18 for non-submission of the information by the State Bank of India a TDS rectification entry was passed for Rs.28,30,670/- for excessively deducted TDS. The error was rectified by taking up the accounting treatment in the books for the Financial Year 2018-19.

f) **Input Tax Credit of GST**

INCOIS is being a Scientific Organization mandated with providing ocean data, information and advisory services to the society, industry, the Government and Scientific Community. There is an imbalance of payment of GST against the Purchases made and services obtained against

input tax credit claimed. The matter is discussed with GST Department. Since Input GST is not agreed by the GST Department as credit allowable, GST is treated as part of expenditure and GST collected as output GST, is treated as Income in the books of Accounts whereas while filing GST return we claim ITC and set off against Output GST.

g) **Other Bank Accounts brought into books in the current year.**

Management considered the decision of the APEX Bodies and brought all the bank accounts managed by INCOIS to its books of accounts. The closing balances as on 31.3.2019 were brought and the next year onwards the transactions for these accounts will be carried out in the books of accounts of INCOIS. Management decided that the interest earned on these accounts and deposits will be credited back to the concerned accounts and not to be shown as income to the Society.

The IOGOOS (Foreign & Local) Accounts are temporary in nature and ceases to be closure upon closure of Secretary ship of the IOGOOS. Hence these accounts are operated separately.

Similarly, the INCOIS Canteen Account even though under the complete control of INCOIS, the same is treated by Management as separate from INCOIS and maintained accordingly. For both the Accounts i.e. IOGOOS (Foreign & Local) and INCOIS Canteen, Audits are carried out periodically.

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

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

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

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

Place: Hyderabad
Date: 02.08.2019

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

(S. Nageswara Rao)
Sr. Accounts Officer

(S.S.C. Shenoi)
Director

ESSO-Indian National Centre for Ocean Information Services

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

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