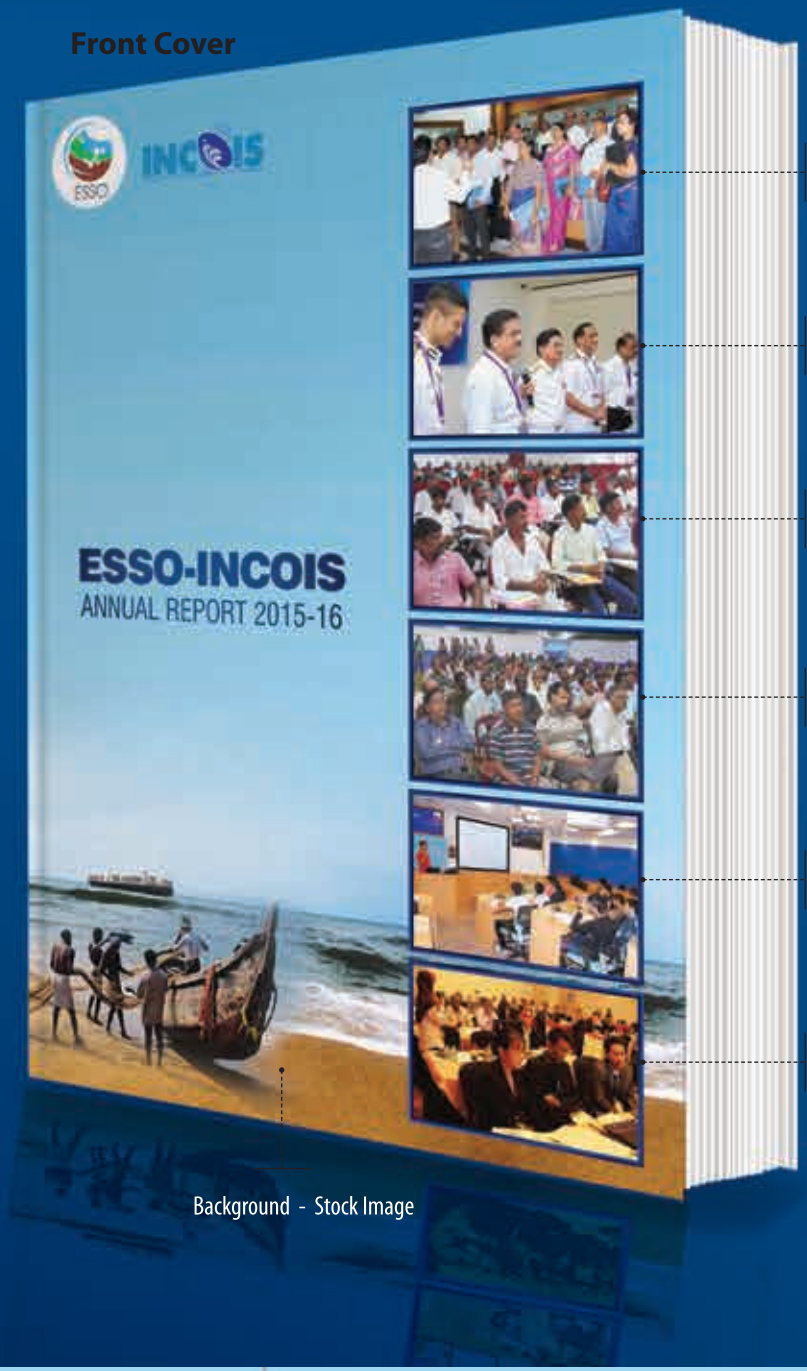
ESSO-INCOIS

ANNUAL REPORT 2015-16

Front Cover



National-level Tsunami Standard Operating Procedure Workshop held at ESSO-INCOIS on 26 August 2016 in which officials from various state DMOs ,NDRF, Indian Navy and Coast Guard participated

Release of Version 2- Online Oil Spill Advisory on 9 April 2015 at the 20th NOSDCP meet organized by the Indian Coast Guard at Goa

Fishers attending "Training Programme for Users and Trainers" organized by ESSO-INCOIS at AMET University, Chennai on 8 March 2016

The User Awareness Workshop organised by ESSO-INCOIS at Digha on 2 February 2016

"Ocean Data Utilization and Ocean Observation Systems" course at ITCOocean, ESSO-INCOIS for student data users during 8-12 December 2015

The Regional-level Tsunami Standard Operating Procedure Workshop held at ESSO-INCOIS from 6-8 November 2015

Background - Stock Image

Back Cover

Entrance to ESSO-INCOIS' Main Building

Photo Courtesy- Knowledge Resource Centre, ESSO-INCOIS

ANNUAL REPORT 2015-16

ESSO-Indian National Centre for Ocean Information Services
(An autonomous body under the Ministry of Earth Sciences, Government of India)
Hyderabad

Contents

From Director's Desk

Inventorying the happenings and achievements during the past year is always a pleasure. It is gratifying to note that ESSO-INCOIS has not only lived up to expectations, but also has made giant strides forward in the areas of ocean information and advisory services. The report of National Council of Applied Economic Research (NCAER) on "Economic Benefits of Dynamic Weather and Ocean Information and Advisory Services in India and Cost and Pricing of Customised Products and Services of ESSO-NCMRW & ESSO-INCOIS" published in August 2015 testifies to the economic benefits available to various stake holders right from fishermen to the Indian Navy due to the usage of services provided by ESSO-INCOIS. I am delighted to present you our inventory of progress through this Annual Report of ESSO-INCOIS for the year 2015-2016.

Earlier we had reported that we have been designated to provide tsunami early warning services to all countries on the Indian Ocean Rim by IOC/UNESCO in 2012 and we have lived up to the expectations of all, without missing a single event or time to provide the right information. During the last year, we have also established the Ocean State Forecast and Information System for Seychelles and Sri Lanka. Dr. Harsh Vardhan, the Hon'ble Union Minister for Earth Sciences and Science and Technology, inaugurated the system in New Delhi on 10 July 2015 during the RIMES Inter-Ministerial Council meeting.

We are not only committed to issuing early warnings and advisories, but also committed to ensuring their reach up to the last user and educating him on how to use that information for his benefit. Accordingly, ESSO-INCOIS conducted tsunami mock drills in the Coastal States and Union Territories of east coast of India on 26 September 2015 and in Kerala on 11 March 2016. We have also conducted 4 user interaction meets with fishermen at Digha, Kanathur, Okha and Krishnapatanam, to explain how to use the PFZ advisories and Ocean State forecasts.

In our endeavour to improve our Tuna fishing advisories, we had tagged 42 Tuna in the Bay of Bengal and Lakshadweep Sea using satellite tracked tags. Based on the track data, it appeared that the Yellow Fin Tuna remains between the sea surface and oxycline. This information has been used to introduce a new parameter in the Tuna fishing advisories, which indicates the depth at which Tuna could be available.

Our observational network has been strengthened in coastal waters, by deploying additional 4 wave rider buoys, 13 ship-mounted Automated Weather Stations and 9 Radar tide gauges along the Indian coast. The ESSO-INCOIS data centre rescued several historical data sets that were available only in typed/handwritten form and converted them to digital format.

The OMM project undertaken by ESSO-INCOIS under the Monsoon Mission is an international collaborative effort to understand the air-sea exchange process over the Bay of Bengal during

the Indian monsoon. Two expeditions, one on board ORV Sagar Nidhi and another on board ORV Sagar Kanya were conducted to map the low-salinity water of riverine origin and to make detailed observations of upper ocean sub-mesoscale (1-10 km) processes that influence the air-sea interactions over the Northern Bay of Bengal.

Significant progress has been made on the ocean modelling and data assimilation front. The second model setup of the High resolution Operational Ocean Forecast and reanalysis System (HOOFS) series has been completed for the Southeastern Arabian Sea. With this setup, we are now providing forecasts of the entire water column along the west coast of India at ~ 2.0 km resolution. Bio-geo-chemical modules integrated with the high resolution setups of the Regional Ocean Modeling System (both for the Indian Ocean and the west coast of India) succeeded in simulating high and low frequency variability accurately. The Local Ensemble Transform Kalman Filter (LETKF)-based data assimilation scheme was successfully implemented in the ocean general circulation models-Modular Ocean Model and Regional Ocean Modeling System (ROMS). The system will make the operational ocean forecast services more accurate.

The International Training Centre for Operational Oceanography (ITCOocean) of ESSO-INCOIS conducted 6 courses on different aspects of operational oceanography. 160 participants, including 19 foreign nationals from 10 countries attended the courses.

On the infrastructure front, the extension of the main building of ESSO-INCOIS has been completed and was opened for occupation after inauguration by Dr. Shailesh Nayak, Secretary to Govt. of India, Ministry of Earth Sciences on 21 August 2015. He also inaugurated the INCOIS Guest House with 27 guest rooms, 3 junior and 5 VIP suite rooms.

Padma Bhushan, Prof. George Joseph, Distinguished Professor, ISRO delivered the Foundation Day lecture on the occasion of our 17th Foundation Day on 3 February 2016. The "Open Day" programme organised at ESSO-INCOIS to celebrate the occasion, attracted several hundred students and public visitors.

A National Scientific Hindi Seminar was held during 29-30 September 2015. Twenty-two oral presentations and 24 poster presentations were made by scientists/research students from various national institutes during the seminar. 'Hindi Pakhwara' was celebrated during 1-15 September 2015 with a special Guest lecture. Apart from this celebration, lectures were also organized to promote the usage of the Hindi language.

In addition to providing services, scientists from ESSO-INCOIS also published 41 research papers in reputed national and international journals with a cumulative impact factor 84.73.

The scientific staff strength enhanced to 47 with the addition of three Scientist-B positions allocated by the Ministry. However, to carry out the tasks envisaged in the projects, we have recruited 9 Project Scientists, 4 Project Assistants, a Scientist Fellow and 2 Consultants on contract- basis. Six Project Scientists, 2 Project Assistants, one Scientist Fellow and a Consultant resigned/completed their terms during the year. A new CSIR-UGC NET-qualified JRF joined INCOIS to carry out research leading to a Ph.D. degree.

ESSO-INCOIS continued its association with the Indian Ocean Global Ocean Observing System (IOGOOS), Regional Coordination of the 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 is hosted at ESSO-INCOIS to coordinate the IIOE-2 project (2016-2020) jointly sponsored by IOC, SCOR and IOGOOS.

ESSO-INCOIS played an active role in organising the International Symposium to celebrate the 50th Anniversaries of IIOE and National Institute of Oceanography, Goa during 30 November to 4 December 2015 and also in launching the First Expedition of IIOE-2 on board ORV Sagar Nidhi from Goa on 4 December 2015.

Website of ESSO-INCOIS was selected for Special Jury Award and the Annual Report (2014-15) of ESSO-INCOIS was selected for the 3rd prize in the category of annual reports by the Public Relations Society of India. Shri. T. Harish Rao, Hon'ble Minister for Irrigation & Legislative Affairs, Govt. of Telangana presented the awards during the 1st Telangana State Public Relations Conference held at Hyderabad on 21 February 2016.

The continuous support and guidance received from the Governing Council under the chairmanship of Dr. Shailesh Nayak and later under the chairmanship of Dr. M. Rajeevan was excellent. I thank Dr. Nayak and Dr. Rajeevan for continued support and guidance in conducting the activities of ESSO-INCOIS. My thanks to the members of the Governing Council for all their support and the time they gave so freely. I also would like to thank the Chairs and members of the Financial Committee and Research Advisory Committee for their help and advices in conducting the affairs of ESSO-INCOIS. My colleagues in Ministry of Earth Science and at the ESSO centres: NIOT, NCAOR, IITM, NCESS, NCMRWF, IMD, CMLRE, and ICMAM were always there with generous support for any issue that we wanted to solve. I thank them all.

I would like to say a heartfelt thank you to ESSO-INCOIS members of staff for whole-heartedly cooperating and contributing to the progress of ESSO-INCOIS. Together, we have made significant progress and I hope ESSO-INCOIS continues to develop well in future. It is a proud moment for all of us. My special thanks to the Editorial Committee of this report under the chairmanship of Francis and its members Hari, Kiran, Praveen, Suprit, Ajay, Nimit, Celsa, Sidhartha and Nisha.

With great pleasure, I present this report of ESSO-INCOIS for 2015-16. I hope, you will enjoy reading this report.

Thank You. Jai Hind.

S. S. C. Shenoi

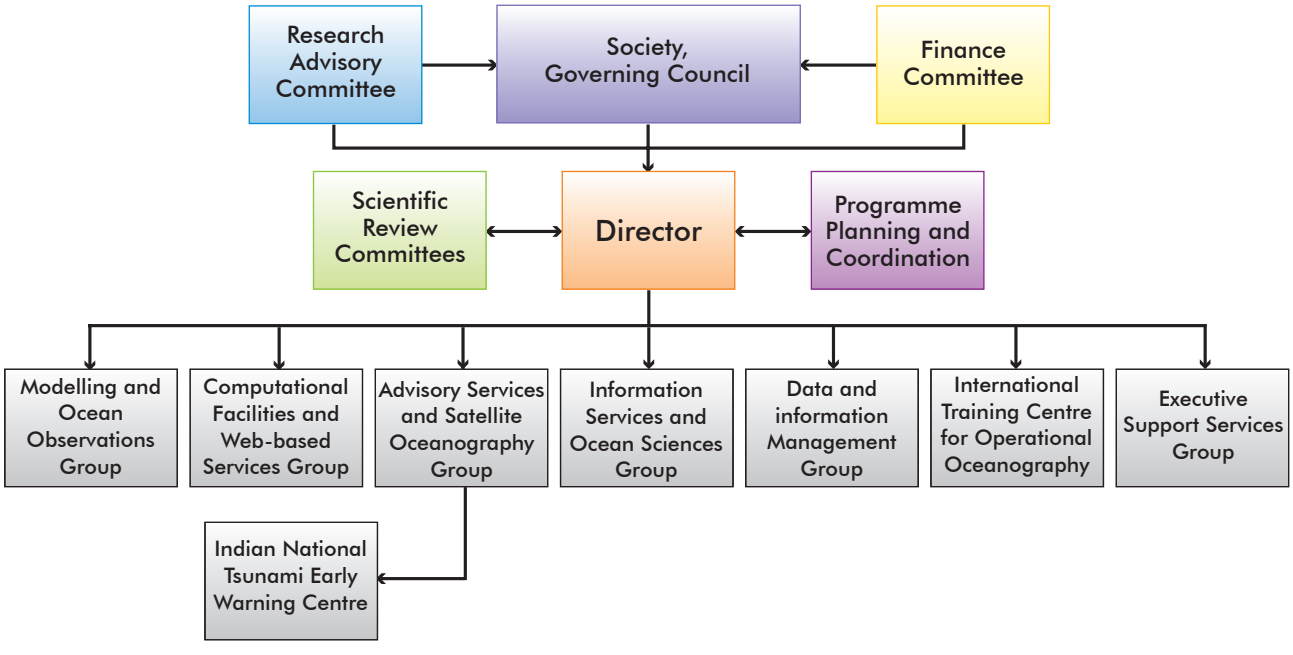
2. ESSO-INCOIS Organizational Structure

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 (Telengana) 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 Antarctic 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.	Director, National Remote Sensing Centre	(Member)
3.	Director General, India Meteorological Department	(Member)
4.	Financial Advisor, Ministry of Earth Sciences	(Member)
5.	Joint Secretary, Ministry of Earth Sciences	(Member)
6.	Director, National Centre for Antarctica and Ocean Research	(Member)
7.	Dr. S.W.A. Naqvi, Director, National Institute of Oceanography	(Member)
8.	Director, National Institute of Ocean Technology	(Member)
9.	Prof. G.S. Bhat, Indian Institute of Science	(Member)
10.	Dr. R. R. Rao, Former Scientist 'G', Naval Physical & Oceanographic Laboratory	(Member)
11.	Advisor (S & T), National Institution for Transforming India Aayog	(Member)
12.	Programme Officer, Ministry of Earth Sciences	(Member)
13.	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. Financial Advisor, MoES, (Chairman)
2. Joint Secretary, MoES, (Member)
3. Director, ESSO-INCOIS, (Member)
4. Director/Deputy Secretary (Finance), MoES, (Member)
5. Programme Officer, MoES, (Member)
6. Sri. E. Pattabhi Rama Rao, Scientist, 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 the Quality Management System, by setting and reviewing quality objectives.

3. Highlights

3.1. Ocean State Forecast for Seychelles and Sri Lanka

The Ocean State Forecast and information system for Seychelles and Sri Lanka was inaugurated by Dr. Harsh Vardhan, the Hon'ble Union Minister for Earth Sciences and Science and Technology, in New Delhi on 10 July 2015.

3.2. 3-D Tuna Advisory

Based on the findings of Tuna Teletracking studies (SATTUNA) that the vertical movement of Yellow Fin Tuna is mainly between sea surface and oxycline depth, a 3D Tuna-PFZ advisory, depicting the location and the maximum fishing depth where Tuna Fish may be available is introduced as a value added service in the PFZ programme.

3.3. Tsunami Mock Drills

As part of improving awareness and preparedness of the administrators and the general public, ESSO-INCOIS conducted tsunami mock drills in the Coastal States and Union Territories of east coast of India on 26 September 2015 and in Kerala on 11 March 2016.

3.4. Rescue of Historical Data

The ESSO-INCOIS data centre made significant progress in rescuing historical data sets, especially those that were available in typed/handwritten form, and converted them to digital format for further quality check and archival.

3.5. Ocean Observational Network

ESSO-INCOIS strengthened the observational network in the coastal waters with the deployment of 4 more wave rider buoys, 13 more ship-mounted Automated Weather Stations and 10 more Radar tide gauges along the Indian coast.

3.6. OMM Cruise

As part of OMM project, two dedicated cruises were conducted in the Bay of Bengal, on board ORV Sagar Nidhi and ORV Sagar Kanya to map low-salinity water of riverine origin and to make detailed observations of upper ocean sub-mesoscale (1-10 km) structures and variability in Northern Bay of Bengal.

3.7. Integration of LETKF Assimilation Scheme with Ocean Models

Local Ensemble Transform Kalman Filter (LETKF) based data assimilation scheme was successfully implemented in the ocean general circulation models- Modular Ocean Model and Regional Ocean Modeling System (ROMS). The system will make the operational ocean forecast services more accurate.

3.8. HOOFS Setup for Southeastern Arabian Sea

The second model setup in the series of High resolution Operational Ocean Forecast and reanalysis System (HOOFS) has been set up for the Southeastern Arabian Sea.

3.9 Biogeochemical Modeling

Biogeochemical modules are integrated with high resolution setups of Regional Ocean Modeling Systems (both for the Indian Ocean and the west coast of India). It was found that the high resolution coastal setup of the model can represent/predict both high and low frequency variability more accurately.

3.10 International Training Centre for Operational Oceanography

International Training Centre for Operational Oceanography (ITCOocean) of ESSO-INCOIS conducted 6 courses on different aspects of operational oceanography. Altogether, about 160 participants, including 19 foreign nationals from 10 countries attended these courses.

3.11. Inaugurated ESSO-INCOIS Phase-II Building

The extension of the main building of ESSO-INCOIS was completed and after inauguration by Dr. Shailesh Nayak, Hon'ble Secretary to Govt. of India, Ministry of Earth Sciences was opened for occupation on 21 August 2015.

3.12. Inaugurated ESSO-INCOIS Guest House

Construction of the INCOIS Guest House with 27 guest rooms, 3 family rooms and 5 suite rooms was completed and opened for occupation after inauguration by Dr. Shailesh Nayak, Hon'ble Secretary to Govt. of India, Ministry of Earth Sciences on 21 August 2015.

3.13. Celebration of ESSO-INCOIS Foundation Day

ESSO-INCOIS celebrated its 17th Foundation Day on 3 February 2016 with an "Open Day" programme for students and pubic visitors. Padma Bhushan, Prof. George Joseph, Distinguished Professor, ISRO delivered the Foundation Day lecture.

3.14. ISO Surveillance Audit

As per the policy of ISO 9001-2008, a Surveillance Audit was conducted during 27-28 January 2016 by the STQC. The audit found that the ESSO-INCOIS services such as Tsunami Warnings, Ocean State Forecast and Potential Fishing Zone advisories continued to fulfill the necessary conditions stipulated for the ISO certification.

3.15. Publications from ESSO-INCOIS

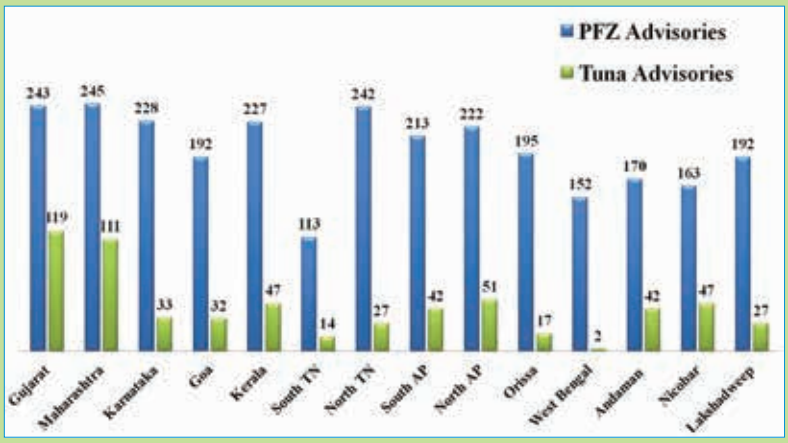
Scientists from ESSO-INCOIS published 41 research papers in reputed national and international journals with a cumulative impact factor of 84.73.

4. Services

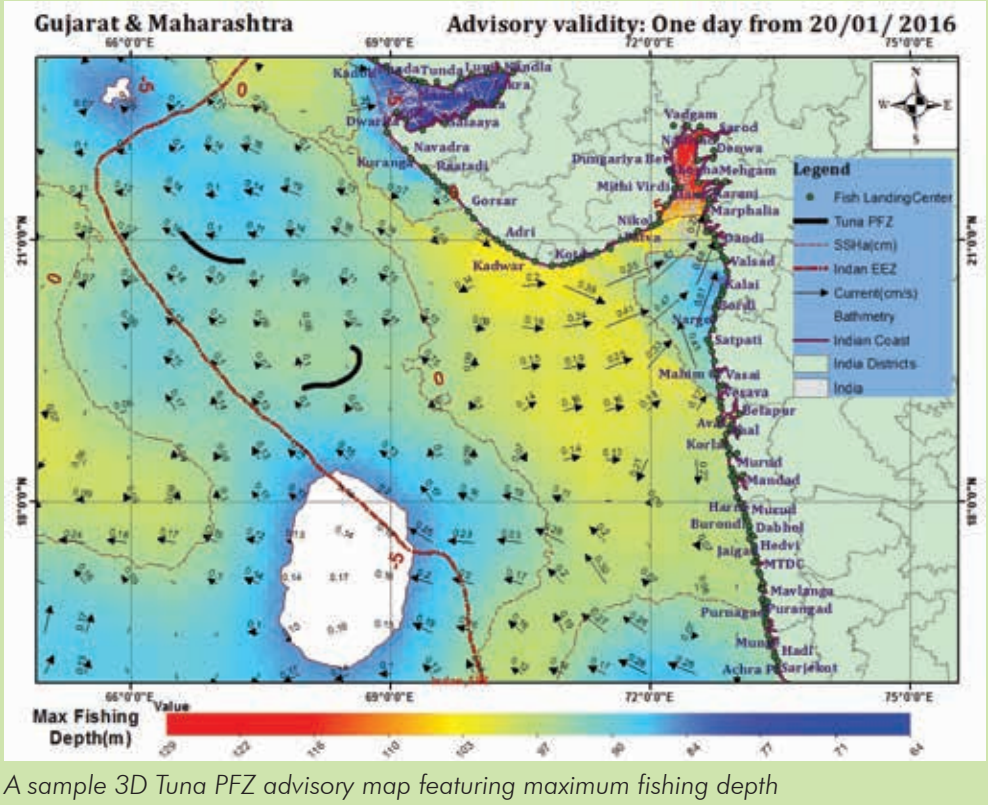
4.1 Marine Fishery Advisory Services

4.1.1 Potential Fishing Zones (PFZ) and Tuna PFZ Advisories

The Potential Fishing Zone advisory programme has evolved as a flagship of ESSO-INCOIS which directly benefits tens of thousands of fishermen and their families. The information on the regions of fish availability are being generated with the help of satellite data on SST and ocean colour and other environmental parameters such as wind/ currents/temperature, etc. The advisories are disseminated in smart map and text form on a daily basis, depending on satellite data availability except during the fishing-ban period and adverse sea-state. During 2015-16, 322 multilingual Potential Fishing Zone (PFZ) advisories were provided, against targeted 300 advisories. In the period April 2015 to March 2016, 137 Tuna PFZ advisories, which include information on the maximum depth for Tuna fishing were also provided.



Statistics of PFZ and Tuna PFZ advisory dissemination



A sample 3D Tuna PFZ advisory map featuring maximum fishing depth

3-D Tuna Advisory

Based on the data obtained from the Tuna telemetry programme (SATTUNA) and historic tuna catches, it is found that the vertical movement of YellowFin Tuna (YFT) is mainly between the sea surface and the oxycline depth. Since the Sea Surface Height Anomaly (SSHA) is

highly correlated to the oxycline depth (below which low oxygen waters lie), it is possible to infer the depth of availability of Tuna fish from the SSHA data. This information is used to generate 3D advisories where the location and the maximum fishing depth (MFD) information are indicated.

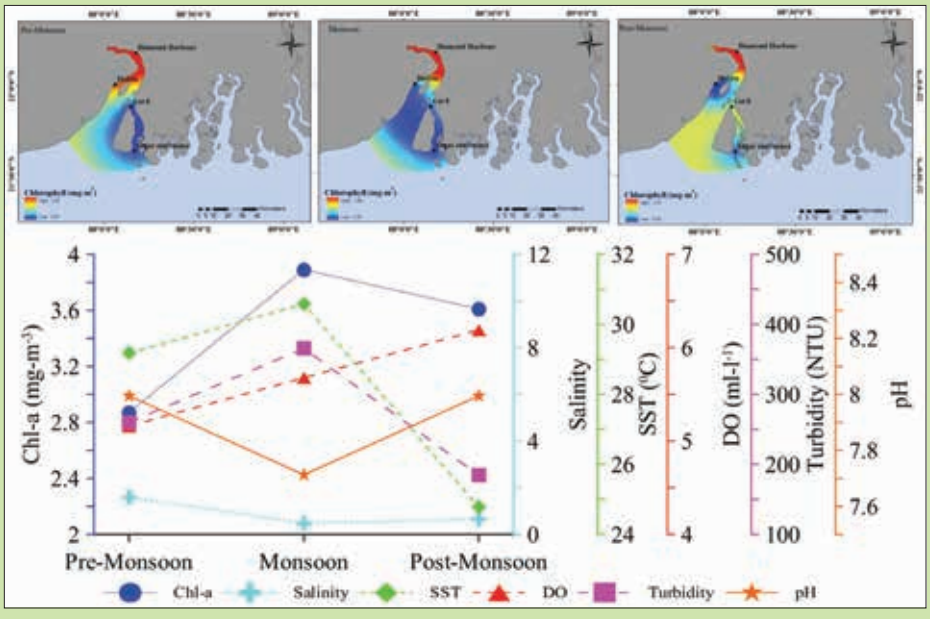
4.1.2 Species specific research efforts

SATTUNA (Satellite Telemetry of Tuna)

Newly procured PSAT tags with magnetometer, and (in bigger tag) accelerometer

In order to study the preferred habitat of Tuna fish, advanced Popup Satellite Archival Tags (PSAT) were procured. So far, ten Yellowfin tuna were tagged with PSATs. In addition to standard depth, temperature, and communication sensors, these tags have a wrapped-on solar cell to measure 360° light. The tag also has a magnetometer to refine underwater latitude estimation with reference to the earth magnetic field; and has a 3-axis accelerometer to study fish activity. Researchers from collaborating organizations, CMFRI and FSI, were trained in activating and deploying these tags. The deployment of tags involves catching the Tuna unhurt and attaching the tag on its fin in least possible time (less than 3 minutes).

Towards development of Hilsa Shad predictive capabilities and monitoring of spawning ground health



Seasonal distribution of chlorophyll concentration in Hugli river (upper panel) and bio-geochemical variability at one of the spawning ground, Diamond Harbour (lower panel)

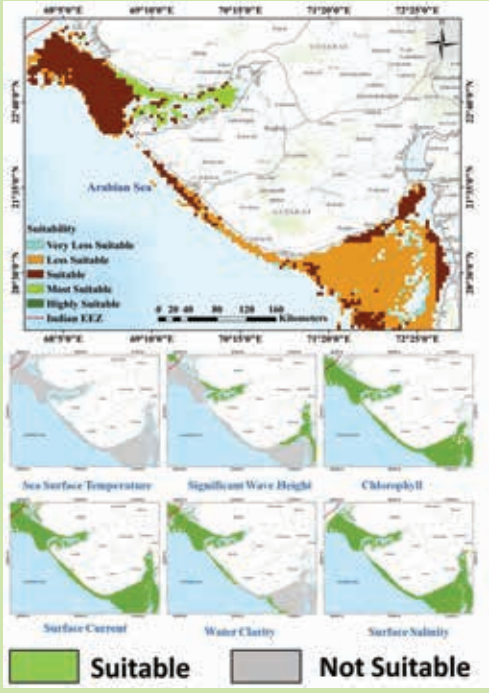
ESSO-INCOIS, in collaboration with Jadavpur University, is working towards developing predictive capabilities of Hilsa (*Tenualosa ilisha*) in Indian waters. Hilsa is a *euryhaline anadromous* shad found in the coastal/ near-coastal shelf off Ganga, Brahmaputra and Meghna riverine system in the Northern Bay of Bengal. The fish spends most of its life in the ocean, feeding on phytoplankton. However, in India, during the southwest monsoon, it migrates towards Hugli-Matla (tributaries of Ganga) Estuary (HME) and other adjacent estuaries of Odisha and Andhra Pradesh for breeding. It was found that adults stop feeding before spawning

and prefer to stay near the ocean/river bed most of the time. Salinity depletion caused by rain over the sea or by increase in river discharge may be one of the key forcing factors that trigger migration for breeding. The recruitment of Hilsa in the next year stock is highly dependent on the rate of fecundity of spawned eggs. Undesirable ecological conditions in the spawning grounds may directly affect the egg/larval mortality. Data on ecological and egg-density parameters are being collected to monitor the health of Hilsa shad spawning grounds in HME.

4.1.3 Mariculture Site Suitability

India is set to become a highly populated country and land-based resources are scanty. A developed mariculture industry can help meet nutritional needs. Marine environment offers untapped resources for bio-fuel, drugs and other bio-active compounds as well.

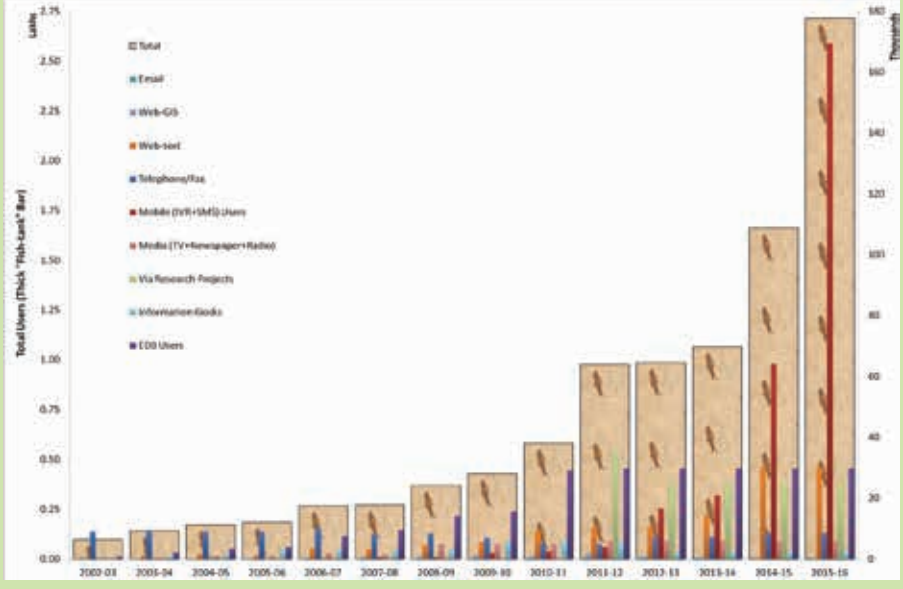
To address this, ESSO-INCOIS took initiative to map sites suitable for mariculture within Indian EEZ. An atlas – envisaged as an initial decision support system – is prepared depicting overall and parameter-wise suitability, for each month and for all the coastal states. Future efforts will focus on species-specific atlases and an advisory service similar to PFZ.



A template example of mariculture atlas under preparation

4.1.4 User-base of MFAS services

The multilingual android app developed in-house for PFZ and Tuna advisories was made available on the Google Play Store. For users with basic or non-android phones, ESSO-INCOIS provide multilingual SMS directly from the PFZ laboratory. Presently, 400 registered users are using this facility to receive multilingual SMS. Partner organization MSSRF launched the Odiya helpline and beta-version of FFMA app in February, 2016. Full version of FFMA Malayalam was also launched in February 2016. Currently, 2.75 lakh users are using PFZ advisories on a regular basis by accessing it through different modes of communication.



Evolution of MFAS user base for various modes

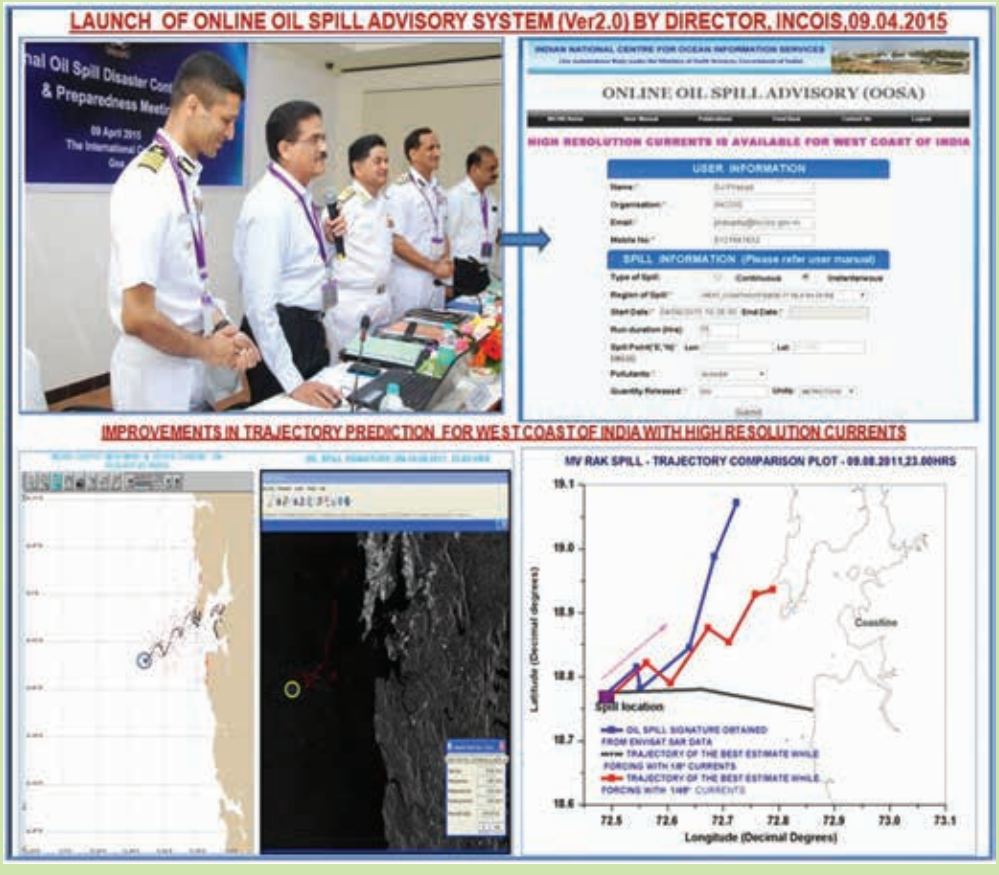
4.2 Ocean State Forecast services

The Ocean State Forecast service continued to provide quality forecasts and advisory services to a wide spectrum of users that include fishermen, ports and shipping industry, defence, oil and energy exploration agencies, disaster management authorities, etc.

4.2.1 Ocean State Forecasts during Ashooba cyclone

ESSO-INCOIS issued a series of joint bulletins with the India Meteorological Department (IMD) for Ashooba cyclone during 8-10 June 2015. Even though the cyclone did not cross the Indian coastline, high waves occurred along the west coast of India during its passage over the Arabian Sea. The ocean state forecasts issued were in good agreement (with average accuracy up to 85%) with wave heights recorded by the wave rider buoys deployed by ESSO-INCOIS at Karwar and Ratnagiri.

4.2.2 Online Oil Spill Advisory (OOSA)

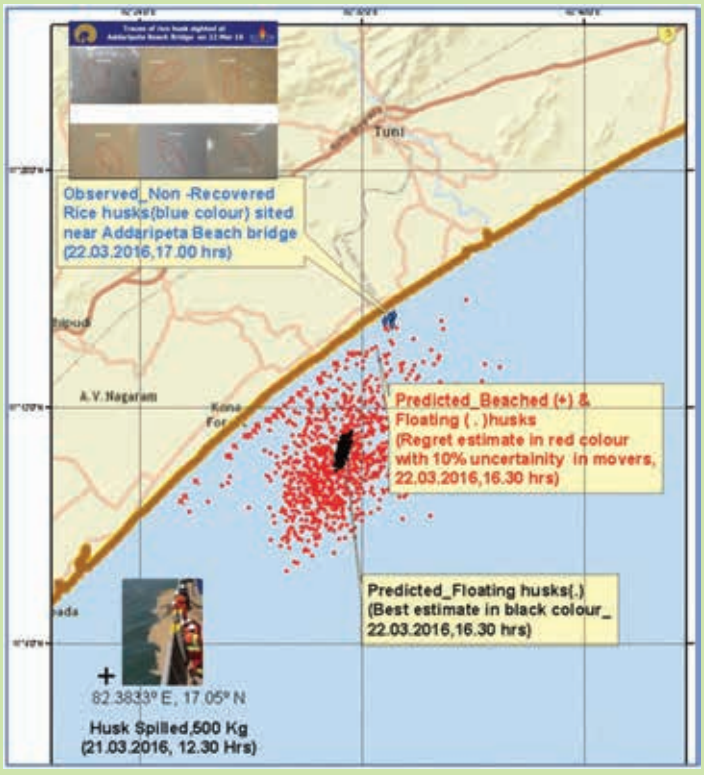


Launch of OOSA version 2.0 by the Director, ESSO-INCOIS

The Online Oil Spill Advisory (OOSA) version 2.0 was inaugurated by Director, ESSO-INCOIS on 9 April 2015 at the 20th National Oil Spill Disaster and Contingency Plan (NOSDCP) meet organised by the ICG and chaired by Vice Admiral HCS Bisht, AVSM, DG-ICG. This version gives the high resolution prediction of trajectory of oil spills (for continuous and instantaneous spills) along the west coast. ESSO-INCOIS also conducted a countrywide table-top exercise on trajectory predictions by OOSA at the spill prone zones – such as jetties, terminals, outer harbours, single point mooring installations, etc. in collaboration with ICG. Sixty users were involved in this exercise spanning the period from May 2015 to April 2016.

OOSA: Mock drill on 21 March 2016

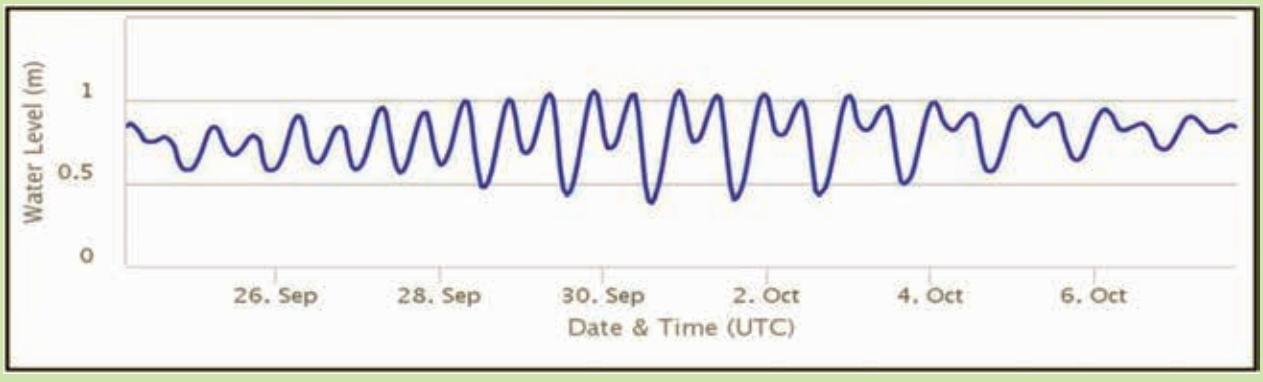
A mock drill to validate OOSA predictions, was conducted in collaboration with Reliance Industries Limited (RIL) on 21 March 2016. Five hundred kilograms of rice husk was spilled at 82.3833°E, 17.05°N by the pollution response team of RIL. 90% of the husk was recovered immediately by the skimmers, while the rest drifted away. The trajectory predicted by the ESSO- INCOIS OOSA system was used to locate the drifted husk, for recovery. The validation results showed that the performance of OOSA is satisfactory.



Synoptic of the OOSA Mock-drill conducted in March, 2016

4.2.3 Tidal Flooding/ Wave Surge Alerts

Tidal flooding/ wave surge alerts for perigean spring tides were issued for the Indian coastline during the period 26 September to 6 October 2015. It was observed that the perigean tides occurred in conjunction with high swells.



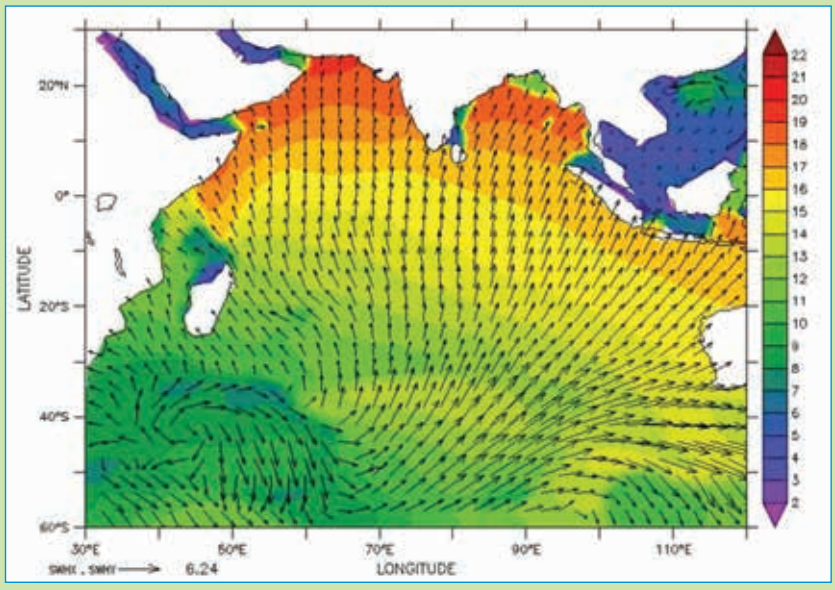
Tides at Cochin during September 26, 2015 – October 6, 2015

4.2.4 Ocean State Forecast system for Seychelles and Sri Lanka

The Ocean State Forecast and information system for Seychelles and Sri Lanka was inaugurated by Dr. Harsh Vardhan, the Hon'ble Minister for Earth Sciences and Science and Technology, in New Delhi on 10 July 2015. With this system, ESSO-INCOIS is providing 3-day forecasts (available at 3-6 hour temporal resolution) on waves, currents, winds and temperature in map-form and location specific forecasts for 18 and 22 important locations in Seychelles and Sri Lanka respectively.

4.2.5 Location and user-specific solutions

Col. Dr. G. Thiruvasagam, Hon. Vice-Chancellor, AMET University, Chennai inaugurated Location-specific Ocean State Forecast & Information Services, and 'Training Programme for Users and Trainers' on 8 March, 2016 at AMET University, Chennai, which was attended by more than 200 fishermen/women. Fifteen volunteers were also trained for facilitating wide reach of ESSO-INCOIS services.



Model simulation depicting the arrival of high period swells along the Indian coastline on 3 October 2015 from the Southern Ocean.

Inauguration of the Ocean State Forecast and Information system for Seychelles and Sri Lanka by Dr. Harsh Vardhan, Hon'ble Minister for Earth Sciences during the Inter-Ministerial council meeting of RIMES in New Delhi on 10 July 2015.

Other Customised services developed during the FY 2015-16 include

- Ocean State Forecasts that were provided to NIOT for the sea trails at the location off Chennai for a period of 22 September to 3 October, 2015.
- Information on wind-waves that was provided to NIOT, Chennai for studies related to cage culture of fishes.
- Ocean State Forecasts that were provided to Sagar Manjusha (NIOT) and MV Chowra (SCI) during their voyages in the Lakshadweep Sea and in the Andaman Sea.

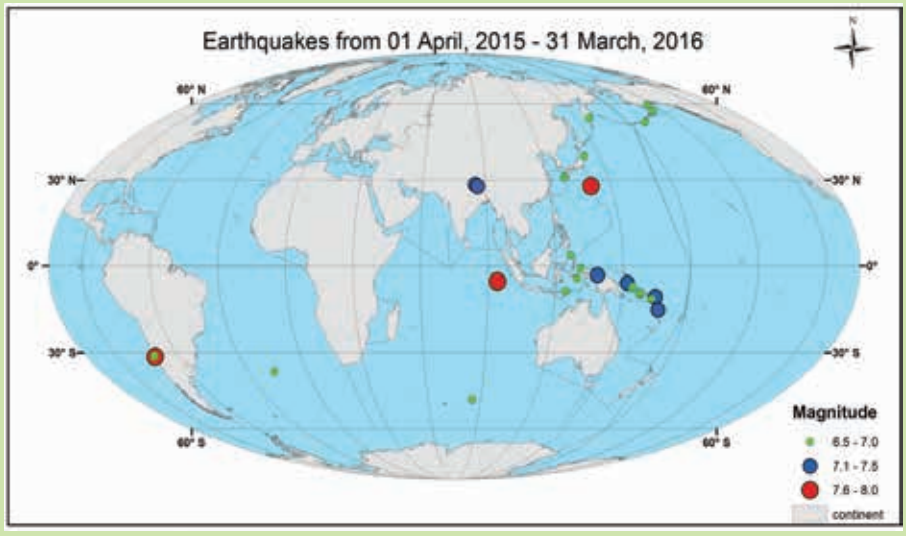
Dr. T.M. Balakrishnan Nair, Head, ISG, ESSO-INCOIS speaking on the occasion of the user interaction workshop on 8th March 2016 at AMET University, Chennai.

4.3 Multi-hazard Early Warning System

4.3.1 Tsunami Early Warning

The Indian Tsunami Early Warning

Centre (ITEWC) has monitored 37 earthquakes of magnitude ≥ 6.5 during the period April 2015 to March 2016. Out of these, only 2 major and 2 moderate earthquakes occurred in the Indian Ocean region. For all these earthquakes, ITEWC disseminated bulletins to all regional and national stake holders through Email, FAX, GTS and SMS.



Location of earthquakes with magnitude ≥ 6.5 monitored at ITEWC during April 2015 to March 2016

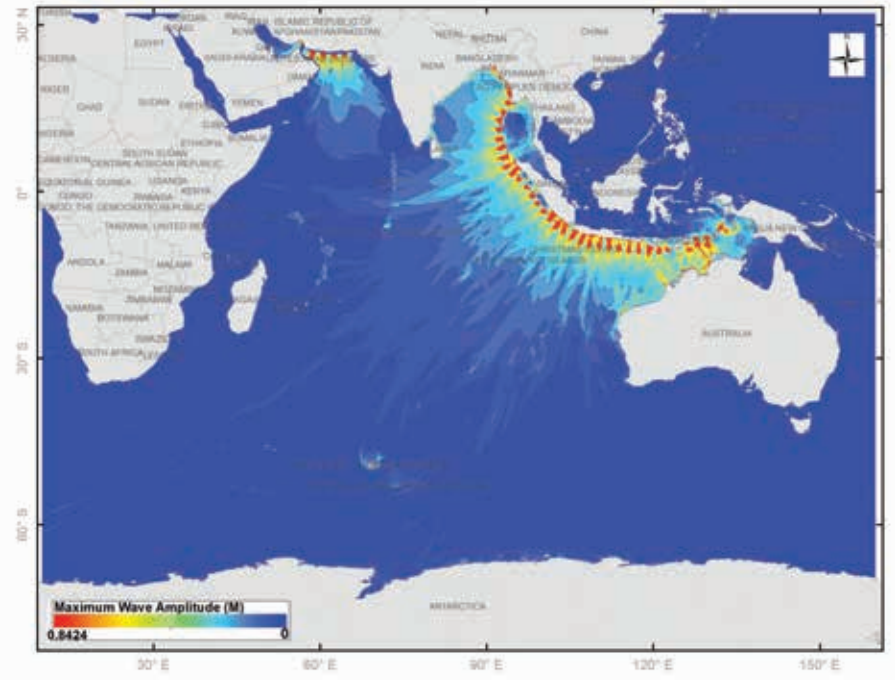
Statistics on the performance of ITEWC during April 2015 - March 2016

		Achievement	
Parameter	**Target**	**Indian Ocean (9)**	**Global Ocean (28)**
Elapse time from earthquake origin time to initial earthquake information issuance	10/15 min	9.8 min	9.57 min
Probability of detection of Indian Ocean earthquakes with Mw ≥ 6.5	100%	100%	100%
Accuracy of hypocenter location (with respect to USGS final estimates)	Within 30 km	14.87 km	18.57 km
Accuracy of hypocenter depth (with respect to USGS final estimates)	Within 25 km	15.41 km	17.52 km
Accuracy of earthquake Mw magnitude (with respect to USGS final estimates)	0.3 Mw	0.15 Mw	0.13 Mw

4.3.2 Tsunami Modeling

Enhancement in Tsunami Modeling:

The scenarios based on Tsunami models were updated to include the South China Sea and Southern Indian Ocean as ITEWC has to provide Tsunami Warning services to these regions. Further, the unit source parameters were modified in accordance with the subduction zone geometry (dip and depth), instead of taking worst case parameters (dip = 45 deg, depth = 10 km), while generating the open ocean propagation scenario database. This helps ITWEC to avoid the higher estimates (due to worst case parameters) in quantitative tsunami forecast.



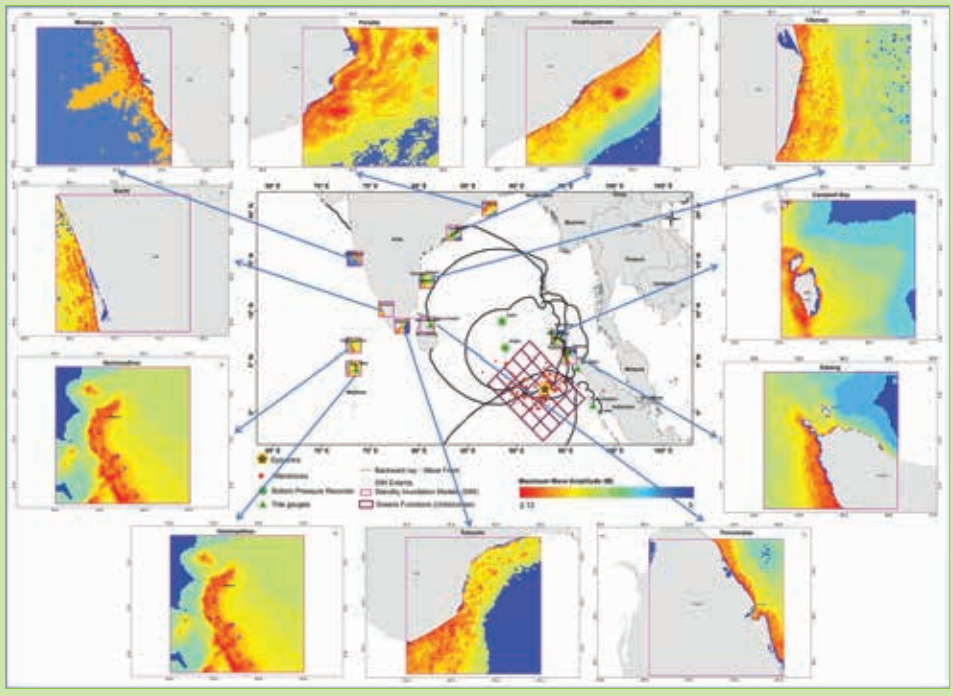
Open Ocean Propagation Scenario Database, including Southern Indian Ocean and South China Sea.

Real Time Tsunami Modeling:

ITWEC started integrating the global ocean tsunami model in real time for assessing the impact of tsunamis originating from global tsunamigenic earthquakes in the Pacific Ocean and South Atlantic Ocean. The global ocean Tsunami model was set up with domain extending from 90° S to 90° N and 180° W to 180° E with a spatial resolution of 15 km. The parallel version of this Tsunami model has been ported to the ESSO-INCOIS High Performance Computing facility so that ITWEC can provide quantitative tsunami forecast based on the predicted scenario within 20 minutes of occurrence of global earthquakes.

Stand-by Inundation Models (SIMs) and Real-time Inundation Models (RIMs):

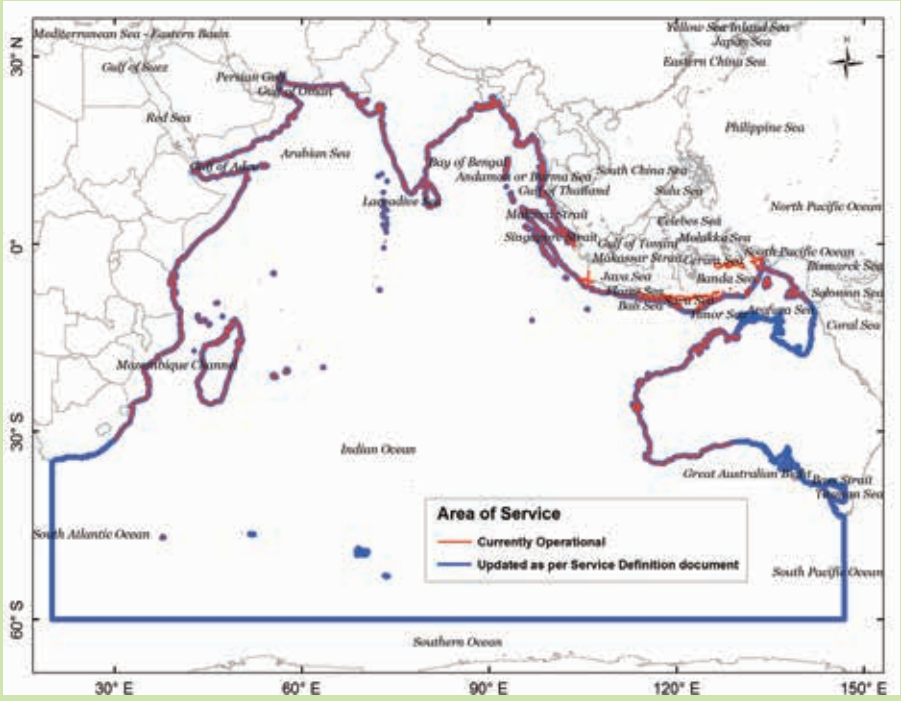
Stand-by Inundation Models (SIMs) and Real-Time Inundation models (RIMs) were set up at ITEWC and tested for the tsunami event on 11 April 2012 (Off the coast of Sumatra), which was generated by a shallow strike–slip earthquake (8.5 Mw) and its largest aftershock (8.2 Mw). A low tsunami was recorded by various tide gauges and tsunami buoys located in the Indian Ocean region. The expected wave amplitudes and inundation extents at the coast due to this event were modeled using the shallow water wave inundation model TUNAMI N2.



Coastal SIMs setups and inundation simulations for the April 2012 tsunami event.

4.3.3 Enhancement in TSP Services for the Indian Ocean

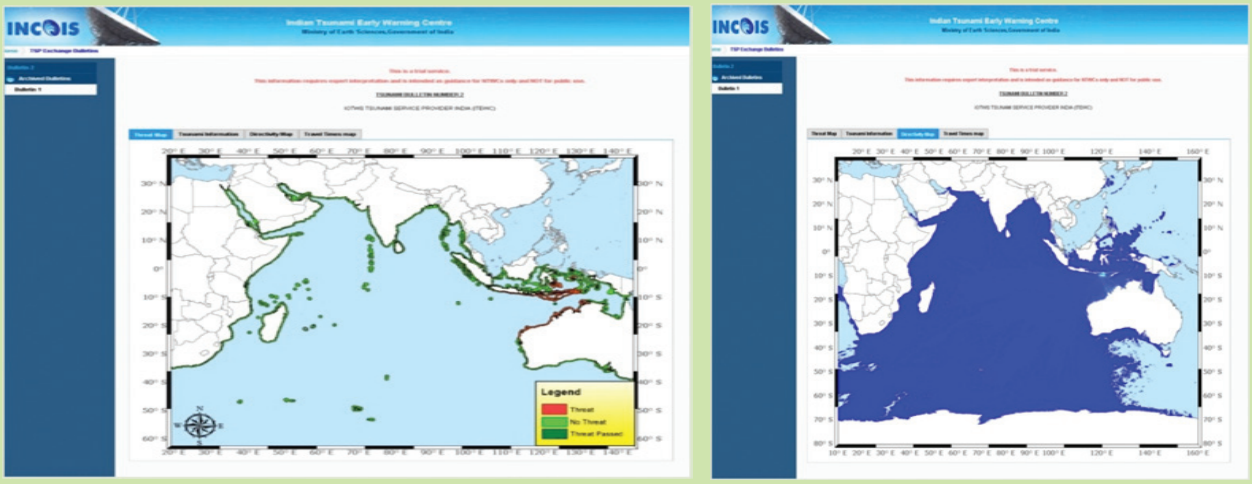
ITEWC has made several operational and technical enhancements in its Tsunami services including extension of earthquake source zones, redefining Area of Service (AoS), extension of the Coastal Forecast Zone(CFZ), dissemination of public products to the IOC public list server and introducing web-based NTWC feedback summary facility. These changes were made in line with the new requirements suggested in the Service Definition Document (SDD) adopted by ICG/IOTWMS.



TSP India Area of Service Map. Red coloured line indicates currently operational service area and blue colour indicates the enhanced service area.

4.3.4 Development of Dissemination server for Tsunami services

A new dissemination server was developed for tsunami services which features functionalities such as publication of automatic/manual bulletins, capturing real-time information from DSS, generation of the necessary graphical products like threat maps, travel time maps and directivity maps, auto publication of tsunami bulletins on the website and dissemination of information through various modes like Email, Fax, GTS and SMS.



Products generated by the new dissemination server

4.3.5 Communication Tests & Tsunami Mock drills

COMMs Test

Two COMMs tests (on 10 June 2015 & 9 December 2015) were conducted to validate the dissemination by TSPs to NTWCs and also to validate the dissemination processes of tsunami notification messages to national disaster management contacts, reception of the notification messages by NTWCs and the access by NTWCs to TSP password-protected web sites. During both COMMs Tests, ITEWS disseminated notification messages to 23 NTWCs and the other two TSPs (Australia & Indonesia) in the Indian Ocean and also received notification messages from other TSPs. During the tests, tsunami notifications were disseminated to contacts through email, Fax, GTS, SMS and the website.

Statistics of the COMM test results

Communication Test	No of Countries participated	TSP-INDIA to NTWC Message Delivery Success Rates			
		SMS	Email	Fax	GTS
June 2015	21	76%	93%	47%	80%
December 2015	20	76%	94%	45%	69%

Tsunami mock drills

i) Tsunami mock drill for the east coast of India

As part of improving the awareness and preparedness of the administrators and the general public, ESSO-INCOIS conducted a tsunami mock drill for the Coastal States and Union Territories along the east coast of India on 26 September 2015, in collaboration with Ministry of Home Affairs. ESSO- INCOIS issued 7 notification messages for the mock scenario (with a 9.0 magnitude earthquake in Andaman Islands) to the pre-designated points of contact by Email, SMS & Fax. All eastern coastal states and UTs of India participated in this mock drill and the public were evacuated from several locations (11 villages in Andhra Pradesh, 6 villages in Odisha, 2 villages in Puducherry, 1 village in Tamil Nadu and 4 villages in West Bengal). A host of last-mile communication systems such as SMS-based alerts, siren, megaphones, etc. were used by local authorities to alert the coastal population.

ii) Tsunami mock drill for the West Coast of India

ESSO-INCOIS, MHA and Kerala State Emergency Operations Centre jointly conducted the tsunami mock drill for Kerala coast on 11 March 2016. The mock drill commenced with an alert of a 9.0 Mw tsunami tremor that originated off the coast of Pakistan. ESSO-INCOIS issued 7 notification messages for the mock scenario to pre-designated points of contacts by email, SMS & Fax. All 9 coastal districts of Kerala participated in the mock drill and involved various stake holders like National Disaster Response Force, Navy, Coast Guard, Coastal Police, Healthcare Department, Fire and Rescue Services Department and various government agencies.

Photos of Tsunami mock drill at various places along the East Coast of India

4.3.6 GNSS technology for tsunami early warning

Although, the early detection of an earthquake is possible using seismic data, the characterization of seismic ground motion/ rupture direction and extent are not available quickly enough to estimate the tsunamigenic potential of an earthquake. The moment magnitude Mw is the critical indicator of tsunamigenic potential of an earthquake, but it requires seismic waveform data for a longer duration and that limits its use in tsunami warning. To overcome this drawback a new approach, making use of GNSS displacement data in real time to characterise the earthquake with determination of the earthquake moment magnitude and generation of the centroid moment tensor solution, is being tried out.

4.3.7 Paleo-tsunami & tectonic related studies in the Indian Ocean Region

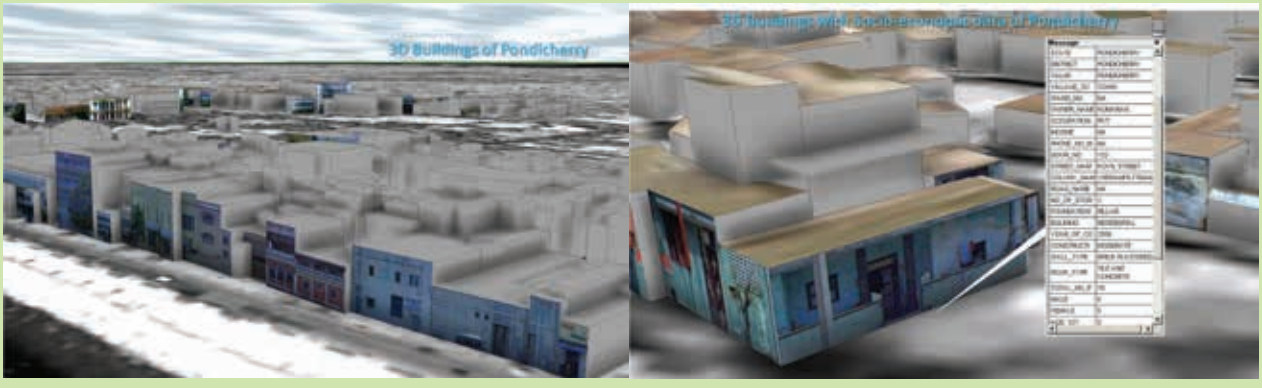
Studies on palaeo-tsunami and seismo-tectonics in the Indian Ocean region have been carried out through various projects outsourced to principal investigators from six universities/institutes. Five major earthquakes (2016 Imphal that EQ, 2014 Bay of Bengal EQ, 2013 Baluchistan EQ, 2005 & 2010 Nicobar EQ) were studied in detail to understand the pattern of seismicity and seismo-tectonic changes in the region and an attempt was made to characterize the seismic anisotropy of the Andaman Nicobar subduction zone and decipher the lithospheric deformation. The anisotropy in the A & N subduction zone was demonstrated for the first time and revealed a dominance of trench parallel fast polarization azimuths. Preliminary studies of cores from areas of Wandoor and Chouldhari indicate multiple tsunami events in the A&N region. Twelve possible transoceanic tsunami events (including the 2004) were identified from a 7000 year-long sedimentary record in this region suggesting the recurrence intervals of catastrophic tsunamis range between 300 to 800 years and the average recurrence interval of Indian Ocean tsunamis is 510± 140 years.

Stratigraphic studies from Badabalu and Chidiyatapu areas in the A&N Islands revealed the evidence of three historical earthquakes and associated transoceanic tsunamis during the past 1000 yrs.

4.4 Coastal MHVM (Multi-hazard Vulnerability Mapping)

Highly vulnerable areas were identified based on 1:10,000 scale maps prepared with the Multi-Hazard Vulnerability Mapping (MHVM) project. 3D-GIS mapping of Pondicherry was taken up as a pilot project and mapping of the 500 km^2 area in Pondicherry was completed. Socio-economic data pertaining to buildings were further used to develop methodology to generate building-level risk assessment for a tsunami disaster. The risk from tsunamis to the buildings was assessed based on the tsunami run-up height at each building derived from the tsunami inundation model and corresponding socio-economic data for that building collected through door-to-door survey. Mapping of remaining areas is now in progress.

Beta version of Visualization and Analysis system for 2D and 3D Geospatial Data (3DVAS) which integrates all geospatial data pertaining to the coastal zone including the outcomes of the 3D-GIS mapping was completed. The application simulates the tsunami and storm surge models during an event and overlays inundation details over the virtual coastal zone. It also generates risk maps and scenarios to be included in tsunami/storm surge advisories.

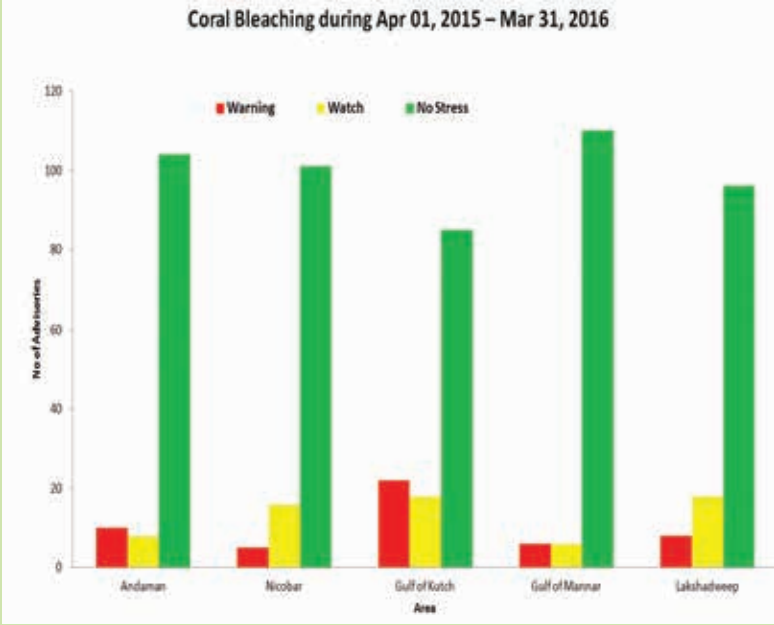


Sample map of 3D-GIS for Pondicherry showing socio-economic data associated with the buildings

Building level risk based on the tsunami inundation mapping.

Coral Bleaching Alert System

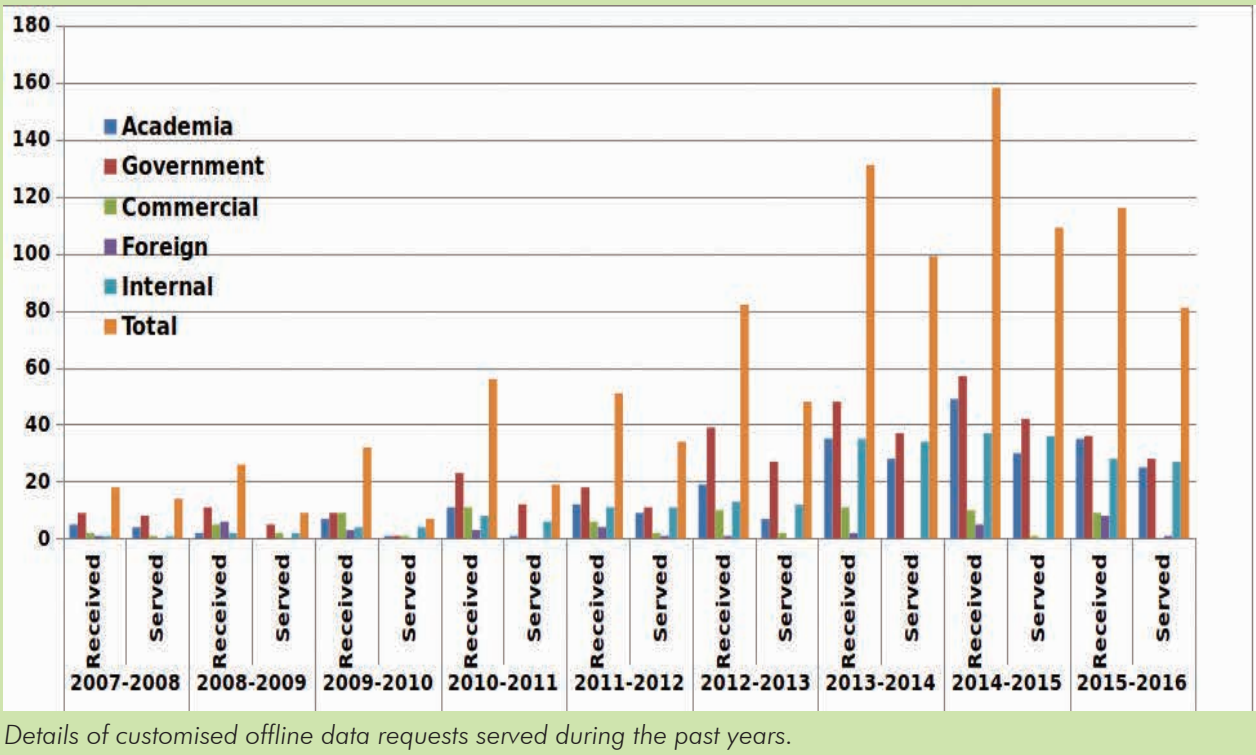
Satellite-based Coral Bleaching Alerts were provided as advisories on the hotspots, degree of heating weeks and the variation of SST anomalies on bi-weekly basis during the summer months. Coral Bleach Warnings were issued and disseminated through web service for Andaman and Nicobar, Gulf of Kutch, Gulf of Mannar and Lakshadweep regions for 10 and 5, 22, 6 and 8 events, respectively and as listed, the maximum no. of warnings were issued for Gulf of Kutch (with review of Hotspot composites).



Number of Coral bleaching advisories issued during 2015-16

4.5 Data Services

Being designated as the Responsible National Oceanographic Data Centre (RNODC) for India by the International Oceanographic Data Exchange (IODE) programme of the Intergovernmental Oceanographic Commission (IOC), ESSO-INCOIS continued to serve as the central repository for oceanographic data. The data centre sustained and strengthened its capabilities of real-time data reception, processing and quality control of surface, meteorological and oceanographic data using a wide variety of ocean observing systems. Further, surface met-ocean data have been



Details of customised offline data requests served during the past years.

disseminated to various operational agencies in the country in near-real time. NODC, on specific request, also provided customized data and products to researchers and other users.

The data centre continued to obtain and archive real time in situ data from various ocean observing systems. The data centre also obtained and archived the delayed mode data from various observing systems such as XBTs/XCTDs, Met observations (NODPAC), OSCAT (SAC), CTCZ programme, ADCP, OMNI buoy etc.

Details of the data received at NODC during 2015-16

Institute/ Programme	Parameters	Period of observation	No. of platforms / stations reported	Status
NIO (XBT, XCTD, SSS)	T Profiles	1990 - 2015	7592 profiles	Updated in the database
	T & S Profiles	2003 - 2015	1272 profiles	
	Sea Surface Salinity	2000 - 2015	18072 records	
	T Profiles	April 2015 - March 2016	27 profiles	
	T & S Profiles	April 2015 - March 2016	62 profiles	
NODPAC (Met Observations along Ship track)	Surface met parameters	April 2015 - March 2016	03 Quarterly data	Archived
NIOT - NDBP (Moored buoys)	Met-ocean parameters	April 2015 - March 2016	20 buoys	Updated in the database
NIO (Drifting buoys)	Met-ocean parameters	April 2015 - March 2016	20 buoys	Updated in the database
NIO (ADCP)	Ocean currents	2011 - 2015	–	Archived
NIO (Equator ADCP)	Ocean currents	2000 - 2014	5 Moorings	Archived
PMEL (RAMA buoys)	Met-ocean parameters	April 2015 - March 2016	19 buoys	Updated in the database
ESSO-INCOIS (Ship-mounted AWS)	Met parameters	April 2015 - March 2016	32 stations	Updated in the database
ESSO-INCOIS (Wave rider buoys)	Wave parameters	April 2015 - March 2016	16 stations	Updated in the database
NIOT (HF Radar)	Current	April 2015 - March 2016	05 pairs of stations	Updated in the database

ESSO-INCOIS (on-board ORV SN – Wave Height Meter)	Wave Parameters	April 2015 - March 2016	1 stations	Updated in the database
Argo CTD	Temperature and Salinity	April 2015 - March 2016	33520 profiles	Updated in the database
CMLRE (Cruise Summary Report)	Biogeochemical and Physical	Hand written copies of Cruise summary report of FORV Sager Samara cruises 51-100		Data reading in process
CTCZ	Radar data	June - September 2013		Archived

4.5.1 Ocean Remote Sensing data products

Remote sensing data from various sensors on board Oceansat-2 and NOAA, Metop and MODIS series of satellites were received in real time at ground stations established at ESSO-INCOIS. The images were processed and made available to operational services within and outside ESSO-INCOIS. The historical data from decommissioned satellites (NOAA 15, NOAA 16 & NOAA 17) were also archived at the data centre. The data centre also provided real-time satellite data for cruise operations such as the Ocean Monsoon Mixing (OMM) and CSIR-NIO cruises. The data centre also fulfilled requests for offline data products to organizations such as ESSO-NIOT, CSIR-NIO and ISRO-NRSC.

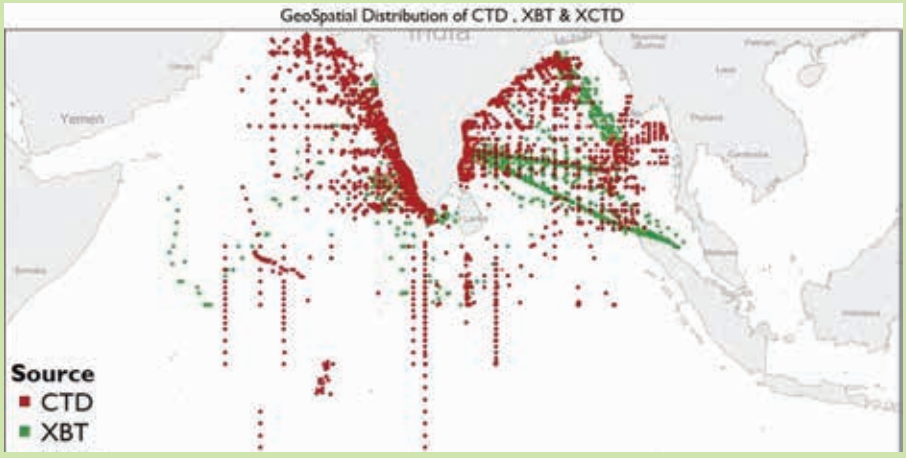
Details of the satellite data received at NODC

Sensor/satellite	Parameters	Period
NOAA AVHRR, ATOVS / (Metop-1, 2 & NOAA-18, 19)	Sea Surface Temperature, Fog, Brightness temperatures, Cloud Top Temperatures and Normalized Difference Vegetation Index (NDVI)	August 2005 to till date (With few gaps)
MODIS/Terra and Aqua	Sea surface temperature and chlorophyll (Several other atmospheric and ocean parameters can also be generated using the radiance data obtained from this sensor)	Near Real-time only
OCM-2/Oceansat-2	Chlorophyll-a, Total Suspended Sediments, Diffuse Attenuation Coefficient (Kd490) and Aerosol Optical Depth (AOD) over Ocean.	February 2011-Till date
Altimeter/TOPEX	Wave height, sea level, sea ice	1996-2007
TMI/TRMM-TMI	SST, rainfall, wind speed	1997-2007
QuikSCAT	Wind vector	1998-2007
Seaways	Chlorophyll	1997-2005

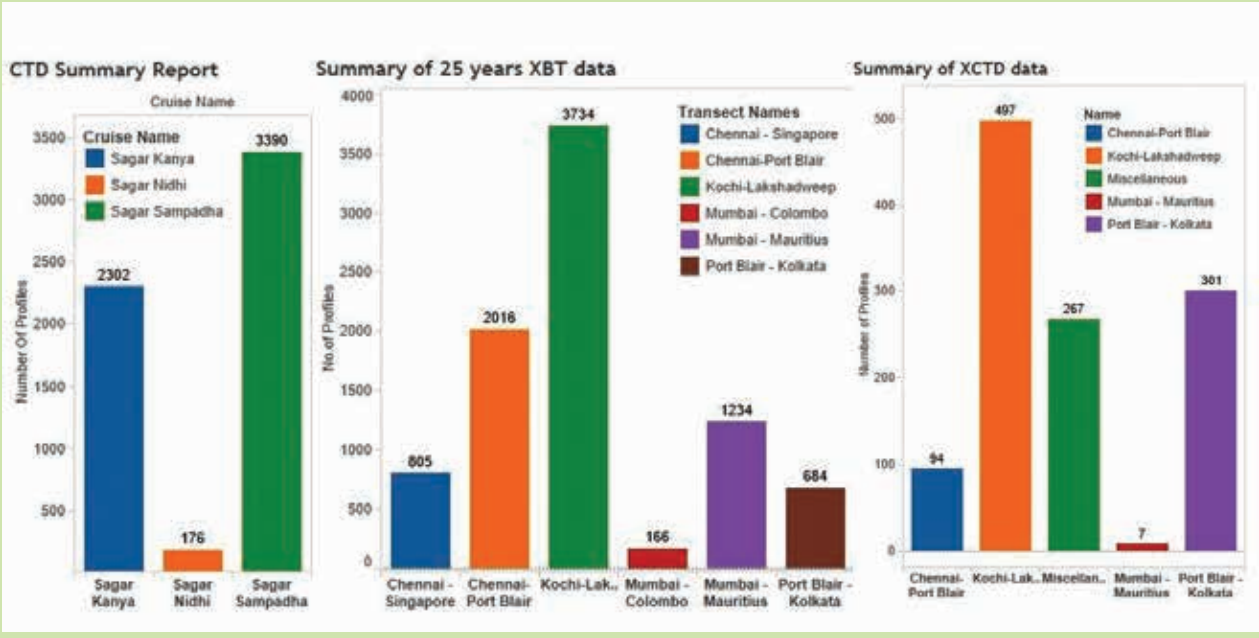
4.5.2 Other Notable Achievements:

CTD data processing tool:

A MATLAB-based GUI was developed to process historical CTD and XBT data. This interactive and user-friendly tool can be used to carry out preliminary analysis of the data and its visualization. The quality control mechanism of the GUI can handle both bulk data as well as individual profiles of temperature, salinity, depth and density.



Spatial Distribution of CTD,XBT and XCTD Data



Summary of CTD/XBT and XCTD data availability

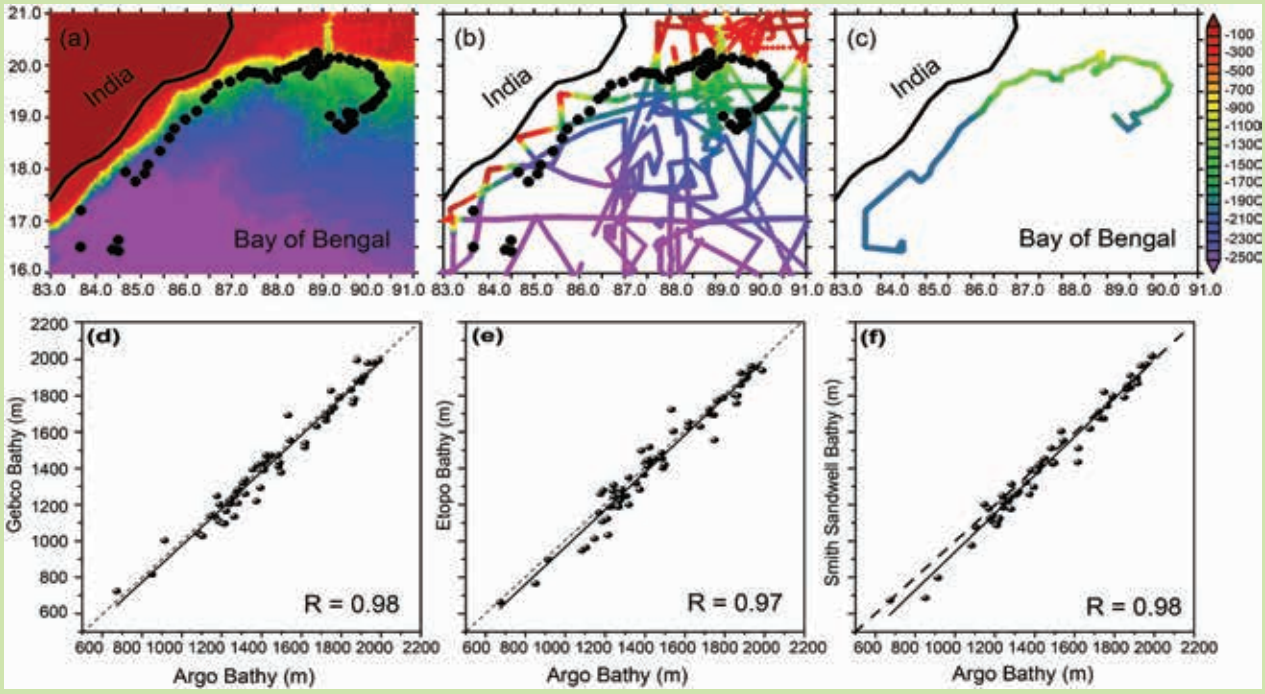
Triplex data:

Triplex data provides accurate, near-real time observations of air-sea heat and momentum fluxes. Radiation and turbulent flux data, wind stress data and all the other basic parameters necessary for the calculation of the air-sea fluxes are available in this dataset. Currently, data from January 1979 to September 2015 at a spatial resolution of 1°x1° on daily and monthly time scales are available at the ESSO-INCOIS data centre.

Ocean bathymetry from Argo floats:

The application of Argo float profiling depth data, to improve bathymetry maps in poorly sampled regions of the continental shelf has been demonstrated. The deepest profiling depth was 2000 m for the majority of Argo floats (~3000 Argo floats were deployed till now in the global oceans).

As these floats drift freely, they may move to shallow regions owing to currents and hit the ground. The profiling depth data from such floats hitting the ground can be used to infer the bathymetry of the region.



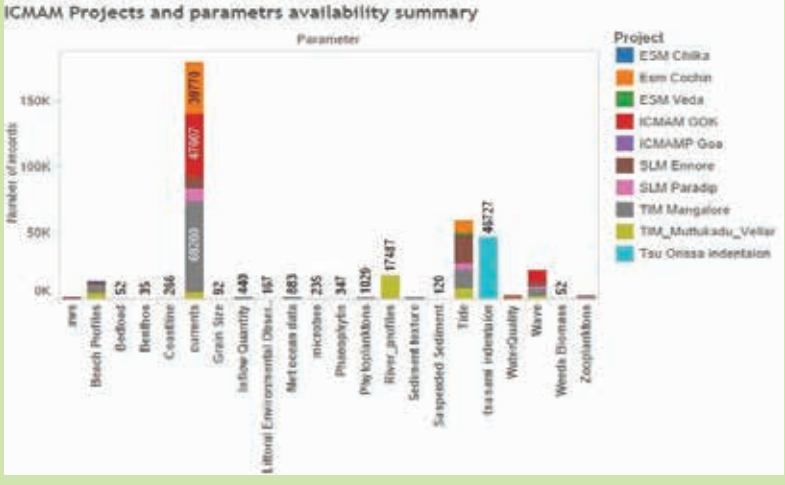
(a) Bathymetry (m) for the Northwestern Bay of Bengal continental shelf from the Global Predicted Bathymetry V18.1 (TOPO18.1) grid. (b) Depth from updated track line data set. (c) Profiling depth obtained from the Argo float during its life time. Color scale for all above panels is shown beside the third panel (top row). In the bottom row, bathymetry is compared between Argo float depth obtained along the trajectory and (d) modified Etopo2, (e) GEBCO, and (f) Smith and Sandwell.

Data archaeology:

The ESSO-INCOIS data centre made significant progress in rescuing historical data sets, especially those which were only available in physical form, converting them to digital form. Data centre obtained 50 physical records of Cruise No.s: 50 – 100 from FORV Sagar Sampada and converted them digitally. With this addition, a total of 100 cruise summary reports have been archived and additional digitization is underway.

ICMAM data Processing and generation of database:

Physical and biogeochemical data from Integrated Coastal and Marine Area Management (ICMAM) for 2002-2007, collected under different projects from 10 coastal regions were processed and archived. Customized database along with a Graphical User Interface were also developed for data discovery and visualization.



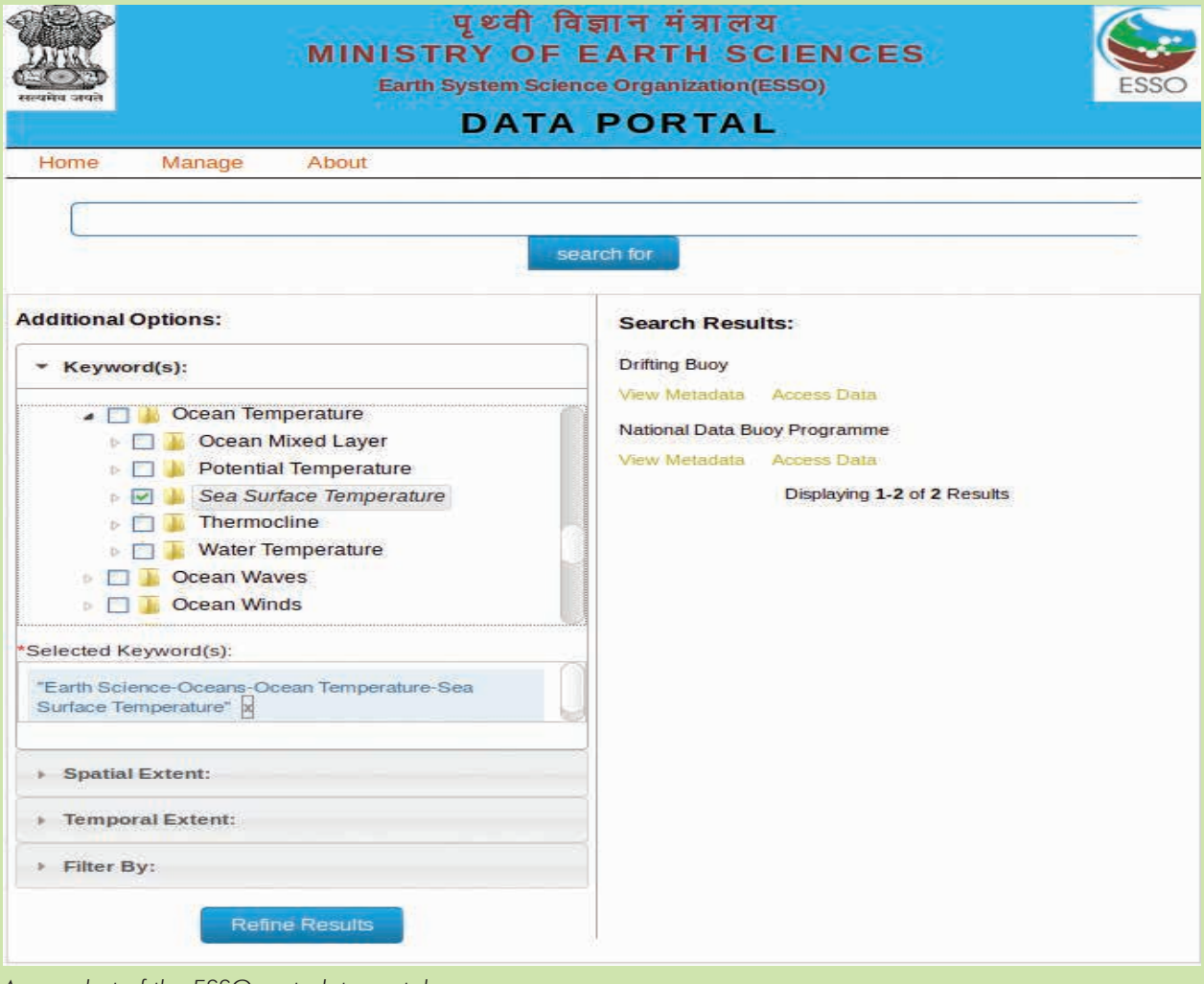
Data records processed for different variables at the ICMAM project locations. Each project location is represented in different colours.

OMNI buoy data:

Meteorological and upper ocean data obtained from the 12 active ESSO-NIOT OMNI buoys were archived at ESSO-INCOIS after standard quality checks. Real-time data was also made available along with metadata information at http://www.odis.incois.gov.in/index.php/in-situ-data/moored- buoy/moored-data. Delayed-mode data were obtained directly from the sensors during servicing and redeployment. Those data were also made available in NetCDF format from October 2010 onwards.

ESSO meta data portal:

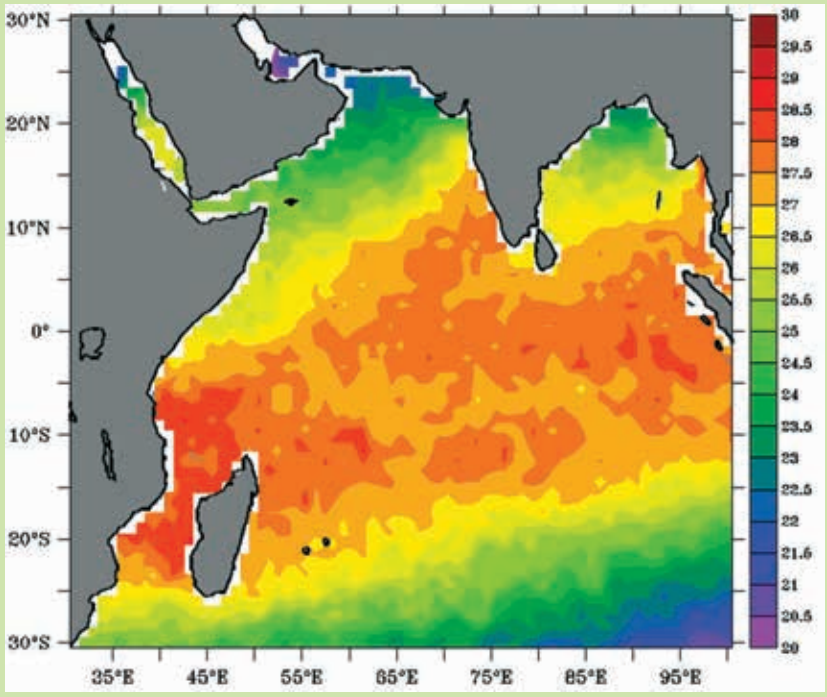
A metadata portal was developed for the ease of search and discovery of various geospatial datasets collected and maintained as part of MoES programmes. This web interface includes a metadata editor based on ISO 19115 standards relevant to the basic geographic information and extensions for imagery and gridded data, which allows submission and updating of metadata of various heterogeneous datasets. An interface based on the standard GCMD Science keywords directory, was also developed to search for relevant datasets by using simple keywords with parameter, sensor, instrument names and location indicated in latitude-longitude etc.



A snapshot of the ESSO metadata portal

Marine Meteorological Atlas

Marine meteorological data from IMD for the period 1961-2012 were used for updating *International Comprehensive Ocean-Atmosphere Data Set (ICOADS)* climatology, especially for the Indian Ocean (IO) region. Approximately 59,00,000 data records on Dry Bulb Temperature (DBT), Dew Point Temperature (DPT), Sea Surface Temperature (SST), air pressure, wind speed, wave parameters, cloud parameters and prevailing weather conditions observed by the Voluntary Observing Ships (VOS) were added to the database. It was found that 11% of this data were unique and not included in the ICOADS climatology. Monthly climatologies of marine meteorological parameters were derived for the Indian Ocean region (30° E-100° E, 30° S-30° N) by adding this unique data to the ICOADS.



Climatology of dry-bulb temperature (in °C) for the month of January

Data awareness campaigns:

To promote the usage of data and bring about awareness among research communities and students at universities, the ESSO-INCOIS data centre participated actively in various training courses and workshops organized at ESSO-INCOIS and other institutes. Also, a specialized data awareness workshop on 'Ocean Data Utilization and Ocean Observation Systems' was conducted by the ESSO-INCOIS data centre for M.Sc. and M.Tech. students from Indian Institute of Technology, Bhubaneswar and University of Hyderabad, during 8-12 December 2015. Twenty-five students participated in this workshop.

Other achievements:

- ESSO-INCOIS data centre archived 10,022 Bio profiles from LUV, France for validation of profiles from bio-Argo floats.
- The centre continued the distribution of quarterly data to NODPAC of the Indian Navy. NODPAC uses ESSO-INCOIS developed software for Visual Quality Control of XBT profiles.
- ESSO-INCOIS Live Access Server (ESSO-INCOIS LAS: http://las.incois.gov.in) was updated with new flux datasets from WHOI.

Apart from the regular dissemination of the data/data products, the data centre also provided the following on specific request.

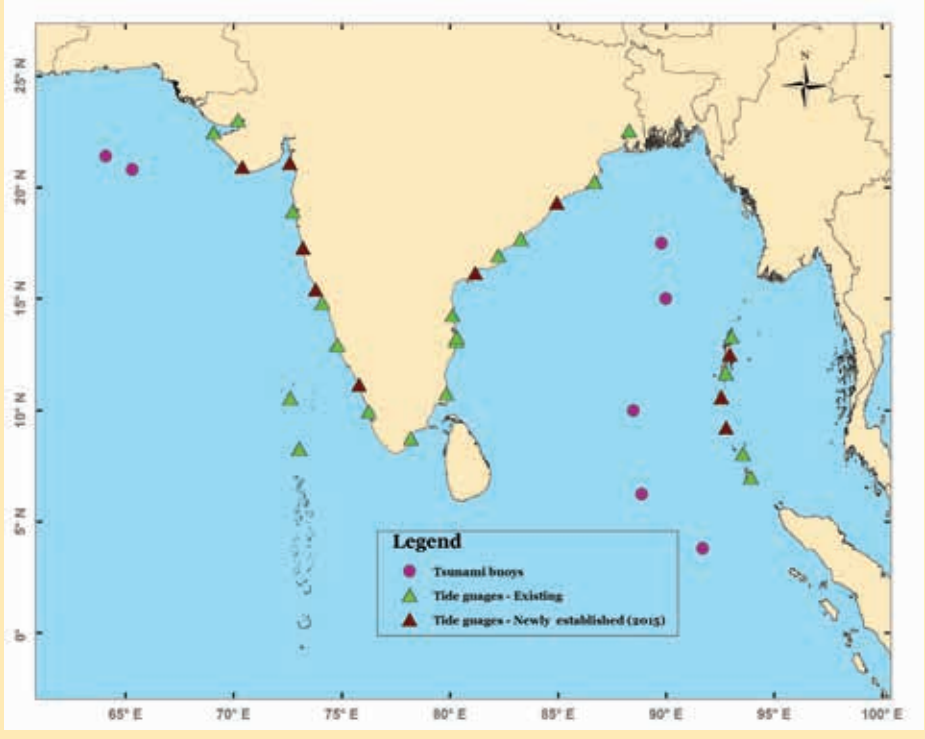
- Wave, currents and wind speed data were provided to Adani Power Ltd (Udupi Power Corporation Ltd) for 4–13 August 2015.
- Data on currents in the Northern Bay of Bengal was provided to the School of Oceanographic Studies, Jadavpur University, Kolkata for their research studies.

5. Ocean Observations

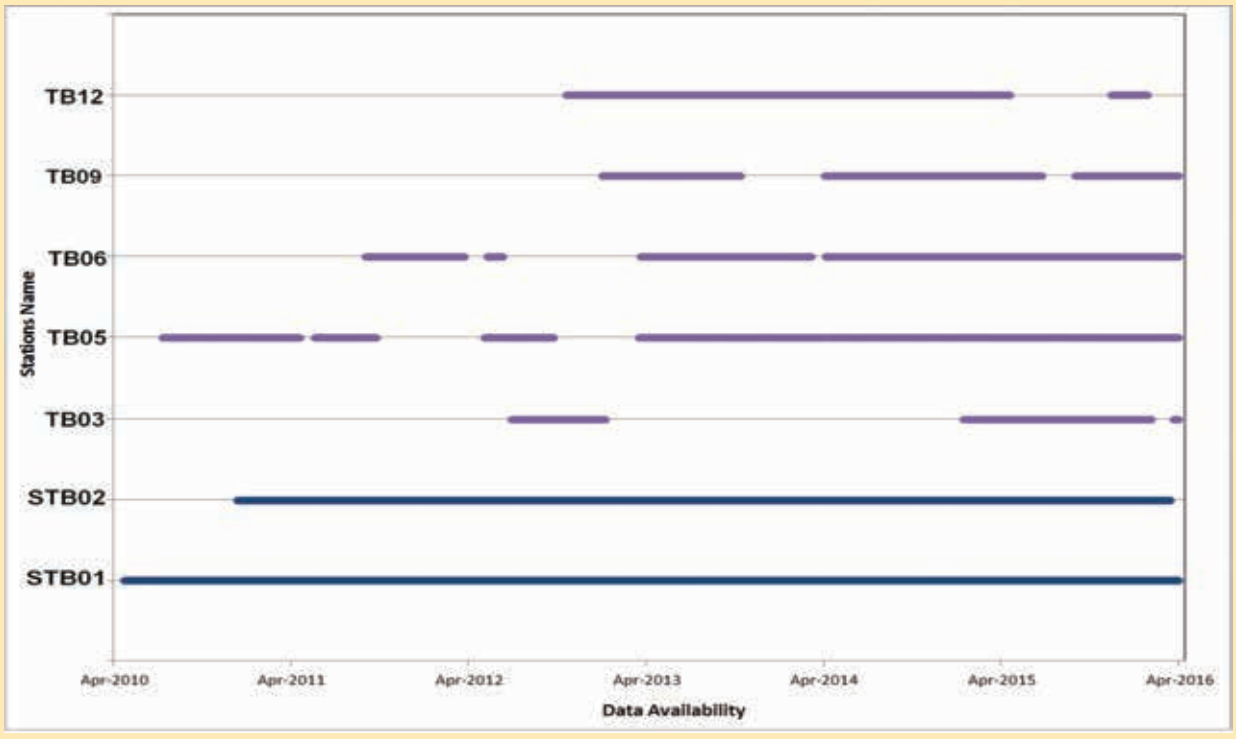
Observing the Oceans is a critical component of operational ocean services as the availability of quality ocean data is one of the most important requirements for providing quality ocean services to stake holders. ESSO-INCOIS is taking a lead in many of the national ocean observation programmes and has partnered with various national/international agencies, which has resulted in the establishment of a formidable ocean observation system in the Indian Ocean. Real-time data from these observation platforms are widely used in process studies and model validations and also for assimilation in the ocean forecast models. In the last fiscal year also, ESSO-INCOIS continued its efforts to collect several critical oceanic and meteorological parameters by deploying and maintaining many observational platforms in the Indian Ocean.

5.1. Tsunami Buoys

ESSO-INCOIS continued to maintain a network of 7 tsunami buoys deployed close to the tsunamigenic source regions in the Bay of Bengal and Arabian Sea in collaboration with National Institute of Ocean Technology (NIOT, Chennai) and through a contract with Science Applications International Corp. (SAIC, USA). These high precision buoys are capable of detecting very minor water level changes of 1.0 cm at water depths up to 6.0 km. The data from these buoys were transmitted in real time to the Indian Tsunami Early Warning Centre (ITEWC) at ESSO-INCOIS through satellite communication. In addition to these buoys, real-time data from around 50 tsunami buoys operated by other countries in the Indian and Pacific Oceans were also received at ITEWC and the data were made available on the tsunami website. The tsunami buoys (STB01 & STB02) continued to provide data to the tsunami warning centre since their deployment in 2010 and 2011 respectively.



Locations of the Tsunami buoys and Tide gauges within the ITEWS network



Data availability chart of tsunami buoys from April 2010 - March 2016
(Blue: INCOIS STBs; Purple: NIOT tsunami buoys)

5. 2. Tide gauges

ESSO-INCOIS had set up additional 10 new Radar-based tide gauge stations and continued to maintain the 21 tide gauges which were earlier established at strategic locations along the coasts of the Indian mainland and islands to monitor the progress of tsunami waves. The data from tide gauges were also used to validate the model results. Continuous real-time data from tide gauges were received at ITWEC through INSAT and GPRS communications. Maintenance of the tide gauges was carried out in collaboration with Survey of India (SoI), Dehradun. In addition, ESSO-INCOIS also received data from around 300 international tide gauges in near-real time which are operated by other countries.

Locations of new Radar-based tide gauges established by ESSO-INCOIS

S. No	Station Name	Installed on
1.	Adani Hazira, Surat	29 October 2015
2.	Marmagao Port, Vasco, Goa	30 October 2015
3.	Jaigarh port, Ratnagiri, Maharashtra	21 October 2015
4.	Machilipatnam, Andhra Pradesh	17 October 2015
5.	Beypore, Kozhikkode, Kerala	21 October 2015
6.	Car-Nicobar, A& N Islands	8 December 2015
7.	Hutbay, A& N Islands	17 December 2015
8.	Rangatbay, A& N Islands	2 December 2015
9.	Veraval, Gujarat	9 January 2016

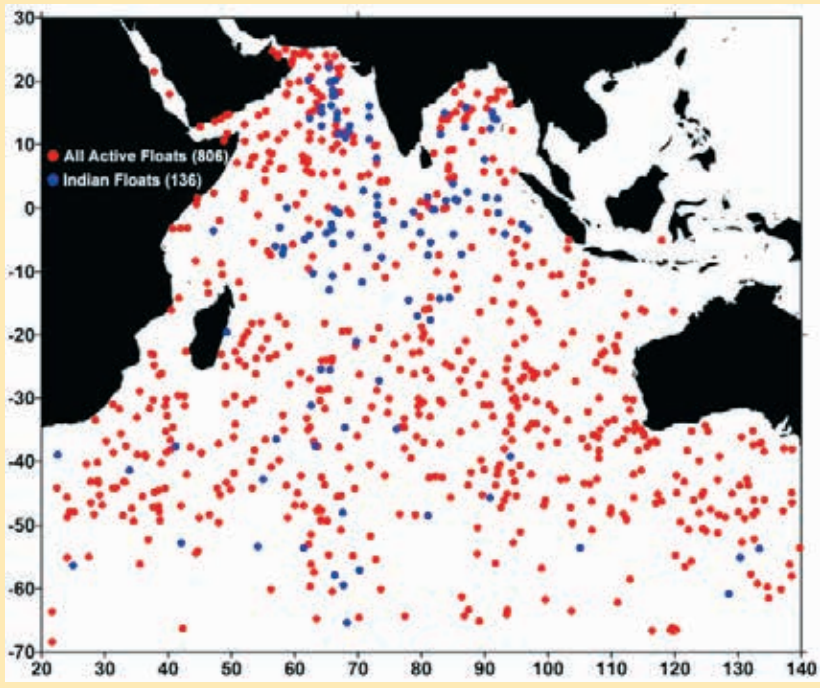
Data availability chart of tide gauge network during April 2010-March 2016

New radar tide gauge stations at Adani Hazira (Left) and Marmagoa (Right)

5. 3. Argo floats

The international Argo programme is one of the important components of the Global Climate Observing System/Global Ocean Observing System (GCOS /GOOS). In order to fulfill India's commitment to the global Argo programme, during the period April 2015 to March 2016,

ESSO-INCOIS deployed 29 Argo floats in the Indian Ocean. These deployments included 19 standard floats (temperature and salinity sensors only) and 10 bio-Argo floats (temperature, salinity, chlorophyll, backscattering and dissolved oxygen sensors). Thus by March 2016, the Indian contribution to this international project has increased to 396 floats, of which 136 are active and transmitting data in real time. In addition to these deployments by India, during the year, 145 Argo floats were deployed in the Indian Ocean by other countries (US, France, Japan, China, UK, Australia, Mauritius, Netherlands) and the data from them are also received at ESSO-INCOIS in real time. As of 31 March 2016, 806 floats are active in the Indian Ocean. 33,520 temperature and salinity profiles from the Indian Ocean were received and archived at ESSO-INCOIS in the past one year.



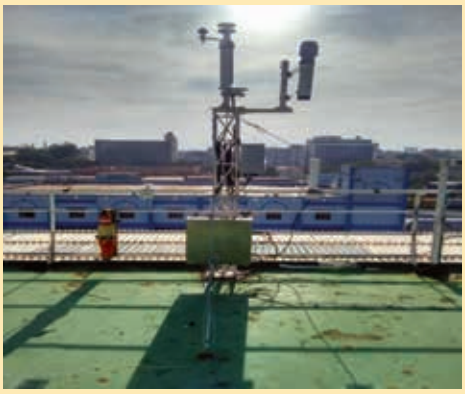
Distribution of active Argo floats in the Indian Ocean. Active Indian floats are shown in blues color while active non-Indian floats are shown in red colour

5.4. Automated Weather Stations (AWS)

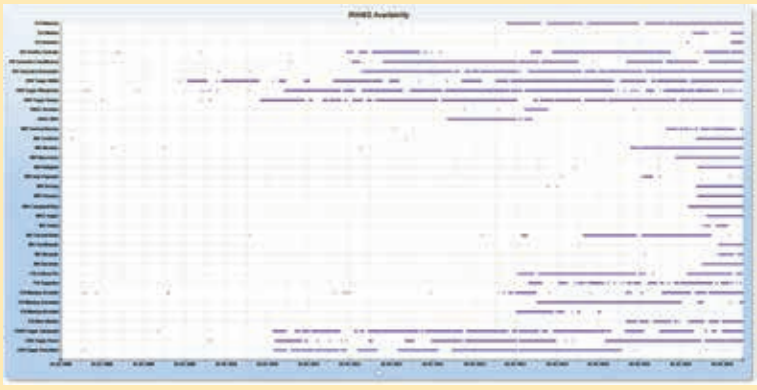
ESSO-INCOIS installed 13 more AWSs during the year on board vessels of Shipping Corporation of India (SCI), Naval Hydrographic Office (NHO) and National Centre for Antarctic and Ocean

AWS Installations during 2015-2016

Agency	Name of the Vessel	Date of Installation
SCI	MV Swaraj Dweep	30 April 2015
	MV Nancowry	10 June 2015
	SCI Yamuna	3 July 2015
	SCI Kundan	28 July 2015
	MC Campbell Bay	4 August 2015
	SCI Mukta	21 August 2015
	MV Sentinel	8 September 2015
	MV Dering	9 September 2015
	MV Chowra	13 September 2015
	MV Kalighat	14 September 2015
NCAOR	MGS Sagar	8 October 2015
NHO	INS Nirupak	11 December 2015
	INS Sandhayak	14 December 2015



AWS installations in the MGS Sagar (NCAOR)



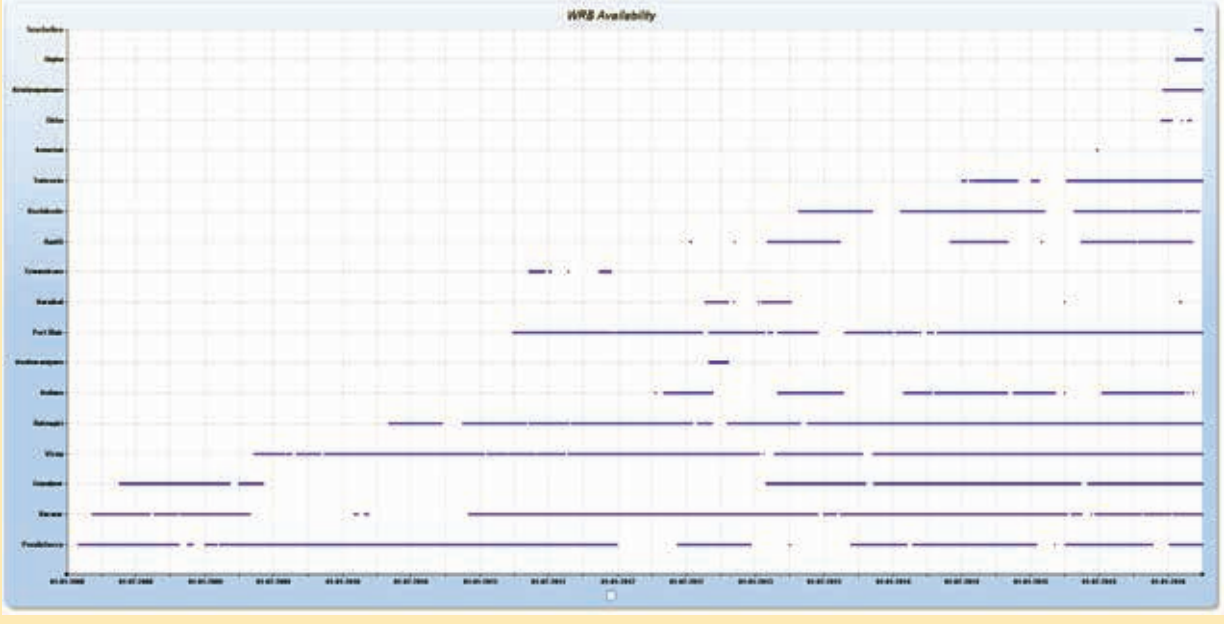
Data availability chart from the Automated Weather Stations installed on board ships

Research (NCAOR). With the above installations ESSO-INCOIS now maintains a network of 33 AWSs on board ships.

5.5. Wave Rider Buoys

With the deployment of four more wave rider buoys off Okha, Digha, Krishnapatnam and Seychelles, the wave rider buoy network was expanded to a strength of 14 buoys in the FY 2015-16. Further, 2 old wave rider buoys (Karwar and Port Blair) were replaced with re-calibrated buoys.

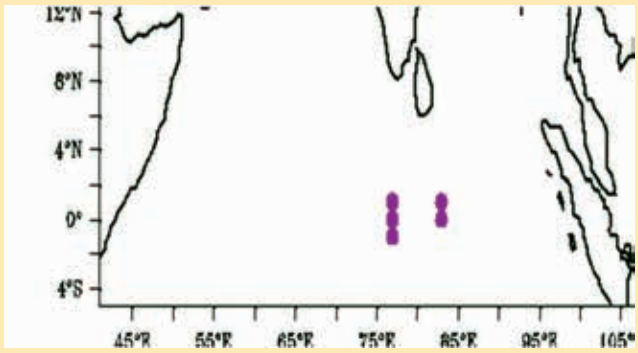
Wave Rider Buoy locations as of March 31, 2016



Data availability chart from the wave rider buoy network established by ESSO-INOIS

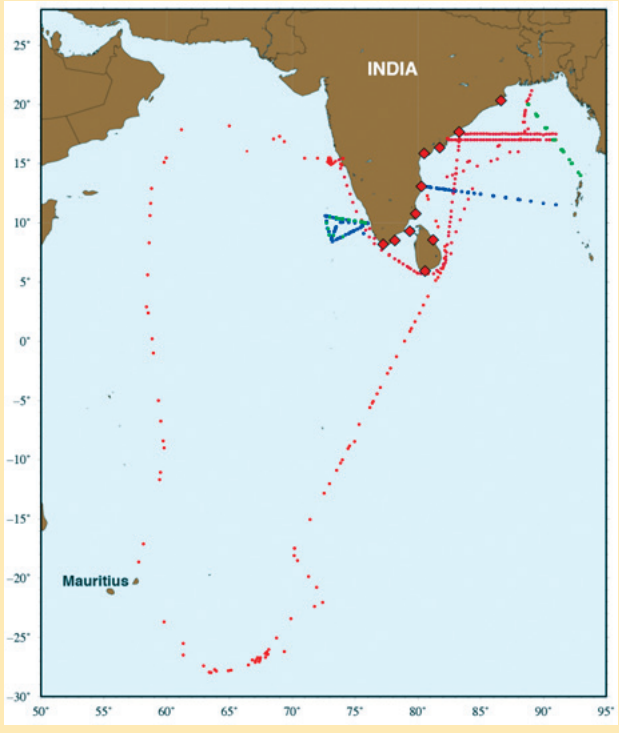
5.6. Current meter moorings in the Equatorial Indian Ocean

With the financial support of ESSO-INCOIS, CSIR-National Institute of Oceanography (NIO) maintained five current meters in the Equatorial Indian Ocean (1°N, 77°E; Eq., 77°E; 1°S, 77°E;1°N, 83°E and Eq., 83°E). Long-time series data from this project were used to study the reversal of the equatorial current system in the Indian Ocean.



Status of the deep-sea current meter moorings in the Equatorial Indian Ocean

5.7. XBT transects



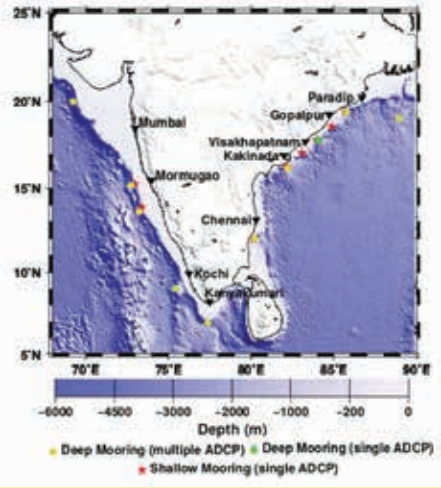
XBT (blue), XCTD (green) and Sea Surface Salinity (red) data coverage in the seas around India during April 2015 – March 2016. Red diamonds indicates coastal salinity collection stations.

XBT observations along the transects is the longest ongoing observational programme executed at CSIR-NIO with financial support from ESSO-INCOIS. The main objective of this programme is to collect high quality temperature/salinity profiles along selected shipping lanes in the seas around India using ships-of-opportunity to understand and document the variability of thermohaline fields on different time scales ranging from inter-annual to intra-annual. During 2015-16, 121 vertical temperature profiles (XBTs), 115 vertical temperature / salinity (XCTDs) profiles and 1285 sea surface water samples were collected under this programme.

5.8. Coastal Acoustic Doppler Current Profiler (ADCP) network

With financial support from ESSO-INCOIS, CSIR-NIO continued to maintain the coastal ADCP network during 2015-16. In this period, NIO conducted two cruises on board RV Sindhu Sankalp, one each on the east and west coasts of the country to retrieve and deploy ADCP moorings. Thirty- nine mooring operations were conducted, which included 16 recovery and 23 deployments.

Currently, 18 moorings are active and recording observations on coastal currents. Data from this network helped to improve our understanding of the variability of coastal circulation and in validating and calibrating the high resolution ocean model setups for operational ocean forecasts. Analysis of ADCP data suggested that the propagation of coastally trapped waves (CTWs) originating from remote locations has a significant impact on near-coastal currents elsewhere.



Locations of coastal ADCP installations

Data availability chart from the coastal ADCP installations

5.9. Ocean Mixing and Monsoon (OMM) Programme

The OMM programme, a part of the Monsoon Mission of MoES, aims to carry out observational campaigns to study the upper ocean physics and air-sea interaction in the Bay of Bengal which will improve the physical paramaterisation of mixing in the ocean general circulation models. Under this programme, during the year, two dedicated cruises were conducted in the Bay of Bengal, on board ORV Sagar Nidhi (23 August - 15 September 2015) and ORV Sagar Kanya (23 January - 8 February 2016). The objectives of both cruises were to map the low-salinity water of riverine origin and to make detailed observations of upper ocean sub-mesoscale (1-10 km) structures and variability in the north Bay of Bengal. Sagar Nidhi covered a total along-track distance of nearly 2500 km and collected over 4000 temperature and salinity profiles using uCTD while Sagar Kanya covered 660 km and collected over 800 profiles. In addition, the WHOI mooring deployed in the Northern Bay during a Sagar Nidhi cruise in 2014 was retrieved during the Sagar Kanya cruise in 2016. Both cruises used a suite of high precision, new generation observation platforms, some of them for the first time in Indian Ocean waters; they include gliders, Lagrangian floats, ASIMET meteorological sensors, intense uCTD and ship-mounted ADCP surveys etc.

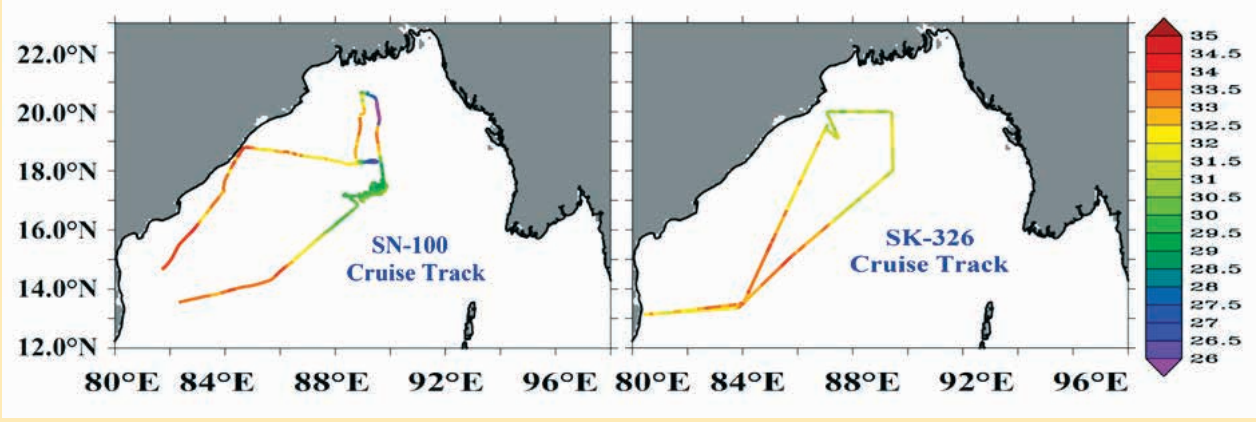
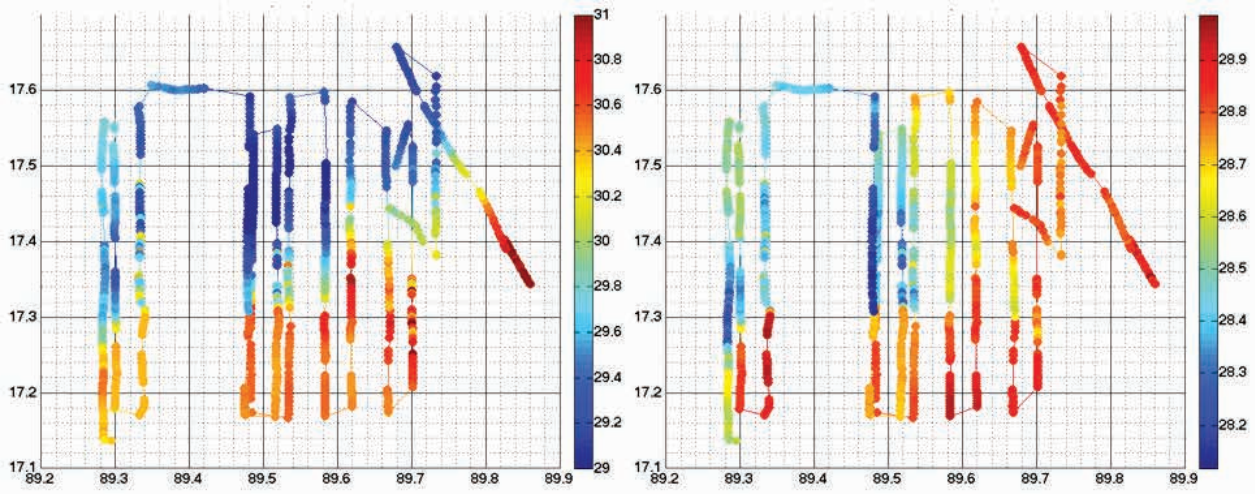


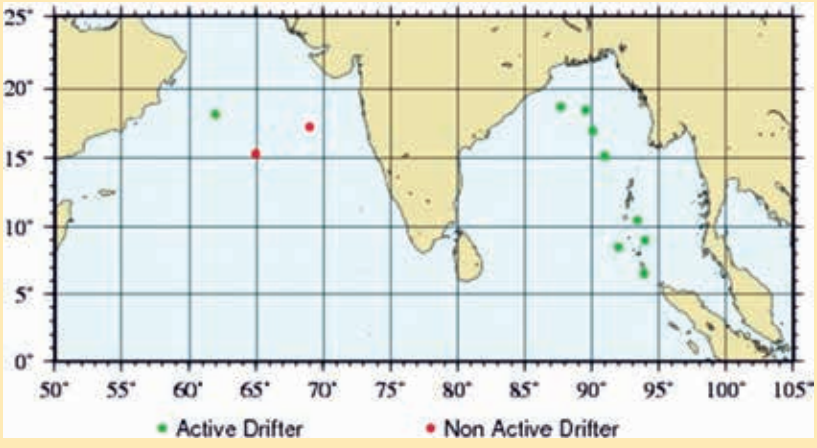
Figure showing the Sagar Nidhi (left panel) and Sagar Kanya (right panel) cruise tracks of the OMM programme during 2015-16 in the Bay of Bengal. The colour indicates the surface salinity as observed in the ship thermosalinograph.



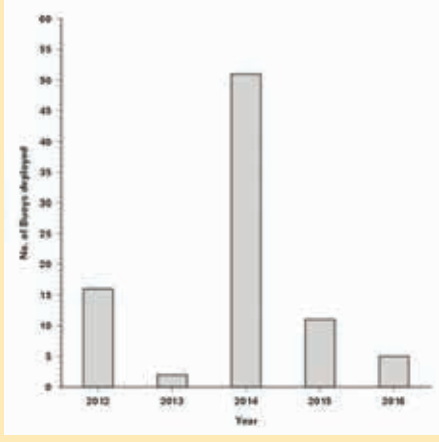
Intense frontal region traversed by Sagar Nidhi in the northern Bay of Bengal. Salinity (psu) at 4.0 m depth from uCTD along Nidhi track during 3-8 September 2015 (left). Temperature (°C) at 4.0 m depth from uCTD along Nidhi track (right).

5.10. Indian Ocean drifting buoy programme

Drifter programme aims to collect data on surface meteorological and oceanographic parameters using satellite tracked surface drifting buoys. Data on sea surface temperature, sea level pressure, surface currents and surface winds obtained from the surface drifters were uploaded to GTS for the benefit of weather prediction. These data are also useful for the validation of satellite-based observations. With financial support from ESSO-INCOIS, CSIR-NIO continued to implement the drifter programme and deployed 11 drifters in the Indian Ocean during the year.



Locations at which the drifter buoys were deployed during 2015-16

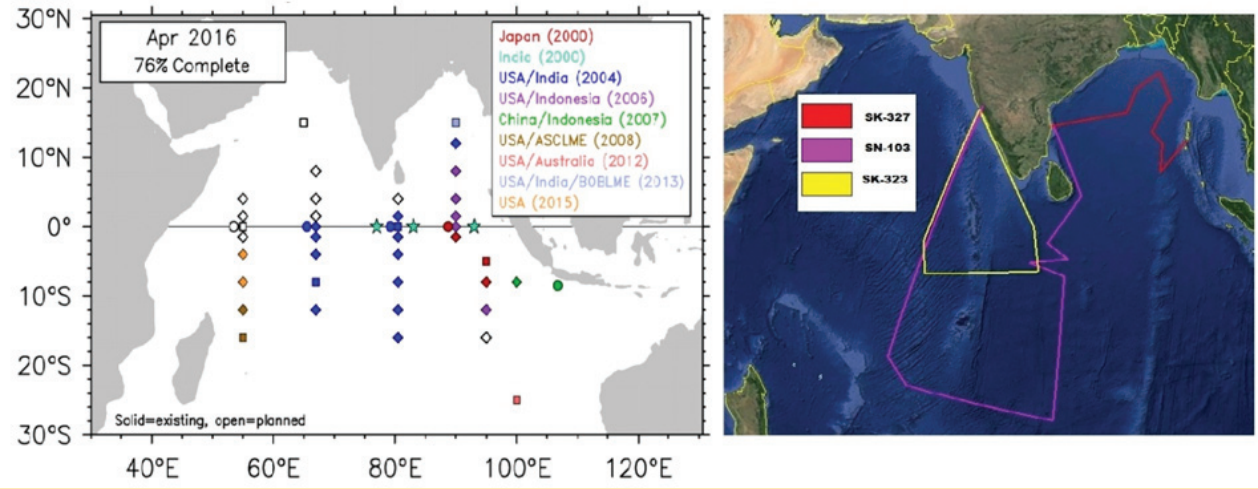


Year-wise distribution of the number of deployment of drifter buoys in Indian Ocean

5.11. RAMA observation network

The RAMA moored buoy array programme is a multinational effort to make systematic ocean observations, for improving our understanding of the monsoon system that affects about one third of the world population. In collaboration with NOAA PMEL, during the year, ESSO-INCOIS completed 45 operations through 3 cruises; 2 on board Sagar Kanya and one on board Sagar Nidhi to retrieve, repair and deploy the RAMA ATLAS, T-FLEX surface moorings and ADCP sub

surface moorings at 17 locations. 76% of the planned RAMA array is completed (35 out of 46) as of March 2016.



Left Panel: Present status of RAMA buoy network. 35 out of 46 locations are occupied. Blue colour in the map indicates Indian contribution to the RAMA network in collaboration with NOAA PMEL. Right Panel: Tracks of three cruises conducted by INCOIS during the year for RAMA operations.

5.12. Network of communication systems

Establishment of Indian Seismic and GNSS Network (ISGN)

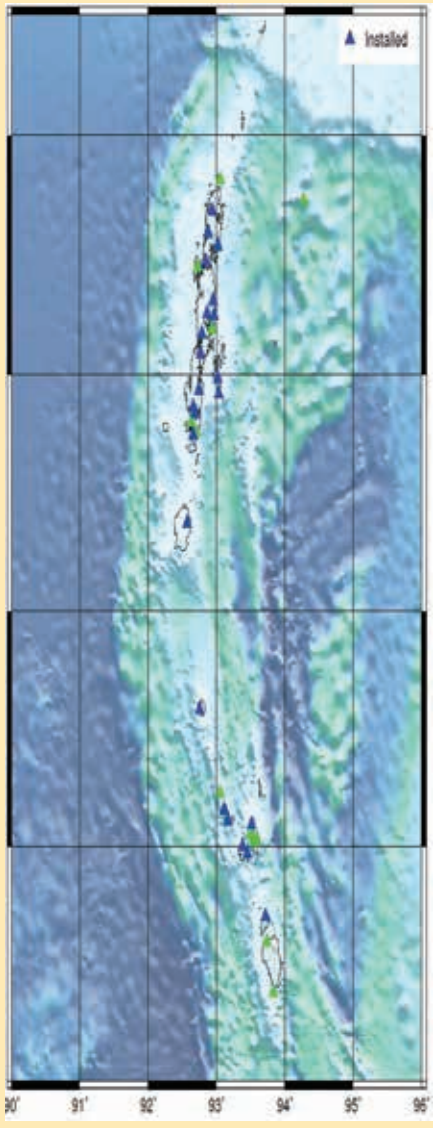
The Indian Seismic and GNSS Network (ISGN) is an important project of the Earth System Sciences Organization (ESSO), Ministry of Earth Sciences (MoES) with the goal of establishing a national seismic & GNSS data repository and for enhancing real-time seismological monitoring. The project also aims at providing high quality data for research & development to the scientific community. ESSO-INCOIS, as a nodal agency for the implementation of the project, provides real-time connectivity through VSATs to various seismic & GNSS stations all over India. Currently ESSO-INCOIS is receiving data from 130 stations. The other major organizations contributing to the ISGN programme are India Meteorological Department (IMD), National Centre for Seismology (NCS), National Geophysical Research Institute (NGRI) and Institute of Seismological Research (ISR). Several universities/academic institutes such as Indian Institute of Astrophysics, Indian Institute of Geomagnetism, Snow and Avalanche Study Establishment (SASE), G. B. Pant Institute of Himalayan Environment and Development, Indian School of Mines, Indian Institute of Science, University of Kashmir, Manipur University, Indian Institute of Technology Kharagpur, Indian Institute of Technology Roorkee, Kumaun University, University Kashmir, Tezpur University etc., also operate stations and contribute to the network.

The real-time data received from all seismic as well as GNSS stations were archived at ESSO-INCOIS & ESSO-IMD/NCS data centres and made available through www.isgn.gov.in. While data from selected stations are made available to all the users for operational use, data from other stations are shared as per the data sharing policy. There were 61 registered users in the ISGN web portal by the end of the reporting period.

Establishment of GNSS & Strong Motion network in A&N Islands

ESSO-INCOIS has taken up a project to install co-located Strong Motion sensors, GNSS receivers and Meteorological sensors with real-time VSAT connectivity at 35 locations in the Andaman & Nicobar (A&N) Islands. As on March 2016, civil construction at 22 locations has been completed and installation of GNSS receivers and Strong Motion Accelerometers was completed at 15 locations. Installations are progressing at the remaining locations.

Co-located SMA & GPS stations in Radhanagar (top) & Kadamtala (bottom)

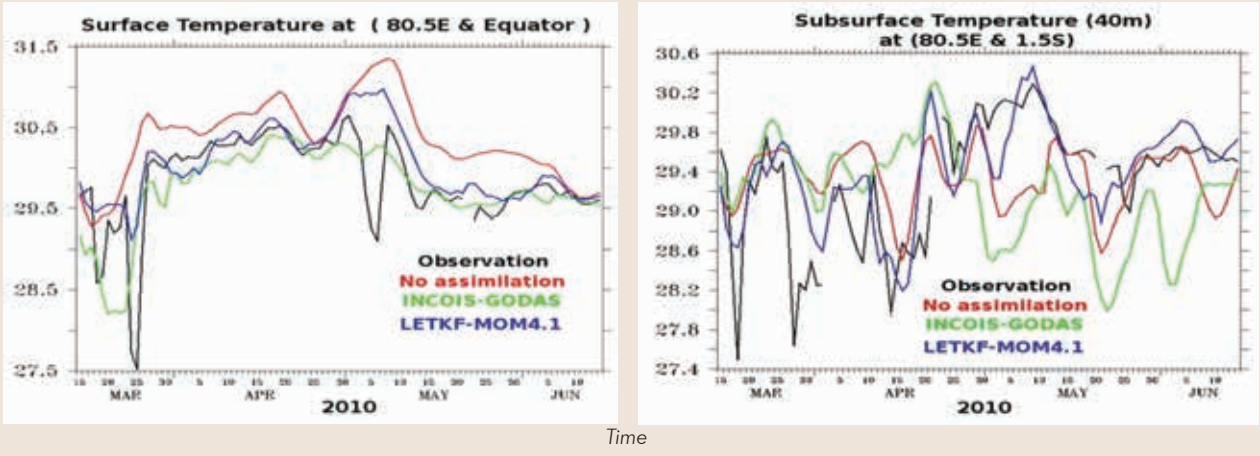


Locations of GNSS installations in Andaman and Nicobar islands.

6. Ocean Modeling and Data Assimilation

6.1. Data Assimilation

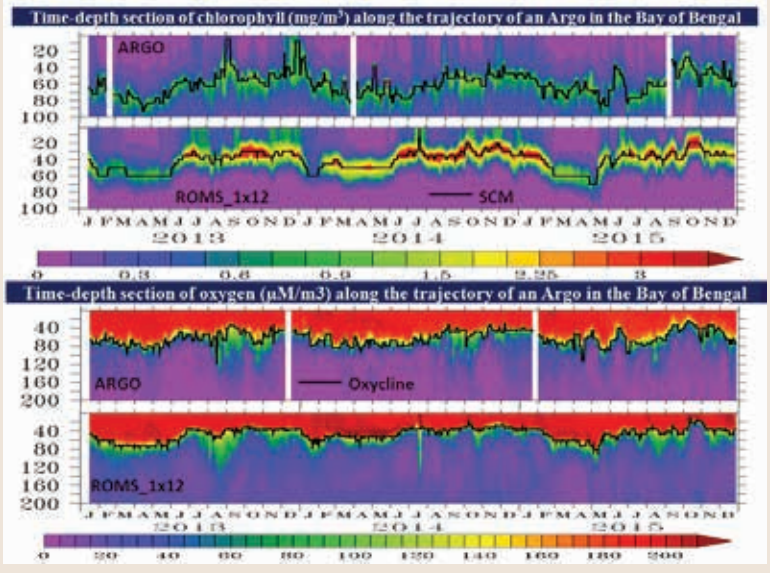
ESSO-INCOIS achieved a major milestone in operational oceanographic research with the implementation of the Local Ensemble Transform Kalman Filter (LETKF) in the ocean general circulation models such as Modular Ocean Model and Regional Ocean Modeling System (ROMS), which are used for routine ocean forecasts/analysis. Experiments to evaluate the performance of this assimilation scheme are being carried out. Scientists of ESSO-INCOIS implemented this assimilation method as a collaborative effort with Prof. Eugenia Kalnay, University of Maryland, USA and her group under the umbrella of the National Monsoon Mission. This is a relatively new method and has been proven to be more efficient and numerically less intensive.



Series of temperature from observation (black), and model simulations with assimilation (green and blue) and without assimilation (red) at (a) 80.5° E & EQ at surface and (b) 80.5° E, 1.5° S at 40 m depth.

6.2. Marine Ecosystem Modeling

The high resolution (1/12 degree), Indian Ocean setup of the Regional Ocean Modeling System (IO-ROMS) has been coupled with a biogeochemical module. This setup simulates and predicts ecosystem parameters better than ever and also provides the boundary conditions for a series of very high resolution ROMS setups in coastal waters. WC-HOOFS (the High resolution Operational Ocean Forecast and reanalysis System for the West Coast of India with horizontal resolution of 1/48



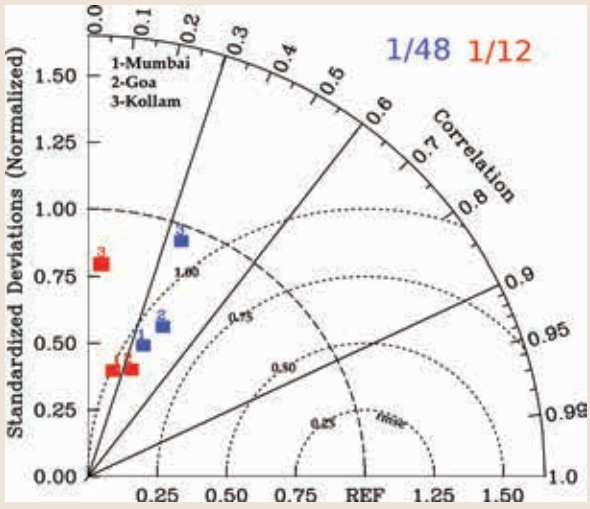
Time-depth section of Chlorophyll and Oxygen along the trajectory of an Argo float in the BoB.

degree) has been successfully integrated with the ecosystem module. The main advantage of WC-HOOFS is its ability to represent/predict both high and low frequency variability more accurately.

6.3. High-resolution Coastal Modeling

6.3.1. HOOFS setup for the South-eastern Arabian Sea

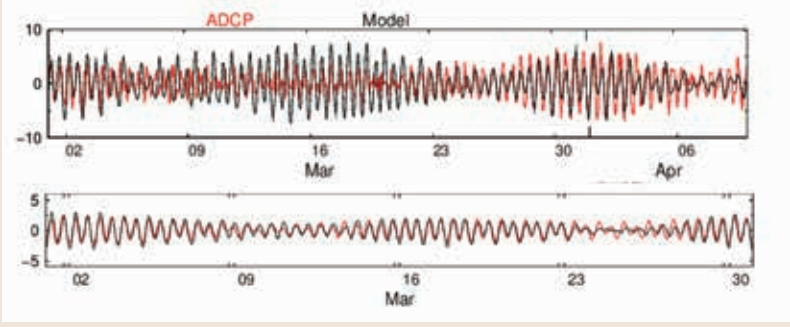
The second model setup in the series of High resolution Operational Ocean Forecast and reanalysis System (HOOFS) has been set up for the Southeastern Arabian Sea. Validation with observations, showed that there is considerable improvement in the performance of the model in terms of simulating the circulation features compared to the lower resolution basin-scale setup of ROMS.



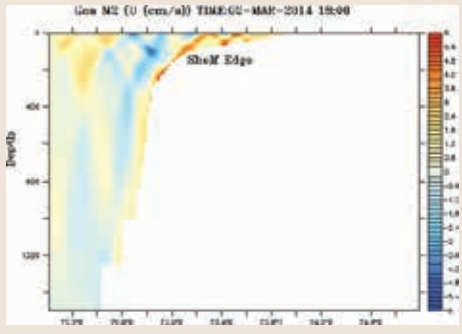
Taylor diagram representing the relative performance of WC-HOOFS (1/48°) and IO-ROMS (1/12°)

6.3.2. Simulation of internal tides by WC-HOOFS

Comparison of the features of internal tides simulated by the west coast setup of HOOFS (WC- HOOFS) with the ADCP observations off the coast of Goa showed that the model could simulate many features of the internal tides realistically. Analysis suggested that the shelf-edge off the west coast is very sensitive to the generation of internal tide. It was also found that the internal tide energy path was directed towards the coast.



Comparison of barotropic tidal current simulated by WC-HOOFS off Goa coast with ADCP observation

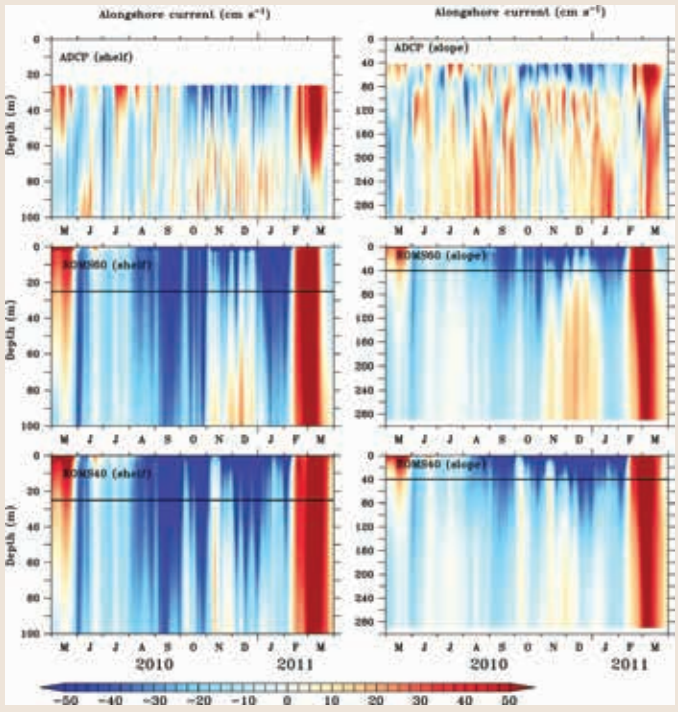


Semidiurnal internal tides simulated by WC-HOOFS on 2 March 2014 at 18:00 hrs

6.3.3. Simulation of coastal undercurrent at southern part of western boundary of Bay of Bengal

Response of the coastal under currents (CUC) along the east coast of India as simulated by the ROMS model with 1/12° x 1/12° horizontal resolution to varying vertical resolutions was explored. It was found that CUC was better simulated by ROMS with 60 sigma vertical levels (ROMS60, out of which 40 levels are in the top 200 m in the continental slope region) compared to ROMS setup with 40 sigma vertical level (ROMS40, out of which 23 levels are in the top 200 m in the same region). Further, model simulations showed that CUC at Cuddalore could be due to the remote forcing (westward propagated sub-surface Rossby waves) from further offshore in the interior Bay

of Bengal and strong propagation was evident even at 200 m water depth. It was also found that a significant decrease of thermocline and mixed layer depth occurred in the simulations of ROMS60 compared to the simulations of ROMS40. This could be due to the difference in the amplitude of Rossby waves which propagate below the surface.

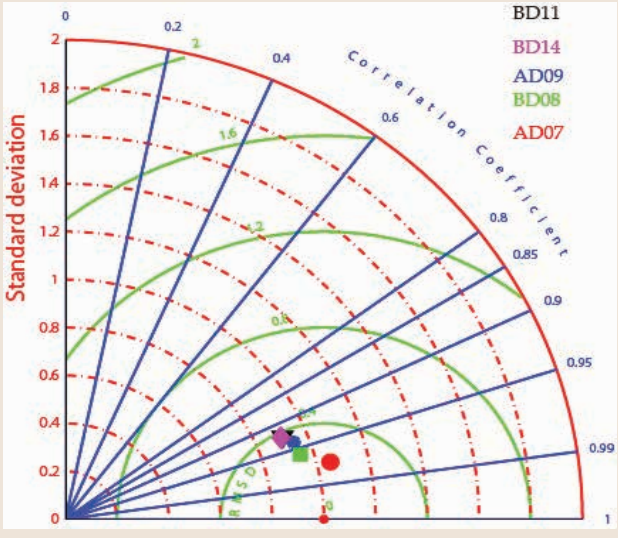


Comparison between ADCP observed and model (ROMS40 and ROMS60) simulated and alongshore current at Cuddalore continental shelf and slope. The location of shelf and slope mooring are at 80.1° E, 12° N and 80.2° E, 12° N respectively. Alongshore component of current is calculated by rotating current at coastal angle and positive (negative) value of current is directed pole ward (equator-ward). Colour bar represent value of alongshore current in cm s^{-1}

6.4. Wave modeling

6.4.1. WAVEWATCH-III

WAVEWATCHIII v4.18 (WWIII) was configured for providing wind-wave forecasts in the open ocean. The model setup is used to provide experimental predictions of significant wave height, mean wave period for swell and sea at 6-hourly interval with lead time up to five days. The model is being forced with ECMWF wind input. Hindcasts for the year 2014 were validated with observations from the moored buoys (AD07, AD09, BD08, BD11 and BD14) located in the Indian Ocean. It was found that the simulated wave heights are highly correlated with the observations with correlation coefficient greater than 0.92 for all buoy locations and RMSE errors in the significant wave height are within the range from 12% to 17 % of the observed standard deviation, which is in the range of 0.6 m to 1.33 m. Scatter indices and bias are very low (0.14 to 0.16 and -0.05 m to 0.08 m respectively) for significant wave height.

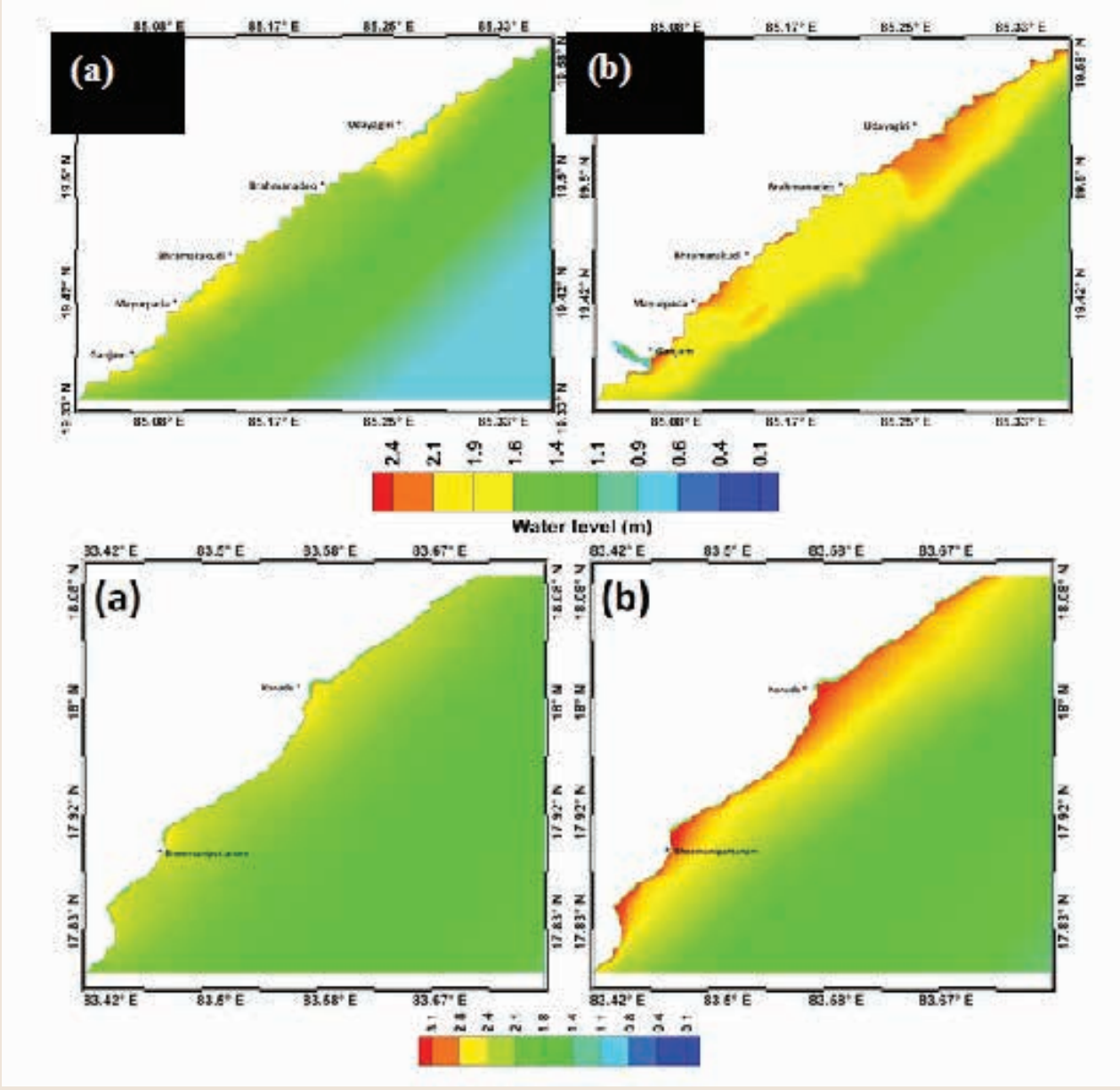


Taylor diagram showing the skill of WAVEWATCH III for significant wave height simulations for the year 2014 at different moored buoys shown in different colours

6.4.2. Impact of wave setup on surge and inundation

Impact of wave setup on the extent of inundation and surge height due to storm surge was studied using a coupled setup of ADCIRC and SWAN for the cases of tropical cyclones Phailin and

Hudhud. It was found that the water levels increase significantly, when the effect of wave setup was included in the simulations.

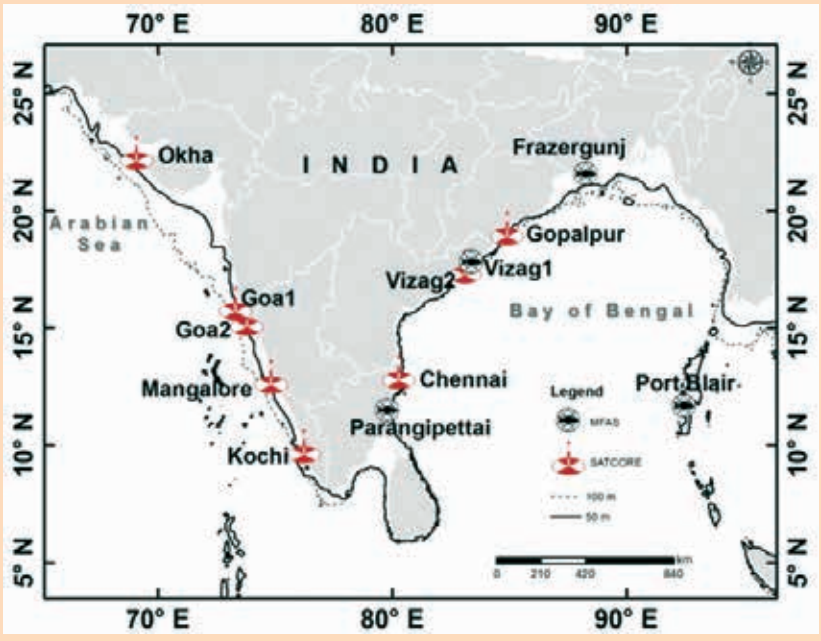


Computed storm tide during Phailin (upper panel) & Hudhud (lower panel) with a) ADCIRC and b) ADCIRC+SWAN

7. SATellite Coastal and Oceanographic REsearch (SATCORE) programme

7.1. Time series stations and data statistics

As part of SATellite Coastal and Oceanographic REsearch (SATCORE) programme, eight time- series stations were established for the measurement of bio-optical and physico-chemical parameters. All time-series stations were equipped with a Spectrophotometer, Integrating Sphere, Sun photometer, Fluorometer, Weighing Balance, Automatic Weather Station, Vacuum Filtration Unit and Aspirator Pump required for the measurement of essential parameters such as chlorophyll- a (chl-a), total suspended matter (TSM), chromophoric dissolved organic matter (CDOM), inherent optical properties (IOP), apparent optical properties (AOP), aerosol optical thickness (AOT), Nutrients, phytoplankton (Phyto), pH, dissolved oxygen (DO), Salinity and water temperature (WT) defined under the SATCORE sampling strategy.



Locations of time series stations for measuring the bio-optical and physico-chemical parameters, as part of SATCORE programme.

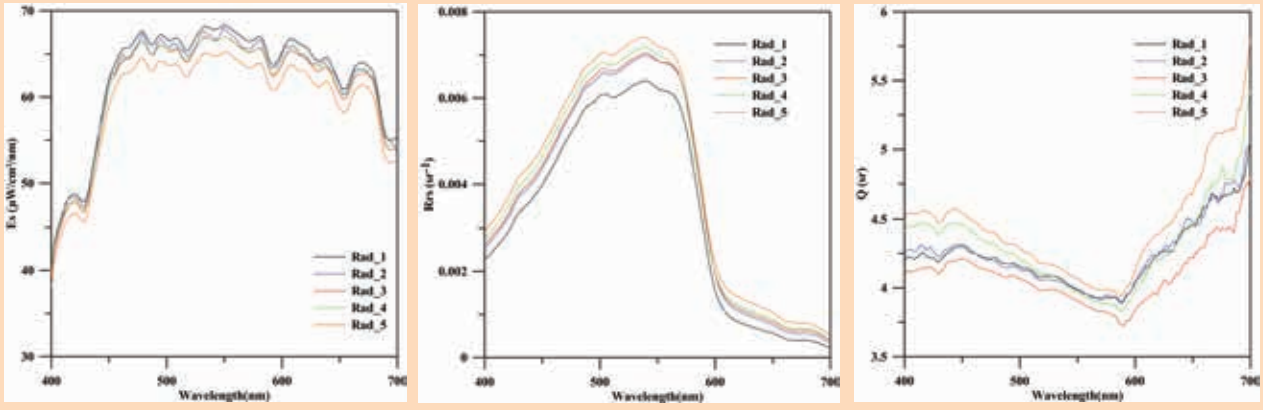
Parameter-wise data statistics measured at different time series locations (2008-15)

	Chl-a	TSM	CDOM	IOP	AOP	AOT	Nutrients	Phyto	pH	DO	Salinity	WT
Okha	157	157	115	151	0	28	301	5	31	157	0	157
Goa-1	133	101	120	21	93	45	0	0	0	0	68	68
Goa-2	1198	1526	787	151	350	1	0	259	0	0	0	0
Mangalore	896	782	0	0	45	0	466	0	0	0	0	892
Kochi	1310	1194	974	890	80	93	4477	302	1250	821	918	807
Parangipettai	2172	93	0	0	0	0	4364	870	868	868	868	868
Vizag	68	271	66	0	78	24	0	0	0	0	58	58
Gopalpur	1368	1269	843	359	406	120	6939	327	1394	1394	1394	1373
Total												

7.2. SATCORE Inter-COMparison Exercise (SICOME) - 2015

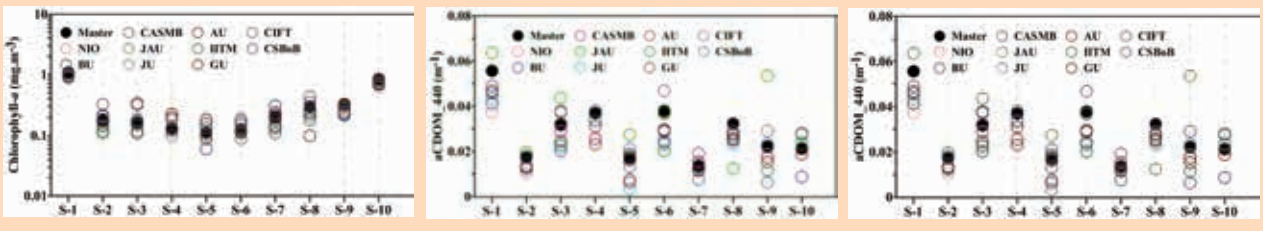
In order to ensure the accuracy of the parameters measured at various laboratories at different time- series locations, SICOME-2015 was conducted off Gopalpur. During the exercise, samples of chl- a, CDOM and TSM were collected from one location. The master samples were immediately analyzed and duplicate samples were sent to different SATCORE laboratories for further analysis. All five radiometers were operated simultaneously to estimate the instrument bias. Different AOP such as surface irradiance (Es), bidirectional reflectance (Q) and remote sensing reflectance (Rrs) were observed to follow similar spectral shape ensuring stable and comparable performance for all the instruments.

Sampling location during SICOME-2015 (left) and radiometer operation in buoy mode (middle) and surface reference (right)



Spectral surface irradiance (left), remote sensing reflectance (middle) and bi-directional reflectance (right) from the five radiometers operated simultaneously during SICOME-2015

Chl-a analysed at all time-series locations were in the range of master results (0.11 to 1.08 mg m^{-3}). Statistical analysis confirmed regression coefficient (R^2) > 0.9 and lower RMSE values (0.080 - 0.202 mg m^{-3}) by all SATCORE laboratories with respect to master values. TSM concentration

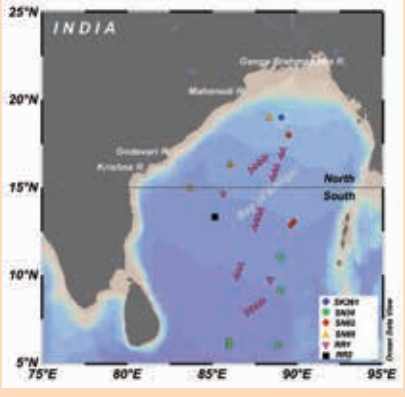


Chl-α (left), TSM (middle) and a_{CDOM}^{440} (right) estimated at various time-series station laboratories during SICOME-2015 (NIO: National Institute of Oceanography-Goa, BU: Berhampur University, CASMB: Centre for Advanced Studies in Marine Biology, JAU: Junagarh Agricultural University, JU: Jadavpur University, AU: Andhra University, IITM: IIT Madras, GU: Goa University, CIFT: Central Institute of Fisheries and Technology, CSBoB: Centre for Studies on Bay of Bengal)

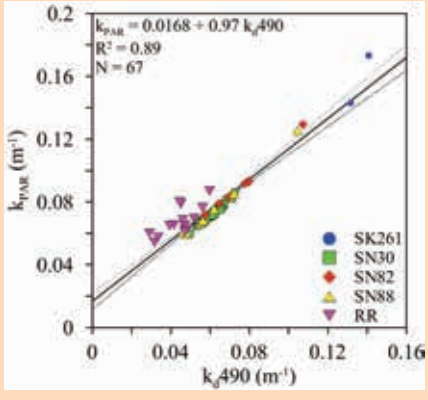
of the master samples were ranged between 5.8 and 17.44 mg l^{-1}. Although there were minor differences in magnitudes, all the results from different laboratories matched with the pattern of master results. TSM analyses at SATCORE laboratories with $R^2 > 0.8$ RMSE within 0.07-0.16 mg l^{-1}. $CDOM_{440}$ magnitude of the master sample was in the range of 0.01 to 0.06 m^{-1} and the values of $CDOM_{440}$ analyzed at all time series locations were in the range of master results.

7.3. Penetrative Radiant Flux in Bay of Bengal

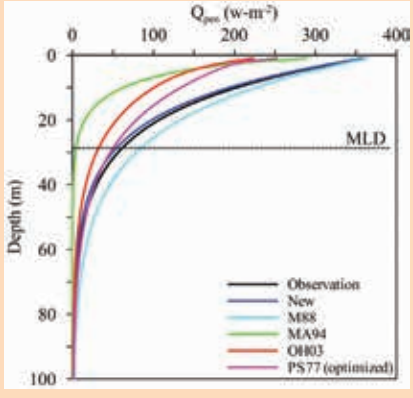
Since Bay of Bengal (BoB) is a semi-enclosed basin in the northern Indian Ocean with large freshwater inputs and strong vertical stratification, the mixed layer (ML) is generally shallow with strong spatial variability. The stratified, shallow MLs inhibit vertical mixing and the larger penetration of solar radiation through the base of the mixed layer can lead to redistribution of upper ocean heat. It is necessary to refine approaches to modeling mixed layer dynamics in the Bay of Bengal. Such refinements are of considerable interest in ongoing efforts to obtain accurate sea surface temperature (SST) from satellite remote sensing. Observations of hyper spectral (400-700 nm) downwelling irradiance (Ed) measured during six research cruises in BoB (75 total profiles), spanning over a broad range of regions and seasons between 2009 to 2014 were analyzed to derive an empirical relationship between the downwelling diffuse attenuation coefficient at 490 nm (kd490) and photosynthetically available radiation (PAR) (kPAR) with an intention to use satellite PAR to estimate penetrative radiant flux. Further, the attenuation length scales for double exponential model of Paulson and Simpson (1977) (PS77) was optimized to quantify the penetration of radiative flux below the mixed layer depth (Q_{pen}). The estimates of Q_{pen} obtained from published chlorophyll-based models were also evaluated and compared with in situ observations.



Map of Bay of Bengal showing the observational coverage of the six cruises



Scatter plot showing the relation between kd490 and kPAR. The symbols represent the sampling during various cruises



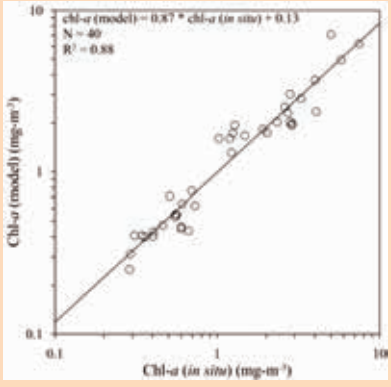
Profile of penetrative radiant flux measured in situ and modeled using various parameterization schemes

Statistical indicators obtained by comparing penetrative radiant flux at MLD using present and published methods. The statistical indicator includes mean ratio (r), slope (S), Intercept (I) regression coefficient (R), root mean-square error (RMSE), absolute (APD), relative (RPD) and unbiased (UPD) percentage difference between measured and modeled parameters.

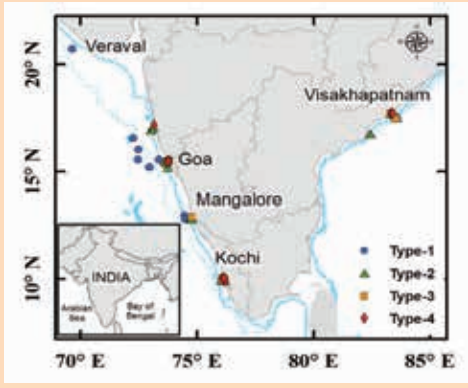
Model	r	S	I	R^2	RMSE	APD	RPD	UPD
Morel (1988): M88	0.79	1.44	0.88	0.68	0.22	14.44	-11.35	-9.94
Morel and Antoine (1994): MA94	1.42	0.73	1.31	0.73	0.20	11.87	9.65	11.08
Ohlmann (2003): OH03	1.95	0.61	-0.17	0.73	0.30	20.64	20.44	24.28
New	0.86	0.83	8.03	0.70	0.16	10.73	-7.75	-6.89

7.4. Optimal spectral bands to estimate chlorophyll-a in coastal waters

Most operational satellite chl-a algorithms are empirical, switching band ratios which relate ratio of remote sensing reflectance (Rrs) to concentration of chlorophyll-a (chl-a). Such algorithms often tend to fail in coastal waters which are dominated by coloured dissolved organic matter (CDOM) and total suspended sediment (TSM) along with phytoplankton. However, there is scope to improve the empirical algorithm by tuning the coefficient at regional scale and by the selection of proper bands. In order to identify suitable bands with optimal effect of chl-a in the presence of CDOM and TSM, 417 Rrs spectra were analyzed from Indian coastal waters. It is found that the estimated chlorophyll-a using the new empirical model provided better estimation of chl-a (R2=0.88) for all water types.



Correlation between in situ measured and modeled chl-a



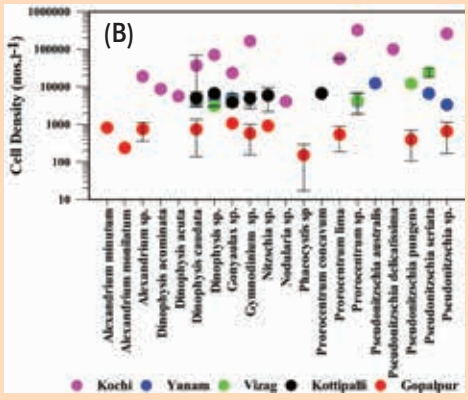
Map of study area showing sampling locations

7.5 Toxic phytoplankton in Indian coastal waters

Phytoplankton monitoring has been carried out at five locations (Kochi, Yanam, Kotipalli, Visakhaptnam, Gopalpur) under the SATCORE programme. The comprehensive phytoplankton inventory depicted a total number of 529 species prevailing in the Indian coastal waters. The species diversity of phytoplankton ranged between 145-283 at the monitoring stations. Highest species diversity was observed off Gopalpur (283). Diatoms dominated in the phytoplankton community at all locations. Analysis confirmed the prevalence of 20 toxic/toxigenic phytoplankton species i.e. 5 diatom, 13

Phytoplankton monitoring locations along Indian coast

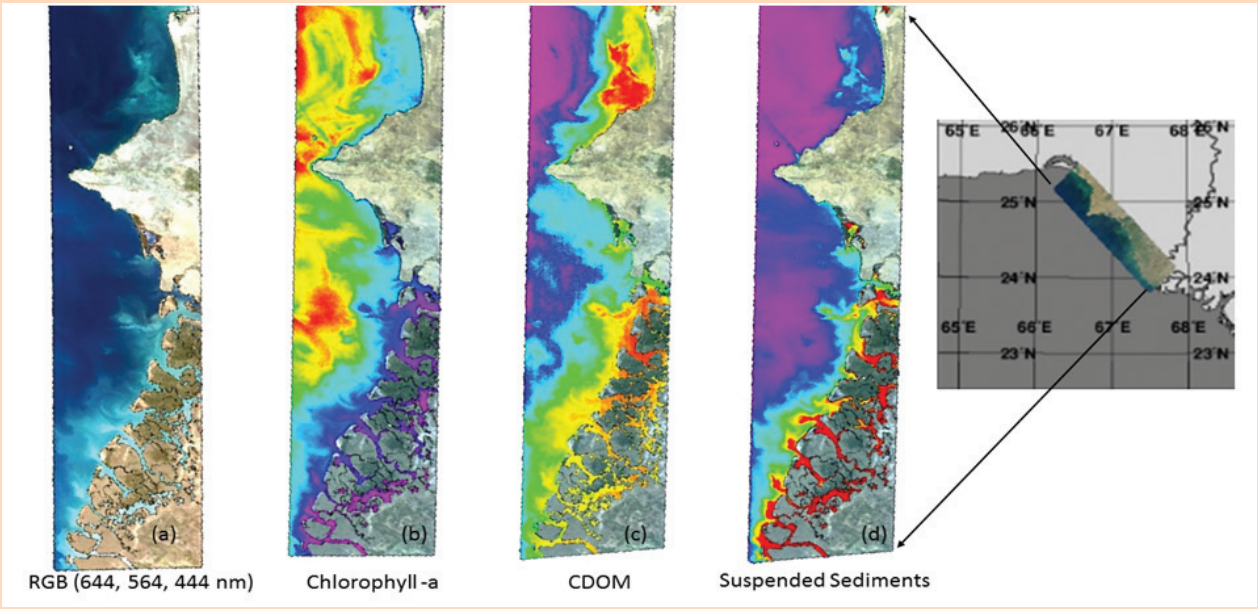
dinoflagellate, 1 blue-green algae and 1 cocolithophore species. The abundance of the toxic species was observed to be higher in coastal waters off Kochi and lower off Gopalpur.



Distribution of toxic species at different phytoplankton monitoring locations

7.6. Classification of Case-II waters (coastal) using Hyper spectral Imager for Coastal Ocean (HICO) Data:

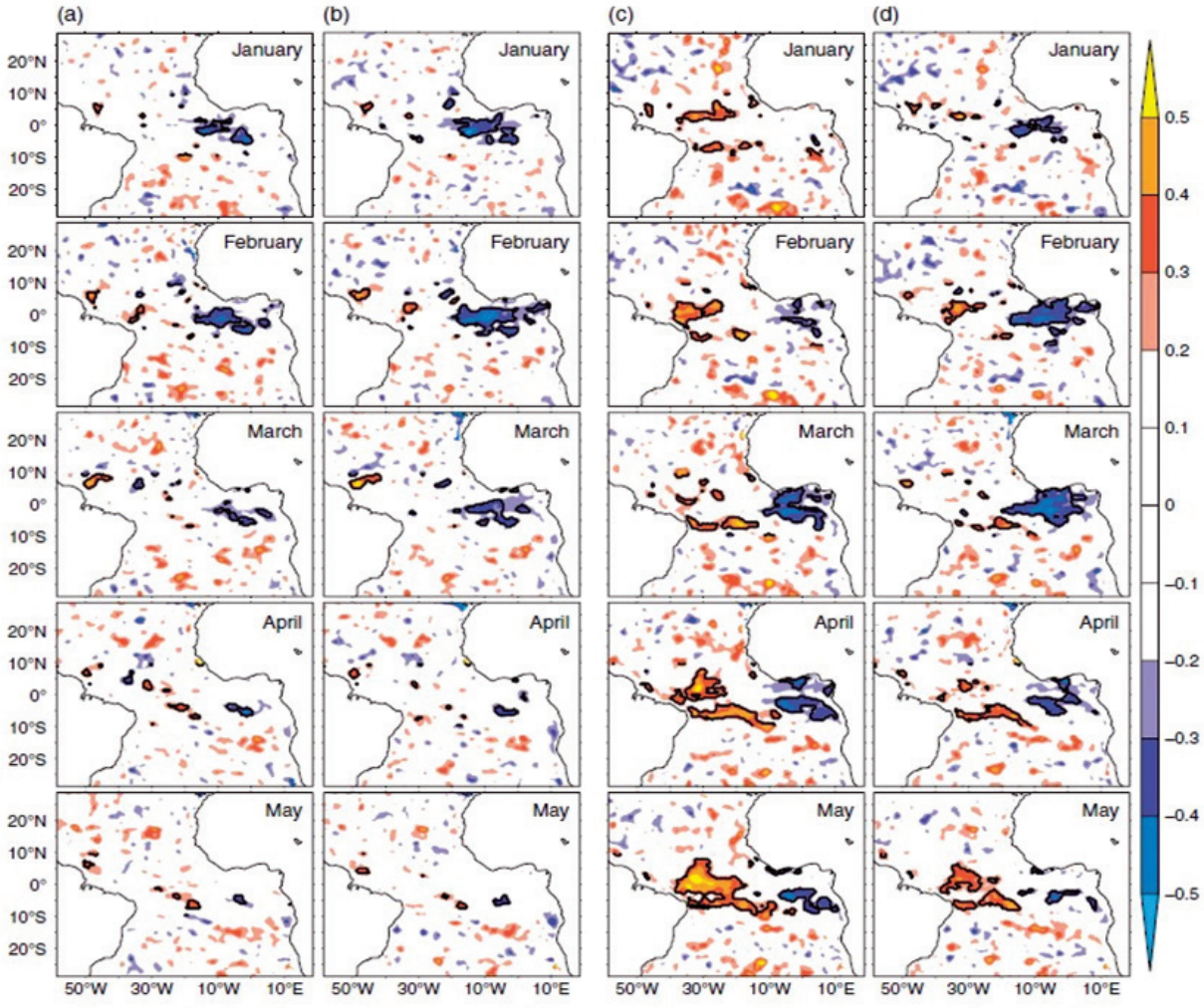
Ocean colour algorithms are available for retrieving the ocean constituents (chlorophyll-a, coloured dissolved organic matter (CDOM), and Suspended Sediments) in case-I waters. However, these algorithms could not perform well for case-II waters because of their optical complexity. Hyper spectral data was found to be suitable to address this lacuna and helped in classifying the case-II waters. Analysis of spectral reflectance curves suggested band ratios of Rrs (Remote sensing reflectance) 484 nm and Rrs 581 nm; Rrs 490 nm and Rrs 426 nm to classify the Chlorophyll –a and CDOM respectively. Rrs 610 nm gives the best scope for suspended sediment retrieval. This suggests the need for future ocean colour sensors with central wavelengths of 426, 484, 490, 581 and 610 nm to study case-II waters.



Classification of Indus River Estuary (inset, right) on 02 Feb 2011 from HICO data (a) RGB of 644, 564 & 444 nm (b) Ratio of Rrs 484 and Rrs 581 used to classify Chlorophyll-α (c) Ratio of Rrs 490 and Rrs 426 used to classify CDOM (d) Rrs 610 nm used to classify suspended sediments.

8. Research Highlights

8.1. Relation between the upper ocean heat content in the equatorial Atlantic during boreal spring and the Indian monsoon rainfall during June–September



Monthly correlations, during January–May, between anomalies of heat content and June-September rainfall anomalies over central India (a and b) and the Western Ghats (c and d), before (a and c) and after (b and d) removing the effect of ENSO on the respective regional rainfall during the monsoon season. Correlations above 90% significance level around the equator are shown in black contours.

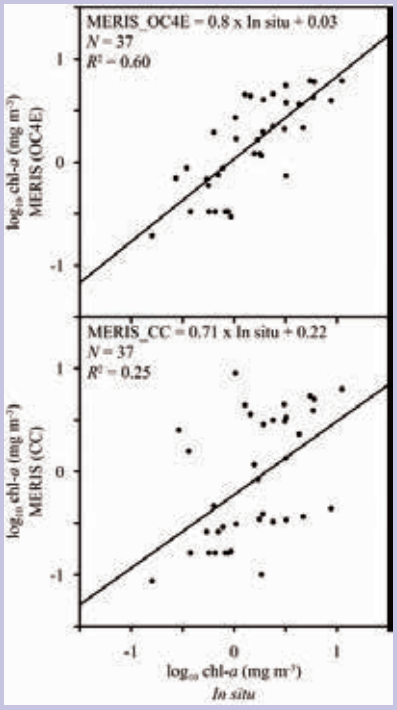
Ref: Vijay P., Girishkumar, M.S., Sivareddy, S., Ravichandran, M. Murtugudde, R(2015) Relation between the upper ocean heat content in the equatorial Atlantic during boreal spring and the Indian monsoon rainfall during June–September, International Journal of Climatology, pp. 1-12, DOI: http://dx.doi.org/10.1002/joc.4506

While teleconnections between the Atlantic zonal mode (AZM) and Indian summer monsoon rainfall (ISMR) have been noted, this study, explored the possibility to derive a predictive relationship between these two climate phenomena by analyzing the evolution of monthly composites of the zonal surface winds, heat content, and sea surface temperature (SST) in the equatorial Atlantic. It was found that there is are significant correlations between ISMR and the low-level zonal winds in the western equatorial Atlantic and heat content in the eastern equatorial Atlantic in the boreal spring season. Tracking coherent changes in these winds and the evolution of the heat content

in the deep tropical Atlantic in the boreal spring may offer the potential for skillful predictions of summer monsoon, especially during non-ENSO years when the predictability of ISMR tends to be low.

8.2. Validation of MERIS sensor's Coast Colour algorithm for waters off the west coast of India (2016)

Chlorophyll-a (chl-a) retrieved using MERIS Coast Colour (CC) algorithm was validated against in situ observations made from the west coast of India as part of the Satellite Coastal and Oceanographic Research (SATCORE) programme. Comparison of chl-a using MERIS-CC and in situ measurements showed wide scatter around the linear trendline. It was also observed that the chl-a derived using MERIS-CC was significantly underestimated in two-thirds of the observations, whereas with MODIS and MERIS it was 51% and 44%, respectively. At the same time, performance of the operational OC4E algorithm in retrieving chl-a was much better compared to that of MERIS-CC. Time-series analysis showed a good match between in situ chl-a and that derived from MODIS using the OC3M algorithm, whereas the MERIS-CC algorithm showed significant differences both in magnitude and trend. This inconsistency was more prominent during the low-chl-a scenario during the northern winter. It is inferred that algorithms such as OC4E and OC3M that use bands from the blue and green regions of the spectrum offer better chlorophyll retrieval in high-TSM or CDOM concentration waters in comparison with Coast Colour, which uses all bands across the spectrum.

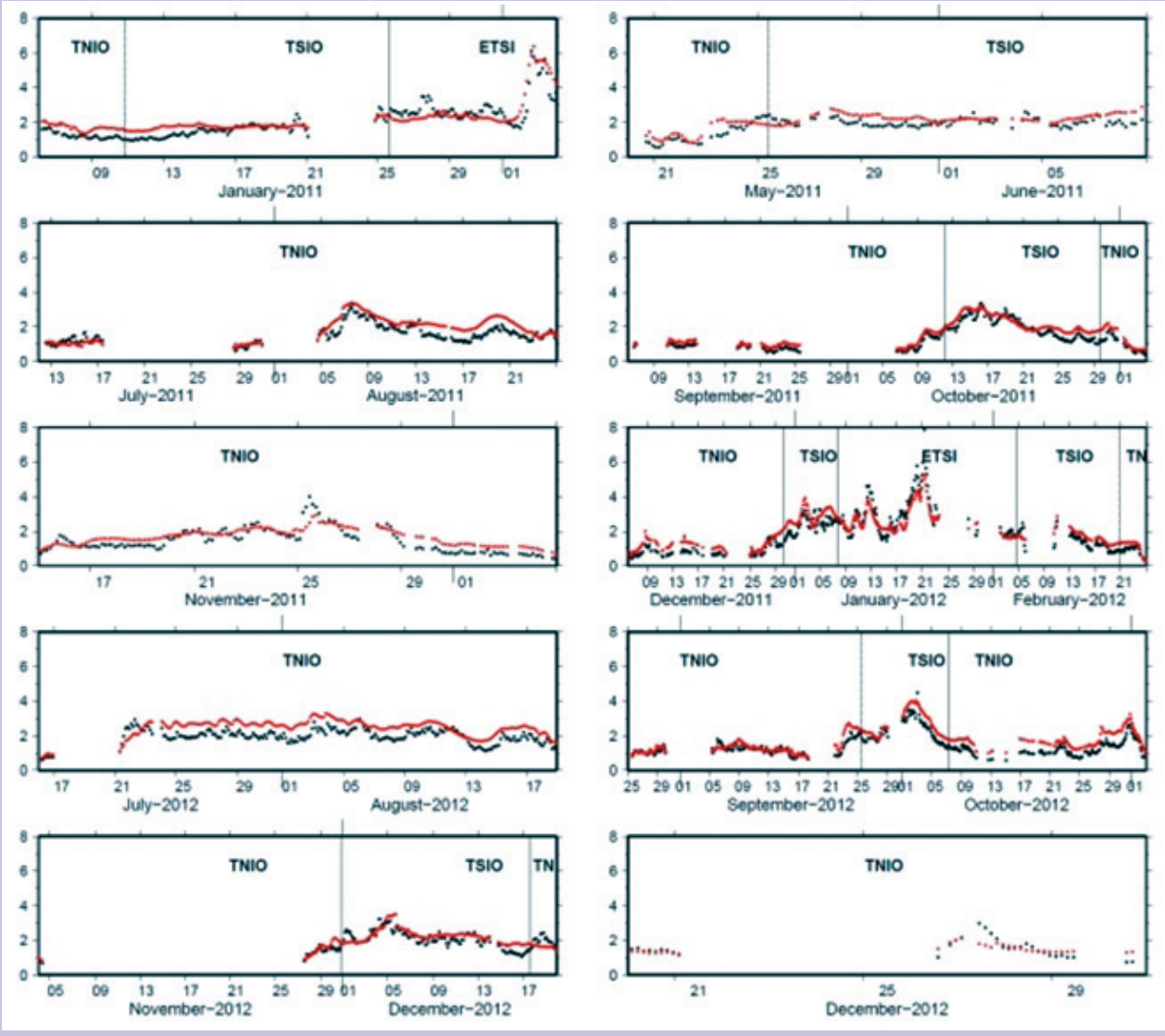


Comparison of chlorophyll derived from MERIS using the OC4E and Coast Colour algorithms against in situ observations. The observations show the standard algorithm performing better than the Coast Colour algorithm.

Ref: Nimit, K., Lotlikar, A., Srinivasa Kumar, T. Validation of MERIS sensor's Coast Colour algorithm for waters off the west coast of India (2016) International Journal of Remote Sensing, pp. 1-11. DOI: 10.1080/01431161.2015.1129564.

8.3. Ocean State Forecast Along Ship routes: Evaluation using ESSO-INCOIS Real-time Ship-Mounted Wave Height Meter and Satellite Observations

Ocean state forecast (OSF) along ship routes is an advisory service of ESSO-INCOIS which helps mariners to safely navigate in the Indian Ocean, particularly during extreme weather conditions. The accuracy of predicted significant wave height (Hs) along the ship track in the Indian Ocean was evaluated using a ship-mounted wave height meter (SWHM) on board the Oceanographic Research Vessel Sagar Nidhi and the measurements from Cryosat-2 and Jason altimeters. The comparison along the ship route using the SWHM showed very good agreement (correlation coefficient 0.80) with a lead time of 48 hours. However, analysis revealed 10% overestimation of predicted significant wave height in the low wave height regimes (< 1.5 m) in the Tropical Northern Indian Ocean.

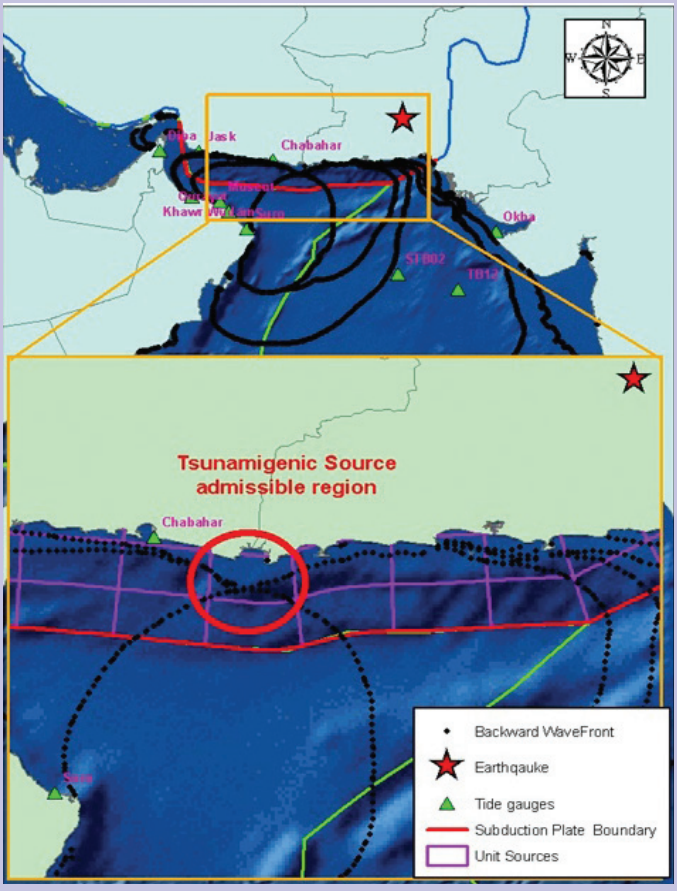


Time series of SWHMHs and OAS first-day forecasted Hs during different periods at different oceanic regimes. OAS first-day forecasted Hs are represented by red dots, and the black dots represent the observed Hs by SWHM.

Ref: Harikumar, R., N. Hithin, T. Balakrishnan Nair, P. Sirisha, B. Krishna Prasad, C.Jeyakumar, S. Nayak, and S. Shenoi, 2015: Ocean State Forecast Along Ship-routes: Evaluation Using ESSO- INCOIS Real-time Ship-Mounted Wave Height Meter and Satellite Observations. Journal of Atmospheric and Oceanic Technology,32, pp. 2211-2222.

8.4. The admissible tsunamigenic source region of 24 September 2013 land-based earthquake application of backward ray tracing technique

A minor tsunami of about 50 cm was generated along the coast of Qurayat near the Makran-subduction zone in the Arabian Sea due to the 24 September 2013 Pakistan earthquake of magnitude 7.6 Mw. The epicentre of the earthquake was ~ 200 km inland of the Makran trench. The real-time sea level observation network in the Arabian Sea recorded a minor tsunami. In an attempt to explain the mechanism of this unusual tsunami, a backward ray tracing technique was used to map the admissible region of tsunamigenic source. The known travel time of the initial waves to the respective tide gauges and tsunami buoys was used in this method. Backward wave front was constructed by joining all end points of the rays from each of the locations. The region where the envelope of all backward wave fronts converge is considered as the source of the tsunami. It was found that the source of the tsunami was approximately 470 km away from the



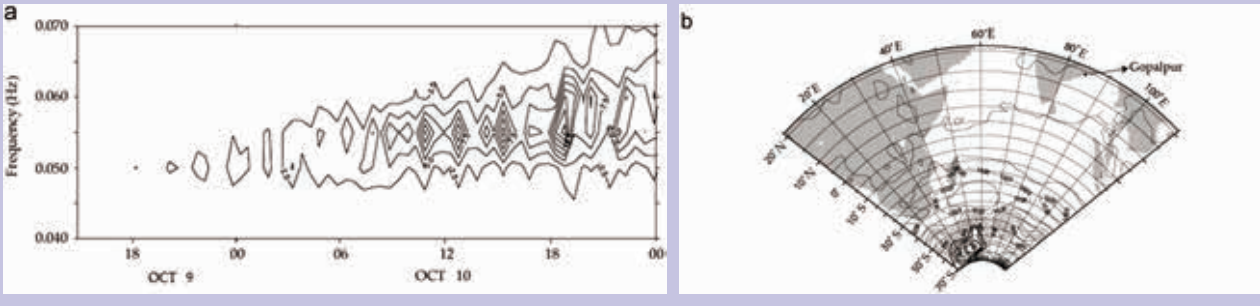
Admissible tsunamigenic region obtained by backward ray tracing technique marked as red circle.

Patanjali Kumar, C.H., Ajay Kumar, B., Devi, E.U., Mahendra, R.S., Sunanda, M.V., Pradeep Kumar, M., Padmanabham, J., Dipankar, S., Srinivasa Kumar, T. (2015) The admissible tsunamigenic source region of 24 September 2013 land-based earthquake application of backward ray tracing technique. Current Science, 108 (9). pp. 1712-1716.

earthquake epicentre located at 24.8°N and 61.5°E. The admissible region identified is an undersea section between Chabahar and Gwadar, where a mud island had appeared subsequent to this earthquake. Convergence of the tsunami source zone and the location of the mud island suggest that the sudden uplift might have caused the tsunami.

8.5. On the coexistence of high energy low-frequency waves and locally-generated cyclone waves off the Indian east coast

Analysis of the evolution of wave energy spectra obtained from a directional wave rider buoy at the landfall location (Gopalpur) of the very severe cyclonic storm Phailin in the Bay of Bengal revealed a rare coexistence of the low-frequency (0.055 Hz), high-energy (21.37 m^2Hz^{-1}) southern ocean swells with local cyclone-generated swells during the period (8–12 October, 2013). Further analysis using 'Ridge Analysis' technique showed that the low-frequency swells were generated approximately 8600 km away from the buoy location in the Southern Ocean (at 12 UTC on 3 October, 2013) and travelled at a speed of 15.6 ms^{-1}.

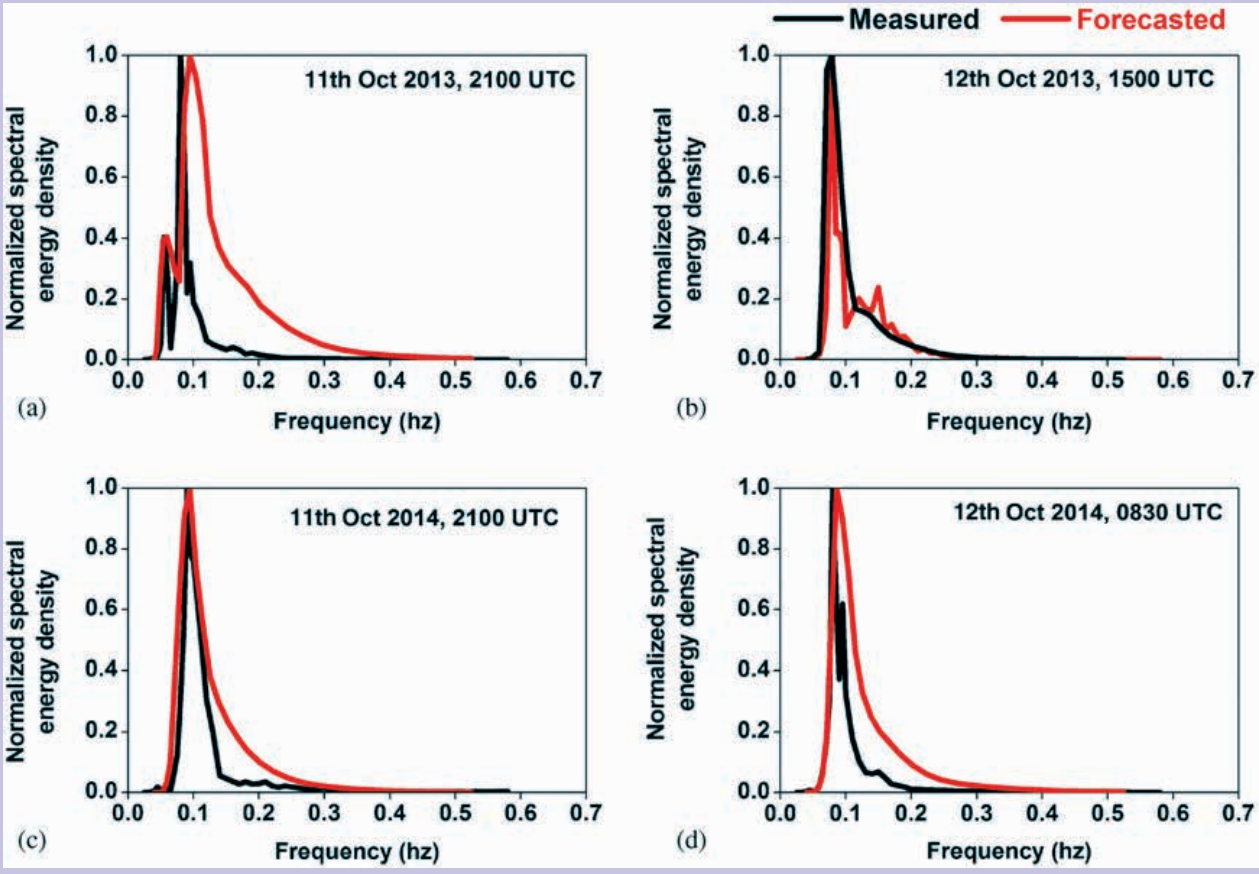


(a) Energy–frequency–time diagram showing wave energy contours in(m^2Hz^{-1}) above 2.5m^2Hz^{-1} and (b) NCEPFNL synoptic surface pressure chart for 12UTC, 3 October, 2013. Predicted source location could be identified with a well defined low pressure area, marked. The location of the Gopalpur buoy is also marked.

Ref: Sandhya, K.G., Remya, P.G. Balakrishnan Nair, T.M., Arun, N., On the co-existence of high-energy low-frequency waves and locally-generated cyclone waves off the Indian east coast, (2016) Ocean Engineering, Volume 111, 2016, pp. 148-154.

8.6. Numerical simulation and observations of very severe cyclone generated surface wave fields in the north Indian Ocean

Accuracy of the wave forecasts issued by ESSO-INCOIS during the occurrences of tropical cyclones were assessed by comparing the predictions using MIKE 21 SW wave models with in situ observations, both in the open ocean and coastal locations. Satellite altimeter observations were also utilized for the validation of wave forecasts in the open ocean. It is found that wave forecasts are in good agreement with in situ observations and altimeter measurements during extreme events. The average Scatter Index less was than 26% and correlation coefficient was more than 0.9. It was also found that maximum wave energy due to the cyclone-induced waves that hit the eastern Indian coastal region was on the right side of the cyclone track. The study also showed that the abnormal waves were mostly present on the right side of the track.



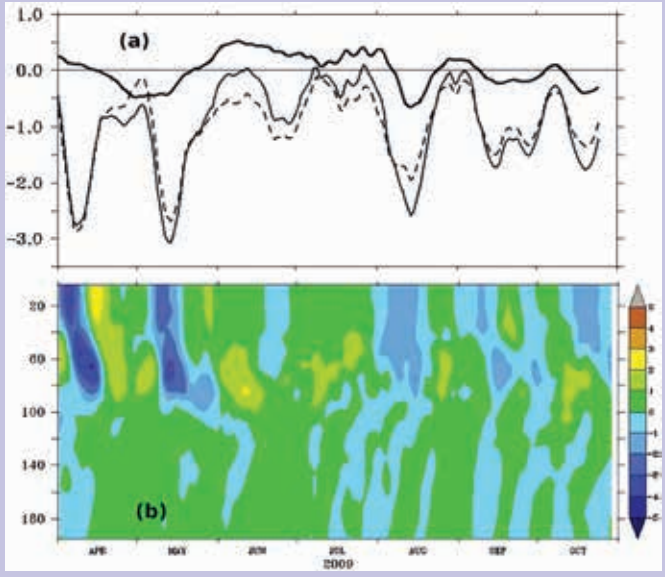
Comparison of measured and forecasted one-dimensional wave spectrum at coastal areas. Plots (a), (b) refer to Gopalpur during Phailin and (c), (d) refer Visakhapatnam during Hudhud.

Ref: Sirisha, P., Remya, P.G., Balakrishnan Nair, T.M., Rao, B Venkateswara, Numerical simulation and observations of very severe cyclone generated surface wave fields in the north Indian Ocean (2015) Journal of Earth System Science, pp. 1-13.

8.7. Assessing the impact of various wind forcings on INCOIS-GODAS simulated ocean currents in the equatorial Indian Ocean

The suitability of an Advanced Scatterometer (ASCAT)-based daily gridded wind product (DASCAT) for forcing INCOIS-GODAS was studied with the help of sensitivity experiments. INCOIS-GODAS was forced by three different momentum fluxes derived from QSCAT, DASCAT, and NCEP-R2

wind products. The simulated ocean currents from these experiments were compared with in situ current measurements from Research Moored Array for African-Asian- Australian Monsoon Analysis and Prediction (RAMA) buoys. Results suggested that the quality of simulated ocean currents from the daily DASCAT forcing is on par with the QSCAT forcing in the tropical Indian Ocean, except for the Equatorial Indian Ocean (EIO). Although QSCAT-forced current simulations were slightly better than DASCAT-forced simulations, both QSCAT and DASCAT provided much better results than NCEP-R2. It was further shown that the better simulations of currents over EIO, with QSCAT forcing compared to DASCAT forcing, can be attributed to the smoothening of the wind field in DASCAT compared to QSCAT. The impact of the error in DASCAT on ocean current analysis is, however, limited to local scales and the upper 100 m of the water column only. Thus, this study demonstrated that, in the absence of QSCAT, DASCAT is a better alternative for INCOIS-GODAS ocean analysis than NCEP-R2.

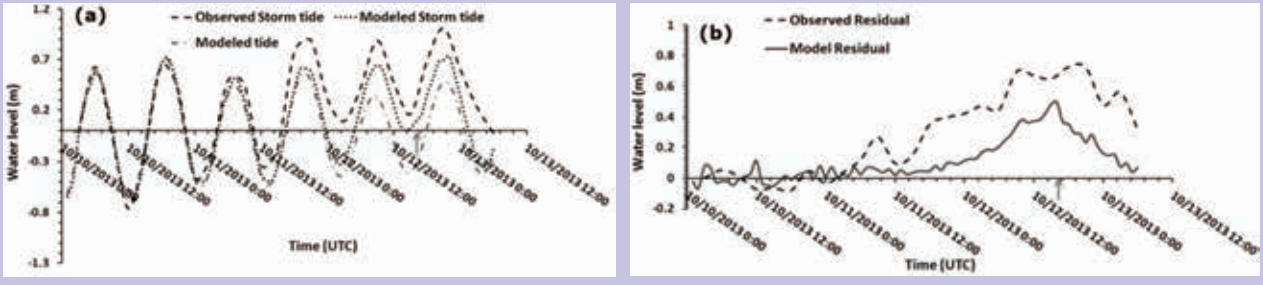


(a) Difference between DASCAT and QSCAT (DASCAT-QSCAT) wind-forced experiments in terms of differences in a Zonal Wind Stress (10^{-7} m s^{-2}, dashed line), Zonal Pressure Gradient (10^{-7} m s^{-2}, thick solid line), and ZWS+ZPG (10^{-7} m s^{-2}, thin solid line) and (b) depth-wise zonal current acceleration (10^{-7} m s^{-2}). All the variables are smoothed by a 10-day running mean and averaged for the CEIO (2°S–2°N and 60°E–90°E) before performing calculations.

Ref: Sivareddy, S., Ravichandran, M., Girishkumar, M.S., Prasad, K.V.S.R. Assessing the impact of various wind forcing on INCOIS-GODAS simulated ocean currents in the equatorial Indian Ocean (2015) Ocean Dynamics, 65(9), pp. 1235-1247.

8.8. Modeling Storm Surge and its Associated Inland Inundation Extent due to Very Severe Cyclonic Storm Phailin

A hindcast simulation of storm surge and inundation associated with the tropical cyclone Phalin, that made landfall at Odisha, India, on 12 October 2013, was carried out using the ADCIRC

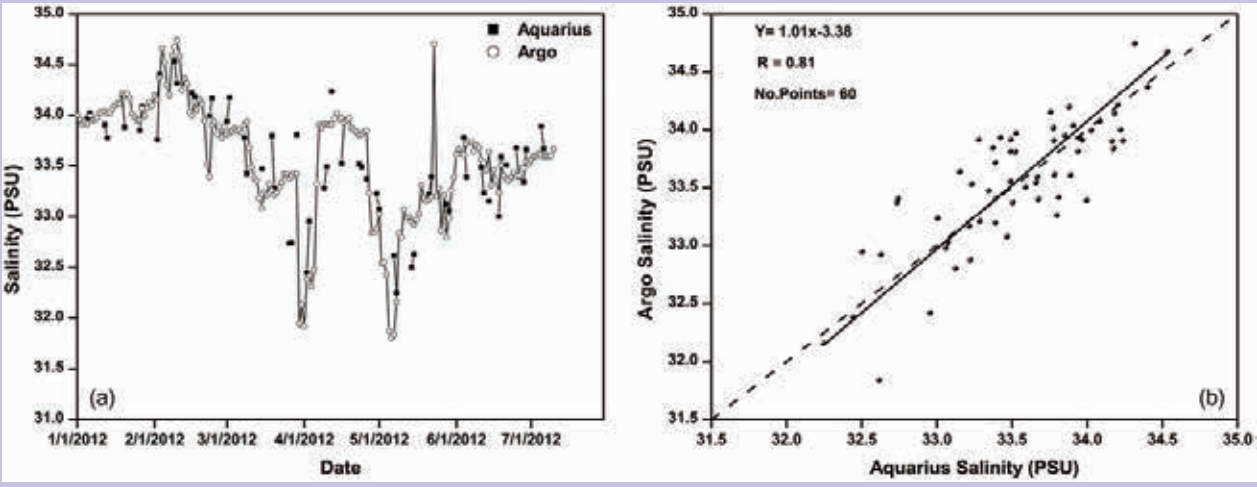


(a) Comparison of model computed storm tide in meters with that of observed at Paradeep. (b) Comparison of modeled residual with that of observed at Paradeep. Arrow indicates the landfall time.

Ref: Srinivasa Kumar, T., Murty, P.L.N., Pradeep Kumar, M., Krishna Kumar, M., Padmanabham, J., Kiran Kumar, N., Shenoi, S.S.C., Mohapatra, M., Nayak, S., Mohanty, P., Modeling Storm Surge and its Associated Inland Inundation Extent Due to Very Severe Cyclonic Storm Phailin (2015) Marine Geodesy, 38(4), pp 345-360.

model. The model-simulated inundation extent matched very well with the field surveys at Ganjam, Odisha, within a few days of landfall. Further, the model reproduced the temporal evolution of surge residual with respect to observations from a tide gauge at Paradip (correlation coefficient of 0.8, RMSE 0.26 m). However, the model marginally underestimated the magnitude of surge residual compared to the observations, which can be attributed to the lack of wave setup in the model and uncertainty in the wind and pressure information. The experiment also involved the use of two idealized scenarios, viz., variation of landfall timings with the ebbing and high tide phase. These scenarios were required for better understanding the sensitivity of inundation to the phase of tide in the model. Simulation with landfall at flooding (ebbing) tide showed greater (lower) inundation than the real scenario. Results from idealized scenarios confirmed the significance of the accuracy needed in forecasting landfall time.

8.9. Evaluation of Aquarius Sea Surface Salinity with Argo Sea Surface Salinity in the Tropical Indian Ocean



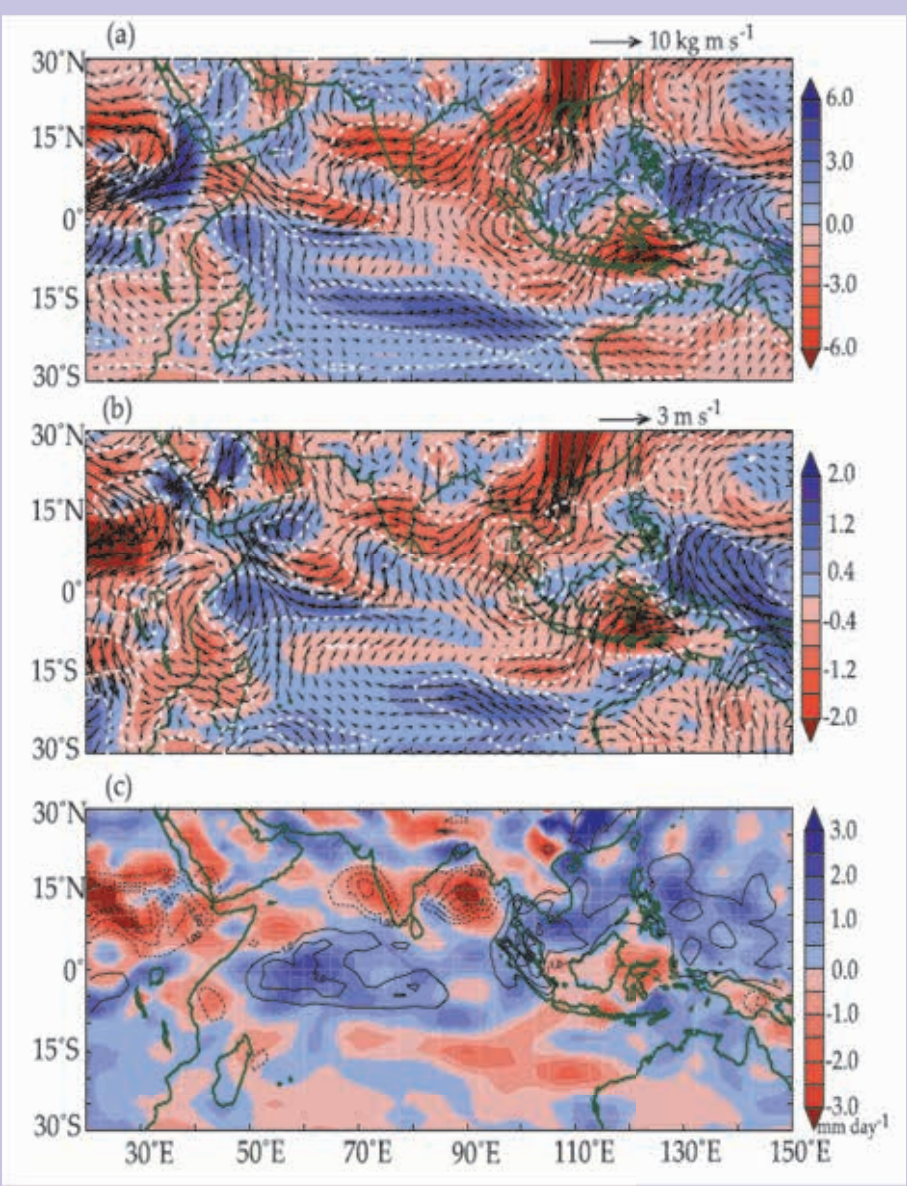
(a) Time series of collocated Ar-SSS and Aq-SSS during 2012 using daily measurements from the Argo float (WMO ID: 2901329). (b) Scatter plot between daily Aq-SSS and Ar-SSS in the BoB region. Regression equation along with correlation coefficient is also provided.

Ref: Udaya Bhaskar, T.V.S., Jayaram, C. Evaluation of Aquarius Sea Surface Salinity with Argo Sea Surface Salinity in the Tropical Indian Ocean (2015) IEEE Geoscience and Remote Sensing Letters, 12 (6), art. no. 7044573, pp. 1292-1296.

The performance of sea surface salinity (SSS) obtained from the Aquarius satellite was evaluated by comparing daily, weekly and monthly SSS data obtained from Aquarius for the period September 2011 and August 2013 for the tropical Indian Ocean (TIO) with the near-surface salinity observations (< 5 m) from Argo floats. It was found that the root-mean-square error (RMSE), bias and correlation coefficient between the daily reporting Argo float (WMO 2901329) and daily Aquarius SSS are 0.32 psu, 0.02 psu and 0.81, respectively. Weekly 1°×1° spatial resolution SSS was generated from the Argo data using variational analysis and was compared with Aquarius SSS data. RMSE was observed to be between 0 and 0.25 psu over most of the region, while the bias in the satellite data was observed to be within 0.3 psu everywhere, except in the Southeastern Arabian Sea and the Southeastern TIO. Good correlation (> 0.6) was observed everywhere, except the coast of Oman, Western Equatorial Indian Ocean and south of 20°S.

A seasonal comparison has also revealed that both Aquarius and Argo are in agreement. The Aquarius SSS showed the seasonal salinity cycle of TIO very clearly.

8.10. On the decreasing trend of the number of monsoon depressions in the Bay of Bengal



The difference in (a) VIMT (vertically integrated moisture transport) and (b) wind at 850 hPa between epoch2 (1981–2010) and epoch1 (1951–1980). Shades represent the epochal difference in the magnitude of respective vectors. The white contours enclose the regions where the difference is significant at the 95% confidence level. (c) Epochal difference in the MFC (moisture flux convergence) term (shaded) and the precipitation (contour) in mm day^{-1}.

Ref: Vishnu, S., Francis, P.A., Shenoi, S.S.C., Ramakrishna, S.S.V.S. On the decreasing trend of the number of monsoon depressions in the Bay of Bengal (2016) Environmental Research Letters, 11 (1), art. no. 014011.

Physical link between the weakening of the monsoon circulation and the decreasing trend in the frequency of monsoon depressions over the Bay of Bengal were investigated. Based on the analysis of the terms of Genesis Potential Index, an empirical index to quantify the relative contribution of large scale environmental variables responsible for the modulation of storms, it was shown that the reduction in the mid-tropospheric relative humidity is the most important reason for the decrease in the number of monsoon depressions. The net reduction of relative humidity over the Bay of Bengal is primarily due to the decrease in the moisture flux convergence, which is attributed to the weakening of the low level jet, a characteristic feature of monsoon circulation. Further, the anomalous moisture convergence over the Western Equatorial Indian Ocean associated with the rapid warming of the sea surface, reduces the moisture advection into the Bay of Bengal and hence adversely affect the genesis/intensification

of monsoon depressions. Hence, the reduction in the number of monsoon depression over the Bay of Bengal could be one of the manifestations of the differential rates in the observed warming trend of the Indian Ocean basin.

8.11. List of Research Papers Published from ESSO-INCOIS (April 2015 - March, 2016)

1. Baliarsingh, S.K., Chandanlal P., Lotilker, A.A., Suchismita, S., Sahu, K.C., Srinivasa Kumar T., Biological implications of cyclone Hudhud in the coastal waters of northwestern Bay of Bengal (2015) Current Science, 109 (7), pp. 1243-1245.
2. Baliarsingh, S.K., Lotliker, A.A., Sahu, K.C., Srinivasa Kumar, T. Spatio-temporal distribution of chlorophyll-a in relation to physico-chemical parameters in coastal waters of the northwestern Bay of Bengal (2015) Environmental Monitoring and Assessment, 187 (7), art. no. 481, pp. 14.
3. Baliarsingh, S.K., Srichandan, S., Sahu, K.C Lotilker, A.A., Occurrence of a new species of toxic Cnidaria (Pelagia noctiluca Forskål, 1775) from estuarine waters of Rushikulya River, Western Bay of Bengal (2015) Indian Journal of Geo-Marine Science. 44(4), pp. 580-582.
4. Baliarsingh, S.K., Srichandan, S., Naik, S., Sahu, K.C., Lotliker, A.A., Srinivasa Kumar, T. Seasonal variation of phytoplankton community composition in coastal waters off Rushikulya Estuary, East Coast of India (2015) Indian Journal of Geo-Marine Science. 44(4), pp.508-526.
5. Baliarsingh, S.K., Srichandan, S., Sahu, K.C., & Lotliker, A.A. First record of Desmoscolex falcatus (Nematoda: Adenophorea: Desmoscolecida: Desmoscolecidae) from Rushikulya estuary, Odisha, India (2015) Indian Journal of Geo-Marine Science. 44(4), pp. 487-489.
6. Baliarsingh, S.K., Srichandan, S., Sahu, K.C., Lotliker, A.A. & Srinivasa Kumar, T. First record of fourteen phytoplankton species off Rushikulya Estuary, northwestern Bay of Bengal (2015) Indian Journal of Geo-Marine Science. 44(4), pp. 490-494.
7. Bhowmick, S.A., Modi, R., Sandhya, K.G., Seemanth, M., Balakrishnan Nair, T.M., Kumar, R., Sharma, R. Analysis of SARAL/AltiKa Wind and Wave over Indian Ocean and its Real-time Application in Wave Forecasting System at ISRO (2015) Marine Geodesy, 38 pp. 396-408.
8. Chakraborty, K., Haldar, S., Kar, T.K. Ecological sustainability of an optimal controlled system incorporating partial closure for the populations (2015) Journal of Biological Systems, 23 (3) pp. 355-384.
9. Chakraborty,K., Manthena,V. Modelling and analysis of spatio-temporal dynamics of a marine ecosystem (2015) Nonlinear Dynamics, 81(4) pp.1895-1906.
10. Chaudhari, H. S., Pokhrel S., Rahman, H., Dhakate A., Saha S.K., Pentakota S., Gairola R. M. (2015) Influence of upper ocean on Indian summer monsoon rainfall: studies by observation and NCEP climate forecast system (CFSv2), Theoretical and Applied Climatology, pp. 1-14. http://dx.doi.org/10.1007/s00704-015-1521-z
11. Das, S., Chanda, A., Dey, S., Banerjee, S., Mukhopadhyay, A., Akhand, A., Ghosh, A., Ghosh, S., Hazra, S., Mitra, D., Lotliker, A.A., Rao, K.H., Choudhury, S.B., Dadhwal, V.K. Comparing the spatio-temporal variability of remotely sensed oceanographic parameters

between the Arabian Sea and Bay of Bengal throughout a decade (2016) Current Science, 110 (4), pp. 627-639.

12. Douluri, D.L., Annapurnaiah, K. Impact of microphysics schemes in the simulation of cyclone Hudhud using WRF-ARW model (2016) International Journal of Oceans and Oceanography, 10 (1), pp. 49-59.
13. Gadgil, S., Francis, P.A. El Nino and the Indian rainfall in June (2016) Current Science, 110 (6), pp. 1010-1022.
14. Gayathri, R., Murty, P.L.N., Bhaskaran, P.K., Srinivasa Kumar, T. A numerical study of hypothetical storm surge and coastal inundation for AILA cyclone in the Bay of Bengal (2015) Environmental Fluid Mechanics. 16(2), pp 429-452
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17. Nagamani, P.V., Ali, M.M., Goni, G.J., Udaya Bhaskar, T.V.S., McCreary, J.P., Weller, R.A., Rajeevan, M., Gopala Krishna, V.V., Pezzullo, J.C. Heat content of the Arabian Sea Mini Warm Pool is increasing (2016) Atmospheric Science Letters, 17 (1), pp. 39-42.
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19. Padhy, P.C., Nayak, R.K., Dadhwal, V.K., Salim, M., Mitra, D., Chaudhury, S.B., Rama Rao, E.P., K.H., Dutt, C.B.S. Estimation of Partial Pressure of Carbon Dioxide and Air-Sea Fluxes in Hooghly Estuary Based on In Situ and Satellite Observations (2015) Journal of the Indian Society of Remote Sensing, 44(1), pp 135-143
20. Pant, V., Girishkumar, M.S., Udaya Bhaskar, T.V.S., Ravichandran, M., Papa, F., Thangaprakash, V.P. Observed interannual variability of near-surface salinity in the Bay of Bengal (2015) Journal of Geophysical Research C: Oceans 120(5) pp. 3315–3329.
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34. Sivareddy, S., Ravichandran, M., Girishkumar, M.S., Prasad, K.V.S.R. Assessing the impact of various wind forcing on INCOIS-GODAS simulated ocean currents in the equatorial Indian Ocean (2015) Ocean Dynamics, 65(9), pp. 1235-1247.

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36. Srinivasa Kumar, T., Murty, P.L.N., Pradeep Kumar, M., Krishna Kumar, M., Padmanabham, J., Kiran Kumar, N., Shenoi, S.S.C., Mohapatra, M., Nayak, S., Mohanty, P., Modeling Storm Surge and its Associated Inland Inundation Extent Due to Very Severe Cyclonic Storm Phailin (2015) Marine Geodesy, 38(4), pp 345-360.

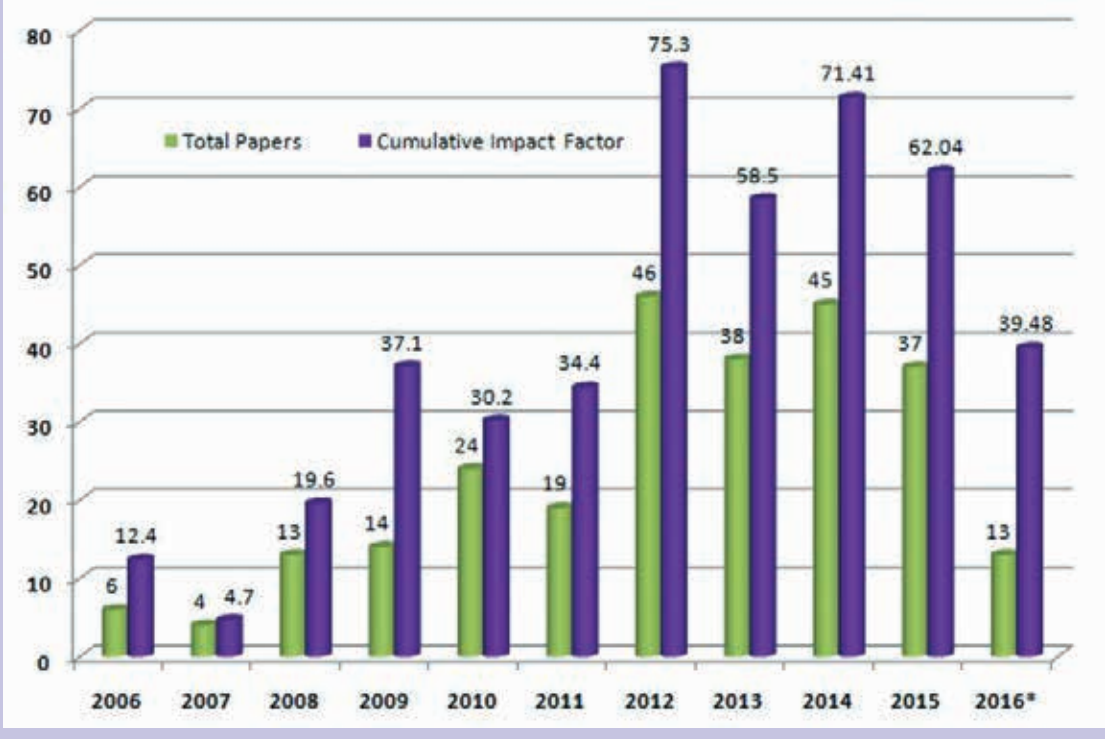
37. Surendran, S., Gadgil, S., Francis, P.A., Rajeevan, M., Prediction of Indian rainfall during the summer monsoon season on the basis of links with equatorial Pacific and Indian Ocean climate indices (2015) Environmental Research Letters, 10 (9), pp. 094004.

38. Udaya Bhaskar, T.V.S., Jayaram, C. Evaluation of Aquarius Sea Surface Salinity with Argo Sea Surface Salinity in the Tropical Indian Ocean (2015) IEEE Geoscience and Remote Sensing Letters, 12 (6), art. no. 7044573, pp. 1292-1296.

39. Vijay P., Girishkumar, M.S., Sivareddy, S., Ravichandran, M. Murtugudde, R., Relation between the upper ocean heat content in the equatorial Atlantic during boreal spring and the Indian monsoon rainfall during June–September (2015) International Journal of Climatology, pp. 1-12, DOI: http://dx.doi.org/10.1002/joc.4506

40. Vipin, P., Sarkar, K., Aparna, S.G., Shankar, D., Sarma, V.V.S.S., Gracias, D.G., Krishna, M.S., Srikanth, G., Mandal, R., Rama Rao, E.P., Srinivasa Rao, N. (2015) Evolution and sub-surface characteristics of a sea-surface temperature filament and front in the northeastern Arabian Sea during November-December 2012, Journal of Marine Systems 150, pp. 1-11.

41. Vishnu, S., Francis, P.A., Shenoi, S.S.C., Ramakrishna, S.S.V.S. On the decreasing trend of the number of monsoon depressions in the Bay of Bengal (2016) Environmental Research Letters, 11 (1), art. no. 014011.



Graph depicting the growth in the number of publications and total impact factor from ESSO- INCOIS.

9. Computing Infrastructure

Being the nodal agency to provide operational ocean services, ESSO-INCOIS hosts state-of-the art computational infrastructure to support operational and R&D activities. The computational infrastructure includes link load balancers, application load balancers, firewalls, core switches, edge switches, 30 km long campus-wide networking, high performance computer facility and its allied infrastructure such as processor cooling system, precision air conditioning units, uninterrupted power supply units, redundant computer facility, 300 TB storage facility, ERP servers, FTP server, web & application servers, Live Access Server, workstations, desktops and laptops. The network and the infrastructure has been set up so that no single point of failure can affect the operational services at ESSO-INCOIS. Office automation was achieved using SAP (Systems, Application and Products).

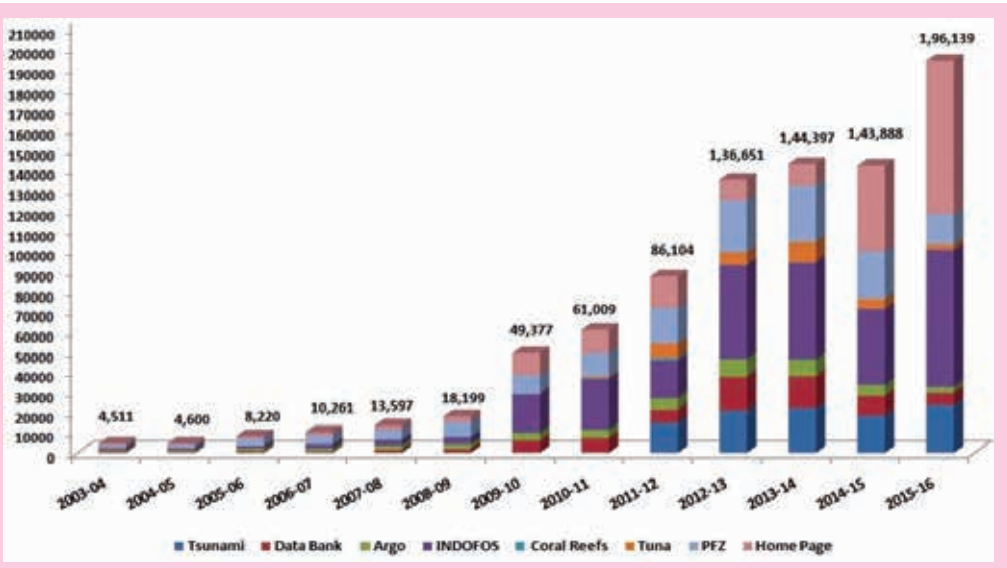
The computer support team of ESSO-INCOIS also supports scientists in porting and running operational and R&D ocean models in the Aditya HPC system located at IITM, Pune. A collaborative project for implementation of GPGPUs in the field of ocean modeling at INCOIS was taken up with C- DAC, Bangalore. The team also initiated the processes to augment the Tsunami Data Centre and high- performance computation facility at ESSO-INCOIS.

Web-Based Services

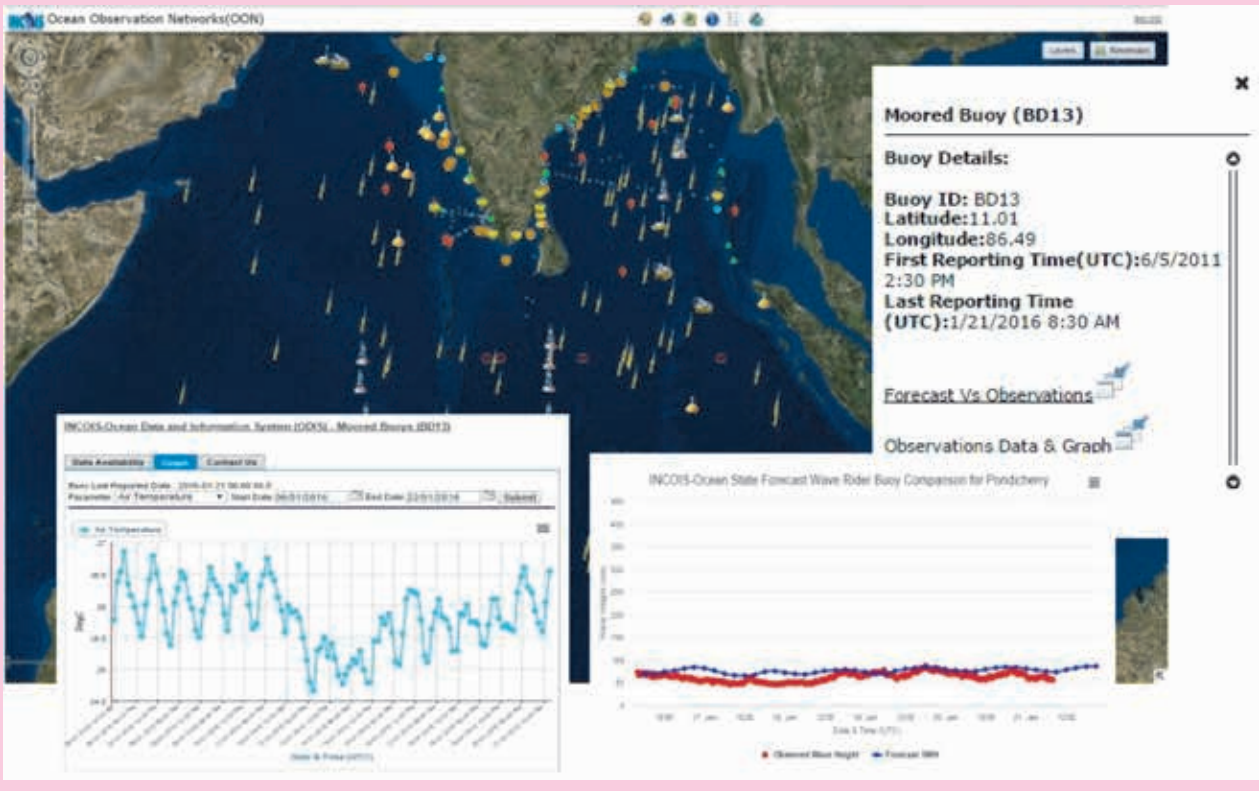
Web pages designed by ESSO-INCOIS during the year

ESSO-INCOIS continued to maintain the multi-lingual, Web-GIS enabled and database driven dynamic website cum ocean data portal that provides ocean information and advisory services to the user community. Significant contributions were made to automate the acquisition,

processing and archival of data to be disseminated through the ESSO-INCOIS website using latest web technologies. The web team also developed a web application for Integrated Ocean Information and Forecast System for Sri Lanka and Seychelles, and improved the Web-GIS application for Real-time Display of Ocean Observations Network (OON). The Web team also developed several web pages such as Login-based application portal for the courses offered by ITCOocean, 2nd International Indian Ocean Expedition (IIOE-2) (www.iioe-2.incois.gov.in), National Hindi Scientific Seminar-2015 (www.incois.gov.in/hindi2015), ISPRS WG VIII/1 Workshop on "Geospatial Technology for Disaster Risk Reduction" (www.incois.gov.in/isprs) etc.



Statistics of the visitors of ESSO-INCOIS web pages



Webpage for disseminating data from ocean observation network

10. Capacity Building, Training and Outreach

10.1. International Training Centre for Operational Oceanography (ITCOocean)

During 2015-16, the International Training Centre for Operational Oceanography (ITCOocean) at ESSO-INCOIS conducted five short-term training courses.

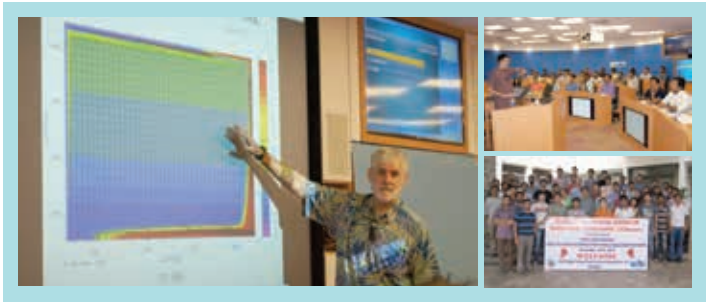
1. An international training course on *Biological Oceanographic Processes* was held between 8-12 May 2015. The faculty, comprising of scientists from National Institute of Oceanography (NIO), Goa and ESSO-INCOIS presented lectures on marine ocean productivity, benthic ecology and demersal resources, remote sensing applications, marine ecosystem analyses, assessment of health of the oceans, fisheries and food security, trans-boundary threats in the marine environment, mariculture and society, climate change etc. A number of demonstration sessions related to biological processes were also included. Thirty two participants - 25 from India and 7 from three foreign countries (Madagascar, South Africa, Sri Lanka) attended the course.

2. The training course, *An Introduction to the Blue Ocean* was held between 1-12 June, 2015 providing a basic introduction to oceanography and aiming to motivate young researchers who intend to work in the areas of physical and dynamical oceanography. Twenty-four participants representing 9 organizations in India attended the course. Prof. Raghuram Murtugudde, University of Maryland, USA, was the principal faculty for this course.

3. A special course on *Fishery Stock Assessment and Ecosystem Modeling* was held between 16-22 September 2015. The faculty for the course consisted of scientists/experts from different fields drawn from the National Oceanic and Atmospheric Administration (NOAA), USA and Central Marine Fisheries Research Organization (CMFRI), India. Faculty members included Dr. Aaron Berger, Dr. Elizabeth Eli Homes, Dr. Juan Zwolinski,

Dr. Kolliyil Sunilkumar Mohamed, Dr. Owen S. Hamel, Dr. E. Vivekanandan. Fifty-one Indian participants attended the course.

4. A training course on *Ocean Dynamics: From the Large-scale Circulation to Small-scale Eddies and Fronts* was conducted between 16-27 November 2015. Topics covered included large-scale circulation of the ocean, ocean observations, simulations with general circulation and simple models, comparison of model simulations with direct current measurements, shelf circulation, instabilities, etc. The primary faculty for the course was Prof. Julian P. McCreary, Jr. from the International Pacific Research Centre (IPRC) / University of Hawaii. Thirty participants from various national-level institutes attended.



5. A training course on *Marine GIS for Operational Oceanography* was conducted by ITCOocean during 18-22 January 2016. It provided an overview and hands-on experience with ArcGIS software, GIS pertaining to operational geospatial applications used in oceanography and coastal zone studies. Twenty participants - 8 from India and 12 from foreign countries (S. Korea, Bangladesh, Kenya, Indonesia, Iran, Maldives, Sri Lanka and Tanzania) attended the course.

6. In order to promote data awareness among the research community and university students, ESSO-INCOIS conducted a five day workshop on *Ocean Data Utilization and Ocean Observation Systems*, for M.Sc. and M.Tech. students from IIT, Bhubaneswar and University of Hyderabad during 8-12 December 2015. 20 students attended the workshop.

10.2. ICG/IOTWMS Training/Workshop

The ICG/IOTWMS Training Workshop was organised by ESSO-INCOIS during 6-8 November 2015. The workshop focussed on developing integrated end-to-end SOPs for tsunami warning and emergency response for member states, assisting National/Local DMOs to develop SOPs for implementing responses to tsunami warnings issued by the NTWCs and preparing more member states to conduct the IOWave16 Exercise scheduled in September 2016 with community-level participation. The workshop also highlighted how TSP products could be used by NTWCs and National/Local DMOs in their SOPs as well as potential gaps and possible challenges for warning chain SOPs at national and local levels.

11. International Interface

11.1. IOGOOS (Indian Ocean-Global Ocean Observation System) Secretariat

ESSO-INCOIS continued to host the Secretariat of Indian Ocean-Global Ocean Observation System (IOGOOS), which is an association of marine operational and research agencies in the Indian Ocean Region to cooperate in promoting Ocean observation and development of operational oceanography. Over 27 organizations from 15 countries are members of IOGOOS. T. Srinivasa Kumar, Scientist-F, Head, ASG held the position of IOGOOS officer for the Central Indian Ocean and M. Nagaraja Kumar, Scientist-D, ASG continued as the Secretary, IOGOOS.

11.2. The Indian Ocean Region Panel and the SIBER (Sustained Indian Ocean Biogeochemistry and Ecosystem Research) International Programme Office

SIBER is an international programme co-sponsored by IMBER and IOGOOS, with an overarching goal to motivate and coordinate the study of the Indian Ocean with respect to global biogeochemical cycles and the interaction between these cycles and marine ecosystem dynamics. The SIBER International Programme Office has been hosted at ESSO-INCOIS since 2010. The office manages various activities of SIBER such as organisation of annual Science Steering Committee (SSC) meetings and sharing of online updates along with management of the SIBER website. M. Ravichandran, Scientist -G & Head, MOG, ESSO-INCOIS represented ESSO-INCOIS in SIBER. The SIBER programme office is being managed by Satya Prakash, Scientist-D, ISG. A joint annual meeting of IORP and SIBER was held between 7-8 December 2015 in Goa.

11.3. International Society for Photogrammetry and Remote Sensing (ISPRS)

ISPRS is an organization dedicated to enabling international cooperation for advancement of photogrammetry, remote sensing and related applications. E. Pattabhi Rama Rao, Scientist-E, Head, DMG chairs the Working Group - IV/4 on Geospatial Data Infrastructure under the Technical Commission IV (Geospatial Databases and Location Based Services) during this current inter-sessional period 2012-16 and T. Srinivasa Kumar, Head, ASG, chairs the Working Group - VIII/1 on Disaster and Risk Reduction under the Technical Commission VIII (Remote

Sensing Applications and Policies). WG-VIII/1 organized an international workshop on "Geospatial Technology for Disaster Risk Reduction" on 17 December 2015, at JK Lakshmipat University, Jaipur, India.

11.4. International Oceanographic Data Exchange

The programme "International Oceanographic Data and Information Exchange" (IODE) of the "Intergovernmental Oceanographic Commission" (IOC) of UNESCO was set up in 1961 to enhance marine research, exploitation and development, by facilitating the exchange of oceanographic data and information between participating member states. IODE designated ESSO-INCOIS as the National Oceanographic Data Centre (NODC) for India in 2004. E. Pattabhi Rama Rao is the national coordinator from India for 'Data Management' under the IODE Programme. He also serves on the Steering Groups on Ocean Biogeographic Information System (SG-OBIS) and IODE Quality Management Framework (SG-IODE QMF).

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

RIMES is an international, intergovernmental, non-profit organization registered with the United Nations aiming to provide regional early warning services and build the capacity of its member states in end-to-end early warnings of Tsunamis and hydro-meteorological hazards. As per the MoU between MoES, Govt. of India and RIMES, Ocean State Forecast services of ESSO-INCOIS are being provided to Seychelles, Sri Lanka and the Maldives Islands in the Indian Ocean on a daily basis. ESSO-INCOIS is also assisting RIMES member countries to deploy and maintain wave rider buoys along their respective coasts. The integrated ocean information and forecast system for Seychelles and Sri Lanka was inaugurated at the 2nd RIMES Inter-Ministerial Conference in New Delhi on 10 July 2015.

11.6. OceanSITES

OceanSITES is a global programme which is a recognized component of the Global Ocean Observing System and part of the international JCOMM structure. ESSO-INCOIS has been identified as the OceanSITES Data Assembly Centre (DAC). E. Pattabhi Rama Rao represents ESSO-INCOIS on the OceanSITES Data Management Team, which developed the data management system with appropriate standards, formats and quality control for ocean time-series data.

11.7. Partnership for Observation of the Global Oceans (POGO)

POGO is a forum that was created in 1999 by directors and leaders of major oceanographic institutions around the world to promote global oceanography, particularly for the implementation of an international and integrated global ocean observing system. ESSO-INCOIS continued to extend its support to POGO.

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

ICG/IOTWS was established by the Intergovernmental Oceanographic Commission (IOC) and coordinates the implementation of Indian Ocean Tsunami Warning System which is being established as a network of national systems. The network comprising of respective National Tsunami Warning Centres (NTWCs) of member states (which receive tsunami advisories from the Regional Tsunami Service Providers (RTSPs)) has the capability to issue regional tsunami bulletins for the Indian Ocean. The Indian Tsunami Early Warning Centre (ITEWC) of ESSO-INCOIS serves as one of the RTSPs for the Indian Ocean (serving over 23 countries). T. Srinivasa Kumar, serves as Chairman of ICG/ IOTWS.

11.9. 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 scientists to exchange their experiences and collectively carry out inter-comparison exercises of various ocean forecast and analysis products. ESSO-INCOIS has been part of this group since October 2010 as a member of the science team. Since July 2013 onwards, S. S. C. Shenoi, Director, ESSO-INCOIS has been serving as a member on 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. The 6th GOVST workshop was organised during 2-6 November 2015 at Q Station, Sydney, Australia. Abhishek Chatterjee, Scientist-C, represents ESSO-INCOIS in GOVST.

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

The Second International Indian Ocean Expedition (IIOE-2) was launched with the first expedition in December 2015 and will continue through to 2020. It is a major global scientific initiative that seeks to build on the legacy of the first and one of the greatest oceanographic expeditions of all time, IIOE (1957-65). IIOE-2 is co-sponsored by the Intergovernmental Oceanographic Commission (IOC), the Scientific Committee on Oceanic Research (SCOR) and the Indian Ocean Global Observing System (IOGOOS), with ESSO-INCOIS spearheading Indian activities. Several international collaborative research programmes and outreach activities within the framework of a comprehensive Science Plan are proposed to be initiated under IIOE-2. Besides seeking to advance our understanding of the dynamics of the Indian Ocean and to determine how those dynamics affect climate, extreme events, ecosystems, and human populations, the activities are focused towards helping to build research capacity in the Indian Ocean Rim countries and in motivating efforts to make the oceanographic data from the region more widely accessible to the scientific fraternity. Satheesh Shenoi, Director, ESSO-INCOIS served as the chair of the Implementation Planning Committee. A Joint Programme Office (JPO), with one node in Perth, Australia and the other at ESSO-INCOIS has been set up to coordinate the planned activities of this international endeavour. S. Rajan (former Director, ESSO-NCAOR) is coordinating the JPO activities at ESSO- INCOIS. A steering committee co-chaired by Vladimir Ryabinin (Executive Secretary, IOC/

UNESCO), Peter Burkill (President, SCOR) and Satheesh Shenoi (representing IOGOOS) has been set up to coordinate and oversee the implementation of IIOE-2. A half-yearly newsletter "The Indian Ocean Bubble-2" is also being published by ESSO-INCOIS, aimed at encouraging informal exchange of ideas between scientists with a sustained interest in studies of the Indian Ocean and in fostering an awareness on the significance of studies among younger researchers (http://iioe-2.incois.gov.in). ESSO-INCOIS played a significant role in the organization of the "IO50 International Symposium" (celebrating both the 50th anniversaries of the IIOE expedition and the Foundation of CSIR-NIO).

Flagging of IIOE-II expedition by Shri. Y. S. Chowdary, Hon'ble Minister for State, Ministry of Earth Sciences on 4 December 2015.

Participants of the IIOE-2 expedition

11.11 Global Argo Programme

ESSO-INCOIS continued to contribute to the global Argo programme by deploying and maintaining more than 300 Argo floats in the Indian Ocean. ESSO-INCOIS is also serving as the National and Regional Argo Data centre where data from Argo floats are received, quality controlled and used to generate products catering to the international oceanographic community. M. Ravichandran is a member of the International Argo Steering Team.

11.12 INdian Ocean DAta REscue (INDARE)

The INdian Ocean DAta REscue (INDARE) initiative of the World Meteorological Organisation (WMO) was launched in April 2014 and focuses on working and participating towards enhanced and accelerated availability of high quality historical long-term weather data and metadata over land and sea in the Indian Ocean rim countries and islands. Participants include directors of National Meteorological and Hydrological Services, international and regional institutional representatives, national and international climate experts. E. Pattabhi Rama Rao was re-elected as the Co-Chair of the Steering Committee (INDARE-SC) during its 2nd meeting held at Mauritius during 19-20 October 2015.

12. Scientific Lectures/Seminars/Events

12.1 Lectures

Dr. G.V.M Gupta, Scientist-E, CMLRE, Kochi presented a seminar on "Upwelling and Biogeochemistry of southwest coast of India: A modeling perspective" on 11 May, 2015.

Dr. Joaquim Goes, Lamont-Doherty Earth Observatory, Columbia University made a presentation on "The state of the Arabian Sea in a post-JGOFS" on 20 May, 2015

Prof. Raghuram Murtugudde, University of Maryland, USA gave talks on: "Do we understand ENSO?" and "Multiscale Interactions from Intraseasonal to Interannual Timescales" on 2 June and 4 June, 2015

Dr. Arun Bapat, Senior Seismologist and Former Head of Earthquake Engineering Research. Central Water and Power Research Station, Pune presented a seminar on "Directivity of Tsunami Waves on East Indian Coast" on 2 September, 2015

Dr. Vera L Trainer, Supervisory Oceanographer, Marine Biotoxins Program,NOAA Northwest Fisheries Science Center & Dr. Mark Wells, Professor, University of Maine made a presentation on "Scientific Writing" on 22 September, 2015

Prof. Ola Johannessen, Nansen Environmental and Remote Sensing Centre, Norway gave a lecture on "Teleconnection between Arctic Sea ice variations and weather and climate in lower latitudes on" 8 February, 2016

Dr. Jerome Vialard, Senior Scientist at LOCEAN/French Research Institute for Development (IRD), France presented a seminar on "Interannual variability along the east and west coasts of India." on 23 March, 2016

12.2. Events

12.2.1. Foundation Stone laying ceremony for construction of "International Training Centre for Operational Oceanography

The Foundation Stone laying ceremony (Bhoomi Pooja) for the building complex of the International Training Centre for Operational Oceanography (ITCOocean) was performed by Shri. Y. S. Chowdary, Hon'ble Minister of State for Science & Technology and Earth Sciences on 4 January 2016. Shri Malla Reddy , Hon'ble Member of Parliament from the Malkajgiri constituency, Dr. Ch. Mohan Rao, Director CCMB & NGRI, Hyderabad and several dignitaries graced the occasion. The ITCOocean building complex will comprise of an academic block with an area

of 80,000 Sq ft and an International Hostel with an area of 40,000 Sq ft. to be built at a cost of about Rupees 50 Cr. The new building complex is expected to be ready in about 18 months.

12.2.2. Inauguration of INCOIS Guest House and Phase II Main Building

Construction work related to the extension of the main building at ESSO-INCOIS was completed. The extension was opened for occupation after the inauguration by Dr. Shailesh Nayak, Hon'ble Secretary to Govt. ofIndia, Ministry of Earth Sciences on 21 August 2015. On the same day, the ESSO-INCOIS Guest House with 27 guest rooms, 3 family rooms and 5 suite rooms was also inaugurated by Dr. Shailesh Nayak.

12.2.3. 17th Foundation Day of ESSO-INCOIS

The 17th Foundation Day was celebrated on 3 February 2016 with an "Open Day" programme for students and public visitors (over 850 participants). Padma Bhushan, Prof. George Joseph, Hon. Distinguished Professor, ISRO (Former Director, Space Applications, Ahmedabad) graced the occasion as Chief Guest and had an in-depth interaction with ESSO-INCOIS staff. Prof. Joseph

delivered the Foundation Day lecture - "How well you understand the Earth Observation Cameras?" and also planted a tree to commemorate the occasion.

12.2.4. National Scientific Hindi Seminar

The Hindi National Scientific Seminar focussing on "The Role of the Ocean In Our Lives: A Scientific Approach" was held during 28- 29 September, 2015. It was inaugurated by Chief Guest Dr. P. K. Verma, Director General, Madhya Pradesh Council of Science &Technology in presence of Guests of Honour, Dr. D.D. Ozha, Hindi Advisory Committee, Government of India and Dr. Ravi Ranjan, Hindi Professor, University of Hyderabad. Workshop themes included Ocean services and their societal relevance, Oceans and Monsoon, Global warming and Climate change, Ocean Technology, Biological and Chemical aspects of Ocean, Cryosphere, Glaciology, Geological

and Geophysical aspects of ocean etc. Twenty-two oral presentations and 24 poster presentations were made by scientists/research students from various national institutes during the Seminar.

12.2.5. Swachch Bharat Drive

A 'Swachch Bharat' drive that involved ESSO-INCOIS staff at all levels was held between 8-18 March 2016 to keep the ESSO-INCOIS campus clean. Several batches lead by respective Team Captains cleaned designated areas of the campus, both indoor and outdoor. The drive was very successful with full-hearted participation of all the staff of ESSO-INCOIS.

13. General Information

13.1. Awards/Honours

13.1.1. Ministry of Earth Sciences Awards 2015

R. S Mahendra, Scientist-D was awarded the Certificate of Merit and B. Krishna Prasad, Scientific Assistant B was awarded the Certificate of Best Employee for 2015 during the MoES Foundation Day celebrations held at New Delhi on 27 July 2015.

13.1.2. Swasraya Bharat-First Prize

ESSO-INCOIS was awarded first prize at the Science & Technology Expo held as part of 'SWASRAYA BHARAT-2015' organized by the Swadeshi Science Movement, Kerala and ICAR-Indian Institute of Spice Research in Kozhikode during 15-21 October 2015.

13.1.3. Public Relations Society of India (PRSI) Awards

The website of ESSO-INCOIS was selected for the Special Jury Award in the category of official websites and the Annual Report (2014-15) of ESSO-INCOIS was selected for 3rd Prize in the category of reports by the Public Relations Society of India. Shri. T. Harish Rao, Hon'ble Minister for Irrigation & Legislative Affairs, Govt. of Telangana presented the awards during the 1st Telangana State Public Relations Conference held at Hyderabad on 21 February 2016.

13.2. Promotion of Hindi

ESSO-INCOIS promotes and propagates the use of the official language, Hindi. K. K. V. Chary, Dy. Chief Administrative Officer and Head, ESG, ESSO- INCOIS chairs the Official Language (Hindi) Implementation Committee. In order to promote the official language, the daily Potential Fishing Zone and Ocean State Forecasts are now made available in Hindi along with other local (coastal) languages. Dr. Ravi Ranjan, Professor of Hindi, University of Hyderabad, delivered a lecture on "Modernity and Hindi Literature" on 14 September 2015, as part of the Hindi Pakhwara celebration held during 1-15 September 2015. Dr. P. Subba Rao, Assistant Director (Telugu), Government Oriental Manuscript and Research Organisation presented a seminar on "Spoken Hindi" on 31 March 2016.

13.3. Visitors

To spread awareness of ESSO-INCOIS' services and products, special Open Day Programmes were hosted celebrating MoES Foundation Day on 27th July 2015, commemorating the 70th Anniversary of the Makran Tsunami on 28th November 2015 (a joint commemorative event with UNESCO) and also for ESSO-INCOIS Foundation Day . On request, Group Visit sessions were organised for several schools and colleges. The Centre also organised field visits for government officials.

Over 4500 visitors were hosted, including 322 government officials, 1601 college students and 2631 school students and general public visitors.

13.4. Other Information

13.4.1. List of students who carried out academic projects at ESSO-INCOIS during April 2015 to March 2016

Sl. No	Name of Student	Institute	Project Guide
1.	D. Akhila	National Institute of Technology Surathkal	Abhisek Chatterjee
2.	S.R. Shahimol	Kerala University of Fisheries and Ocean studies (KUFOS)	Aneesh A Lotliker
3.	Vemula Varaprasad	University of Hyderabad	Aneesh A Lotliker
4.	K. Sowmya	Mangalore University	Ch. Patanjali Kumar
5.	Meera M Nair	Cochin University of Science and Technology, Kochi	P. A. Francis
6.	Arijeet Dutta	University of Hyderabad	Hasibur Rahman
7.	K. Anjusha	Indian Institute of Information Technology and Management, Kerala	N. Kiran Kumar
8.	M. K. Thomas	Indian Institute of Information Technology and Management, Kerala	N. Kiran Kumar
9.	Bodepalli Renuka	MVGR College of Engineering, Vizianagaram	N. Kiran Kumar
10.	M. Anand	Andhra University	R. S. Mahendra
11.	M. Dhivya Sri	University of Madras	R. S. Mahendra
12.	B. Binisha	Kerala University of Fisheries and Ocean studies (KUFOS)	R.S. Mahendra
13.	Sanjay Kumar	Haryana Space Applications Centre	R. S. Mahendra
14.	T. X. Alan	Kerala University of Fisheries and Ocean studies (KUFOS)	M. Nagaraja Kumar
15.	Santosh N Naik	Mangalore University	S. J. Prasad
16.	P. Mohammed Irshad	Mangalore University	S. J. Prasad
17.	S. Arul Gnana Selvan	Bharathidasan University	N. Srinivas Rao
18.	V. Abhijith	Indian Institute of Information Technology and Management, Kerala	N. Srinivas Rao
19.	S. Vipin	Indian Institute of Information Technology and Management, Kerala	N. Srinivas Rao
20.	Ch. Sarath	Vasavi College of Engineering, Hyderabad	N. Srinivas Rao
21.	D. Gyaneshwar	Vasavi College of Engineering, Hyderabad	N. Srinivas Rao
22.	B. Jeevan Kumar	Andhra University	Sudheer Joseph
23.	T. V. Swathy	Cochin University of Science and Technology, Kochi	Suprit Kumar
24.	G. Vivek	SRM University, Chennai	T. Srinivasa Kumar

25.	C. H. Murali Krishna	Anil Neerukonda Institute of Technology and Sciences, Visakhapatnam	T. V. S. Udaya Bhaskar
26.	T. Satyanarayana Raju	Anil Neerukonda Institute of Technology and Sciences	T. V. S. Udaya Bhaskar
27.	T. R. Rinjusha	Kerala University of Fisheries and Ocean studies	T. V. S. Udaya Bhaskar
28.	M. Jyothi	Kerala University of Fisheries and Ocean studies	T. V. S. Udaya Bhaskar
29.	Konjarla Johnny	R.V.R. & J.C.College of Engineering, Guntur	R. Venkat Shesu
30.	M. Deepthi	R.V.R. & J.C.College of Engineering, Guntur	R. Venkat Shesu
31.	P. Bharat	R.V.R. & J.C.College of Engineering, Guntur	R. Venkat Shesu
32.	L. Trinadh	Anil Neerukonda Institute of Technology and Sciences (ANITS), Visakhapatnam	R. Venkat Shesu
33.	U. Deekshitha	College of Engineering & Technology, Hyderabad	V. Venugopala Rao
34.	C. Divya	College of Engineering & Technology, Hyderabad	V. Venugopala Rao
35.	A. S. Komale	College of Engineering & Technology, Hyderabad	V. Venugopala Rao
36.	Harshita Ande	IIIT, Allahabad	V. Venugopala Rao
37.	M. Mercy Monica	Anil Neerukonda Institute of Technology and Sciences, Visakhapatnam	S. P. Vighneshwar
38.	D. J. Santosh Kumar	Anil Neerukonda Institute of Technology and Sciences, Visakhapatnam	S. P. Vighneshwar
39.	L. Srinivasa Reddy	Anil Neerukonda Institute of Technology and Sciences, Visakhapatnam	S. P. Vighneshwar

13.4.2. Deputations

Name of the Official (Dr./Mr./Ms.)	Meeting/Conference/Training
S. S. C. Shenoi Director, INCOIS	To participate in the meeting of IIOE-2 interim planning committee as chairman from India held at UNESCO HQ, Paris during 20-21 April 2015
	To attend 28th session of the IOC assembly, 48th session of the IOC executive council and the IOC science day held at Paris, France during 16-25 June 2015
	To attend the 1st Indo-China Joint workshop for cooperation on marine science and technology at Guangzhou, China during 14-18 December 2015
M. Ravichandran, Scientist 'G'	To participate in the science and observational planning meeting held at University of Massachusetts, Dartmouth, USA during 20-29 May 2015

	To attend the meeting on joint scientific investigations in the Indian ocean between MoES and JAMSTEC, Japan, at JAMSTEC, Tokyo during 6-7 July 2015
	To participate in the High North Study tour, Norway during 27 July-3 August 2015
T. Srinivasa Kumar, Scientist 'F'	To participate in 28th session of the IOC Assembly at Paris, France during 22-24 June 2015
	To attend the 10th meeting of the ICG/IOTWS steering group scheduled at Bureau of Meteorology, Perth, Australia during 19-20 August 2015
	To participate in the National Ocean and Coastal Information Management System key stakeholder workshop and post-workshop discussions at Cape Town, South Africa during 14-16 October 2015
	To participate in the 9th Meeting of the working group on tsunamis and other hazards related to sea level warning and mitigation systems (TOWS-WG-IX) preceded by TOWS Inter- ICG Task Team 2 on Tsunami Watch Operations at Paris, France scheduled during 23-26 February 2016
T.M. Balakrishnan Nair, Scientist 'F'	To participate in Seasonal Forum organised by Regional Integrated Multi-Hazard Early Warning System (RIMES) at Seychelles during 11-15 May 2015 and in Sri Lanka during 18-22 May 2015
E. Pattabhi Rama Rao, Scientist 'E',	To participate in the second meeting of INDARE-SC held at Ebene, Mauritius during 19-20 October 2015
T. V. S. Udaya Bhaskar, Scientist 'E',	To participate in 16th meeting of ADMT-16 at St. George, Bermuda during 2-6 November 2015
	To participate in the workshop on "Coordinated quality control system for the historical subsurface ocean temperature and Salinity observations" held at University of Hamburg, Germany during 3-5 December 2015
Venkat Shesu Reddem Scientist 'D'	To attend the INDARE working group - 2 (WG-2) meeting at Vacos, Mauritius during 27-30 July 2015
Satya Prakash, Scientist 'D'	To Participate in the 1st expedition of IIOE-2 aboard "ORV Sagar Nidhi" and to participate in the post -cruise symposium on arrival at Mauritius during 4-24 December 2015

Aneesh A. Lotliker, Scientist-D	To participate in the science and observational planning meeting held at University of Massachusetts, Dartmouth, USA during 26-29 May 2015, discussion on past data analysis and future sampling strategy at University of Rhode Island, Narragansett, USA during 1-5 June 2015 and acquiring training on operation, calibration, data processing and interpretation of 'ac-s' meter at WET Labs Site, Philomath, Oregon, USA during 8-12 June 2015
	To Participate in the 1st expedition of IIOE-2 aboard "ORV Sagar Nidhi" and to participate in post -cruise symposium on arrival at Mauritius during December 04-24, 2015
S. Shivaprasad, Scientist 'C'	To participate in Seaglider training at University of Washington and Kongsberg (OEM of Seaglider), Seattle, USA during 22 June -3 July 2015
M.S. Girish Kumar, Scientist 'D'	To participate in Seaglider training at University of Washington and Kongsberg (OEM of Seaglider), Seattle, USA during 22 June -3 July 2015
	To participate in Seaglider piloting at University of Washington Seattle, USA from 18 August - 14 September 2015
	Visited Florida State University, Tallahassee, USA for joint research as part of Monsoon Mission project during 1 January – 15 May 2016
R. S. Mahendra, Scientist 'D'	To participate in the Regional Workshop on " Coastal Hazard Assessment : Applications in Risk Assessment, Management and Mitigation" held at Colombo, Sri Lanka during 2-5 June 2015
Ch. Patanjali Kumar, Scientist 'D'	To participate in the inaugural meeting of the ICG/IOTWMS (IOC UNESCO) Sub-Regional Working Group for the North West Indian Ocean at Muscat, Oman during 14-15 October 2015
Arya Paul, Scientist 'D'	To attend training under the Monsoon Mission project entitled : Improving Monsoon Predictions with a Coupled Ensemble Kalman Filter Data Assimilation System at University of Maryland, USA from 25 February – 31 October 2015
Siva Reddy, Scientist 'C'	To attend training under the Monsoon Mission project entitled : Improving Monsoon Predictions with a Coupled Ensemble Kalman Filter Data Assimilation System at University of Maryland, USA from 25 February- 31 October 2015
Abhisek Chatterjee, Scientist 'C'	To participate in 6th Meeting of the GODAE Ocean View Science Team (GOVST) held at Sydney, Australia during 2-6 November 2015
Vijaya Sunanda, Scientist 'C'	To participate in the inaugural meeting of the ICG/IOTWMS (IOC UNESCO) Sub-Regional Working Group for the North West Indian Ocean at Muscat, Oman during 14-15 October 2015

B. Praveen Kumar, Scientist 'C'	To participate in Lagrangian Float training at the Applied Physics Laboratory of the University of Washington, Seattle, USA during 8 November -7 December 2015
Dipankar Saikia, Scientist 'C'	To participate in the inaugural meeting of the ICG/IOTWMS (IOC UNESCO) Sub-Regional Working Group for the North West Indian Ocean at Muscat, Oman during 14-15 October 2015
P.L.N. Murty, Scientist 'C'	To participate in "Fourth Capacity Building workshop of the WMO/ IOC Data Buoy Cooperation Panel for the North Pacific Ocean and its Marginal Seas (NPOMS-4) held in Busan, Korea during 2-4 November 2015
Arun Nherakkol, Scientist 'C'	Deputed for deployment of Wave rider buoy at Seychelles to establish an Integrated Ocean Information System for Indian Ocean Countries through Regional Integrated Multi-hazard Early-warning System (RIMES) during 9-18 March 2016
B. Ajay Kumar, Scientist 'B'	To participate in "Regional workshop on training modules for tsunami exercise policy support" Jakarta, Indonesia during 15-17 June 2015
V.P. Thangaprakash, Scientist 'B'	To participate in the OMM-ASIRI Joint meeting and to present a paper in the AGU Ocean Sciences 2016 meeting held at New Orleans, USA scheduled during 21-27 February 2016
	To Washington and Kongsberg (OEM of Seaglider), Seattle, USA during 22 June – 3 July 2015
B. Madhusudan Rao, Consultant	To participate in IODE & Ocean Teacher Global Academy (OTGA) Steering Group II Meeting at Oostende, Belgium during 8-11 March 2016
Jeyakumar Chelliah, Scientific Assistant 'B'	Deputed for deployment of Wave rider buoy at Seychelles to establish an Integrated Ocean Information System for Indian Ocean Countries through Regional Integrated Multi-hazard Early-warning System (RIMES) during 9-18 March 2016

13.4.3. Vigilance Activities

M. Ravichandran, Scientist 'G' & Head - MOG continued to serve as the Vigilance Officer at ESSO- INCOIS. During the period April 2015 to March 2016 three complaints were received which were promptly addressed. "Vigilance Awareness Week" was observed at ESSO-INCOIS during 27-31 October 2015 and staff took the Vigilance Pledge on 27 October 2015.

13.4.4. Right to Information Act

In fulfillment of the "Right to Information" Act (RTI), 2005, information related to ESSO-INCOIS was regularly updated on the ESSO-INCOIS website in the prescribed format, during the period April 2014 to March 2015. E. Pattabhi Rama Rao, Scientist 'E' & Head - DMG is the Public Information Officer and S.S.C. Shenoi, Director, ESSO-INCOIS is the First Appellate Authority. Twenty-six requests under RTI were received and the requested information was provided. Three appeals were received during this period.

13.4.5. ESSO-INCOIS Human Capital

ESSO-INCOIS Human Capital category wise as on 31 March 2016

Category/Designation		Regular	Category/ Designation	Project Mode
Scientific Staff				
	Director	1	Project Sci - C	3
	Scientist 'G'	1	Project Sci - B	25
	Scientist 'F'	3	Project Assistant	27
	Scientist 'E'	5		
	Scientist 'D'	13		
	Scientist 'C'	17		
	Scientist 'B'	7		
Scientific Support Staff				
	Scientific Assistant B	17		
	Scientific Assistant A	2		
Administrative Support				
	Dy.CAO	1		
	Manager	1		
	Jt. Manager	2		
	Asst. Manager	4		
	Sr. Executive	2		
	Admin Assistant			5
	Lab Attendants			5
	Driver-cum-Attendant			4
Others:				
	Consultants			4
	Quick Hire Fellows			2
	Research Fellows under Ph.D Programme			5
Total		**76**		**80**
Grand Total		**76**		**80**

Acronyms

3D GIS	-	Three Dimension Geo Information System
3DVAS	-	Three Dimension Visualization and Analysis System
A&N	-	Andaman and Nicobar islands
ADCIRC	-	Advanced Circulation (Storm surge model)
ADCP	-	Acoustic Doppler Current Profiler
ADMT	-	Argo Data Management Team
AMET	-	Academy of Maritime Education and Training
AOP	-	Apparent Optical Properties
AOT	-	Aerosol Optical Thickness
Argo/ ARGO	-	Array for Real-time Geotropic Oceanography
ASCAT	-	Advanced Scatterometer
ASG	-	Advisory Services Group, ESSO-INCOIS
ASIMET	-	Air-Sea Interaction Meteorology
ASIRI	-	Air-Sea Interactions in the northern Indian Ocean–Regional Initiative
AST	-	Argo Steering Team
ATCHP	-	Accumulated Tropical Cyclone Heat Potential
ATLAS	-	Autonomous Temperature Line Acquisition
AU	-	Andhra University
AVHRR	-	Advanced Very High Resolution Radiometer
AVISO	-	Archiving, Validation and Interpretation of Satellite Oceanographic
AVSM	-	Ati Vishisht Seva Medal
AWS	-	Automatic Weather Station
AZM	-	Atlantic zonal mode
BoB	-	Bay of Bengal
CC	-	Coast Colour
CCMB	-	Centre for Cellular & Molecular Biology: CSIR, Hyderabad
CDAC	-	Centre for Development of Advanced Computing, Hyderabad
CDOM	-	Colored dissolved organic matter
CFZ	-	Coastal Forecast Zone
Chl-a	-	Chlorophyll-a
CIFT	-	Central Institute of Fisheries Technology, Cochin
CLIVAR	-	Climate Variability and Predictability (World Climate Research)
CMFRI	-	Central Marine Fisheries Research Institute, Kochi
CMLRE	-	Centre for Marine Living Resources & Ecology, Cochin

CMLRE	-	Centre for Marine Living Resources and Ecology
COMMs	-	Communications Test
CSAMB	-	Centre of Advanced Study in Marine Biology
CSBoB	-	Center for Studies on Bay of Bengal, Visakhapatnam
CSIR	-	Council of Scientific and Industrial Research
CSIRO	-	Commonwealth Scientific and Industrial Research Organization
CSIR-UGC NET	-	Council of Scientific and Industrial Research-University Grants Commission-National Eligibility Test
CTCZ	-	Continental Tropical Convergence Zone
CTD	-	Conductivity-Temperature-Depth
CTW	-	Coastally Trapped Waves
CUC	-	Coastal Under Currents
CUSAT	-	Cochin University of Science and Technology, Cochin
DA	-	Data Assimilation
DASCAT	-	Daily Advanced Scatterometer
DBT	-	Dry Bulb Temperature
DG-ICG	-	Director General (DG) of Indian Coast Guard (ICG)
DMG	-	Data Management Group, ESSO-INCOIS
DMO	-	Disaster Management Official
DNOM	-	Directorate of Naval Oceanology and Meteorology (Indian Navy)
DO	-	Dissolved Oxygen
DPT	-	Dew Point Temperature
DSS	-	Decision Support System
DST	-	Department of Science and Technology
E-AIMS	-	Euro-Argo Improvements for the GMES (Global Monitoring for Environment and
ECMWF	-	European Centre for Medium-Range Weather Forecasts
EEZ	-	Exclusive Economic Zone
EMAC-IOD	-	Equatorial Mooring Array for Current Observations and Research
ENSO	-	El Nino Southern Oscillation
Envisat	-	Environmental Satellite
EQ	-	Earth Quake
ERP	-	Enterprise Resource Planning
ERS	-	ERS (European Remote Sensing) d'Archivage et de Traitement, France
ESSO	-	Earth System Science Organisation
ETM	-	Landsat Enhanced Thematic Mapper
FFMA	-	Fisher Friend Mobile Application

FORV	-	Fisheries Ocean Research Vessel
FTP	-	File Transfer Protocol
FY	-	First Year
GCMD	-	Global Change Master Directory
GCOS	-	Global Climate Observing System
GFZ	-	GeoForschungsZentrum - German Research Centre
GIS	-	Geographic Information System
GNSS	-	Global Navigation Satellite System
GODAE	-	Global Ocean Data Assimilation Experiment
GODAS	-	Global Ocean Data Assimilation System
GOOS	-	Global Ocean Observing System
GOVST	-	Ocean View Science Team
GPGPU	-	General-Purpose Graphics Processing Unit (GPU)
GPI	-	Genesis Potential Index
GPRS	-	General Packet Radio Service
GPS	-	Global Positioning System
GTS	-	Global Telecommunication System
GUI	-	Graphical User interface
HF Radar	-	High Frequency Radar
HICO	-	Hyper spectral Imager for the Coastal Ocean
HME	-	Hugli-Matla (tributaries of Ganga) Estuary
HOOFS	-	High Resolution Operational Ocean Re-Analysis and Forecast System
HQ	-	Head Quarters
HRD	-	Hurricane Research Department (NOAA)
HWRF	-	Hurricane Weather Research and Forecast
ICAR	-	Indian Council of Agricultural Research
ICOADS	-	International Comprehensive Ocean-Atmosphere Data Set
ICG/IOTWS	-	Intergovernmental Coordination Group for the Indian Ocean Tsunami
ICMAM	-	Integrated Coastal and Marine Area Management
ICTP	-	International Centre for Theoretical Physics, Italy
ICWRCOE 2015	-	International Conference on Water Resources, Coastal And Ocean Engineering, NIT Surathkal
IIIT	-	International Institute of Information Technology
IIOE	-	International Indian Ocean Expedition
IISc	-	Indian Institute of Science, Bangalore
IIT	-	Indian Institute of Technology
IITM	-	Indian Institute of Tropical Meteorology, Pune

IMBER	-	Integrated Biogeochemistry and Ecosystem Research
IMD	-	Indian Meteorological Department
INCOIS	-	Indian National Centre for Ocean Information Services
INDARE	-	Indian Data Rescue initiative
IndOOS	-	Indian Ocean Observing System
INSAT	-	Indian National Satellite System
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
IOM	-	Indian Ocean Model
IOP	-	Inherent Optical Properties
IOTWS WG-2	-	Indian Ocean Tsunami Warning System Worging Group
IOWave14	-	IOTWS Indian Ocean Tsunami Exercise 2014
IPRC	-	International Pacific Research Centre, University of Hawaii
IRF	-	IndOOS (Indian Ocean Observation System) Resource Forum
IRS	-	Indian Remote Sensing
ISG	-	Indian Society of Geomatics
ISGN	-	Integrated Seismic and GNSS Network
ISLANDS	-	Investigation of Seismicity & Lithospheric structure in the
ISMR	-	Indian summer monsoon rainfall
ISO	-	International Organization for Standardization
ISPRS	-	International Society for Photogrammetry and Remote Sensing
ISR	-	Institute of Seismological Research
ISRS	-	Indian Society of Remote Sensing
IST	-	Indian Standard Time
ISV	-	Intra Seasonal Variability
ITCOocean	-	International Training Centre for Operational Oceanography,
ITEWC	-	Indian Tsunami Early Warning Centre, ESSO-INCOIS
ITEWS	-	Indian Tsunami Early Warning System
JAMSTEC	-	Japan Agency for Marine-Earth Science and Technology
JAU	-	Junagadh Agricultural University, Okha
JCOMM	-	Joint Technical Commission for Oceanography and Marine Meteorology
JNCASR	-	Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore.
JPO	-	Joint Programme office
JTWC	-	Joint Typhoon Warning Center (JTWC) - U.S. Navy

JU	-	Jadavpur University
LAN	-	Local Area Network
LAS	-	Live Access Server
L'OCEAN	-	Laboratoire d'Oceanographie et du Climat, France
LEGOS	-	Laboratoire d'Etudes en Géophysique et Océanographie Spatiales,
LETKF	-	Local Ensemble Transform Kalman Filter
LISS	-	Linear Imaging Self Scanning Sensor
MATLAB	-	MATrix LABoratory
MERIS	-	MEdium Resolution Imaging Spectrometer
Met	-	Meteorological
METOP	-	Meteorological Operational (satellite programme)
MFAS	-	Marine Fisheries Advisory Services
MFD	-	Maximum Fishing Depth
MHA	-	Ministry of Home Affairs
MHVM	-	Multi-Hazard Vulnerability Map
MJO	-	Madden–Julian Oscillation
ML	-	Mixed Layer
MLA	-	Member of the Legislative Assembly
MLD	-	Mixed layer Depth
MODIS	-	Moderate Resolution Imaging Spectroradiometer
MoES	-	Ministry of Earth Sciences
MOG	-	Modelling Ocean Group, ESSO-INCOIS
MOM	-	Modular Ocean Model
MoU	-	Memorandum of Understanding
MSc	-	Master of Science
MSSRF	-	M.S. Swaminathan Research Foundation
MTech	-	Master of Technology
MV	-	Merchant Vessel
MVHM	-	Multi-Hazard Vulnerability Map
NCAER	-	National Council of Applied Economic Research
NCAOR	-	National Centre for Antarctic and Ocean Research
NCEP	-	National Centers for Environmental Prediction, USA
NCEP FNL	-	National Centers for Environmental Prediction Final
NCESS	-	National Centre for Earth Science Studies
NCMRWF	-	National Centre for Medium Range Weather Forecasting, Noida
NCS	-	National Centre for Seismology
NDBP	-	National Data Buoy Programme

NDMA	-	National Disaster Management Authority
NDRF	-	National Disaster Response Force
NetCDF	-	Network Common Data Format
NF-POGO	-	Nippon Foundation - Partnership for Observation of the Global Oceans
NGO	-	Non Governmental Organization
NGRI	-	National Geophysical Research Institute, Hyderabad
NHO	-	National Hydrographic Office
NIDM	-	National Institute of Disaster Management
NIO	-	National Institute of Oceanography, Goa
NIOT	-	National Institute for Ocean Technology, Chennai
NMHEWS	-	National Multi Hazard Early Warning System
NOAA	-	National Oceanic and Atmospheric Administration, USA
NOC	-	No Objection Certificate
NODC	-	National Oceanographic Data Center, USA
NODPAC	-	Naval Oceanographic Data Processing and Analysis Centre
NOSDCP	-	National Oil Spill Disaster Contingency Plan
NRSC	-	National Space Research Centre, Hyderabad
NS	-	*Noctiluca Scintillans*
NTWC	-	National Tsunami Warning Centre
NWS	-	National Weather Service
OBIS	-	Ocean Biogeographic Information System
OceanSITES	-	Ocean Sustained Interdisciplinary Time series Environment
OCM	-	Ocean Colour Monitor
OD	-	Other Dinoflagellates
OEM	-	Original Equipment Manufacturer
OGCM	-	Oceanic General Circulation Model
OMM	-	Ocean Monsoon and Mixing project
OMNI	-	Ocean Moored Buoy Network for Northern Indian Ocean
OMZ	-	Oxygen Minimum Zone
ONGC	-	Oil and Natural Gas Corporation
ONI	-	Oceanic Niño Index
OON	-	Ocean Observations Network
OOPC	-	Ocean Observations Panel for Climate
OOS	-	Ocean Observing System
OOSA	-	Online Oil Spill Advisory
ORV	-	Ocean Research Vessel
OSCAT	-	Oceansat-2 Scatterometer

OSF	-	Ocean State Forecast
OTGA	-	Ocean Teacher Global Academy
PAR	-	Photosynthetically Active Radiation
PFZ	-	Potential Fishing Zone
PMC	-	Project Monitoring Committee
PMEL	-	Pacific Marine Environmental Laboratory, USA
POGO	-	Partnership for Observation of the Global Oceans
PRL	-	Physical Research Laboratory, Ahmedabad
PSAT	-	pop-up satellite archival tag
QMF	-	Quality Management Framework
Quick SCAT, QSCAT	-	Quick Scatterometer
R&D	-	Research & Development
Radar	-	RAdio Detection And Ranging
RAMA	-	Research Moored Array for African-Asian-Australian Monsoon Analysis
RCI	-	Research Centre, Imarat
RI	-	Rapid Intensification
RIL	-	Reliance Industries Limited
RIM	-	Real-Time Inundation models (RIMs)
RIMES	-	Regional Integrated Multi-Hazard Early Warning System for Africa
RMSE	-	Root Mean Square error
RNODC	-	Responsible National Oceanographic Ocean Data Centre
ROMS	-	Regional Ocean Modeling System
Rrs	-	Reflectance
RTI	-	Right to Information Act
RTSP	-	Regional Tsunami Service Provider
RTWP	-	Received Total Wideband Power
RV	-	Research Vessel
S & T	-	Science and Technology
SAC	-	Space Application Centre, Ahmadabad
SAIC	-	Science Applications International Corp ,USA.
SAP	-	System Application Products
SASE	-	Snow and Avalanche Study Establishment
SATCORE	-	Satellite Coastal and Oceanographic Research
SATTUNA	-	Satellite Telemetry Studies on Migration Pattern of Tuna in Indian Seas
SC	-	Steering Committee
SCI	-	Shipping Corporation of India

SCOR	-	Scientific Community on Ocean Research
SDD	-	Service Definition Document
SeaWifs	-	Sea-Viewing Wide Field-of-view Sensor
SG	-	Steering Group
SIBER	-	Sustained Indian Ocean Biogeochemistry and Ecosystem Research
SICOME	-	SATCORE Inter-COMparison Exercise
SIM	-	Stand-by Inundation Models (SIMs)
SMA	-	Strong Motion Accelerograph
SMS	-	Short Messaging Service
SoI	-	Survey of India
SOT	-	Ship Observations Team
SSC	-	Science Steering Committee
SSH	-	Sea Surface Height
SSHA	-	Sea Surface Height Anomaly
SSS	-	Sea Surface Salinity
SST	-	Sea Surface Temperature
STB	-	Science Applications International Corporation (SAIC) Tsunami Buoy
SWAN	-	Simulating Waves Nearshore (Model)
SWH	-	Sea Wave Height
SWHM	-	Ship-mounted Wave Height Meter
SWM	-	Sea Wave Measurement
T	-	Temperature
T & S	-	Temperature & Salinity
TC	-	Tropical Cyclone
TFLEX	-	Tropical FLEXible data acquisition system
TI	-	Temperature Inversion
TIO	-	Tropical Indian Ocean
TMI	-	TRMM Microwave Imager
TRMM	-	Tropical Rainfall Measuring Mission Tropical Rainfall Measuring
TOPEX	-	Topography Experiment
TOWSWG	-	Tsunamis and other Ocean hazards Warning and mitigation Systems-Working Group
TSM	-	Total Suspended Matter
TSP	-	Tsunami Service Providers
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
UNWCDRR	-	United Nations World Conference on Disaster Risk Reduction
US /USA	-	United States of America

UT	-	Union Territories
UTC	-	Coordinated Universal Time
VECS	-	VSAT-Aided Emergency Communication System
VIMT	-	Vertically Integrated Moisture Transport
VOS	-	Voluntary Observing Ships
VSAT	-	Very Small Aperture Terminal
VSCS	-	Very Severe Cyclonic Storm
WC	-	West Coast
WCRP	-	World Climate Research Programme
WebGIS	-	Web Geo Information System
WET	-	Western Environmental Technologies, USA
WHM	-	Wave Height Meter
WHOI	-	Woods Hole Oceanographic Institution,USA
WIO	-	Western Indian Ocean
WMO	-	World Meteorological Organization
WRF	-	Weather Research and Forecasting model
WW	-	Wire Walker
XBT/XCTD	-	Expendable Bathythermograph Expendable Conductivity-Temperature
YFT	-	YellowFin Tuna
ZPG	-	Zonal Pressure Gradient
ZWS	-	Zonal Wind Stress

14. Finance

Appendix-1

Y Chakravarthy Associates
CHARTERED ACCOUNTANTS

Head Office:
#6-3-841/1/A,
Padma Plaza, II Floor, Ameerpet,
Hyderabad - 500 016
email: yca_fca@yahoo.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

We have audited the attached Balance Sheet of the ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES as at 31st March 2016, 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 the notes forming part of accounts, the Balance Sheet as at 31st March 2016, 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 **Y Chakravarthy Associates**
Chartered Accountants

(Y Chakravarthy)
Partner
M.No. : 206456
FRN No.: 007907S

Place: Hyderabad
Date: 11-08-2016

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 2016

(Amount in Rs.)

Particulars	Schedules	Current Year (2015 - 16) Rs	Previous Year (2014 - 15) Rs
LIABILITIES			
Corpus fund	1	17,95,01,304	7,99,24,417
Earmarked funds	2	3,98,75,963	17,69,98,716
Current liabilities & Provisions	3	7,96,44,939	6,56,26,574
Total		**29,90,22,206**	**32,25,49,707**
ASSETS			
Fixed Assets	4	9,51,27,327	2,99,47,594
Current Assets, Loans & Advances	5	20,38,94,879	29,26,02,113
Total		**29,90,22,206**	**32,25,49,707**
Notes forming part of Accounts	11		

As per our report of even date
For Y Chakravarthy Associates
Chartered Accountants

Y Chakravarthy
Partner
M.No. 206456
FRN No: 007907S

Place: Hyderabad
Date: 11-08-2016

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

(S. Nageswara Rao)
Sr. Accounts Officer

(K.K.V.Chary)
Dy. C A O

(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

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31st MARCH 2016

(Amount in Rs.)

Particulars	Schedules	Current Year (2015 - 16) ₹	Previous Year (2014 - 15) ₹
INCOME			
Income from Sales / Other Income	6	23,44,064	11,18,502
Interest Earned on Investments	7	7,73,945	7,91,226
Recurring Grants	8	35,00,00,000	26,00,00,000
TOTAL - A		**35,31,18,009**	**26,19,09,728**
EXPENDITURE			
Establishment Expenditure	9	8,68,62,590	7,90,48,771
Other Administrative Expenses	10	14,67,38,312	13,13,08,255
Depreciation	4	1,99,40,220	2,77,65,387
TOTAL - B		**25,35,41,122**	**23,81,22,413**
Excess of Income over expenditure (A-B)	1	9,95,76 ,887	2,37,87,315
Add / Less: Prior Period Items			-
Balance being net income / deficit transferred to Corpus Fund		9,95,76,887	2,37,87,315
Notes forming part of Accounts	11		

As per our report of even date
For Y Chakravarthy Associates
Chartered Accountants

Y Chakravarthy
Partner
M.No. 206456
FRN No: 007907S

Place: Hyderabad
Date: 11-08-2016

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

(S. Nageswara Rao)
Sr. Accounts Officer

(K.K.V.Chary)
Dy. C A O

(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 2016

(Amount in Rs.)

RECEIPTS	CURRENT YEAR 2015-16		PAYMENTS	CURRENT YEAR 2015-16	
	₹	₹		₹	₹
Opening Balance			**Establishment Expenses**		
INCOIS Current A/c-SBI-HAL Campus Br.	1,24,37,005		Pay, Leave Salary Allowace	7,26,95,966	
INCOIS Current A/c-AB-Pragathi Nagar Br.	31,41,737		NPS, CPF, IDBPS	50,99,485	
INCOIS Consultancy SB A/c - Pragathi Nagar Br.	6,50,838		Staff Welfare	18,25,633	
Short Term Deposits with Bank	14,00,00,000	15,62,29,580	Leave Travel Concession	13,95,994	8,10,17,078
Earmarked Funds			**Administrative Expenses**		
Construction of New Building (Phase II)	3,40,00,000		Maintenance & Repairs	3,05,06,260	
Ocean Information and Advisory Services(O-IAS)	25,65,00,000		Travel Expenses - Inland	25,66,766	
Ocean Observation Systems (OOS)	21,34,00,000		Foreign	2,56,216	
Satellite Coastal and Oceanographic Research	3,00,00,000		Others	7,00,420	
V Sat Terrestrial Link	4,10,66,745		Emoluments to Consultants	3,58,969	
Monsoon Mission	7,20,00,000		Vehicle Hiring	5,36,529	
RIMES Afro Asian Region	6,15,00,000		Garden Expenses	8,57,100	
Fund Received from NCES	49,73,121		House Keeping Expenses	78,80,546	
IIOE 2	45,00,000	71,79,39,866	Security Expenses	1,08,65,935	
			Electricity Expenditure	3,51,20,068	
Recurring Grants	35,00,00,000	35,00,00,000	Water Expenses	57,02,224	
			Postage & Telegraphs	1,41,930	
Other Receipts			Telephone & Fax Expenditure	7,08,901	
Consultancy Projects - Sundry Debtors	1,69,350		Honorarium to External Experts	1,72,395	
Earnest Money Deposits	1,12,25,292		Conveyance Expenses	1,60,528	
Security Deposits	73,437		Internet Expenses	45,14,055	
IIOE 2 (Symposyum)	45,00,000		Printing & Stationery	21,74,976	
Interest on Short Term Deposits	98,85,675		Advertisement & Publicity	24,27,155	
Interest on Bank Account	2,05,323		Papers & Periodicals	28,899	
Interest on Bank Account	2,05,323		General Expenses	10,78,743	
Inspire Fellowship	8,92,676		Audit Fee	20,291	

Income from Staff Quarters (lic. Fee)	1,74,230		Seminar, Conference & Workshop Expenses	20,13,587	
Other Receipts	16,83,916		International Interface	1,64,21,874	
Guest House	67,550		Material Consumable	82,66,310	13,34,80,677
RTI Fee	3,758				
Liquidated Damages & Penalty	31,99,886		**Payments Against Earmarked Funds**		
Sale of Tender Forms	42,798		**a) Ocean Information and Advisory Services (OIAS)**		
Hindi Seminar	9,00,000				
UNESCO	13,41,499		Equipment	1,97,94,130	
Parliament of India	2,66,598		Consumables	15,46,560	
IISC, Bangalore	4,140,552		Advance to Sub Projects	4,55,07,950	
Refund from NRSC-NDC	13,93,239		Advance to Purchase	20,44,68,042	
Inspire Fellowship	8,92,676		Technical Support Expenses	1,68,49,726	
Telephone Deposit refund	7,776		Travel Expenses	53,15,670	
BG Clousre fund of Antrix	12,16,294		Manpower	2,16,35,850	
Refund on account of missing journals	6,280	4,24,94,128	Deposit Work - APWD	1,09,15,103	
Unspent Balances received from Sub Projects			Administrative Expenses	1,48,72,970	34,09,06,001
Ocean Information and Advisory Services (OIAS)	20,140		**b) Satellite Coastal and Oceanographic Research**		
Satellite Coastal and Oceanographic Research	3,71,692	3,91,832			
			Consumables	32,71,448	
			Advance to Sub Projects	90,27,603	
			Advance to Purchase	1,31,47,450	
			Travel Expenses	6,17,739	
			Manpower	9,32,570	
			Administrative Expenses	41,60,603	3,11,57,413
			c) Ocean Observation Networks		
			Equipment	2,03,190	
			Technical Support Expenses	30,05,153	
			Consumables/Data	58,69,655	
			Advance to Purchase	9,83,14,477	
			Advance to Sub Projects	3,44,28,000	
			Travel Expenses	14,87,638	
			Manpower	31,16,918	
			Administrative Expenses	88,82,210	15,53,07,241
			d) HROOFS		
			Equipment	17,05,287	
			Advance to Sub Projects	1,36,67,931	
			Advance to Purchase	16,97,738	
			Technical Support Expenses	15,76,115	

			Travel Expenses	3,86,387	
			Manpower	14,16,582	
			Administrative Expenses	34,43,062	2,38,93,102
			e) International Training Centre (ITCOocean)		
			Manpower	7,79,710	
			Administrative Expenses	36,08,663	
			Travel Expenses	21,94,635	
			Deposit Work	6,61,70,483	7,27,53,491
			f) Monsoon Mission		
			Advance to Purchase	2,97,76,926	2,97,76,926
			g) Construction of New Building (Phase II)		
			Equipment	51,04,242	
			Advance to Purchase	44,45,028	
			Travel Expenses	92,474	
			Construction of Building	4,12,09,106	5,08,50,850
			h) RIMES Afro Asian Region		
			Advance to Sub Projects	8,15,88,450	8,15,88,450
			i) V Sat Terrestrial Link		
			Equipment	39,64,147	
			Consumables	2,02,477	
			Technical Support Expenses	2,54,99,756	
			Travel Expenses	49,638	
			Manpower	3,49,122	
			Administrative Expenses	50,70,115	3,51,35,255
			j) Multi Hazard Vulnerability		
			Equipment	13,07,463	
			Technical Support Expenses	4,14,39,111	
			Travel Expenses	76,489	
			Administrative Expenses	24,770	4,28,47,833
			k) IIOE 2		
			Administrative Expenses	2,18,628	
			Consumables	1,22,117	
			Travel Expenses	1,57,917	4,98,662
			Expenditure on Fixed Assets		
			Office Equipment	99,705	
			Furniture & fixtures	1,30,369	
			Computer & Peripherals	81,25,032	

			Library	61,65,594	1,45,20,700
			Other Payments		
			Earnest Money Deposits	57,52,000	
			Security Deposits	44,42,995	
			Service Tax paid	25,319	
			Experiment over BOB-IITM	39,27,730	
			Inspire Fellowship	1,97,167	
			Electricity Deposit	6,18,975	
			LTC Advance	14,20,239	
			IIOE-2 Expenditure	35,46,217	
			Advance under Purchase	45,300	1,99,75,942
			Closing Balance		
			INCOIS Current A/c-SBI-HAL Campus Br.	4,21,11,878	
			INCOIS Current A/c-AB-Pragathi Nagar Br.	1,03,84,057	
			INCOIS Consultancy SB A/c - Pragathi Nagar Br.	8,49,850	
			Short Term Deposits with Bank	10,00,00,000	15,33,45,785
Total	**1,26,70,55,406**	**1,26,70,55,406**	**Total**	**1,26,70,55,406**	**1,26,70,55,406**

As per our report of even date
For Y Chakravarthy Associates
Chartered Accountants

Y Chakravarthy
Partner
M.No. 206456
FRN No: 007907S

Place: Hyderabad
Date: 11-08-2016

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

(S. Nageswara Rao)
Sr. Accounts Officer

(K.K.V.Chary)
Dy. C A O

(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 2016

SCHEDULE 1 – CORPUS FUND

(Amount in Rs.)

Particulars	**Current Year (2015 - 16) ₹**	**Previous Year (2014 - 15) ₹**
Corpus Fund at the beginning of the year	7,99,24,417	6,36,37,102
Less: Transfer to Ministry of Earth Sciences, New Delhi	-	75,00,000
Add: Net income transferred from Income & Expenditure Account	9,95,76,887	2,37,87,315
BALANCE AS AT THE YEAR END	**17,95,01,304**	**7,99,24,417**

As per our report of even date
For Y Chakravarthy Associates
Chartered Accountants

Y Chakravarthy
Partner
M.No. 206456
FRN No: 007907S

Place: Hyderabad
Date: 11-08-2016

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

(S. Nageswara Rao)
Sr. Accounts Officer

(K.K.V.Chary)
Dy. C A O

(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	Ocean Information and Advisory Services(O-IAS)	Ocean Observation Networks	SATCORE	ITCOO	HROOFS	IT & E Governance Fund	V SAT Node	MH Vulnerability	Monsoon Mission	RIMES	CSS	IIOE2	NCS	Current Year 2015-16	Previous Year 2014-15
a) Opening balance of the funds	-28,83,878	-4,92,73,295	-7,62,01,803	34,61,211	16,04,61,773	5,45,20,672	27,06,227	-1,84,79,608	4,53,99,027	2,76,33,118	2,77,87,542	18,67,730	-	-	17,69,98,716	40,02,71,148
b) Additions to the Funds:																
i. Grants	3,40,00,000	25,65,00,000	21,34,00,000	3,00,00,000	-	-		4,10,66,745	-	7,20,00,000	6,15,00,000	-	45,00,000	49,73,121	71,79,39,866	45,00,97,000
ii. Interest if any	-	1,09,059	4,43,579	72,829	83,52,977	12,91,557	82,078	4,31,328	11,30,776	22,90,276	8,84,953	56,801	1,10,996	-	1,52,57,209	2,90,17,049
iii. Advance for sub projects utilised	-	5,47,00,053	5,31,36,560	1,11,08,173	-	1,41,73,216	-	-	-	82,14,000	2,21,77,736	-	-	-	16,35,09,738	22,90,16,929
iv. Advance for purchase Utilised	36,09,653	4,66,49,973	23,33,23,644	2,99,63,885	64,15,726	33,45,744	-	5,72,10,071	-	2,13,04,617	-	-	-	-	40,18,23,313	1,35,23,745
v. Margin Money Reversed	-	93,85,000	10,89,58,000	96,55,000	-	-	-	-	-	-	-	-	-	-	12,79,98,000	17,49,91,412
vi. Mobilisation Advance Reversed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
vii. Other Revenue	26,39,393	-	-	-	-	16,427	-	-	-	-	-	-	-	-	26,55,820	47,44,782
TOTAL (a+b) - A	3,73,65,168	31,80,70,790	53,30,59,980	8,42,61,098	17,52,30,476	7,33,47,616	27,88,305	8,02,28,536	4,65,29,803	13,14,42,011	11,23,50,231	19,24,531	46,10,996	49,73,121	1,60,61,82,662	1,30,16,62,065
c) Utilisation/Expenditure																
i. Capital Expenditure																
W.I.P	4,12,09,106	-	-	-	-	-	-	-	-	-	-	-	-	-	4,12,09,106	6,60,28,058
Architect fee	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20,290
Equipments	51,04,242	5,04,43,240	25,54,56,313	3,94,75,814	-	22,78,006	-	2,71,06,368	-	2,14,37,780	-	-	-	-	40,13,01,764	8,19,75,986
Computers / Software	-	1,96,60,868	1,78,500	-	-	53,69,149	-	3,40,67,848	13,07,463	-	-	-	-	-	6,05,83,829	1,71,87,204
Other Assets	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	4,63,13,348	7,01,04,108	25,56,34,813	3,94,75,814	-	76,47,155	-	6,11,74,217	13,07,463	2,14,37,780	-	-	-	-	50,30,94,699	16,52,11,538
ii. Revenue Expenditure																
Technical support	-	3,02,22,427	35,05,153	-	-	28,49,430	-	2,54,99,756	4,14,39,111	-	2,21,77,736	-	-	-	12,56,93,613	7,14,65,186
Adminisrtrative expenses	-	7,02,47,760	2,30,64,187	97,73,266	43,88,374	1,28,27,187	-	54,19,238	24,770	-	-	-	2,18,628	-	12,59,63,410	10,17,50,346
Travel	92,474	88,20,186	25,26,305	13,93,889	21,94,635	11,30,938	-	49,638	76,489	-	-	-	1,57,917	-	1,64,42,471	1,68,23,052
Consumable Materials / Data	-	85,50,912	2,52,94,510	32,71,448	-	5,91,683	-	2,02,477	-	-	-	-	1,22,117	-	3,80,33,147	11,10,58,951
Total	92,474	11,78,41,285	5,43,90,155	1,44,38,603	65,83,009	1,73,99,238	-	3,11,71,109	4,15,40,370	-	2,21,77,736	-	4,98,662	-	30,61,32,641	30,10,97,535
iii. Others																
Advance against subprojects	-	4,55,07,950	3,44,28,000	90,27,603	-	1,36,67,931	-	-	-	-	8,15,88,450	-	-	-	18,42,19,934	16,47,83,143
Advance for Purchase	80,54,681	20,44,68,042	9,83,14,477	1,31,47,450	64,15,726	16,97,738	-	-	-	2,97,76,926	-	-	-	-	36,18,75,040	34,74,57,577
Deposit Work (APWD)	-	1,09,15,103	-	-	6,61,70,483	-	-	-	-	-	-	-	-	-	7,70,85,586	93,89,144
Margin Money against LC	-	93,85,000	10,89,58,000	57,95,000	-	-	-	-	-	97,60,800	-	-	-	-	13,38,98,800	13,67,24,412
Total	80,54,681	27,02,76,095	24,17,00,477	2,79,70,053	7,25,86,209	1,53,65,669	-	-	-	3,95,37,726	8,15,88,450	-	-	-	75,70,79,360	65,83,54,276
TOTAL (i+ii+iii) - B	5,44,60,503	45,82,21,488	55,17,25,445	8,18,84,471	7,91,69,218	4,04,12,062	-	9,23,45,326	4,28,47,833	6,09,75,506	10,37,66,186	-	4,98,662	-	1,56,63,06,699	1,12,46,63,349
Amount Refunded - C		-	-		-	-	-	-	-	-	-		-	-	-	-
NET BALANCE AS AT THE PERIOD END {A -(B+C)}	-1,70,95,335	-14,01,50,698	-1,86,65,465	23,76,627	9,60,61,258	3,29,35,554	27,88,305	-1,21,16,790	36,81,970	7,04,66,505	85,84,045	19,24,531	41,12,334	49,73,121	3,98,75,963	17,69,98,716

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE - 3 CURRENT LIABILITIES & PROVISIONS **(Amount in Rs.)**

Particulars	Current Year (2015 - 16) ₹	Previous Year (2014 - 15) ₹
A. CURRENT LIABILITIES		
Earnest Money Deposit	79,93,294	24,61,000
Security Deposit	70,52,141	75,67,082
Performance Deposit	-	-
Outstanding Expenses	2,85,67,131	2,33,39,243
Sundry Creditors	1,60,80,151	1,69,30,873
RTF-DCS Fellowship	1,29,311	2,56,452
Monsoon Mission Fund (IITM)	2,12,812	-
Total – A	**6,00,34,840**	**5,05,54,650**
B. PROVISIONS		
Gratuity	53,66,870	45,77,847
Accumulated Leave Encashment	1,42,43,229	1,04,94,077
Total – B	**1,96,10,099**	**1,50,71,924**
Total (A+B)	**7,96,44,939**	**6,56,26,574**

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 31.03.2015	Additions during the year	As at 31.03.2016	As at 31.03.2015	For the year 2015-16	As at 31.03.2016	As at 31.03.2016	As at 31.03.2015
1. Land (0%)	1,000	-	1,000	-	-	-	1,000	1,000
2. Plant, Machinery & Equipments (15%)	4,53,57,169	-	4,53,57,169	4,42,37,739	1,00,207	4,42,37,946	10,19,223	11,19,430
3. Furniture & Fixtures (10%)	1,52,02,448	1,30,369	1,53,32,817	1,02,57,953	2,76,698	1,05,34,651	47,98,166	49,44,495
4. Office Equipment (15%)	28,71,096	99,705	29,70,801	22,73,801	53,645	23,27,446	6,43,355	5,97,295
5. Computer / Peripherals (60%)	4,44,47,033	7,87,24,286	12,31,71,318	3,83,25,785	80,75,141	4,64,00,926	7,67,70,392	61,21,248
6. Electric Installations (10%)	20,66,959	-	20,66,959	10,47,342	57,734	11,05,076	9,61,883	10,19,617
7. Library Books (100%)	5,58,12,912	61,65,594	6,19,78,506	4,50,66,306	1,08,85,283	5,59,51,589	60,26,917	1,07,46,606
8. Other Fixed Assets (15%)	64,73,696	-	64,73,696	16,28,641	4,42,023	20,70,664	44,03,032	48,45,055
9. Vehicles (15%)	18,49,835	-	18,49,835	12,96,987	49,489	13,46,476	5,03,359	5,52,848
Total	**17,40,82,148**	**8,51,19,954**	**25,92,02,101**	**14,41,34,554**	**1,99,40,220**	**16,40,74,774**	**9,51,27,327**	**2,99,47,594**
Previous Year	13,78,02,028	3,62,80,120	17,40,82,148	11,63,69,167	2,77,65,387	14,41,34,554	2,99,47,594	2,14,32,861

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

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

Particulars	Current Year (2015 - 16) ₹		Previous Year (2014 - 15) ₹	
A. CURRENT ASSETS				
1. Inventories (Valued at cost)	10,13,777	10,13,777	6,53,999	6,53,999
2. Cash & Bank Balance :				
a) With Scheduled Banks – Current Account				
State Bank of India HAL CAMPUS A/c	4,21,11,878		1,24,37,005	
Andhra Bank Pragathinagar A/c	1,03,84,057		31,41,737	
Andhra Bank Pragathinagar-Consultancy A/c	8,49,850	5,33,45,786	6,50,838	1,62,29,580
b) Short Term Deposits with SBI	10,00,00,000		14,00,00,000	
c) Short Term Deposits with AB	-	10,00,00,000	-	14,00,00,000
TOTAL A:		**15,43,59,563**		**15,68,83,579**
B. LOANS, ADVANCES & OTHER ASSETS				
1. Deposits				
a) Telephone	1,96,574		2,04,350	
b) Electricity	61,49,489		55,30,514	
c) Gas	13,100		13,100	
d) Petrol/Diesel	1,01,400	64,60,563	1,01,400	58,49,364
2. Advances & other amounts recoverable in cash or in kind or for value to be received				
a) Vehicle Advance to Employees	6,39,550		7,31,550	
b) Advance - NRSA (NDC)	-		13,93,239	
c) Advance to Seminars/Conference	-		1,26,500	
d) Interest Accrued	89,28,880		62,65,490	
e) Other Advances	3,100		73,98,063	
f) Advance for Purchase	96,62,859		9,10,68,545	
g) Sundry Debtors	-		-	
h) Tour Advance – Foreign	2,15,760		-	
i) LTC Advance	9,422		90,900	
j) TDS Opening Balance	1,88,53,216		1,59,31,451	
k) TDS Accumulation during the year	17,61,966		29,21,765	
l) Margin Money against Bank Guarantee	30,00,000	4,30,74,753	39,41,667	12,98,69,170
TOTAL B: (1+2)		4,95,35,316		13,57,18,534
GRAND TOTAL (A + B)		**20,38,94,879**		**29,26,02,113**

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 6 - INCOME FROM SALES / OTHER INCOME

(Amount in Rs.)

Particulars	Current Year (2015- 16) ₹	Previous Year (2014- 15) ₹
a) Sale of Tender Forms	42,798	36,700
b) Other Receipts	19,57,686	10,64,724
c) Consultancy Services	1,69,350	4,395
d) Income from staff quarters	1,74,230	12,683
TOTAL	**23,44,064**	**11,18,502**

SCHEDULE 7 - INTEREST EARNED

a) Interest on Short Term Deposits & Others	4,99,915	4,59,390
b) Bank Accounts	2,05,323	2,40,941
c) Staff Advances	68,707	90,895
TOTAL	**7,73,945**	**7,91,226**

SCHEDULE 8 - IRRECOVERABLE GRANTS & SUBSIDIES RECEIVED

a) Central Government (Recurring Grant received from MoES)	35,00,00,000	26,00,00,000
TOTAL	**35,00,00,000**	**26,00,00,000**

SCHEDULE 9 - ESTABLISHMENT EXPENDITURE

a) Salaries, Wages & Allowances	7,80,51,191	7,10,66,880
b) Staff Welfare Expenses	18,25,633	17,51,176
c) Contributory Provident Fund	2,95,914	2,63,406
d) New Pension Scheme	39,51,662	31,78,780
e) IDBPS Trust	13,42,196	12,32,452
f) Leave Travel Concession	13,95,994	15,56,077
TOTAL	**8,68,62,590**	**7,90,48,771**

ESSO-INDIAN NATIONAL CENTRE FOR OCEAN INFORMATION SERVICES

SCHEDULE 10 - OTHER ADMINISTRATIVE EXPENSES **(Amount in Rs.)**

Sl No.	Particulars	Current Year (2015 - 16) ₹	Previous Year (2014 - 15) ₹
1.	Electricity & Power Expenses	3,59,70,698	3,24,36,322
2.	Water Charges	57,52,405	52,10,895
3.	Operation & Maintenance expenses	4,21,50,389	5,31,00,982
4.	Garden Expenses	8,09,113	11,99,093
5.	Vehicle Hiring Expenses	5,98,145	7,98,225
6.	Postage, Telephone, Fax & ISDN Charges	8,39,784	7,73,182
7.	Printing & Stationery	22,23,411	7,02,549
8.	Travelling Expenses :		
	Inland	25,66,766	5,66,012
	Foreign	2,56,216	2,18,265
	Others	7,00,420	9,56,908
9.	Seminar/Workshops Expenses	20,13,587	23,46,426
10.	General Expenses	10,78,744	11,84,943
11.	Audit Fee	15,467	20,291
12.	House Keeping Expenses	88,47,492	50,51,794
13.	Security Expenses	1,09,23,579	85,42,356
14.	Advertisement & Publicity	24,27,155	14,59,957
15.	Membership / Registration fees		35,169
16.	Internet Expenses	45,14,055	13,89,323
17.	Legal Expenses	-	-
18.	Papers & Periodicals	28,899	22,539
19.	Conveyance Expenses	1,61,389	1,47,734
20.	Material/Consumable	82,66,310	18,81,062
21.	International Interface	1,64,21,874	1,31,31,766
22.	Others	1,72,414	1,32,462
	TOTAL	**14,67,38,312**	**13,13,08,255**

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 2015-16, the Society received Rs.35.00 Crores towards Recurring Grant as shown in the Schedule-8.

The remaining Grant-in-aid of Rs. 71.79 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:

- Fixed Assets register was maintained by the Society.
- In schedule-4, out of the amount of Rs.7,87,24,286 shown under computer and peripherals, an amount of Rs.7,05,99,254/- which was under advance for purchase for the previous financial year 2014-15 was transferred to fixed assets in the current financial year as there was a technical problem in software SAP-ERP in the year 2014-15. Accordingly, the depreciation for this asset is charged in the current year.
- The management verified the assets physically by appointing a sub-committee.
- The additions to the fixed assets during the period of audit were stated at cost.
- Depreciation on Fixed Assets was provided on written down value.
- In schedule-4, opening balances of Fixed Assets have been regrouped wherever necessary.
- Change in rate of depreciation: During the current year 2015-16, management adopted the rates fed in SAP-ERP for providing depreciation on its fixed assets which are different from rates adopted in the previous year. Due to this change Current year (2015-16) Income over expenditure got increased by 2,30,94,075 and the impact on Income over expenditure is as follows:

S. No	Particulars	Depreciation as per Rates in SAP-ERP adopted by the management	Depreciation as per Income Tax rates adopted up to Financial year 2014-15	Impact on Income over expenditure
1	Land	0	0	0
2	Plant, machinery & equipment	1,00,207.00	1,67,915.00	67,708.00
3	Furniture & fixtures	2,76,698.00	5,00,968.00	2,24,270.00
4	Office Equipment	53,645.00	1,00,470.00	46,825.00
5	Computers & peripherals	80,75,141.00	2,72,91,528.00	1,92,16,387.00
6	Electrical Installations	57,734.00	1,01,962.00	44,228.00

7	Library Books	1,08,85,283.00	1,40,61,949.00	31,76,666.00
8	Other Fixed Assets	4,42,023.00	7,26,758.00	2,84,735.00
9	Vehicles	49,489.00	82,927.00	33,438.00
	Total	**1,99,40,220.00**	**4,30,34,477.00**	**2,30,94,257.00**

d) Inventories:

Inventory of stores, stationery items and other material of significant value are valued at cost.

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.

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:

The IDBPS (INCOIS Defined Benefit Pension Scheme) is managed by a separate trust and employers contributions for the year 2015-16 towards pension for the employees joined prior to 01-01-2004, was transferred by INCOIS to LIC of India Ltd.

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

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.

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.

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.

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.

Periodical contributions to IDBPS are charged to revenue up to August 31, 2015 only.

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 2015-16, an amount of Rs.97,36,126/- 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. 97,36,126/-, the management had transferred an interest of Rs.93,65,175/- to various projects classified in Earmarked Funds under Schedule – 2 and the balance interest of Rs.3,70,951/- was considered as income of the Society under Schedule – 7.

The details are furnished below:-

(Amount in Rs.)

a.	Interest earned on regular STDRs	97,49,693.00
b.	Add: TDS deducted by bank on interest earned	12,67,485.00
c.	Add: TDS deducted by bank & TSSPDCL on interest accrued	47,296.00
d.	Add: Accrued Interest as on 31.03.2016	4,25,608.00
e.	Total Interest	1,14,90,082.00
f.	Less: Accrued Interest as on 31.03.2015	17,53,956.00
g.	Net Interest earned for the F Y 2015 - 16	97,36,126.00

In addition to the above an amount of Rs.1,28,964/- earned as interest on the consultancy revenues during the year 2015-16.Interest on Short terms Deposits as apportioned to the Society is Rs.3,70,951/-. Thus, the interest earned by the Society during the financial year is Rs.4,99,915/- as shown in the Schedule-7.

2. **Notes on Accounts:**

a) **EARMARKED FUNDS:**

The Society during the year 2015-16, received Rs. 71.79 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 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.

The 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 31-03-2016 was Rs.70.71. Crores.

The accumulated value of the capital expenditure as on 31-03-2016 (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:

Sl No.	Name of the Fund/ Project	As on 01-04-2015 ₹	Additions 2015-16 ₹	Total Amount as on 31-03-2016 ₹
i)	Building Fund	50,93,61,789	4,63,13,348	55,56,75,137
ii)	MDC & Equipment Fund	6,59,21,618	0	6,59,21,618
iii)	Ocean Information and Advisory Services (O-IAS)	1,14,85,40,711	7,01,04,108	1,21,86,44,819
iv)	Computational Facilities	15,28,06,467	0	15,28,06,467
v)	INDOMOD & SATCORE Projects	38,58,65,480	3,94,75,814	42,53,41,294
vi)	Ocean Observation Networks	30,18,26,367	25,56,34,813	55,74,61,180
vii)	International Training Center- ITCOocean	2,75,94,223	0	2,75,94,223
viii)	HROOFS	33,97,526	76,47,155	1,10,44,681
ix)	HPC System - INCOIS	13,64,14,440	0	13,64,14,440
x)	IT & E Governance Fund	5,76,21,080	0	5,76,21,080
xi)	HPC Systems - Others	1,33,61,57,396	0	1,33,61,57,396
xii)	V SAT Node	7,11,82,783	6,11,74,217	13,23,57,000
xiii)	Ernet India	72,00,000	0	72,00,000
xiv)	IOAS	51,25,986	0	51,25,986
xv)	MHVM	0	13,07,463	13,07,463
xvi)	MSMN	0	2,14,37,780	2,14,37,780
	Total	**4,20,90,15,866**	**50,30,94,698**	**4,71,21,10,564**

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 : NIL
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 advise 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 an Executive Petition at III Additional Chief Judge of City Civil Court, Hyderabad for recovery of the amount available in the bank account of M/s Victory Genset Pvt.Ltd. at SBI, Versova Branch, Mumbai. The case is in progress.

e) Figures of the previous year were regrouped wherever necessary.

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

As per our report of even date
For **Y Chakravarthy Associates**
Chartered Accountants

Y Chakravarthy
Partner
M.No. 206456
FRN No: 007907S

Place: Hyderabad
Date: 11-08-2016

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

(S. Nageswara Rao)	**(K.K.V.Chary)**	**(S.S.C.Shenoi)**
Sr. Accounts Officer	Dy. C A O	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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