SUPREME AUDIT INSTITUTION OF INDIA
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Report of the Comptroller and Auditor General of India on the Activities of Indian National Centre for Ocean Information Services

Union Government
Ministry of Earth Sciences
Report No. 8 of 2025
(Compliance Audit-Civil)

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Contents

Preface

The Report for the year ended March 2022 has been prepared for submission to the President of India under Article 151 of the Constitution of India.

This Report of the Comptroller and Auditor General of India contains the observations of Compliance Audit on the Activities of Indian National Centre for Ocean Information Services (INCOIS) for the period 2017-2022.

The instances mentioned in this Report are those which came to notice in the course of test audit for the period 2017-2022 as well as those which came to notice in earlier years but could not be reported in previous Audit Reports; matters relating to the period subsequent to 2021-2022 have also been included, wherever necessary. References to the activities carried out by organisations such as National Institute of Ocean Technology, Centre for Marine Living Resources and Ecology (constituent units under Ministry of Earth Sciences) and National Institute of Oceanography (constituent unit of Council for Scientific and Industrial Research) are also made in this report in the instances where they were partners in the implementation of the INCOIS projects/activities.

The audit has been conducted in conformity with the Auditing Standards issued by the Comptroller and Auditor General of India.

Executive Summary

Executive Summary

Introduction and Background

India's extensive 7517 km coastline supports millions of fishermen and coastal communities and thus the Blue Economy is vital to the country's growth. Oceans, as the driving force behind monsoons and a rich source of resources, play a crucial role in the Economy of the country. Government of India has recognised Blue Economy as Sixth dimension in its 2030 New India Vision Document. Comprehending dynamic ocean processes is vital for sustainable resource utilisation, accurate weather forecasts and the development of marine ecosystems.

The Ministry of Earth Sciences (MoES) established Indian National Centre for Ocean Information Services (INCOIS) to serve as a hub for oceanic knowledge and to provide timely and reliable oceanic information and advisory services. INCOIS is engaged in providing Science-based products and essential services to various stakeholders, that can support the development of Blue Economy. The services provided by INCOIS include Ocean State Forecast, Potential Fishing Zones, Data Services and Tsunami Early Warning for disaster preparedness. Considering the importance of these services, it was decided to take up a Audit on "Activities of INCOIS". The objective of the audit was to assess the achievement of objectives set under the programmes executed by INCOIS during the period 2017-2022. The Audit focussed on the planning and execution of the projects and achievements of objectives/deliverables against the targets set by INCOIS/MoES.

INCOIS has been rendering valuable service towards Ocean Information Services for decades. Despite facing technological challenges, INCOIS was able to largely carry out activities allocated to it as per mandate and secure India's recognition in this field on the global fora. However, the overall achievements fell short of the targets set under specific projects/programmes. Delays in project approvals, lack of clearly defined project objectives and deliverables indicated weak project management. Securing optimal human resources and in-house High Performance Computing system were key limitations in the implementation of projects.

Systematic planning for procurement of Ocean Observation Platforms was not in place. Resultantly, INCOIS was not able to meet the target in deployment and maintenance of Platforms such as Argo floats, Drifters, *etc.* The efforts towards indigenisation of Argo floats and Drifters suffered due to performance and economic viability concerns. The safeguards such as a strategic IT Plan, IT Security Policy, Business Continuity and Disaster Recovery Plan to protect its data were found wanting.

Audit also noted that due to delayed procurement and deployment of platforms, INCOIS could not achieve the objectives under its Research and Development projects. While INCOIS made progress, it was unable to develop/ improve the models as envisaged in the program objectives. INCOIS has been successfully providing Potential Fishing Zone advisories for the past two decades. However, the efforts to overcome cloud cover limitation in providing these advisories did not fructify.

INCOIS did not carry out any activity relating to SDG 14 – Life Below Water, though advised by MoES. Audit also revealed that in some cases identification of highly vulnerable coasts and generation of Multi-Hazard Vulnerability maps was yet to be carried out.

The key Audit findings and recommendations of Audit are as under:

Key Audit Findings and Recommendations

Project Management

Audit observed that the project approvals from MoES were received after commencement of the project period. MoES also reorganised the projects midway and did not revise the deliverables under the projects to align with reduced budget and timeframe. Hence, the projects were not amenable to efficient monitoring. There were sub-optimal financial resources available for execution of the projects. INCOIS did not pursue sanction of permanent posts and handled the projects with contractual staff, which had an adverse impact on knowledge transfer and consolidation.

Recommendations

1) ***MoES may ensure timely issue of project approvals and sanctions providing scope for planning and execution of projects in a time bound manner.***
2) ***MoES may clearly define the revised targets commensurate with the resources during reformulation to enable assessment of achievements against the targets.***
3) ***MoES may ensure deploying sufficient regular manpower with technical expertise so that the activities of INCOIS are not hampered.***

(Paras 2.1.1, 2.1.2, 2.2 and 2.3)

Procurement and deployment of Ocean Observation Platforms

There was no systematic procurement/deployment plan for Ocean Observation Platforms. It was observed that INCOIS could not deploy and maintain the targeted network of platforms such as Argo Floats, Drifters, *etc.* INCOIS could not fulfil its commitment under the International Argo Programme. INCOIS was required to deploy only indigenously developed

Drifters but it could neither achieve this nor meet the targeted number through imports. The indigenous production of Argo floats and Drifters was not successful due to performance and economic viability concerns. Audit observed absence of coordinated efforts with the industry resulting in continued dependence on imports. INCOIS was required to maintain the existing 34 ship mounted Automatic Weather Stations and deploy five new ones and incorporate pCO_2 sensors in two research vessels. The collection of atmospheric data along the ship's route using these instruments was essential for operational and research purposes including providing of forecasts and validation of/assimilation into various models. INCOIS did not procure new Automatic Weather Stations, due to fund constraints. INCOIS had the target of procuring and deploying seven Wave Rider Buoys in addition to the maintenance of the existing ones, towards collection of actual wave measurements for validation of its models and for enhancing the quality of the forecasting system. INCOIS did not expand the Wave Rider Buoy Network as planned. The existing network of these two platforms was also not maintained adequately resulting in data gaps, despite incurring considerable expenditure.

Recommendations

4) ***INCOIS may devise and follow a systematic procurement and deployment plan for ocean observation platforms considering the operational and research needs, international commitments and resources.***
5) ***MoES may ensure that organisations under its supervision, work in sync with each other and strengthen ties with the industry for realisation of indigenous development of observational platforms.***

(Paras 3.1, 3.3.1 and 3.3.2)

Data Management

INCOIS, recognised as National Oceanographic Data Centre, did not put in place a Data Quality Management System which was essential for seeking accreditation from UNESCO-IOC. INCOIS also did not have a Data Management Plan. Though most of the data held by INCOIS were unique and non-replicable, there was no strategic IT Plan; no documented Business Continuity and Disaster Recovery Plan; no off-site Disaster Recovery site, except for the Tsunami Early Warning Centre. Despite occurrence of security breach incidents, INCOIS is yet to put in place an IT Security Policy. Foolproof Physical Access Control was also not enforced, even to areas hosting critical IT infrastructure and periodical Security Audit was also not conducted.

Recommendations

6) ***INCOIS may implement adequate data safety and security measures; develop and implement the Business Continuity and Disaster Recovery Plan; establish and maintain off-site Disaster Recovery site for all applications.***
7) ***INCOIS may document and follow the Data Quality Management System and Data Management Plan.***
8) ***INCOIS may put in place the IT Security Policy in a time-bound manner and take effective steps for its prompt implementation.***

(Paras 4.2, 4.2.1, 4.2.2, 4.3 and 4.4)

Execution of Research and Development projects

It was observed in audit that the execution of the Ocean-Modelling, Data Assimilation and Process Specific Observations project aimed at bringing in improvements to the models used for generating the Advisory Services, was hampered due to manpower and in-house High Performance Computing facility constraints. Under the Monsoon Mission project, INCOIS was responsible for collecting and providing ocean data for development of models to improve monsoon predictions. Delay in procurement of ocean observation platforms under these two projects resulted in non-achievement of objectives. The efforts of INCOIS to carry out enhancements to the models did not yield results. INCOIS aimed to deploy six automated observatories under the Coastal Monitoring project towards collection of water quality parameters and met-ocean data. It could deploy only two, that too very recently. INCOIS did not develop location-specific coastal models as envisaged. Grantee Institutions could not collect *in-situ* sample data due to insufficient funding.

Recommendations

9) ***In order to achieve improvements in advisories and forecasts, INCOIS may strive towards acquisition of adequate data essential for running the models and for model validation.***
10) ***The data collection under the Mission Mode projects may be executed in a time-bound manner since this would have impact on the overall execution of the project.***
11) ***INCOIS may ensure that the grantee organisations are provided sufficient funding in a timely manner to ensure that they execute their activities effectively.***

(Paras 5.1.1, 5.1.1.2, 5.1.2, 5.1.2.1, 5.1.2.2, 5.1.3 and 5.1.3.1)

Advisory Services

INCOIS provides Potential Fishing Zone advisories on a daily basis based on visual interpretation of the features observed in satellite imagery. These advisories could not be given on cloudy days due to non-availability of satellite data. INCOIS could not overcome this limitation despite prolonged efforts and thus continued the service with inherent limitations. It also could not operationalise a Potential Fishing Zone Forecasting System that would facilitate pelagic fishing activities in deep sea, which require multi-day fishing. INCOIS could not provide species specific advisories for Hilsa and Oil Sardine despite studies for a long time. Audit observed that INCOIS did not build effective linkages with other organisations for collection of fish-catch data to aid in validation and improvement of its services.

Small Vessel Advisory Service was in great demand from the coastal communities, as it would help reduce the number of accidents caused by capsizing vessels. Audit noticed that though INCOIS designed and developed a Small Vessel Advisory Service in 2018-19, it operationalised the same in February 2023 only. It is yet to receive feedback from the users to confirm the correctness and usefulness of this service.

Tsunami buoys are deployed in deep ocean, to detect tsunamis and provide early warning for disaster preparedness. INCOIS could not maintain the optimal network of seven tsunami buoys suggested by the Technical Committee during the period from 2017-18 onwards. Only two to three tsunami buoys were active during most of the time. Maintenance of tsunami buoys was impeded due to repeated instances of vandalism, paucity of ship-time, communication issues *etc.* INCOIS could not overcome these, despite various recommendations of the Technical Committee.

Recommendations

12) ***INCOIS may build effective linkages with other organisations to get essential inputs towards validation and improvement of its services.***
13) ***INCOIS may strive to maintain ideal tsunami buoy network to alleviate the risk of missing timely detection of events.***

(Paras 5.2.2.1, 5.2.2.2, 5.2.3 and 5.4.1)

Sustainable Development and Climate Change

MoES is the nodal Ministry for Sustainable Development Goal 14 – Life Below Water and INCOIS was specifically mapped for certain targets. INCOIS did not carry out programme on Ocean Acidification despite specific directions by MoES. The Tsunami-Ready programme initiated to improve coastal community's preparedness for tsunami emergencies contributes to

SDG-11 focussing on urban resilience and disaster reduction. Only two villages in Odisha were certified as Tsunami Ready under this programme. The target of identifying one village from each coastal district for implementing the programme has only been partially achieved.

INCOIS took up Multi-hazard Vulnerability Mapping in 2010-2013 for India's entire coastline, including Islands, to aid in identification of most vulnerable and high-risk areas for prioritised action. INCOIS generated 1054 Multi-hazard Vulnerability maps between July 2013 and March 2020 for the mainland and Andaman and Nicobar Islands. The Atlas comprising of these maps aimed to help disaster management, was released only in 2023. Some of the base data used for preparation of the Atlas was as old as 2007. For the west coast (from Kochi to Gujarat) and Andaman and Nicobar, though Multi-hazard Vulnerability maps have been generated, INCOIS has not yet identified the highly vulnerable coasts. For Lakshadweep Islands, one of the most vulnerable coasts, Multi-hazard Vulnerability maps itself have not been generated.

Recommendations

14) ***INCOIS/MoES may formulate the research programmes/activities targeting the achievement of Sustainable Development Goals***
15) ***INCOIS may establish coordination among the various State and Central agencies to improve coastal community's preparedness for tsunami emergencies.***
16) ***INCOIS may prepare Multi-hazard Vulnerability maps for Lakshadweep Islands. INCOIS may also carry out vulnerability studies for the West coast (from Kochi to Gujarat), Andaman and Nicobar and Lakshadweep Islands for preparation of 3D GIS maps.***

(Paras 6.1.1, 6.1.2 and 6.2)

Chapter - I

Introduction

Chapter I: Introduction

1.1 About INCOIS

Oceans exercise a vital influence over human life and significantly impact weather, climate and environmental conditions, including air quality. The oceanic economy, with its vast and diverse nature, plays a pivotal role in sustaining numerous livelihoods.

The concept of Blue Economy pertains to oceans' economic contributions and it is imperative to ensure ocean's environmental and ecological sustainability. Recognising this, the Government of India (February 2019) has enshrined Blue Economy as the sixth dimension in its 2030 New India Vision document[1]. This requires creation of coherent policy framework that integrates various sectors to uplift the lives of the coastal communities, spur development and enhance employment opportunities.

The accurate prediction of oceanic parameters is critical in driving Blue Economy initiatives and facilitating the sustainable management of oceans. The Ministry of Earth Sciences (MoES) plays a central role in studying regional ocean and atmosphere processes and its connection with the weather and climate. The mandate of MoES encompasses providing services related to weather, climate, ocean, coastal conditions, natural hazards and the exploration and sustainable utilisation of marine resources.

In 1999, MoES established the Indian National Centre for Ocean Information Services (INCOIS) as an autonomous entity. INCOIS has a mission to disseminate ocean data and provide information and advisory services to society, industry, the government and the scientific community. To translate its Mission into action, INCOIS undertakes the following activities:

i. Deploy and maintain a suite of Ocean Observing Systems in the Indian Ocean to collect data on oceanic parameters to understand the processes in the ocean and to predict their changes;

ii. Carry out systematic quality checks and archive all observational, satellite and other oceanic data and make it available to students, researchers and any other users;

iii. Carry out Research and Modelling to optimise the performance of mathematical models used for ocean state forecasts, prediction of tsunami waves, storm surges, *etc.*, along the coast;

[1] ***The Government of India has unveiled its vision for the next decade, listing thereby ten important dimensions.***

iv. Providing round-the-clock services for tsunamis, storm surges, high waves, *etc*., through Indian Tsunami Early Warning Centre (ITEWC); and

v. Training and capacity building in Operational Oceanography.

1.2 National and International linkages

INCOIS receives data from various organisations such as National Remote Sensing Centre (NRSC) under Department of Space, National Centre for Medium Range Weather Forecast (NCMWRF) and National Centre for Seismology (NCS), under MoES, *etc*. INCOIS also works in coordination with its sister organisations – National Institute of Ocean Technology (NIOT) and Indian Institute of Tropical Meteorology (IITM) with regard to indigenous development of platforms and high-performance computing facilities.

Figure 1: Linkages with national and international institutions

INCOIS provides services to organisations like Indian Navy, Ports, Oil and Natural Gas Companies, India Meteorological Department, Universities and research organisations. INCOIS represents the nation at various international agencies/fora[2] in the field of operational oceanography.

[2] ***SIBER - Sustained Indian Ocean Biochemistry and Ecosystem Research; IOGOOS – Indian Ocean Global Ocean Observing System; ARGO Program; Global Drifter Program.***

1.3 Organisational Setup

INCOIS is headed by Director and has three major Scientific Groups, headed by Group Directors. Each Group has two Divisions, each headed by a Division Head. In addition, there are two Divisions, one to support the programme, planning, coordination and capacity building and another to render administrative support for the functioning of the organisation. These two Divisions report directly to the Director.

1.4 Finance

1.4.1 Core grant

INCOIS receives grant-in-aid from MoES for carrying out its core activities (Operation and Maintenance of INCOIS). In addition, it also receives grants (earmarked funds) towards IT & E-Governance, construction activities and other specific activities (other than projects). The approved budget, actual funds received, expenditure and closing balance during the years 2017-18 to 2021-22 are given below.

Table 1: Details of core grant (Operation and Maintenance) for the period 2017-18 to 2021-22

(₹ in crore)

Year	Approved Budget	Opening Balance	Actual funds received	Expenditure	Closing Balance
2017-18	31.55	5.86	23.17	26.25	2.78
2018-19	35.92	2.78	25.00	25.90	1.88
2019-20	28.00	1.88	21.80	24.11	-0.43
2020-21	26.50	-0.43	22.60	23.84	-1.67
2021-22	24.50	-1.67	22.78	21.11	0.00
Total	**146.47**		**115.35**	**121.21**	

Table 2: Details of funds received for other earmarked activities[3] for the period 2017-18 to 2021-22

(₹ in crore)

Year	Approved Budget	Opening Balance	Actual funds received	Expenditure	Closing Balance
2017-18	5.71	3.17	2.00	1.54	3.63
2018-19	0.45	3.63	0.00	7.88	-4.25
2019-20	5.58	-4.25	4.80	0.16	0.39
2020-21	0.54	0.39	0.00	0.00	0.39
2021-22	0.54	0.39	0.00	0.07	0.32
Total	**12.82**		**6.80**	**9.65**	

[3] *IT & E-Governance - Development and implementation of content managed website of the Ministry, Construction of New Building (Phase II), Celebration of 50th Anniversary of International Indian Ocean Expedition (IIOE2).*

1.4.2 Grants received under projects

Apart from the above-mentioned grants, INCOIS receives funds separately from MoES for execution of specific research projects to fulfil its mandate. During the period 2017-18 to 2021-22, INCOIS executed 11 projects. The details of approved budget, funds received and expenditure incurred under these projects during the aforementioned period are given in the following table.

Table 3: Details of projects carried out by INCOIS during 2017-18 to 2021-22

(₹ in crore)

Sl. No.	Name of the Project	Budget	Opening Balance	Released	Expenditure	Closing Balance
1	Ocean Advisory and Information Services, Computational Infrastructure and Communication System (OASIS)	179.58	-2.68	98.53	91.21	4.64
2	Ocean Observation Networks (OON)	159.88	-4.81	65.43	56.10	4.52
3	Ocean-Modelling, Data Assimilation and Process Specific Observations (O-MASCOT)	31.48	2.00	13.78	15.13	0.65
4	Multi-hazard Vulnerability Mapping for the Indian Coast	16.08	14.36	16.78	31.14	0
5	Coastal Monitoring by INCOIS	81.00	1.30	17.27	16.39	2.18
6	International Training Centre for Operational Oceanography (ITCO Ocean)	113.08	4.82	45.81	50.63	0
7	Monsoon Mission Phase-I & II	0.30	7.75	6.34	14.09	0
8	Establishment of VSAT Terrestrial Link to Seismic and GPS Network of stations Operated by various National Agencies	2.99	3.39	1.58	4.97	0
9	Deep Ocean Mission (DOM)	25	0	19.53	3.27	16.26
10	Implementation of Prioritised technical capacity development project in Regional Integrated Multi-Hazard Early Warning System for Afro Asian Region	17.34	0.79	10.18	10.94	0.03
11	Characterisation of Seismic Sources in the Peninsular shield	0.00	0.01	0	0.01	0
	Total	**626.73**	**26.93**	**295.23**	**293.88**	**28.28**

1.5 Human Resources

During the period under audit, INCOIS had a sanctioned strength of 71 regular posts covering various categories. In addition, it engaged staff on contract basis for execution of envisaged activities as shown in the tables.

Table 4: Details of regular staff in position

Men in position as on 31st March						
Category	**Sanctioned**	**2018**	**2019**	**2020**	**2021**	**2022**
Scientific	42	42	42	41	41	38
Technical	19	19	18	18	18	19
Administrative	10	10	10	10	10	10
Total	**71**	**71**	**70**	**69**	**69**	**67**

Table 5: Details of Contract Staff and Research Fellows

As on 31 March	Contract Staff		Research Fellows	
	Sanctioned	**Manpower in position**	**Sanctioned**	**Manpower in position**
2018	222	73	31	11
2019		100		11
2020		88		13
2021		79		11
2022		66		8

1.6 Audit Objectives

Audit framed the following four objectives, aligned with the activities of INCOIS.

i. To examine if the Ocean Observation Networks were adequately established and well maintained to ensure uninterrupted and reliable data acquisition;
ii. To examine if the data and computational facilities were sufficient to meet the organisational goals;
iii. To examine if the services rendered by INCOIS resulted in delivering the intended societal benefits; and
iv. To examine the activities of INCOIS in the context of International Collaboration and Cooperation including Sustainable Development Goals (SDGs)

1.7 Audit criteria

The Audit was conducted to evaluate the activities of INCOIS against the following criteria:

i. Expenditure Finance Committee (EFC) proposals and approvals, Administrative Orders and Financial Sanctions;
ii. Minutes of Meetings of the Earth System Science Organisation (ESSO) Governing Council (GC), Research Advisory Committee (RAC), Project Management Council, Project Monitoring Committees (PMC), Independent Peer Review Committee (IRC) and other Monitoring Committees;
iii. Memoranda of Understanding and Agreements, Project specific records including proposals, reports, *etc.*, SDG indicators; and

iv. Delegation of Financial Powers, Orders/Instructions and Notifications issued by MoES and other Departments of the Government to the extent relevant, General Financial Rules, International agreements, guidelines, *etc.*

1.8 Audit Scope and Sampling

Audit covered the activities of INCOIS for the period 2017-2022 and those pertaining to the periods prior to this, to the extent relevant. Activities carried out by other organisations such as NIOT, CMLRE[4] and NIO[5] were also covered in audit in the instances where these institutions were partners in the implementation of the INCOIS projects. During the period 2017-22, INCOIS carried out eleven projects (as given in Table 3), funded by MoES. Out of these, eight projects[6] were selected and examined based on value, quantum of activities undertaken during the review period and materiality. Even though each project had different objectives/mandate, the projects also complemented and supplemented the others.

Apart from examining the economy and efficiency in the implementation of the projects, Audit also examined the quality and timeliness of the services rendered, to assess if these delivered the intended societal benefits; the maintenance of the Observation Network; improvements in Modelling Capabilities; the adequacy of Data and Computational Facilities and communication networks; achievement of International Commitments and SDG including trainings and capacity building.

1.9 Audit Methodology

The objectives, scope and methodology of the Audit were discussed with the INCOIS in an Entry Meeting held in July 2022. Field audit included examination of records at INCOIS and also discussions with the scientists/staff of INCOIS and collection of information from collaborating organisations. The draft report was forwarded to MoES in January 2023 for which response was received in March 2023. Taking cognizance of the replies, the report was revised and again issued in July 2023 and a meeting was also held at INCOIS in September 2023. MoES furnished replies in September 2023. This was followed by an Exit Meeting with the Secretary of the Ministry on 12 December 2023. Based on the discussions held, MoES furnished replies again in December 2023. The report was redrafted and forwarded to the Ministry once again in March 2024. The response of the Ministry to this Draft Report was received in April 2024. Based on the opinion expressed by the Ministry that an international

[4] ***Centre for Marine Living Resources and Ecology.***
[5] ***National Institute of Oceanography, a constituent unit of Council for Scientific and Industrial Research – CSIR.***
[6] ***Sl.No.1 to 8 of Table 3.***

consultant familiar with the nature of work be engaged, C&AG's Office hired an expert working in the relevant field and obtained the inputs. The report was finalised after taking into account, the experts' opinion. The replies and responses received from MoES at various stages have also been taken into consideration while finalising the report.

1.10 Structure of the Report

INCOIS carries out its functions in Project mode. It deploys and maintains ocean observation platforms to collect oceanographic data. Being a national repository of oceanographic data, it stores and manages the data. INCOIS utilises data for development and improvement of models and uses it for operational and research purposes. It provides ocean information and advisory services to a wide spectrum of users from scientific community, government, industry and society. INCOIS also plays an important role in the international fora and has responsibility towards achievement of certain SDG goals. The chapters in the report have been arranged to mirror the above flow of activities executed by INCOIS.

1.11 Acknowledgement

Indian Audit and Accounts Department acknowledges the co-operation of INCOIS and MoES in providing necessary information and records to Audit.

Chapter - II

Management of Projects, Finances and Human Resources

Chapter II: Management of Projects, Finances and Human Resources

2.1 Project Management

INCOIS implemented various projects covering aspects such as deployment and maintenance of Ocean Observation Networks, Modelling, Services, *etc.* Audit findings with regard to the overarching issues in Management of the Projects, Finances and Human Resources available for execution of these projects are discussed in this Chapter. The detailed audit findings related to achievement of the broader objectives of INCOIS under different projects which were impacted by these overarching issues are included in the succeeding chapters.

2.1.1 Delays in approval of projects

Ministry of Finance (MoF), in August 2016, issued revised guidelines for formulation, appraisal and approval of public funded schemes and projects. It was specified that the Scheme/Project cycle would commence with the submission of a Concept Paper/Feasibility Report by the Administrative Ministry/Department, as applicable. The guidelines *inter alia* prescribed the timeframe permissible for each stage of appraisal and approval of Schemes and Projects.

Throughout the XII Plan Period (2012-2017), several significant projects such as Ocean Advisory and Information Services, Computational Infrastructure and Communication Systems (OASIS), Ocean Observation Network (OON), Ocean Modelling Data Assimilation and Process Specific Observations (O-MASCOT) received funding from MoES. An Independent Review Committee (IRC) conducted assessments and recommended (October 2016) the continuation of all these projects beyond March 2017. Consequently, MoES issued Administrative Orders, between July and December 2017, for executing the projects during 2017 to 2020.

Subsequently, in November 2018, MoES issued an administrative order introducing an Umbrella Scheme named "Ocean Services, Modelling, Application, Resources and Technology (O-SMART)" with an allocated budget of ₹1623 crore for three years (2017-20). This umbrella scheme amalgamated several projects executed by various organisations within MoES. Notably, the three major projects, namely Ocean Advisory and Information Services, Computational Infrastructure and Communication Systems, Ocean Observation Network and Ocean Modelling Data Assimilation and Process Specific Observations of INCOIS, were brought under the purview of this umbrella scheme. The table below provides an overview of the status of the issuance of administrative orders for various projects:

Table 6: Details of Administrative Orders issued for projects during 2017-18 to 2019-20

Sl. No.	Name of the project scheme	Duration of the project	Date of issue of Administrative Order	Date of commencement of the project	Time lag in issue of Administrative Order Month/Days
1	O-MASCOT	2017-20	12 July 2017	1 April 2017	3 months 11 days
2	Monsoon Mission PHASE II	2017-20	24 August 2017	1 April 2017	4 months 23 days
3	OASIS	2017-20	01 November 2017	1 April 2017	7 months
4	OON	2017-20	12 December 2017	1 April 2017	8 months 11 days
5	REACHOUT	2017-20	20 June 2018	1 April 2017	14 months 19 days
6	O-SMART	2017-20	12 November 2018	1 April 2017	19 months 11 days
7	COASTAL MONITORING (Under O-SMART)	2017-20	12 November 2018	1 April 2017	19 months 11 days

The table reveals that the administrative orders for all the above projects were issued after project initiation. In four instances, administrative orders were delayed by over six months after project started and Ocean Services, Modelling, Application, Resources and Technology project restructuring occurred more than 19 months into its execution.

Issuing administrative order after project commencement creates uncertainty regarding the continuity of the project that impacts optimal planning which has a cascading effect on the execution of the projects and ultimate achievement of objectives.

2.1.2 Absence of defined deliverables in projects

As per MoF guidelines (May 2016) for projects/schemes executed during the period 2017-20, measurable outcomes were mandated for the medium term i.e. up to 2019-20. Yearly physical outputs had to align with budget projections and the defined measurable outcomes. MoF had also directed all Ministries/Departments to define measurable outcomes, which deal with the quality aspect of schemes and programmes over the relevant medium-term framework, while physical and financial outputs were to be targeted on year-to-year basis in such a manner that it aggregates to achieve the measurable outcomes over the medium-term.

Audit examination revealed that when the administrative orders were originally issued for the projects (Ocean Observation Network, Ocean Advisory and Information Services, Computational Infrastructure and Communication Systems, Ocean Modelling Data Assimilation and Process Specific Observations, *etc.*) for the period 2017-20, specific targets and deliverables under each project (including the targets and deliverables under each sub-component) and the year-wise budget allocated for each component, the manpower, the recurring and non-recurring expenditure, the assets to be procured, *etc.* were clearly defined in each administrative order. When projects were incorporated into Ocean Services, Modelling, Application, Resources and Technology, MoES adjusted their budgets and issued various updates like corrigenda, amendments, revisions and extended the project up to March 2021.

For the period 2021-2026, MoES further reclassified projects, introducing a new group called "Ocean Modelling and Advisory Services (OMAS)" under Ocean Services, Modelling, Application, Resources and Technology. The grouping and extension of projects between 2017-2022 is illustrated in Figure 2.

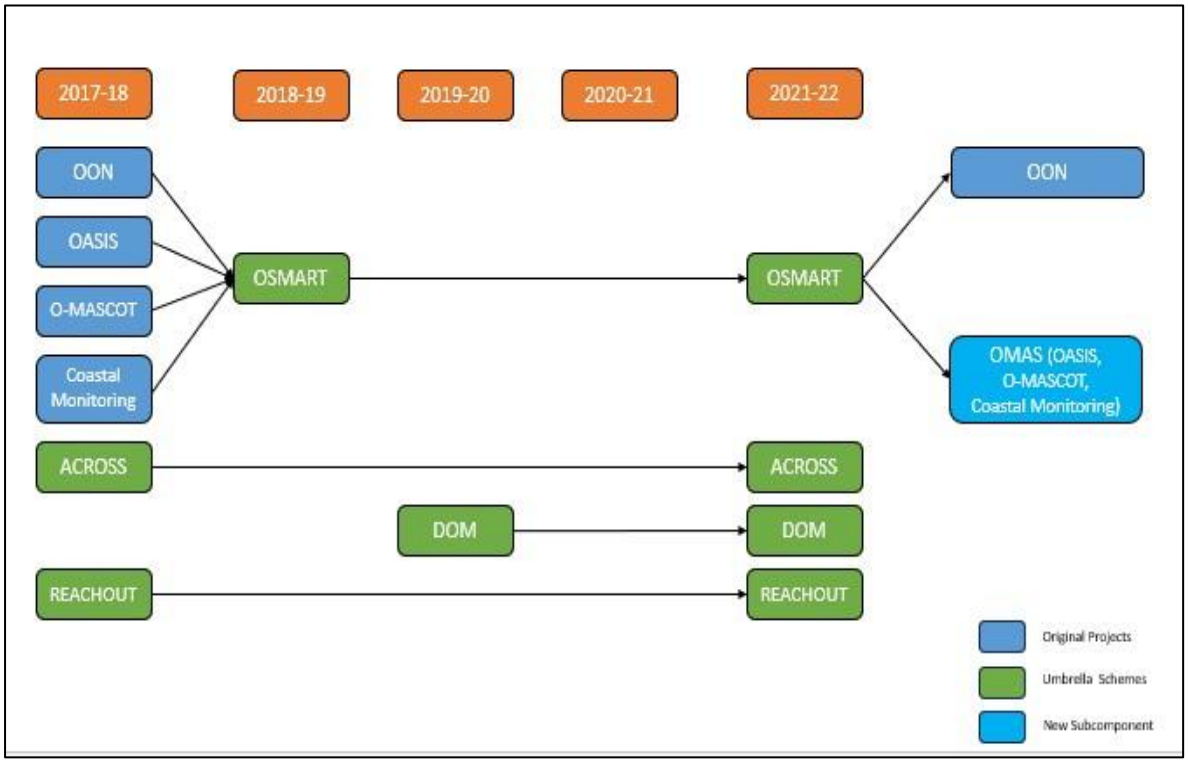

Figure 2: Illustration of Grouping and Extension of Projects between 2017-22 – Picture courtesy - INCOIS

We observed that, during these reorganisations in Ocean Services, Modelling, Application, Resources and Technology and O-MAS, MoES did not specify the project deliverables. It also reduced the budget for various components. MoES/INCOIS however, did not revise the activities/targets commensurate with the reduced budget.

To illustrate - MoES approved the Ocean Modelling Data Assimilation and Process Specific Observations project in July 2017, for the period 2017-20 at a cost of ₹31.80 crore. In November 2018, during the process of re-orientation, Ocean Modelling Data Assimilation and Process Specific Observations project was made a sub-component under the umbrella scheme "Ocean Services, Modelling, Application, Resources and Technology" and the budget revised to ₹19.78 crore for the same period. The project was granted periodical extensions. The final revised budget for Ocean Modelling Data Assimilation and Process Specific Observations for the period 2017-2022 was ₹31.48 crore, against which an amount of ₹13.78 crore (43.77 *per cent* of the revised budget) was released. INCOIS incurred an expenditure of ₹15.13 crore[7] on the project during the above period. Thus, the final budget allotment was

[7] ***Balance was met from opening balance of funds available.***

₹31.48 crore for the period 2017-22, as against the original allotment of ₹31.80 crore for the period 2017-20 itself and the amount released for the entire five-year period was ₹13.78 crore. INCOIS/MoES did not carry out an analysis of the activities proposed for the period and prune the activities and re-define/revise the deliverables commensurate with the reduced budget. Thus, assessment of achievements against the targets was not feasible.

While INCOIS stated (December 2022) that if there are any changes in the activities or budget after issue of administrative orders, such modifications are implemented based on revised administrative orders, MoES stated (September 2023) that the high-level objectives defined in the administrative orders are broken down into distinct activities at the Institute level and monitored by various Committees, based on performance metrics and that readjustment of activities is done at Institute level.

The reply is not acceptable since audit examination found that MoES did not revise the objectives/deliverables based on the revised budget as discussed above. Further, even though audit requisitioned documents defining the activities/deliverables whenever the projects were re-oriented, no such documents were made available, revealing that INCOIS did not carry out any such readjustments. Thus, it is clear that INCOIS/MoES did not re-define/revise the deliverables commensurate with the reduced budget. Such a lack of clearly defined deliverables at the Institute level rendered benchmarking of achievements/shortfalls unfeasible.

2.2 Financial Management – Delayed Release of Funds

Audit analysis revealed that there were instances of short release, delayed release and non-release of funds approved for a particular year. The project-wise funds budgeted, released and expenditure incurred in respect of eight major projects, out of the eleven projects is depicted in the figure given below.

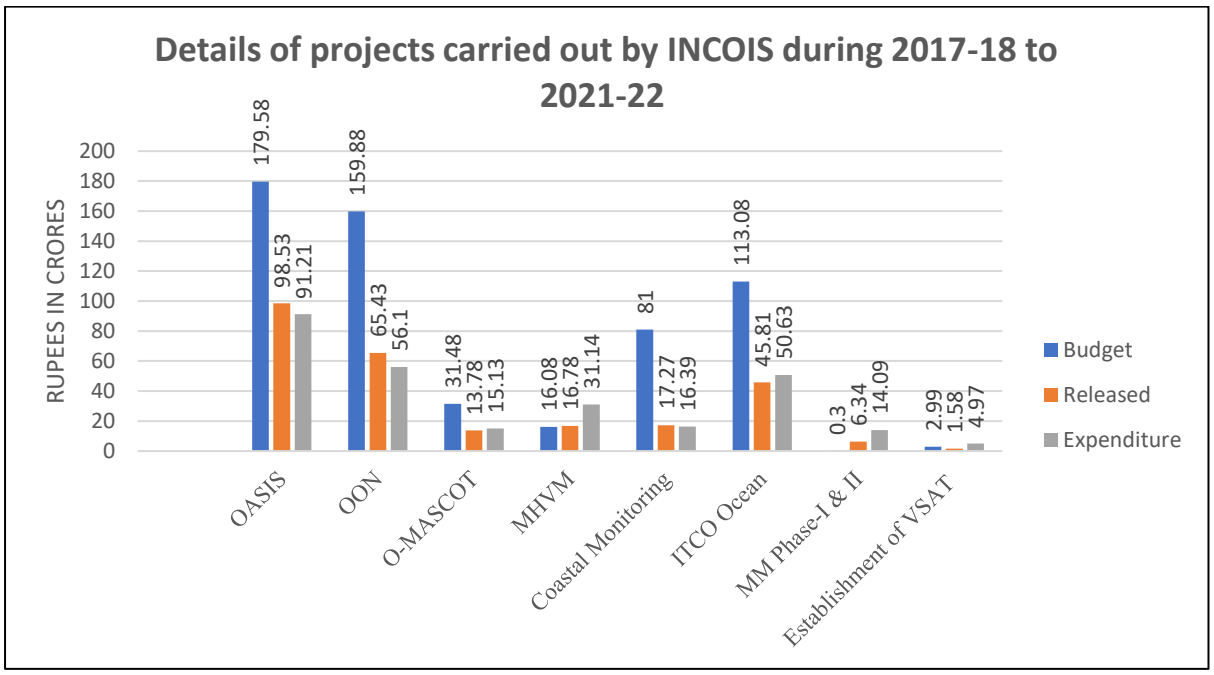

Figure 3: Details of project-wise Budget, Release and Expenditure

The overall release during 2017-2022 was less than 50 *per cent* of the budgeted amount in three out of the eight projects.

MoES stated (September 2023) that the less release during the first year of the cycle i.e., 2017-18, was due to delay in release of administrative orders and during 2020-2021 and 2021-2022, due to the pandemic situation. It also added that the delays in procurement/supply of specialised items with long lead time were also reasons for the delayed release/utilisation of the funds.

Audit noted that in numerous cases, funds were disbursed only after repeated requests from INCOIS. These delays and funding uncertainties adversely affected significant procurements, directly impinging on project execution. As project implementation and goal attainment relies on fund availability, delayed or insufficient fund disbursement had a cascading effect on project execution.

2.3 Human resource management – Manpower position in INCOIS

INCOIS had many national and international commitments[8] in the field of research and development as well as operational oceanography, which require specialised knowledge. INCOIS had a strength of 57 Scientific and Technical personnel to execute its commitments. For the period 2017-20, additional 34 posts (Scientific and Technical) were mentioned in the administrative orders for the following projects, subject to the approval of MoF.

[8] ***National commitments include providing of various societal benefit services and international commitments include, establishment of International Training Centre for Operational Oceanography (ITCOO), functioning of National Oceanographic Data Centre (NODC), Indian Ocean Global Ocean Observing System (IOGOOS) Secretariat, National and Regional Argo Data Centre, etc.***

Table 7: Requirement of posts for projects

Sl. No.	Name of the project	No. of posts
1.	REACHOUT	17
2.	O-SMART	15
3.	ACROSS	02
	Total	**34**

Audit found that these posts were not sanctioned by MoF. INCOIS approached MoES for the creation of permanent posts only twice: once in February 2019 for the posts envisaged under REACHOUT and again in May 2019 for the posts envisaged under Ocean Services, Modelling, Application, Resources and Technology.

The Independent Review Committee (IRC) constituted by MoES (June 2019), which reviewed the activities of INCOIS, emphasised that the available manpower at INCOIS was insufficient for the challenging and field-intensive ocean-related activities. The Independent Review Committee strongly recommended (November 2019) the provision of an adequate number of scientists and supporting staff in regular mode to achieve objectives within stipulated timelines. Despite the Independent Review Committee's specific recommendations, neither INCOIS nor MoES impressed upon MoF the need for additional regular posts. For instance, though 17 regular scientific positions were sanctioned under International Training Centre for Operational Oceanography (ITCOO-under REACHOUT) in December 2012 itself, approval for these posts by MoF is awaited as of December 2023. These posts were crucial for coordinating with international organisations like IODE/IOC[9], SCOR[10], POGO[11], conducting courses, trainee evaluations, *etc.*

Audit examination also indicated that the Governing Council recommended INCOIS in August 2018 to get the regular manpower sanctioned for carrying out the training activities under International Training Centre for Operational Oceanography, a UNESCO Category 2 Centre. In May 2022, Governing Council again highlighted the importance of having a regular workforce for fulfilling high-level international commitments made by the Government of India with organisations such as UNESCO. The Governing Council recommended (May 2022) submitting a revised proposal to MoF to underscore this importance. INCOIS, however, was yet to (December 2023) submit the revised proposal. Consequently, INCOIS manages International Training Centre for Operational Oceanography activities with only one regular scientist and a small number of contractual staff.

[9] ***International Oceanographic Data and Information Exchange/Intergovernmental Oceanographic Commission.***
[10] ***Scientific Community on Oceanic Research.***
[11] ***Partnership for Observation of the Global Ocean.***

Audit also observed that:

(i) In the absence of regular manpower, MoES approved the appointment of staff on contract basis until regular posts were sanctioned by MoF. INCOIS, however, faced challenges in recruiting personnel with the necessary technical knowledge and experience on contract basis and retaining them. Despite the sanctioning of 222 contract positions, INCOIS could engage only 66 to 100 staff (approximately) on contract basis for all projects during the period under review.

(ii) Due to the shortage of both regular and project manpower, INCOIS had to outsource many key activities, including the maintenance of IT infrastructure, ocean observation platforms, satellite ground stations, *etc.*, which were crucial for efficient operations.

Engaging staff on a temporary basis and outsourcing activities resulted in a lack of knowledge consolidation and transfer. INCOIS had to conduct repetitive on-the-job training whenever new personnel joined because they lacked experience in the organisation's work. The turnover of experienced personnel further hindered the consolidation of acquired knowledge thereby, weakening organisational memory.

MoES replied (March 2023) that INCOIS continues to work closely with MoES to provide necessary inputs for seeking approvals for sanction of regular manpower from MoF.

2.4 Conclusion

Project approvals and release of funds were not in consonance with the timelines and were delayed. MoES/INCOIS did not clearly re-define the deliverables when the projects were restructured or when the funding was reduced. Due to this, the projects were not amenable to efficient monitoring. INCOIS had to execute the projects with sub-optimal financial and human resources.

2.5 Recommendations

- ***MoES may ensure timely issue of project approvals and sanctions providing scope for planning and execution of projects in a time bound manner.***
- ***MoES may clearly define the revised targets commensurate with the resources during reformulation to enable assessment of achievements against the targets.***
- ***MoES may ensure deploying sufficient regular manpower with technical expertise so that the activities of INCOIS are not hampered.***

Chapter - III

Ocean Observation Network – Deployment and Maintenance of Platforms

Chapter III: Ocean Observation Network – Deployment and Maintenance of Platforms

Ocean Observation Systems or Platforms are deployed in the Indian Ocean by INCOIS under various programmes/projects to collect data to meet operational and research needs, including forecasting, model validation and long-term climatological studies. Regular deployment and maintenance of these platforms aids in ensuring availability of sustained time series data of the state of the ocean. Such data is also a prerequisite for monitoring and understanding the impact of Climate Change and sustainable development of the country's Blue Economy. An illustrative list of such platforms deployed and maintained by INCOIS is given below.

Table 8: Illustrative list of Ocean Observation Platforms with description

Name of the Platform	Purpose
Argo Floats	Argo floats are robotic floats that drift below the ocean surface. They take temperature and salinity measurements along the water column (profiles) when they surface
Drifters	Drifters are freely floating drifting buoys deployed in the ocean near the surface or at a particular depth to measure ocean currents, salinity, temperature and other parameters
XBT/XCTD	An Expendable Bathy Thermograph (XBT) is a probe that is dropped from a ship to measure temperature throughout the water column. Expendable Conductivity-Temperature-Depth (XCTD) probe has an additional conductivity sensor
Automatic Weather Stations on ships	Automatic Weather Stations (AWS) installed on the ships are equipped with a suite of sensors to measure atmospheric parameters such as wind speed, direction, air pressure, temperature, relative humidity *etc.*
Coastal Wave Rider Buoys	Wave Rider Buoys are used for measurement of ocean surface wave parameters such as height, direction, *etc.*
Bottom Pressure Recorder	Bottom Pressure Recorders are used to detect sea level changes near to tsunamigenic source regions and consequent propagation of Tsunami waves in the open ocean
Tide Gauges	Tide Gauges are deployed near the coast to acquire tidal data to watch the sea level variations and quantify the size of tsunamis

3.1 Ocean Observation Platforms under the Ocean Observation Network Project

3.1.1 Procurements and deployment of Ocean Observation Platforms under Ocean Observation Network Project

MoES approved the Ocean Observation Network Project, for a three-year period (2017-2020), for a value of ₹108.92 crore in December 2017. The Ocean Observation Network Project was later incorporated into the Ocean Services, Modelling, Application, Resources and Technology Umbrella Scheme in November 2018 and granted extension up to March 2021. This was subsequently continued under Ocean Services, Modelling, Application, Resources and Technology during 2021-2026. The revised budget for the period 2017-2022 was ₹159.88 crore, against which INCOIS received ₹65.43 crore and incurred an expenditure of

₹56.10 crore. A Project Management Council was constituted (December 2017) for monitoring the progress of the project.

During reformulation or extension or while releasing the budget, MoES did not revise the targets and deliverables. Thus, INCOIS took the targets set initially in the Administrative Order (December 2017) as basis for achievement during 2017-2022. The targets set and the gist of achievements are given in the table below.

Table 9: Achievement of targets under Ocean Observation Network Project

Platform	Target (2017-2020)	Achievement (2017-2022)
Argo	Deployment of 50 Argo Floats/per year [33 Argo with Temperature and Salinity sensors (Core floats) and 17 Argo with enhanced biogeochemical (BGC) sensors]	Deployed 76 (40 procured during 2018-19 and 36 procured prior to 2017-18)
Drifters	Deploy 50 indigenously developed drifters/per year with INSAT communication	26 imported drifters deployed; Deployment of Indigenously developed drifters did not take place
XBT/XCTD	Maintain five XBT/XCTD Lines (subject to availability of cargo/passenger ship) Bi-weekly transects along Kochi-Lakshadweep (72 voyages); Monthly transects[12] along Chennai-Port Blair and Port Blair-Kolkata (36 Voyages each); Bi-Monthly transects along Mumbai-Mauritius and Chennai-Singapore transects (18 voyages each)	Executed through National Institute of Oceanography (NIO), Goa by giving sub-project. Conducted - seven voyages along Kochi- Lakshadweep eight voyages along the Chennai-Port Blair; four voyages along Port Blair-Kolkata; two voyages to Mauritius.
Coastal ADCP Moorings	Deploy and maintain ADCP mooring in every 2.5-3 degrees of the Indian coast (~22 mooring)	Executed through NIO, Goa by giving sub-project
Equatorial Current Meter Array	Deploy and maintain 2/3 mooring in the Equatorial Indian Ocean	Executed through NIO, Goa by giving sub-project
Automatic Weather Stations installed on the Ships	Maintain existing 34 ship mounted AWS network and deploy five new AWS. Incorporate pCO_2 sensors in two research vessels (Total 39 AWS and two pCO_2 sensors)	Five new AWS not procured; pCO_2 sensors not procured for incorporation in two research vessels. 34 existing AWS also not maintained adequately as evidenced from the fact that only 10 AWS (30 *per cent*) were working (elaborated in subsequent paragraphs)
Wave Rider Buoys	Maintain existing network of 15 WRBs along the Indian Coast and one WRB at Seychelles. Deploy three new WRB along the coast of India and four in the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia countries. (Total 18 WRB along Indian Coast and five in Regional Integrated Multi-Hazard Early Warning System (RIMES) Countries, including the one in Seychelles)	Procured only five new WRBs as against the target of seven; All five new ones were deployed at existing locations as replacement for old ones along the coast of India; No new additions in Regional Integrated Multi-Hazard Early Warning System Countries. The existing one at Seychelles also stopped functioning in March 2022 (elaborated in subsequent paragraphs)
Bay of Bengal Observatory	Maintain existing mooring in the northern Bay of Bengal with addition of direct covariance flux measurements sensors, ADCP, ASIMET sensors and biogeochemical sensor measurement	Executed by INCOIS
Tsunami Buoys	Service and maintain the existing network of five imported Tsunami Buoy systems with the help of NIOT	Only one STB functioning
Tide Gauges	Upgradation and maintenance of the existing 36 Tide Gauges	Only 30 functioning

[12] ***The path along which data collection is made.***

Audit found that INCOIS lacked a documented strategy to achieve its platform deployment/replacement and maintenance targets within budget and timelines. INCOIS did not prepare a consolidated Project Completion Report, containing the detailed achievements, reasons for shortfalls and variations from the initial plan.

MoES stated (December 2023) that there cannot be systematic deployments with respect to ocean observations (other than moored buoys). Deployments are generally opportunity based and uses voluntary ships of opportunity and accordingly all observational platforms will be deployed based on available ship time.

The reply is not acceptable since the targets in the Administrative Order originated from the proposals submitted by INCOIS itself during 2016-17. Hence, there was every need to have a procurement and deployment strategy (with reference to the quantum and timelines for achievement in a given timeframe), with provisions for mid-course alterations that arise due to extraneous factors (like COVID and other natural calamities which are beyond the control of the organisation). Further, the targets would have principally accounted for all the factors including the ship-time availability. If not, then it reveals an inherent flaw in the target-setting process itself. Such planning and strategy are all the more crucial in view of the imperative need for collection of time-series data through diverse platforms, considering the substantial scientific and societal impact this holds.

Audit findings and analysis of shortfall in achievements under the Ocean Observation Network project are discussed in succeeding paragraphs.

3.1.2 Deployment and Maintenance of Argo Floats - ARGO Programme under Ocean Observation Network

Argo floats drift below the ocean surface at predefined depth, say 2000 m. They record temperature and salinity measurements at specified intervals (profiles) along the water column as they surface and transmit the recorded data to satellites.

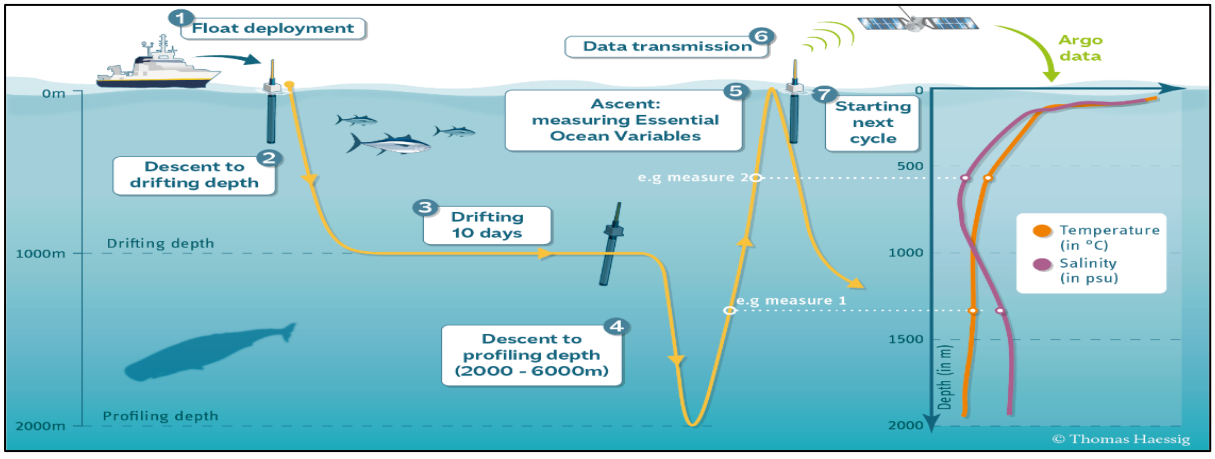

Figure 4: Illustration on working of Argo float

The Argo floats return to the defined depth to drift for the next cycle. They are programmed such that they come to the surface at stipulated intervals (cycles) of five or ten days.

India is a participant in the Argo Programme - an international programme being operated with cooperation among meteorological and oceanographic organisations of many nations, as well as WMO[13] and IOC[14]. The programme entails deploying more than 3000 free-drifting Argo floats by various nations, for measuring temperature and salinity in the upper 2000 m of ocean waters. This continuous monitoring aids in understanding ocean climate patterns, with data promptly shared publicly. INCOIS represents India in the programme and oversees the procurement and deployment of Argo Floats in the Indian Ocean region.

INCOIS initiated Argo float deployments in 2002, deploying 418 floats by March 2017. In March 2017, INCOIS committed to deploy 50 Argo floats each year from 2017 to 2020. MoES also approved deployment of 50 Argo Floats per year in the Administrative Order (December 2017).

Audit observed that as against the above targets, INCOIS deployed only 76 Argo floats during the period 2017-2022 (including 36 procured during the earlier period). Even for the 40 procured during 2017-2022, there were delays of up to 21 months due to challenges in securing competitive bids. Delayed/insufficient fundings also hampered the procurement of further Argo Floats. Despite having an international commitment and project target, INCOIS did not put in place a Deployment Plan (specifying the quantum and timelines). As of December 15, 2022, only 52 floats deployed by INCOIS remained active, including 24 deployed before March 2017 and 28 of the 76 deployed between 2017 and 2022. This number further declined to 35 by March 2023.

Earlier, the Indian Ocean Observing System (IndOOS)[15] brought out a roadmap in December 2019 for sustained observations of the Indian Ocean for 2020-2030. While highlighting the core findings and making actionable recommendations, IndOOS pointed out that the Indian Ocean region required 450 floats north of 40°S, to meet the global Argo design density of one float per 3° x 3°. IndOOS noted (December 2019) that there were persistent gaps in the Central Indian Ocean, Northern Bay of Bengal and Andaman Sea. IndOOS recommended that efforts should be taken to increase coverage in under-sampled regions like the Northern Bay of Bengal and Central Equatorial Indian Ocean.

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[13] ***World Meteorological Organisation.***

[14] ***Intergovernmental Oceanographic Commission/UNESCO.***

[15] ***IndOOS is the sustained observing system for the Indian Ocean Region. It is a network operated and supported by various national agencies and coordinated internationally.***

During the International Argo Steering Team (IAST)[16] Meeting held in March 2022, concerns were raised about the decreasing number of Argo floats in the Indian Ocean Region. The need for deployment planning was also stressed due to low densities in the region. INCOIS, while presenting its Annual Report and Action Plan in the above meeting, committed to deploying 30-40 floats per year from 2021 to 2026 in areas with gaps. Despite the concerns expressed and recommendations made during the above meeting and the commitment made by INCOIS, it did not establish an effective procurement and deployment plan to plug the gaps effectively.

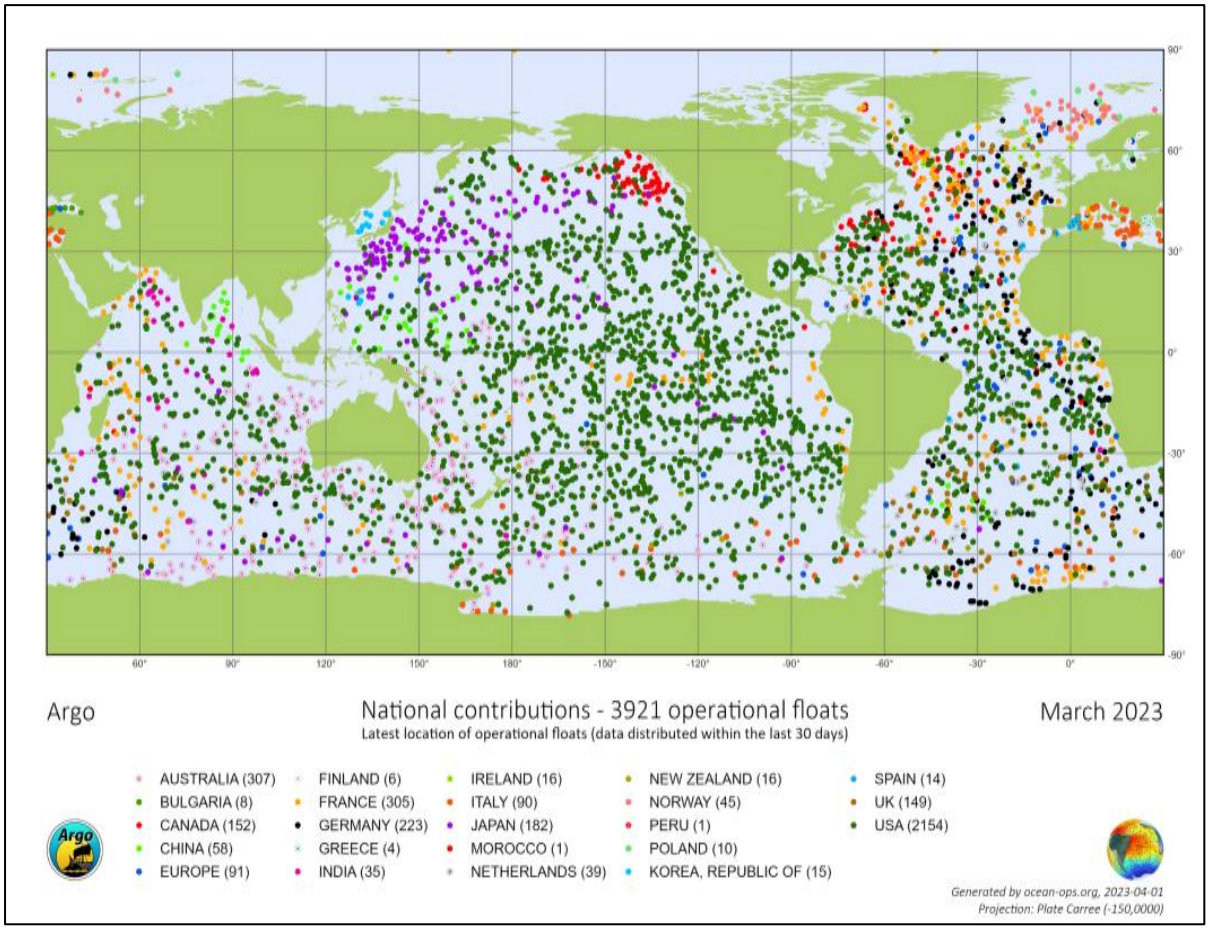

Figure 5: Argo Float Density

Thus, while on one hand procurements/deployments did not happen as per target, the existing ones also stopped functioning in large numbers with the result that number of active Argo floats deployed by INCOIS in the Indian Ocean region reduced drastically[17]. Argo floats distribution picture showed sparse floats in the Indian Ocean Region surrounding the country.

Thus, INCOIS could not contribute to the International Argo Network as contemplated.

MoES stated (September 2023) that the Global Tender procedures and COVID related supply chain issues hampered the procurements and assured that INCOIS has now put in place plans for regular procurement and deployment of 50 Argo floats per year.

[16] ***ARGO programme is governed by International Argo Steering Team. It comprises of representatives of float-providing countries.***
[17] ***138 were functioning at the end of March 2017 and 35 as at the end of March 2023.***

Audit check, however, showed that the plans were apparently not so effective since INCOIS deployed only 35 Argo floats during 2023 and 26 Argo floats during 2024 (until October 2024) and this was less than the target of 50 Argo floats per year.

Further, MoES also added (December 2023) that deployment of Argo floats cannot be planned *a priori* as these floats are dynamically changing their position and the purpose of this programme will be defeated by doing so. It further added that deployment in the Indian Ocean is not the responsibility of India alone but also by all other countries taking part in the International Argo program.

This reply of MoES needs to be viewed in the light of the fact that INCOIS/MoES on behalf of India, committed in 2017, the deployment of 50 numbers of Argo Floats per year as its contribution to the Indian Ocean region and was required to orient its resources towards achievement of the commitment/target, which were also built into specific programmes being implemented by INCOIS.

3.1.3 Deployment of Drifters – Global Drifter Program

The Global Drifter Programme is an international programme that aims to collect Ocean Current, Sea Surface Temperature and Atmospheric Pressure using drifting buoys, that are essential for documenting the large-scale surface current patterns.

India's participation in Global Drifter Programme is facilitated by MoES, which allocates funds to INCOIS for drifter procurement and deployment under the Ocean Observation Network Project. The programme was initially implemented by INCOIS through National Institute of Oceanography, Goa, until March 2017, with a target of deploying 30 drifters annually from 2012 to 2017; later extended up to September 2017 without additional funding.

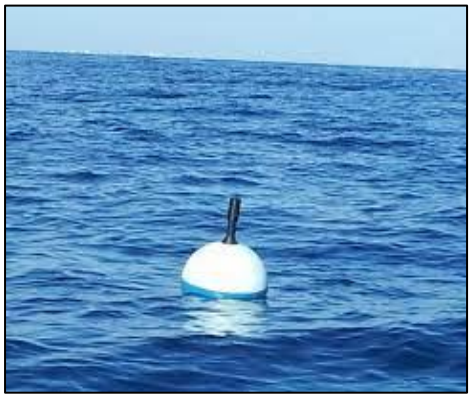

Figure 6: Drifter

During the project execution, National Institute of Oceanography apprised the Project Management Council (January 2016) about the poor performance of imported drifters. The Project Management Council advised against importing drifters from a specific supplier if it failed to replace the failed drifters. Project Management Council again advised (November 2016) to use only indigenous drifters from April 2017 onwards. Earlier, Independent Review Committee also suggested (October 2016) that INCOIS should continue the Drifter Programme with indigenised buoys developed by National Institute of Ocean Technology. MoES set a target in December 2017 for deploying 50 indigenously developed drifters annually with

INSAT Communication during 2017 to 2020. Audit review of the Drifter Programme revealed the following:

i. INCOIS informed the Technical Committee (February 2018) and the Project Management Council (April 2018) that instruments developed by private vendors, to whom the indigenous technology was transferred by National Institute of Ocean Technology, did not perform well.

ii. INCOIS commenced the process of procurement with an indent in September 2017 and decided (February 2018) to import drifters to meet the 2017-2020 target. The procurement process took an inordinately long time. INCOIS resorted to repeated revision of technical specifications and multiple tendering efforts. There were also delays at each step of procurement process. INCOIS placed the order for 30 drifters only in March 2021. INCOIS received 30 drifters in August 2021, out of which it deployed 26 between January and September 2022. However, this fell far short of the target of 50 drifters each year. Even these 30 drifters were imported rather than indigenous ones.

iii. Though INCOIS imported drifters, citing poor performance of indigenously developed ones, the imported drifters also faced performance issues. Many of them did not function for their expected one-year lifespan, with six drifters failing immediately after deployment and seven of them stopped functioning within three months.

MoES stated (March 2023) that INCOIS put the best possible efforts towards procurement and deployment of drifters in the Indian Ocean including the indigenous drifters. MoES added (September 2023) that the supplier initiated the process to replace the six drifters that failed immediately on deployment. MoES further added (December 2023) that globally all the drifters use polar orbiting satellites for transmitting the data. As there was a need for studying diurnal variability[18] and also to utilise Indian satellites, it was proposed to check the possibility of using Geo-Stationary satellite which has resulted in delay in developing the indigenised drifters. Using the Indian Satellites for communicating with indigenised drifters is a unique opportunity which should be appreciated even though there is a delay in realisation of the program.

While appreciating the efforts being made, the response needs to be viewed in light of the fact that technical modalities of the equipment should be an integral part of the planning process before committing to a deliverable. Further, the fact remained that INCOIS could not achieve the drifter procurement/deployment targets set in the Administrative Order (December 2017) neither through indigenous development nor through import.

[18] ***Diurnal variability refers to natural changes that occur over 24-hour period due to earth's rotation.***

3.1.4 Expendable Bathythermograph/Expendable Conductivity-Temperature-Depth probe (XBT/XCTD)

XBT/XCTD are probes that are dropped from a ship to measure temperature throughout the water column and collect time series data required for understanding climate variability. Between 2017 and 2020, INCOIS had the target to maintain five XBT/XCTD lines across various transects[19], as per the Administrative Order of Ocean Observation Network (December 2017). INCOIS entrusted National Institute of Oceanography with this task in February 2018, allocating ₹5.81 crore for the period 2017 till 2020 (later extended to March 2022 without additional funding). INCOIS, however, released only ₹2.22 crore, while National Institute of Oceanography spent ₹2.19 crore during 2017-2022.

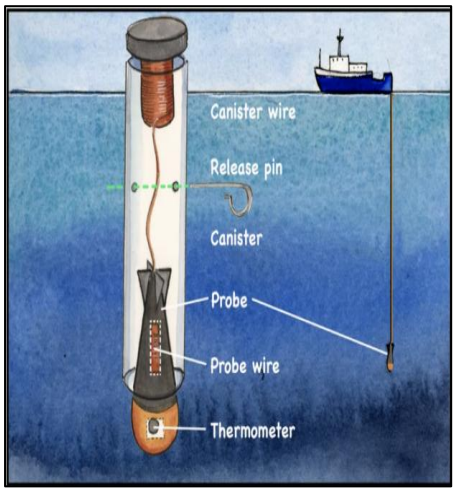

Figure 7: XBT/XCTD

Audit observed that when INCOIS assigned the work to National Institute of Oceanography in 2018, it did not specify targets for the number of voyages per transect and priority areas to be covered within the available budget, in line with the targets contained in the Administrative Order (December 2017). Consequently, there was no effective way to assess project achievements. The targets in the Administrative Order and the achievements by National Institute of Oceanography are tabulated below:

Table 10: XBT voyages- Targets and Achievements

Transect/Line	Target	Achievement
Kochi-Lakshadweep	72 voyages	7 voyages
Chennai-Port Blair	36 voyages	8 voyages
Port Blair – Kolkata	36 voyages	4 voyages
Mumbai- Mauritius	18 voyages	2 voyages
Total	**162 voyages**	**21 voyages**

The above data indicates less than 15 *per cent* overall achievement. Despite being advised by Project Management Council in November 2016, that National Institute of Oceanography should continue Mumbai-Mauritius XBT line as per the international commitment, which is important to understand the equatorial dynamics, National Institute of Oceanography only performed two voyages on this line (target: 18 voyages) resulting in a lack of crucial data for understanding equatorial dynamics.

MoES acknowledged (September 2023) the Audit's findings and confirmed that they have now included specific targets in the new project sanction orders issued to National Institute of

[19] ***Bi-weekly transects along Kochi-Lakshadweep; Monthly transects along Chennai-Port Blair and Port-Blair-Kolkata; Bi-Monthly transects along Mumbai-Mauritius and Chennai-Singapore transect, subject to availability of cargo/passenger ship.***

Oceanography. But later, MoES stated (December 2023) that XBT is implemented through Ships of Opportunity Programme and number of XBT lines are indicative and can only be executed based on the Ships of Opportunity Programs and also approval of Captains of the respective shipping lines.

The reply needs to be viewed in light of the fact that project requirements and deliverables commensurate with forecasted logistics and means of achievement should form part of planning process rather than an evolving afterthought. All the more, while submitting the proposal, National Institute of Oceanography itself had committed that it would collect data along shipping lines and coastal areas regularly.

3.1.5 Automatic Weather Stations installed on Ships

INCOIS installed 35 Automatic Weather Stations on Government-owned ships between March 2009 and September 2014. These Automatic Weather Stations units are equipped with various sensors and INSAT transmitters to collect atmospheric data along the ship's route and transmit the data in real time. This data is used for operational and research purposes, including Ocean State Forecasts and validation/assimilation of various models. The Vessel Sagar Paschimi sunk during the Hud Hud Cyclone in 2014, resulting in the loss of the Automatic Weather Stations onboard. Consequently, INCOIS maintained 34 AWS units.

During the period 2017-2020, INCOIS aimed to expand its network of 34 existing Automatic Weather Stations by adding five new Automatic Weather Stations and incorporating pCO_2 sensors (to measure partial pressure carbon dioxide for measuring ocean acidification[20]) in two research vessels (totalling to 39 Automatic Weather Stations and two pCO_2 sensors). However, INCOIS did not achieve these targets due to funding constraints, resulting in an unchanged Automatic Weather Stations network and the inability to gather crucial pCO_2 data for measuring ocean acidification.

INCOIS attempted to maintain the 34 Automatic Weather Stations by outsourcing Comprehensive Annual Maintenance Contracts, incurring a cost of ₹3.18 crore from 2015-16 to 2021-2022. Despite this expenditure, INCOIS struggled to effectively maintain the Automatic Weather Stations network. Audit examination revealed that only seven out of the 34 Automatic Weather Stations were operational by the end of the Comprehensive Annual Maintenance Contracts period in September 2021, with the others facing technical issues and licence expiration.

Further INCOIS failed to award the Comprehensive Annual Maintenance Contracts for the subsequent period in a time bound manner. Though INCOIS initiated the process in June 2021,

[20] ***One of the indicators under SDG-14 – Life Below Water (dealt in Chapter 6).***

it eventually awarded the contract only in November 2022 after a delay of one and half years. Consequently, there was no Comprehensive Annual Maintenance Contracts from February 2022 to November 2022 and only 30 *per cent* (10 Automatic Weather Stations) were active and transmitting data at the end of October 2022.

MoES stated (September 2023) that though Annual Maintenance Contracts was underway now, several key components of the systems were more than ten years old and became obsolete and attempts would be made to replace them in a phased manner. MoES added (December 2023) that given the harsh conditions existing in ocean and the fact that these Automatic Weather Stations are installed in ships belonging to different organisations, maintaining Automatic Weather Stations network is a herculean task. COVID caused additional disruptions in the availability of ships for maintaining the Automatic Weather Stations. Despite these problems, the network was maintained to the best possible extent within the available resources.

The reply needs to be viewed in light of the fact that only 30 *per cent* of the Automatic Weather Stations were functional and INCOIS did not monitor the performance of the service contractor adequately, to ensure effective functioning of the Automatic Weather Stations network.

3.1.6 Wave Rider Buoys

As part of the Ocean State Forecast Programme, INCOIS deployed Coastal Wave Rider Buoys along the Indian Coast for getting the actual wave measurements and for validation of forecast data. INCOIS had deployed 15 Wave Rider Buoys along the Indian Coast and one Wave Rider Buoy at Seychelles by the end of March 2017. INCOIS planned to expand the Wave Rider Buoy network. Under the Ocean Observation Network program, INCOIS had the target to maintain the existing network and in addition deploy three new Wave Rider Buoys along the Indian Coast and four in Regional Integrated Multi-Hazard Early Warning System countries[21], bringing the total to 18 Wave Rider Buoys along the Indian Coast and five in Regional Integrated Multi-Hazard Early Warning System Countries. INCOIS also planned to ensure that a minimum of two Wave Rider Buoys were deployed along each Indian Coastal State (including the Island territories) for enhancing the quality of the forecasting system.

Figure 8: Wave Rider Buoy

Audit examination, however, revealed the following:

[21] ***RIMES - Regional Integrated Multi-Hazard Early Warning System for Africa and Asia, is an international and intergovernmental institution owned and managed by its member states, for generation of early warning system.***

i. INCOIS managed to procure only five new Wave Rider Buoys between 2017 and 2022, falling short of the target of seven. Even for these five, the procurement process was delayed. INCOIS initiated the purchase process in June 2017 but placed the order after a prolonged delay, in September 2019 only. The first Wave Rider Buoy was received in November 2019. INCOIS conducted the sea trials during December 2019 - January 2020. Subsequently, the remaining four were delivered in June 2020. Deployment took place between August and December 2020, resulting in a three-year delay from the initial indent in June 2017.

ii. INCOIS did not expand the Wave Rider Buoy Network as proposed. It deployed the newly procured five Wave Rider Buoys only as replacement to the old Wave Rider Buoys along the Indian Coast. No new Wave Rider Buoy was deployed in the Regional Integrated Multi-Hazard Early Warning System countries. Additionally, the Wave Rider Buoy in Seychelles also stopped working in March 2022.

iii. Despite collaborating with various organisations and funding sub-projects for Wave Rider Buoy deployment and maintenance, INCOIS could not adequately maintain the Wave Rider Buoys. Only ten Wave Rider Buoys along the Indian Coast were functional as of October 2022. Data logs also revealed frequent data gaps indicating recurrent Wave Rider Buoy failures, which were also corroborated with sub-project reports.

MoES stated (December 2023) that from the experience of operating various ocean observations for the past 20 years, it was observed that data gaps are inevitable in coastal regions due to very rough seas, vandalism and other such issues.

Audit acknowledges the challenges in maintaining the Wave Rider Buoy network. However, the fact remains that INCOIS could neither expand the network nor maintain the existing network, as planned under the program.

As discussed above, there were large variations between the targets and achievements in the deployment and maintenance of various Platforms under the Ocean Observation Network project.

MoES justified (December 2023) that frequent gaps in data from observations in the oceans is inevitable and necessary redundancies are built into the network design to the extent possible so that non-availability of few systems will not impact the overall objectives. This is the case with most ocean observing platforms that have to survive the rigor of rough ocean conditions, vandalism, beaching, ship time availability, remote locations, communication, *etc.*

MoES statement that necessary redundancies are built into the network design is not acceptable, since there was no documented deployment plan, indicating the redundancies in

the network. Further, ocean observing system design should include these factors in the network design stage itself and there should be a proper maintenance plan/redundancy for each instrument, so that the failures due to harsh conditions can be attended to by replacement/maintenance and keep them working without any gap. Further, INCOIS did not prepare a consolidated Project Completion Report showing the overall achievement against the targets and the constraints faced during project execution as well as the future recourses to be taken to mitigate such problems. Further, all the ocean observation platforms are designed to perform in harsh ocean conditions only. Since these platforms are not in confined environs, they are naturally prone to vagaries of sea and are also exposed to risks such as vandalism, beaching, *etc.* But sustained ocean observations from diverse platforms covering different spatio-temporal scales are very much essential for operational and research purposes and thus the targets for deployment and maintenance are set in the Ocean Observation Network Project. These targets are also set considering the potential risks and also long-drawn procedures involved in procurement, ship-time, *etc.*

3.2 Deployment of Ocean Observation Platforms under other Projects

In addition to the procurement of platforms under Ocean Observation Network project, INCOIS also had targets for procuring and deploying various platforms under different Research and Development (R&D) and Mission Mode Projects, such as Ocean Modelling, Monsoon Mission and Coastal Monitoring. The targets for procurement of ocean observation platforms and achievements under these projects are given below. A more comprehensive audit assessment of project activities and the consequences of non-procurement or non-deployment of these platforms on modelling and services is discussed in Chapter V.

3.2.1 Procurement and Deployments under the Ocean Modelling Data Assimilation and Process Specific Observations Project

Table 11: Targets and Achievements for deployment of platforms under Ocean Modelling Data Assimilation and Process Specific Observations Project

Platform	Target	Achievement
Eddy Covariance Flux System (ECFS)	1	Equipment received in January 2021. Measurements carried out during February 2022 and June/July 2023 cruise.
Lowered Acoustic Doppler Current Profiler (LADCP)	2	Equipment received in June 2019. Measurements carried out during October 2019 and June/July 2023 cruise.
Vertical Microstructure Profiler (VMP)	3	Procured only one in December 2018 as against three. Measurements carried out during 2019 and also in June/July 2023.

3.2.2 Procurement and Deployments under Monsoon Mission Project

Under the Monsoon Mission project, INCOIS proposed to procure 14 platforms/equipment during 2012-2017 period to meet the operational targets of the project but could procure only three during the said period. INCOIS procured five more during 2017-2022 and even at the end of March 2022, six of them were not procured. INCOIS reported that procurement could not carried out due to shortage of funds.

Table 12: Equipment proposed under Monsoon Mission Project

Sl.No.	Name of the equipment	Placed purchase order during
1	Seagliders	2013-18
2	Lagrangian Profiling floats	2015-16
3	Radiosonde receiver Vaisala and accessories	2015-16
4	Woods Hole Oceanographic Institution (WHOI) Met-Ocean Surface Flux Mooring	2017-18
5	Microcats sensors	2018-19
6	Nortek Aquadopp Current meter	2018-19
7	ASIMET Sensors	2018-19
8	Sentinel V ADCP	2018-19
9	Nushuttle Towed Vehicle	Not Procured
10	Spray Glider	Not Procured
11	Wire Walker	Not Procured
12	Nortek Aquadep ADCP	Not Procured
13	RBR Maestro 13ch & processing tool	Not Procured
14	RBR Solo and Duo	Not Procured

3.2.3 Procurement and Deployments under Coastal Monitoring Project

Table 13: Targets and Achievements for deployment of platforms under Coastal Monitoring

Platform	Target	Achieved
Moored buoy based Autonomous Coastal Observatory	Six locations (Veraval/Diu, Goa, Kochi, Chennai, Visakhapatnam and Digha)	Procured platforms for deployment at two locations, Kochi and Visakhapatnam in January 2022. Deployed only recently in December 2023.

As could be seen from the above, INCOIS was not successful in procurement and deployment of the platforms as envisaged in the above three projects. This had an impact on the project deliverables since the execution of activities targeted in the projects relied on collection of in-situ data covering various oceanic parameters for scheduled durations.

3.3 Indigenous development of observation platforms

3.3.1 Indigenous Development of Argo floats

The Indian Argo Project commenced during the X Plan period (2002-2007) with a sanction of ₹21.36 crore by MoES. INCOIS, in collaboration with National Institute of Ocean Technology and Indian Institute of Science, Bengaluru, was entrusted with its implementation. National Institute of Ocean Technology was tasked with procuring and deploying 150 Argo floats, including at least 10 indigenous ones. By the end of the project period in 2007, INCOIS had

deployed 133 Argo floats, but the deployment of indigenously developed floats did not occur because National Institute of Ocean Technology was still in the development phase at that time. The project continued in subsequent plan periods.

Audit scrutiny revealed that National Institute of Ocean Technology transferred Argo Float technology to industry in November 2010, with a trial production of four Argo Floats. These four floats had significant issues, with one not functioning at all and the remaining three having lifespans of only three to nine months, far shorter than the expected four-year lifespan of an Argo float. Furthermore, data quality checks were performed on only one of the floats.

Table 14: Performance report in respect of these four floats

	Date of Deployment	Worked up to	Remarks
Argo Float 1	14 May 2013	8 February 2014	Functioned for less than nine months and transmitted 135 profiles. Out of this, data quality of only 94 profiles was found to be good.
Argo Float 2	2 June 2015	28 October 2015	Functioned for less than five months and transmitted 74 profiles. Data quality not checked
Argo Float 3	31 May 2015	-	No data was received from this float
Argo Float 4	2 June 2015	21 August 2015	Functioned for less than three months and transmitted 40 profiles. Data Quality not checked

National Institute of Ocean Technology declared (August 2013) that they had indigenised the technology and transferred it to industry for production of Autonomous Underwater Profiling Drifters, with a capability to go ~ 2000m depth. INCOIS, however, continued to import Argo floats during the XII plan period (2012-2017) and beyond, since they found that these indigenously developed floats did not meet international standards. INCOIS and National Institute of Ocean Technology did not advance the indigenisation efforts. They did not conduct field trials, make necessary improvements, or demonstrate the technology's performance on a production scale. This raises concerns, as National Institute of Ocean Technology declared the technology as developed solely based on the trial production of four Argo floats, without even demonstrating the technology adequately.

After a decade, National Institute of Ocean Technology issued a license for this technology to a company in August 2021, but production had not commenced as of June 2023.

Given that the Argo Project is a long-term international commitment and highly valuable from both operational and research perspectives, INCOIS was required to deploy floats regularly to sustain the network. INCOIS faced challenges even in importing the Argo floats, due to high costs, limited funds and delays in the import process. Thus, there was every requirement of promoting indigenisation efforts.

MoES stated (December 2023) that though National Institute of Ocean Technology transferred the technology to private players, they are not producing Argo Floats due to volume constraints.

Further, the production cost of indigenous float is much higher than imported one and hence there is no progress from private players. MoES added that efforts were on with private players to produce floats in cost efficient manner, so that the possibility of exporting floats to other countries could be explored, thereby increasing the volume for production.

3.3.2 Indigenous development of Drifters

National Institute of Ocean Technology informed the Project Management Council in August 2014 that it was successful in the indigenous development of Drifter buoy (PRADHYU) with INSAT communication and the performance was satisfactory. Independent Review Committee recommended (October 2016) that the Drifter Programme under the Ocean Observation Network project should be continued only with indigenous buoys developed by National Institute of Ocean Technology, since this will give an opportunity to test the indigenously developed technology. The Project Management Council also reiterated (November 2016) that only indigenous drifters should be used from April 2017. MoES, in the Administrative Order (December 2017) specifically approved the deployment of only indigenous drifters.

Audit examination showed that National Institute of Ocean Technology transferred technology to two private vendors during 2017-2018. INCOIS, however, found that the drifters developed by these vendors did not perform well. Thus, it continued to import the drifters.

Subsequently, National Institute of Ocean Technology signed a technology licensing agreement with one company in August 2018 and also transferred the technology to three more companies in March 2021. Despite these transfers, neither National Institute of Ocean Technology nor INCOIS placed orders with these companies for drifters.

One of the companies which acquired the technology, supplied three drifters to INCOIS as part of their Proof of Concept under a No Cost and No Commitment basis, which INCOIS deployed in March 2020. However, performance reports indicated that the three drifters worked for only a short period, falling far short of the expected one-year lifespan for a drifter.

Table 15: Details of deployment/data transmission of indigenous drifters

Drifter No	Period of Deployment/Data transmission details		Remarks
	Start Date	End Date	
DB 33	16 March 2020	30 April 2020	Worked for less than two months.
DB 34	16 March 2020	25 April 2020	Worked for less than two months.
DB 35	16 March 2020	16 May 2020	Worked for two months but data not continuous from 5 April 2020.

MoES replied (December 2023) that private players are producing drifters and INCOIS could procure indigenous drifters for its use.

The reply is to be viewed in the light of the fact that INCOIS placed the first purchase order for ten indigenous drifters only recently in March 2023, while National Institute of Ocean Technology had declared the technology as developed as far back as August 2014.

3.3.3 Indigenous development of Automatic Weather Stations

During the Project Management Council Meeting in August 2014, National Institute of Ocean Technology informed the committee about the ongoing efforts of development of indigenous Automatic Weather Stations. National Institute of Ocean Technology stated (June 2023) that as part of Ocean Observation Network project, it had developed data logger for moored buoy systems which could be used for Automatic Weather Stations also. Audit, however, observed that INCOIS did not procure these data loggers from the industries to which National Institute of Ocean Technology had transferred the technology.

MoES stated (March 2023) that for future procurements, INCOIS would include provisions in the tender documents for vendors to consider using data loggers developed by National Institute of Ocean Technology as part of a turnkey solution.

It is apparent from the above, that while, National Institute of Ocean Technology, on one hand, declared successful development of these indigenous technologies, INCOIS continued to rely on imports for its operational needs. There was a lack of coordination in developing industry and production capabilities, despite investing significant amount of time, money and manpower in this direction. Taking into consideration the priority given by Government of India to promote indigenous production, MoES needed to have encouraged a coordinated approach among its constituent units (National Institute of Ocean Technology and INCOIS) and develop the industry towards standardisation of the indigenous technology and ultimate production to meet the operational needs.

3.4 Conclusion

INCOIS did not have a strategy for procurement, deployment, replacement and maintenance of ocean observation platforms, leading to absence of focused approach in meeting the targets. INCOIS could not deploy and maintain the targeted number of platforms required for sustaining and strengthening the ocean observation network of data collection platforms. This had an impact on the development and improvement of models, which in turn had a bearing on the services rendered. Indigenous development of platforms such as Argo floats and Drifters did not fructify, due to absence of coordinated efforts by INCOIS, National Institute of Ocean Technology and MoES with the industry. This resulted in continued dependence on imports and hindered the achievement of self-reliance in this critical area.

3.5 Recommendations

- ***INCOIS may devise and follow a systematic procurement and deployment plan for ocean observation platforms considering the operational and research needs, international commitments and resources.***
- ***MoES may ensure that organisations under it work in sync and strengthen ties with the industry, for realisation of indigenous development of observational platforms.***

Chapter - IV

Data Management

Chapter IV: Data Management

4.1 INCOIS Data Services

Oceanic data constitutes the fundamental substrate of operational infrastructure of INCOIS. The proficiency and efficacy with which INCOIS delivers its services, as well as the quality and rigor of research conducted by its scientific community, are contingent upon the availability, accessibility and utilisation of high-caliber oceanographic data supported by high-speed computing and data storage infrastructure.

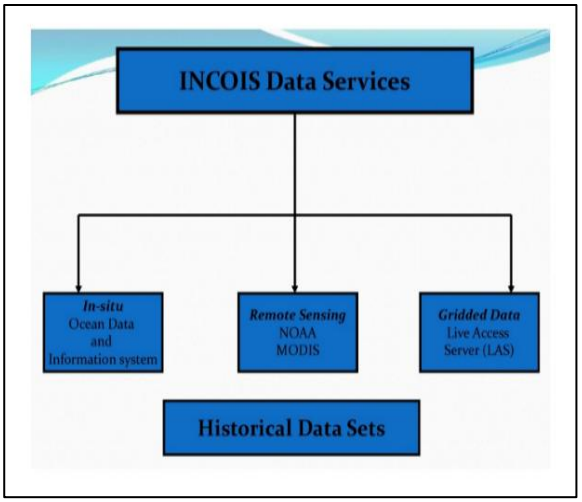

Figure 9: Details of data services offered by INCOIS

The major objectives of INCOIS include generation and dissemination of data along with value added products such as Tsunami Early Warnings, Storm surge, Potential Fishing Zone, Ocean State Forecast, *etc*. These products are unique operational data products. For generating data products and providing ocean information services, INCOIS collects in-situ[22] data through the deployment of ocean observation platforms. Additionally, remote sensing[23] data is acquired from satellites like Oceansat.

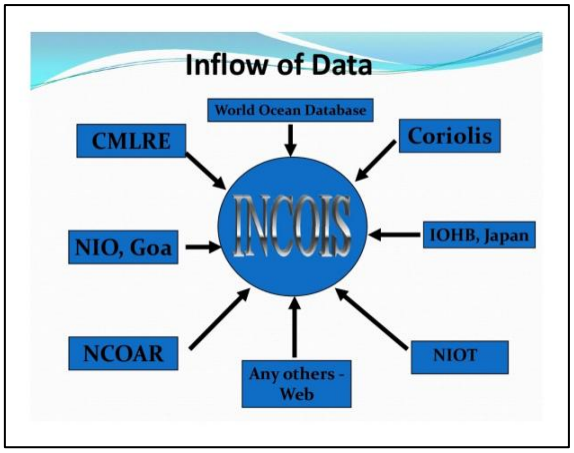

Figure 10: Data Inflow Chart

Moreover, INCOIS collaborates with various national and international entities, such as NRSC[24], ECMWF[25], NCMRWF[26], NOAA[27], *etc.* to procure a diverse range of in-situ and remote sensing datasets. INCOIS has the following roles and responsibilities in the field of Oceanographic Data Management.

[22] ***Data collected through instruments that measure properties directly from the sea.***
[23] ***Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites.***
[24] ***National Remote Sensing Centre.***
[25] ***European Centre for Medium-Range Weather Forecasts.***
[26] ***National Centre for Medium Range Weather Forecasting.***
[27] ***National Oceanic and Atmospheric Administration.***

Table 16: Roles and responsibilities in the field of Oceanographic Data Management

Sl. No.	Responsibility	Description
1.	Central repository for the Oceanographic Data in the Country	Processing, Quality Control, Dissemination and Archival of heterogeneous oceanographic datasets.
2.	National Oceanographic Data Centre	Interaction with national and international organisations, data stewardship, focal point of oceanographic data in the country.
3.	National Argo Data Centre	Process, Quality Control, Archive and Disseminate data pertaining to floats deployed by India.
4.	Regional Argo Data Centre	Perform regional analysis of all the Argo data in the region to assess its consistency. Provide feedback about the results of the regional analysis and possible outliers. Facilitate development of a Reference Database for delayed mode quality control. Prepare and distribute Argo data products on a regular basis.
5.	SIBER[28] Data Centre	To maintain information about SIBER on website. To conduct meetings, Symposia and workshops related to SIBER program.

INCOIS collects, quality-controls and archives the oceanographic data thus obtained. The details of data holdings available (as of July 2022) at INCOIS are given in ***Annexure I*.**

4.2 National Oceanographic Data Centre

INCOIS was recognised as National Oceanographic Data Centre by UNESCO-IOC. Recognition as National Oceanographic Data Centre entails interaction with national and international organisations, stewardship of oceanographic data and acting as focal point of oceanographic data in the country.

4.2.1 National Data Management Plan

As per National Oceanographic Data Centre guidelines 2016, there was a requirement to have a high-level National Data Management Plan for ocean data. A Data Management Plan is a formal document that outlines how to handle data in the course of a research project. The goal of the Data Management Plan is to ensure that data is properly collected, documented, made accessible and archived for future use. INCOIS has not prepared such a Data Management Plan.

MoES replied (March 2023) that INCOIS was in the process of preparing the same.

4.2.2 International Oceanographic Data and Information Exchange Quality Management Framework

[28] ***Sustained Indian Ocean Biogeochemistry and Ecosystem Research – SIBER.***

The International Oceanographic Data and Information Exchange Committee established the International Oceanographic Data and Information Exchange Quality Management Framework in 2013, with the objectives to provide the overall strategy, advice and guidance to National Oceanographic Data Centres to establish organisational Quality Management System for delivery of oceanographic and related data, products and services and apply the necessary capacity development activities to ensure accreditation of National Oceanographic Data Centres according to agreed criteria in order to bring all National Oceanographic Data Centres to a minimum agreed level.

A Quality Management System encompasses National Oceanographic Data Centre's overall administration, including financial resources, personnel and objectives, along with technical documentation. National Oceanographic Data Centres seek accreditation post- Quality Management System establishment and stabilisation. The adherence to agreed standards and the requirements of the International Oceanographic Data Exchange Policy[29] must be met and sustained. The accreditation also requires exhibiting commitment to provide sufficient resources for National Oceanographic Data Centre operations - staff resources, IT resources and sufficient funding, including a budget for attending meetings.

Existing National Oceanographic Data Centres were encouraged to apply for accreditation and meet the prescribed accreditation requirements. National Oceanographic Data Centres that meet the accreditation requirements will be awarded the status of "Accredited International Oceanographic Data and Information Exchange National Oceanographic Data Centre". Thus, INCOIS, as National Oceanographic Data Centre, was required to aspire to set up a Quality Management System that is robust enough to meet International Oceanographic Data and Information Exchange accreditation criteria.

Audit examination, however, revealed that:

i. INCOIS is yet to put in place a Quality Management System.
ii. No separate manpower resources were identified for the National Oceanographic Data Centre operations and the same were being managed only by the available manpower of INCOIS.
iii. No additional funding was provided to INCOIS for this purpose.

MoES replied (December 2023) that INCOIS was in the process of preparation of Quality Management Framework for the data services.

[29] ***International Oceanographic Data Exchange Policy, which was adopted in the IOC Assembly in 2003, promotes free and open access to data, metadata and products and aims to maximise the amount of data exchanged without infringing the rights of data originators.***

4.3 IT resources of INCOIS

The operational efficacy of INCOIS heavily relies on IT resources. INCOIS, however, was yet to put in place a Strategic IT Plan. INCOIS also lacks a structured policy for systematic hardware upgrades in response to technological advancements. Such a plan/policy would also form the basis of the budgeting exercise. Instead of putting in place a strategic IT plan, INCOIS resorted to technology refreshment of the various facilities from time to time on *ad-hoc* basis. For example, though setting up of private cloud to host and manage data was one of the objectives of Ocean Advisory and Information Services, Computational Infrastructure and Communication Systems project during 2017-21, INCOIS has made no progress in this direction. Instead, it has gone in for refurbishment of the Central storage facility installations. During the last five years, INCOIS undertook technology refreshment of Tsunami Early Warning Centre; refreshment of laptops and data migration (in progress); technology refreshment of INCOIS web environment (in progress). However, in the absence of a structured policy or plan governing IT upgrades, it becomes difficult to ascertain the adequacy of these enhancements or the degree to which the objectives set have been realised.

4.4 Data Safety and Security

Indian Computer Emergency Response Team (Cert-In) issued "Information Security Policy for protection of critical information infrastructure" in May 2006, for protection of information assets by Government and critical sector organisations. International Oceanographic Data and Information Exchange Accreditation requirements also enumerated the security requirements to be followed by National Oceanographic Data Centres for the purpose of accreditation.

The National Cyber Security Policy has also prescribed strategies in order to protect information and information infrastructure in cyberspace, build capabilities to prevent and respond to cyber threats, reduce vulnerabilities and minimise damage from cyber incidents. The Policy encourages all organisations to develop information security policies, to promote adoption of global best practices in information security and compliance and thereby enhance cyber security posture; to mandate security audit of critical information infrastructure on a periodic basis; to encourage organisations to designate a member of senior management as Chief Information Security Officer, responsible for cyber security efforts and initiatives; to mandate certification for all security roles right from Chief Information Security Officer/Chief Security Officer to those involved in operation of critical information infrastructure, *etc*. The Policy further underlines the need to identify and classify information infrastructure facilities

and assets at entity level with respect to risk perception, for undertaking commensurate security protection measures.

INCOIS maintains huge volumes of spatio-temporal oceanographic data (refer ***Annexure I***) most of which are non-replicable. This underscores the heightened significance of ensuring the safety and security of its IT assets.

Audit, however, observed following lacunae relating to the safety and security of IT assets of INCOIS.

4.4.1 Business Continuity/Disaster Recovery Plan

INCOIS did not have a written down Business Continuity/Disaster Recovery Plan. Off-site Disaster Recovery facility site for data (except for the Indian Tsunami Early Warning Centre) was also not in place, despite the Governing Council's repeated emphasis on this issue. For data and services other than Indian Tsunami Early Warning Centre, only backup was being taken and maintained locally.

MoES informed (December 2023) that INCOIS had completed the hardware procurement process and that the hardware would be delivered and DR site would be operational very soon.

4.4.2 IT Security Policy

Audit noted that in March 2018, the CERT-In identified vulnerabilities on the INCOIS website, including SQL Injection, Cross-Site Scripting and Directory Listing. As a follow up to this, CERT-In recommended (March 2018), comprehensive security measures, including regular security audits of web applications, web servers and database servers, following significant configuration changes and presenting error messages that reveal little or no useful information to the user (hacker) to prevent attacks; using an application firewall; and implementing proper security measures on INCOIS server, that disallow directory listing and forceful browsing. In January 2019, the National Critical Information Infrastructure Protection Centre also flagged directory listing vulnerabilities. Again in 2022, CERT-In reported three incidents involving suspicious communications from INCOIS-controlled network resources to attacker-controlled Command and Control infrastructures. INCOIS has not put in place IT Security Policy as required under National Cyber Security Policy Guidelines.

Further, as a follow up of Cert-In recommendation in 2018, INCOIS conducted a Security Audit for its website encompassing 28 web applications for the period from November 2018 to December 2019.

Audit examination revealed that several web applications, such as Live Access Server and File Transfer Protocol remained unexamined. Also, out of the four available Database servers, only

one, the Oracle Database, underwent a Security Audit. Thereafter, no audits were conducted for subsequent periods.

The security measures to prevent directory listing and forceful browsing, advised by CERT-In in March 2018, remained pending. INCOIS had also not yet implemented a web application firewall, recommended by CERT-In in March 2018. Similarly, the security enhancement suggestions from National Critical Information Infrastructure Protection Centre in January 2019 had not been addressed.

While INCOIS stated to be adhering to National Information Security Policy and Ministry of Home Affairs (MHA) guidelines, Audit noted that INCOIS was yet to take action towards certifying security roles from Chief Information Security Officer/Chief Security Officer to critical infrastructure personnel. INCOIS mentioned ongoing efforts to establish these roles and incorporate them into their cybersecurity and crisis management plans.

The formulation and implementation of robust IT security measures, in alignment with the National Cyber Security Policy, is imperative for INCOIS due to its handling of sensitive and confidential data, sourced from various agencies including strategic organisations like National Remote Sensing Centre (Department of Space).

MoES stated (September 2023) that it was in the process of getting the Security Policy prepared. Further, MoES assured (December 2023) that INCOIS was implementing the advisories received from regulatory agencies based on the honeypot sensors[30] deployed at INCOIS. It further stated that INCOIS has also initiated process of engaging a technical agency for conducting the security audit and recommendations would be implemented soon.

Given the IT security incidents and the critical nature of the data handled, it is of paramount importance for INCOIS to conduct regular security audits and promptly implement the security measures advised by the IT security agencies, to avoid recurrence of security breach incidents. INCOIS may also put in place the IT Security Policy in a time-bound manner and take effective steps for its prompt implementation.

4.4.3 Physical Access Control

The National Information Security Policy requires that in order to securitise IT infrastructure, organisations must implement robust access control measures, permitting entry solely to authorised personnel. Only approved individuals should possess physical access to areas housing systems or devices with access to sensitive data. Access controls should encompass hardware, network infrastructure, backup media and other components. Facilities should be categorised into zones like Public, Reception, Operation, Security and High Security.

[30] ***Honeypots are decoy systems or servers used in cyber security to attract and trap cyber attackers.***

Additionally, organisations should institute 24/7 surveillance mechanisms, employing technology like security cameras or closed-circuit TV systems.

Audit observed that INCOIS lacked a comprehensive physical access control system for data centers, including critical IT infrastructure areas, with no facility zoning or surveillance. Maintenance of IT peripherals primarily relied on outsourced on-site engineers, except for mission-critical infrastructure managed by their Information and Communication Technology (ICT) Division. Audit also observed that the practice of carrying out antecedent checks on such third-party personnel, like outsourced maintenance staff, was not followed.

MoES stated (September 2023) that Physical Access control for areas hosting critical IT infrastructure is being implemented.

Considering the imperative need to safeguard IT assets, INCOIS needs to put in place adequate measures to secure them in a time-bound manner.

4.5 Data Availability

4.5.1 Non-Receipt of Real-time Data from XBT/XCTD

As an output from sub-project sanctioned to National Institute of Oceanography, INCOIS receives XBT/XCTD data which was to be utilised for assimilation into ocean models. The XBT/XCTD data is also required for verifying the Argo data. The project sanctioned to National Institute of Oceanography, Goa in February 2018 envisaged automated transmission of data to INCOIS. Project Management Council had been suggesting from the first meeting in September 2012 that XBT/XCTD data should be made available in real-time and repeatedly advised INCOIS/National Institute of Oceanography to explore the possibility of online transmission of data directly from the ship immediately after every cast. INCOIS/National Institute of Oceanography has been unable to achieve real-time data transmission and there have been inconsistencies in the timely receipt of data from National Institute of Oceanography voyages. To illustrate, INCOIS received from National Institute of Oceanography, the data collected during the voyages held in July 2017, only in May 2019 after one and half years. The data collected during the voyages in January 2020 and February 2020 had not been received even as of June 2023. Due to this, the real-time XBT/XCTD data was not available for assimilation in models. Further, the data was also not available for verification of Argo data, which was the main purpose of XBT/XCTD data.

MoES stated (December 2023) that the real time data transmission system has been developed and tested in recent cruises.

The fact remains that the real-time data transmission from XBT/XCTD has not been made operational and is still in the development/test phase, even after lapse of over ten years. The availability of real time data would serve to enhance the outcomes of models.

4.6 Data Quality

4.6.1 Quality Control procedure for Automatic Weather Stations data

Quality control of ocean data is paramount in establishing a robust global ocean database, enhancing data reliability and enabling the effective utilisation of oceanic parameters for operational and research purposes. Consequently, periodic development and testing of quality control measures and methodologies is imperative.

INCOIS devised a quality control procedure for Automatic Weather Stations Dataset. The quality of the data received from the platforms (in respect of each parameter) was indicated by a reference number representing its quality as given below:

Table 17: Details of Quality Flags used for data by INCOIS

Sl.	Flag	Meaning	Comment
1	0	No QC	No quality control procedure applied
2	1	Good	All real-time test passed
3	2	Probably Good	Values may be adjusted/probably good data
4	3	Stuck value	Repeating same values
5	4	Bad	Data marked as bad due to spike
6	5	Reserved	Reserved for future use
7	6	Reserved	Reserved for future use
8	7	Soft Range	When values received which is out of climatological ranges
9	8	Hard Range	When values received which is out of sensor ranges
10	9	Missing value	Missing value

INCOIS subjected the real-time data up to October 2018 (containing approximately nine lakh records), to this quality control procedure and released a Technical Report in November 2019 enumerating the results obtained. The report revealed that only seven lakh observations, on an average, passed the quality control, indicating 22 *per cent* unreliability. The report identified limitations, such as the absence of Sea Surface Temperature parameter and also highlighted improvements required in quality control procedure. INCOIS prepared a technical report in March 2022 elaborating the enhanced quality control procedure to increase the user reliability of the data. INCOIS carried out a comparison study between the data checked by the old quality control procedure and the new one. The report of the comparison study (March 2022) revealed that in the revised quality control procedure, the instances of failed records had increased. This report also emphasised the necessity for proper Sea Surface Temperature measurement methods. The report also indicated the ongoing development of quality control procedures for certain other parameters and also efforts towards fully automating the quality control process.

Apparently, a comprehensive quality control procedure for all parameters remained incomplete, posing a risk to data accuracy and reliability. Further, the fact that 22 *per cent* of observations failed the initial quality control, with a higher failure rate in enhanced quality control, warranted an analysis of reasons for failure and taking effective measures for sensor performance improvement.

MoES replied (March 2023) that feedback on the quality control was being shared with the vendors for possible improvements to the sensors. The reply did not address the issue of bringing in robustness to the quality control procedure covering the points brought out in the Technical Report.

4.6.2 Difficulty in uploading of Argo trajectory files [31]

INCOIS had been uploading the Argo profile data and also the Delayed Mode Quality Controlled data to GEOTRACES Data Assembly Centre[32]. However, the trajectory files in new format have not been uploaded since 2018, i.e., for over five years. These trajectory files store positions, cycle timings, surface data and park-phase data of the Argo float, which is required to compute the drift velocities. While attributing this to technical issues and non-availability of manpower, MoES assured that it would be taken up in due course.

4.7 Data Visualisation through Digital Ocean

The Data Centre/Ocean Data and Information System established at INCOIS had been facilitating the users to search for the data availability, visualisation of data (2D plots, graphs) and download the data in different formats. Further, the INCOIS Live Access Server provided the spatially gridded data products, with variety of functionalities for analysis of data. INCOIS felt that these systems offer limited visualisation capabilities to the users and felt a need to integrate heterogeneous and voluminous oceanographic data and provide enhanced visualisation capabilities online for analysis of oceanographic data.

INCOIS proposed development of "Digital Ocean" and setting up of a state-of-the-art "Ocean Data Processing Lab" during the XII Plan period (2012-2017). INCOIS planned to develop the Digital Ocean by 2014-15 at a cost of ₹2.05 crore. INCOIS commenced the process of procurement in June 2015. Subsequently, INCOIS realised the need for enhanced budget of ₹6 crore, which MoES approved in September 2016.

[31] ***Trajectory file contains information on three-dimensional movement of the float. It consists of set of co-ordinates of the floats during its transmissions from the sea surface. To compute the drift velocities, surface trajectory information is required.***

[32] ***GEOTRACES Data Assembly Centre is responsible for the compilation, quality control and secure archiving of data received from all data centers and making this data accessible to larger science community.***

INCOIS issued Purchase Orders (September and November 2016) [33], to an agency, for Design, Development and Deployment of Digital Ocean for a total value of ₹5.99 crore. As per the terms of the Purchase Order, the agency had to complete the work by November 2017. Extensive delays occurred due to technical issues, leading to multiple extension requests by the firm. These were granted by INCOIS. The Digital Ocean system was made operational in January 2020, over two years later than planned. INCOIS disbursed ₹5.15 crore to the firm. The Digital Ocean was inaugurated in December 2020.

Audit examination revealed significant deficiencies in the live Digital Ocean system, as evidenced by correspondence between INCOIS and the contractor during the warranty period. The Digital Ocean was supposed to cater to at least ten concurrent users at any given time for visualisation and at least 50 concurrent users for querying and downloading the data. INCOIS did not test if the Digital Ocean could cater to this requirement. Even the Project Evaluation Team, in the meeting held in December 2019, just before the launch of the Digital Ocean in January 2020, highlighted the need for maintaining the stability of the application with many concurrent users. It provided conditional clearance, indicating that the vendor needs to resolve the pending issues as soon as possible, preferably before the launch. The contractor ceased communication after the warranty period ended in January 2022, leaving INCOIS unable to address the persisting issues. Completion Report for the development of the application was also not available.

The Digital Ocean application encountered glitches during demonstration and did not generate the results to the queries. The application was taking inordinately long time to respond.

INCOIS stated (December 2022) that the system configuration was made as per certain understanding of the data, but over a period, volume of data increased and one reason for such failure could be because of improper load sharing.

Further, MoES replied (December 2023) that the Digital Ocean system was functional and available for use by INCOIS and the scientific community. Digital Ocean was first of its kind application that was conceived, designed and developed entirely within the country as part of Digital India initiative. Considering that this was not an off-the-shelf product and required to be developed from scratch for the first time in the world, the development process did face some technical challenges and associated time delays. The application was operationalised in January 2020 after which COVID 19 impacted the in-person trainings and further development process. MoES further assured that INCOIS was continuously improving the application.

[33] ***Including two years warranty and three years post-warranty Comprehensive Annual Maintenance Contracts support.***

The contention of MoES that the application was the first of its kind in the world is not tenable, since organisations like European Centre and NASA already possess such visualisation applications. Further, the reply of MoES that the Digital Ocean was functional and available for use by INCOIS and scientific community needs to be viewed in the light of the fact that the vendor ceased to respond since January 2022 and INCOIS did not have any alternate arrangement in place to resolve the issues. Further, INCOIS/MoES did not make available any documentary evidence to show that all the technical glitches were resolved and that the Digital Ocean developed at a cost of ₹5.15 crore was functional to its intended levels.

4.8 Conclusion

INCOIS, designated as National Oceanographic Data Centre, is still in the process of putting in place a Data Quality Management System and a high-level Data Management Plan. It was yet to seek accreditation from International Oceanographic Data and Information Exchange. INCOIS did not have in place a documented Business Continuity and Disaster Recovery plan. INCOIS did not maintain off-site Disaster Recovery site for the data. Despite security incidents and alerts, INCOIS had not implemented data safety and security measures as recommended by information security agencies. Quality Control for the data received needed improvement. The Digital Ocean application, developed at a cost of ₹5.15 crore faced functionality issues, that impacted its performance.

4.9 Recommendations

- ***INCOIS may implement adequate data safety and security measures; develop and implement the Business Continuity and Disaster Recovery Plan; establish and maintain off-site Disaster Recovery site for all applications.***
- ***INCOIS may document and follow the Data Quality Management System and Data Management Plan.***
- ***INCOIS may put in place the IT Security Policy in a time-bound manner and take effective steps for its prompt implementation.***

Chapter - V

Modeling, Forecast and Advisory Services

Chapter V: Modelling, Forecast and Advisory Services

INCOIS has the mission to provide advisory services to society, industry, Government and scientific community through sustained ocean observations and constant improvements through systematic and focused research in information management and ocean modelling.

Prediction of essential ocean variables holds paramount importance for driving Blue Economy initiatives and for sustainable management of oceans through science-informed policy responses. Two important services carried out by INCOIS in this direction are Ocean State Forecast and Marine Fisheries Advisory Services. These services of INCOIS were aimed at benefitting a wide variety of users, ranging from fishermen to offshore industries. By providing such daily advisories, INCOIS aimed to help seafarers to navigate smoothly and also to help fisherfolk to easily locate areas of abundant fish in the ocean while saving on both fuel and time used to search for the same.

Another important activity of INCOIS is to provide round-the-clock monitoring and warning services for the coastal population on tsunamis, storm surges, high waves, *etc.* For this purpose, it established Indian Tsunami Early Warning Centre.

These forecast and advisory services were carried out by INCOIS under a continuing programme, *viz.*, the Ocean Advisory and Information Services, Computational Infrastructure and Communication Systems.

INCOIS carries out various R&D projects, aimed at generation of ocean models that are useful for providing weather prediction, Ocean State Forecast, Potential Fishing advisories, Tsunami and Storm Surge advisories. During the period 2017-22, INCOIS carried out three R&D projects, *viz.*, Ocean Modelling Data Assimilation and Process Specific Observations, Monsoon Mission and Coastal Monitoring. In-situ data collected from the ocean observation platforms, data from remote sensing satellites and from other external sources along with high performance computational facilities are essential for the R&D projects carried out for development of the models.

The observations of Audit with regard to services rendered by INCOIS and the R&D activities carried out for development/improvement of models in order to provide the services are discussed in this chapter.

5.1 Modelling and Research and Development activities

INCOIS, being the nodal organisation to provide operational oceanographic services, is involved in the numerical modelling of ocean circulation, waves, tsunami and storm-surge as

well as regional coupled ocean-atmosphere models for prediction of track and intensity of natural events (such as tropical cyclones or hurricanes). Figure 11 indicates the value-chain of INCOIS observation and modelling systems.

5.1.1 Ocean Modelling, Data Assimilation and Process Specific Observations

The broad aim of the Ocean Modelling Data Assimilation and Process Specific Observations project was to bring in improvements to the models and data assimilation schemes, which were being used to generate Ocean State Forecast, Potential Fishing Zone and other Advisory

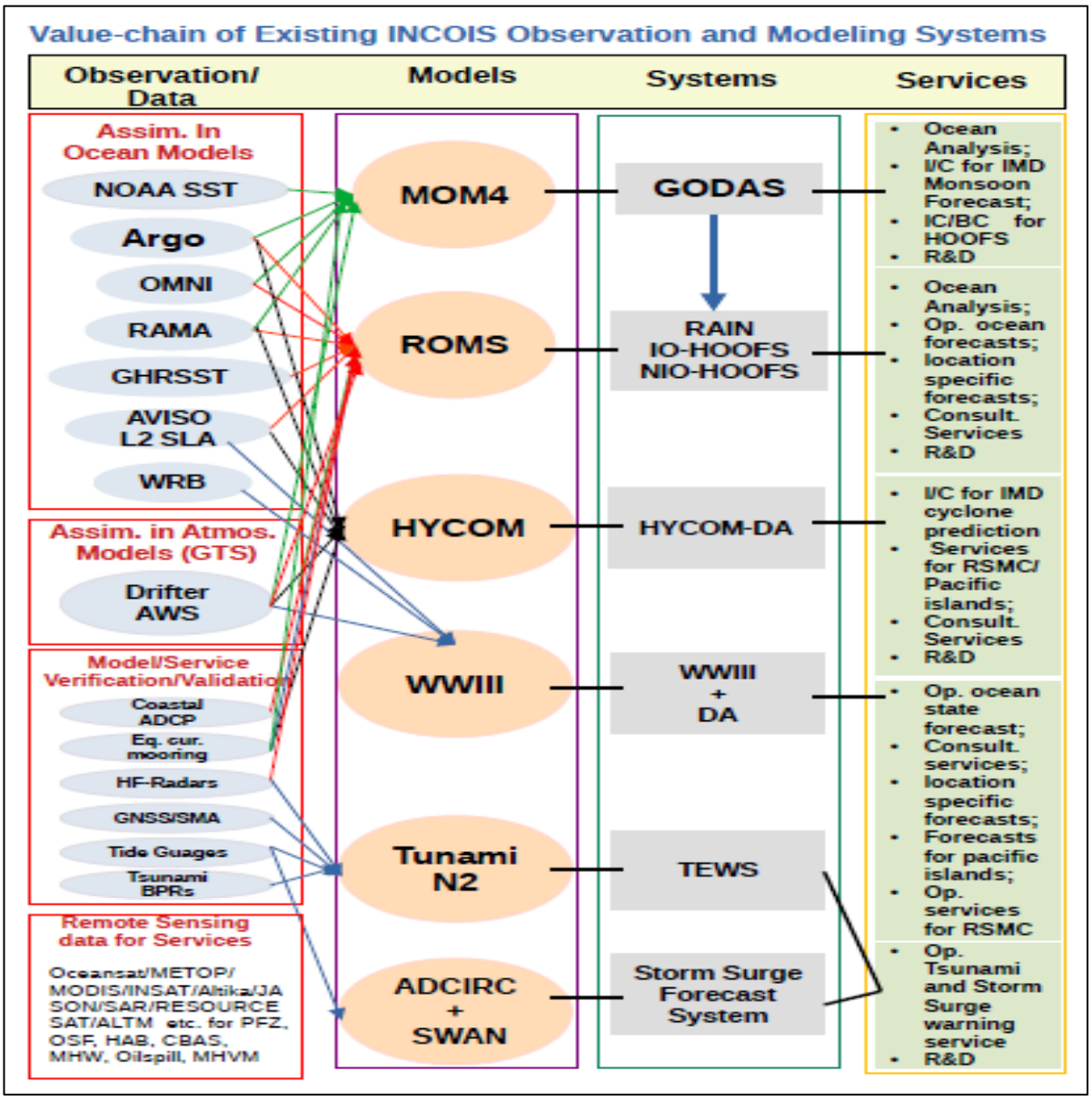

Figure 11: Value Chain Models (Picture Courtesy-INCOIS)

Services. The specific objectives of the project were to set up an integrated basin-wide forecast system; to provide ocean re-analysis (1979 to present) products for the global ocean and analysed Sea Surface Temperatures over the globe on a day-to-day basis to India Meteorological Department for forecasting track and intensity of tropical cyclones. It also

aimed at carrying out focused research and development activities on various aspects of ocean modelling and data assimilation.

During the period 2017-22, INCOIS carried out development/improvement of models such as INCOIS-GODAS[34], HYCOM[35], ROMS[36], Wavewatch III, *etc.* The following table shows some of the models and systems on which INCOIS carried out R&D during 2017-22 and the services which INCOIS provides utilising the data derived from these model setups.

Table 18: Details of models utilised for providing services

Sl.No.	Name of the model	Models utilised for providing these services
1.	INCOIS-GODAS	Provides analysed Sea Surface Temperature to IMD on day-to-day basis for seasonal forecast of monsoon.
2.	HYCOM-HWRF	Provides inputs to IMD for cyclone prediction services.
3.	HYCOM-DA	Provides inputs to IMD for cyclone prediction services.
4.	HOOFS	Utilised by INCOIS for providing Operational Ocean Forecasts, location specific forecasts and for ocean analysis.
5.	ROMS – biogeo	Useful to INCOIS for providing Potential Fishing Zone forecasts.
6.	ADCIRC, SWAN, Wavewatch III	Utilised/useful for providing advisories/forecasts for wave parameters, sea level projections, swell surge/storm surge early warning system, Tsunami advisories.

Audit findings related to setting up of these model configurations/refinements and data assimilation methods are included as part of discussion on the respective services (Paras 5.2 and 5.3). Regarding the overall achievement of objectives of the Ocean Modelling Data Assimilation and Process Specific Observations project, Audit observed that INCOIS encountered the following constraints:

i. In-house High-Performance Computing was very much essential to generate and issue early warnings, forecasts and advisories, in a timely manner, with little or no influence of external factors on the availability of computing resources. The total requirement was projected (2015-16) as 1.5 PF[37] computational power and eight PB[38] storage. Out of this, it was estimated (April 2016) that about 800 TF[39] of computational power was required to provide high resolution forecasts for the Indian coastal waters within four hours. During the occurrence of extreme events such as tsunami, storm surge, cyclones, *etc.,* these operational models are to be run frequently. Thus, INCOIS reported that it was essential that INCOIS possessed in-house core computing facility of at least 800 TF and four PB storage to cater to various operational requirements, though the balance

[34] ***Global Ocean Data Assimilation System.***
[35] ***Hybrid Coordinate Ocean Model.***
[36] ***Regional Ocean Modelling System.***
[37] ***Petaflop – a unit of computing speed equal to one thousand million million (10^{15}) floating-point operations per second.***
[38] ***Petabyte – a unit of information equal to one thousand million million (10^{15}) or, strictly, 2^{50} bytes.***
[39] ***Teraflop – a unit of computing speed equal to one million million (10^{12}) floating-point operations per second.***

requirement of computational power and storage could be located centrally (elsewhere) to meet the requirements of research and development in ocean modelling.

Audit observed that INCOIS did not possess the in-house High-Performance Computing of the above required capacity. Presently, INCOIS possesses in-house High-Performance Computing with 37.5 TF computational power and 500 TB storage and was allocated 100 TF computational power and one PB storage in the Aaditya High-Performance Computing available at Indian Institute of Tropical Meteorology, Pune. The High-Performance Computing capacity available with INCOIS was far below the minimum requirement. Due to this, the development/improvement of models as well as validation of models were hampered.

MoES stated (December 2023) that the procurement process for establishing the in-house High-Performance Computing is under process.

ii. In addition to the regular manpower of about seven scientists, requirement of 10 scientist positions were projected for 2017-20. The additional positions have not been released and the current requirements were being met through the project manpower to the extent possible. Thus, as against the requirement of 10 regular posts, only 6-8 persons, that too engaged through contract, were in position.

iii. INCOIS undertook seven cruises covering 184 days during the period 2017-2019. The cruises planned for 2021 and 2022 could not be undertaken in view of the restrictions during the pandemic. Since the number of cruises to be undertaken was not quantified in the project document, it could not be ascertained if INCOIS carried out the targeted number of cruises. INCOIS reported to the Independent Review Committee in October 2016 that availability of ship-time was a constraint for making process-specific observations. Audit also observed that non-availability of cruises had an impact on the project activities, deployment of the equipment procured under the project, as well as for collection of data.

While agreeing to audit comments, MoES stated (March 2023) that availability of additional manpower, compute power and ship-time would further enhance the modelling capabilities of INCOIS.

5.1.1.1 Implementation of Sub-projects under Ocean Modelling Data Assimilation and Process Specific Observations

INCOIS carried out the activities under the Ocean Modelling Data Assimilation and Process Specific Observations project through in-house activities as well as by granting sub-projects to

various organisations. INCOIS sanctioned nine such sub-projects (six in March 2018, two in August 2018 and one in March 2019).

Audit examination showed that, while MoES sanctioned the Ocean Modelling Data Assimilation and Process Specific Observations project in July 2017 and released the first instalment in August 2017, INCOIS commenced release of the Sanction Orders for the sub-projects only in March 2018, indicating delay in sanction of sub-projects. The sub-projects were originally sanctioned up to March 2020 and were subsequently extended up to March 2021.

INCOIS attributed this time delay in issue of the sanctions for the sub-projects to the administrative procedures involved in award of sub-projects. The fact remains that due to delayed sanction, the sub-projects had only two to three years (March 2018 to March 2021) to complete the project activities. The details of activities undertaken under the sub-projects and the output generated/present status is given in ***Annexure II***.

Audit observed that, out of the nine sub-projects sanctioned (expenditure incurred- ₹3.15 crore), one was closed mid-way and the models developed under four sub-projects were not utilised by INCOIS, in view of its decision to move over to the New Uniform Modelling Framework.

As regards the other four sub-projects, data collected through the sub-projects was received by INCOIS. However, further utilisation of the data by INCOIS was not evident.

MoES stated (December 2023) that there was no lapse from INCOIS in this regard. The Project Monitoring Committee of Ocean Modelling Data Assimilation and Process Specific Observations noted the progress of all the sub-projects and found the outcome of all the projects satisfactory. The Principal Investigator(s) of the sub-projects transferred the project deliverables of their projects to INCOIS in a time-bound manner. The main outcome of the scientific projects is measured in terms of publications and in this case, 98 publications in high impact peer reviewed journals were achieved which ranged from identifying a new process, parametrising it into a model, validating the product and so on. This knowledge over time translates into enhancing not only Indian but also global capabilities.

The reply is not tenable since the sub-projects were sanctioned in a delayed manner, leading to reduced time for executing the activities, aggravated by the pandemic restrictions. Though the generation of 98 publications emanating from these sub-projects is highly commendable, the above reply does not address the audit observation relating to underutilisation of the research results transferred by the grantee organisations to INCOIS. The reply of MoES that main outcome of such scientific projects is measured in terms of publications is also not tenable,

given that sustained data collection and development and improvement of models was an important component of the project.

5.1.1.2 Utilisation of equipment procured at a cost of ₹2.38 crore

Audit examination revealed that three major equipment, *viz.*, Eddy Covariance Flux System, Lowered Acoustic Doppler Current Profiler and Vertical Microstructure Turbulence Profiler were procured under the Ocean Modelling Data Assimilation and Process Specific Observations project. Of these, Eddy Covariance Flux System costing ₹1.05 crore procured in January 2021 was taken onboard Sagar Tara and collected data during February 2022. Lowered Acoustic Doppler Current Profiler costing ₹0.90 crore procured in June 2019, was utilised during cruises in October 2019. Vertical Microstructure Turbulence Profiler costing ₹0.45 crore procured during December 2018, was deployed in 2019.

This shows that the equipment were utilised very minimally during the tenure of the project. The observational data to be acquired by deploying the above equipment was very much essential for data assimilation/validation and to bring in improvements to the models that were under development during the period 2017-21. Thus, poor utilisation of the equipment resulted in the expenditure of ₹2.38 crore not deriving the intended benefits.

MoES stated (November 2023) that measurements using the above three equipment were carried out during the scientific expedition onboard RV Sagar Nidhi in June/July 2023.

Thus, it could be seen that all these activities have been carried out only at the fag end of the project or after the project duration (2017-2021), thereby the objective of collection of time-series ocean data not being achieved during the project period.

As evident from the foregoing audit observations, the Ocean Modelling Data Assimilation and Process Specific Observations project was carried out amidst computing, manpower and ship-time constraints. Further, the procurements and deployments did not materialise as intended, leading to non-collection of data required for development/improvement of models as envisaged.

5.1.2 Monsoon Mission

MoES is engaged in carrying out Research and Development activities to develop and improve the capabilities of weather and climate forecast and hazard related phenomena for societal, economic and environmental benefits. Monsoon Mission was one such project sanctioned for the period 2012-2017 (July 2012), as a multi-institutional and inter-agency research programme with the ultimate aim to improve the monsoon prediction over the country, on all spatial and temporal scales. The programme was implemented by MoES with the support of four units (Indian Institute of Tropical Meteorology, National Centre for Medium Range

Weather Forecasting, IMD and INCOIS). INCOIS had the responsibility to procure and deploy various observational networks, compile and provide the ocean observations to other associate agencies, required for the Monsoon Mission programme for development of various models. In addition, INCOIS also had to engage itself towards development of models.

Table 19: Evolution of Monsoon Mission Project

Sl. No.	Name of the project	Project period	Budget ₹	Objectives for INCOIS
1.	Monsoon Mission I	2012-17 Extended up to March 2019	17.54 crore	To compile and provide the ocean observations required for the monsoon mission program.
2.	Monsoon Mission II (under ACROSS[40] umbrella scheme)	2017-20	0.65 crore	1. Develop high resolution (12 km) global ensemble prediction system with emphasis on prediction of extremes. 2. Develop seamless prediction system using monsoon mission model and initiate working partnership between Indian and foreign institutes.
3.	Monsoon Mission III (ACROSS)	2021-26	10.40 crore	Not specified in Administrative Order.

Despite the fact that the project was approved in July 2012 and INCOIS had a crucial task of procurement and deployment of various platforms for collecting ocean observations, INCOIS was granted non-recurring grant of only ₹20.80 crore that too, in February 2014, after a lapse of 18 months. Further, the amount was later reduced to ₹17.54 crore in February 2015. The project that was initially sanctioned up to March 2018 was later extended till March 2019. Meanwhile, in December 2018, the project was re-formulated and brought under the umbrella scheme "ACROSS" for the period commencing 2017-18 onwards.

5.1.2.1 Procurement of equipment

Under the Monsoon Mission I Project, INCOIS proposed to procure 14 platforms/equipment during 2012-2017 period to meet the operational targets of the project. INCOIS could not carry out these procurements, as committed/proposed. Audit examination revealed that out of the 14 items, six items were not procured at all (Refer Para 3.2.2 of Chapter 3). As regards the eight items procured, four were procured by 2017-18 and four more were procured in 2018-19, much after the completion of the originally scheduled duration.

In particular, the Woods Hole Oceanographic Institution Mooring (Moorings) was a major instrument valuing USD 1.08 million (₹7.52 crore appr.), procured and deployed for collection and studies on various oceanic parameters. These Moorings had a suite of sensors (valuing

[40] ***Atmosphere and Climate Research-Modelling Observing Systems and Services.***

₹4.57 crore[41]), fitted and configured to provide measurements of a wide range of parameters[42] and capable of transmitting the in-situ data in real time. INCOIS commenced the purchase process in January 2015, but finally placed the order only in January 2018, due to delay in release of funds by MoES. INCOIS deployed the Woods Hole Oceanographic Institution Moorings along with sensors in May 2019 and retrieved the same in October 2020. The Direct Covariance Flux System was also a part of the purchase order placed for the Woods Hole Oceanographic Institution Moorings. The data from the Direct Covariance Flux System was sent to Woods Hole Oceanographic Institution for processing in November 2020 and received back in INCOIS in March 2021. Evidently, the entire process of deployment, retrieval and processing of data from the Moorings happened only during the later part of the project duration. The valuable data required for development/improvement of various models could be collected only during the fag end of the period 2017-2022. Thus, there was no scope for using this data for development of models during the project period.

Since the very objective of INCOIS under the Monsoon Mission Project was to compile and provide the ocean observations required for the said programme to the participating institutions, it was imperative that these instruments needed to have been procured and deployed and datasets collected, in a time-bound manner.

Further, INCOIS had an approved budget of only ₹0.65 crore for the period 2017-2020 under the Monsoon Mission and hence it could not get the Sensors and Moorings recalibrated and plan redeployment. After the issue of the administrative order in February 2022, INCOIS took action to send the Sensors for calibration (March 2022). The same have not been received back as on September 2023. The surface buoy and Mooring were also required to be serviced/replaced. But this required huge financial resources and ship-time planning. INCOIS is awaiting the release of funds for redeployment of the Moorings and Sensors procured at a cost of ₹12.09 crore.

Clearly, INCOIS/MoES did not put in place a long-term maintenance plan, considering the equipment life cycle, to meet the recurring maintenance and deployment expenditure, while investing such large sum of money on the procurement of the Woods Hole Oceanographic Institution Moorings.

MoES replied (March 2023) that the Moorings are highly specialised equipment with very limited global suppliers and were procured for the first time in the country. So, the process of

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[41] ***Microcats Sensors – ₹ 2.11 crore, Nortek Aqua Dopp Current Meter – ₹ 0.60 crore, Sentinel Acoustic Doppler Current Profiler – ₹ 0.25 crore, Air-Sea Interaction Meteorology Sensors – ₹ 1.61 crore.***

[42] ***Woods Hole Oceanographic Institution mooring measures the wind, air temperature, humidity, solar radiation (sunlight), infrared radiation, barometric pressure, precipitation, ocean temperature, ocean salinity and ocean currents using satellite communications in an hourly or four –hourly basis.***

finding the right vendors and contractual mechanisms for procurement were time consuming. It added that the Mooring was undergoing refurbishment and it was planned that the next deployment would be made in the Arabian Sea. The data collected was being processed for publications and enhancement of covariance fluxes to be used in the models. MoES stated (December 2023) that the Mooring is a unique buoy deployed for the very first time in the Indian Ocean and it has successfully measured direct covariance fluxes[43] and a multitude of other met-ocean-parameters over a period of 18 months in the Bay of Bengal. Despite the severe restrictions posed by COVID, INCOIS team retrieved the buoy and the data retrieved is being analysed. This itself is considered a huge achievement by the entire global oceanographic community. MoES added that Woods Hole Oceanographic Institution is not a commercial vendor and the buoy is not a commercially off the shelf product. Hence, there are bound to be some delays in designing and building such a complex system in collaborative mode between two scientific institutions. This buoy is primarily for understanding the scientific processes and the unavoidable delays in procurement or refurbishment have no direct impact on the operational services of INCOIS.

Although commendable efforts were exerted by INCOIS in procuring, deploying and retrieving the Mooring, it is vital to underscore the importance of devising a long-term maintenance and deployment strategy, considering the huge investment made, as well as the difficulties in designing and building of the system. The very unique nature of such equipment and investment required warranted a sustained plan, rather than treating its deployment as a one-time achievement. Further, the claim of MoES that the buoy was primarily for understanding the scientific processes and the delays in procurement had no direct impact on the operational services of INCOIS is also not acceptable, since the Monsoon Mission Project itself was targeted towards improving the operational monsoon forecast skills.

The impact of the above delays on the achievement of the project objectives are detailed below:

5.1.2.2 Achievement of Objectives

During the XII Plan period (2012-17), INCOIS had set up the INCOIS- Global Ocean Data Assimilation System model and has been providing ocean analysis from this model to provide inputs to ocean-atmosphere coupled models for the seasonal and extended range forecast of monsoon.

During the period 2017-20, INCOIS, along with Indian Institute of Tropical Meteorology, National Centre for Medium Range Weather Forecasting and IMD, was responsible for the

[43] ***Covariance flux in the ocean is a technique that measures the change of momentum and buoyancy between the air and the ocean. It is also known as the eddy covariance technique.***

sub-scheme, Monsoon Mission II, including High Resolution (12 km) global ensemble forecast system. An amount of ₹107.25 crore was earmarked for Monsoon Mission II, out of which ₹0.65 crore was allocated to INCOIS. Development and running of high-resolution models for giving forecasts in all temporal and spatial scales, with particular emphasis on monsoon research, was one of the major objective of the project.

INCOIS, on its part, was required to carry out enhancement of model resolution and data assimilation technique, for improving forecasts. For this purpose, INCOIS was working on an improved model setup with a more sophisticated assimilation method, *viz.*, INCOIS Global Ocean Analysis. This model, however, was not yet ready for operationalisation.

Other activities carried out by INCOIS during this period to develop/improve the models with different assimilation techniques and varied resolutions also did not yield good results and hence were discontinued. Thus, by the end of March 2022, INCOIS could not achieve the target of carrying out enhancement of model resolution and data assimilation techniques for improving forecasts.

5.1.3 Coastal Monitoring Programme

The Indian coastal waters did not have reliable time series data to interpret and quantify the changes that might occur due to the anthropogenic activities. During the XII Plan period, INCOIS carried out the Coastal Monitoring activities under the Project titled "Satellite Coastal and Oceanographic Research" program. It was a continuing project from previous plan periods. The primary focus of this project was on in-situ data collection and providing ocean colour satellite data products to users in near real time. This was carried out in collaboration with various R&D Institutes. Under the project, in-situ data collection was carried out at 12 transects along the Indian coast.

Subsequently, INCOIS proposed to carry out the project for the period 2017-24, as a new programme named "Marine Observation System Along Indian Coast". This programme aimed at establishing automated and manual observing systems in the Indian coastal waters to continuously monitor all aspects of coastal waters and to set up models to forecast physical, chemical and bio-geochemical changes in the coastal waters around India, on time scales varying from few hours to few days. Proposal for approval of Standing Finance Committee was submitted in August 2016. The Secretary, MoES, in the Review Meeting held in October 2017, indicated that the project should be undertaken on priority basis, as it was recommended by Group of Secretaries. Secretary, MoES, again reiterated (April 2018), that the programme should be considered as approved and all activities pertaining to the project should be commenced immediately, though Cabinet approval was pending.

Despite the urgency shown, the project was sanctioned only in November 2018, that too, not as Marine Observation System Along Indian Coast, but as "Coastal Monitoring", as a component under the umbrella scheme Ocean—Services, Modelling, Application, Resources and Technology for the period 2017-2020. The project duration was subsequently extended for the period up to March 2021. It is continued as "Coastal Research" under Ocean—Services, Modelling, Application, Resources and Technology during the period 2021-26.

Under the Coastal Monitoring project, INCOIS was required to establish long-term time series of water quality parameters and met-ocean measurements data through automated observatories for the understanding of coastal oceanic processes and establish coastal water quality monitoring and forecast system. The long-term data collected under this project, would help to assess the impact of climate change/anthropogenic activities on the coastal water quality.

INCOIS planned to execute the project in two components. The first component aimed to establish six[44] Moored buoy based Automated Coastal Observatories, housing multiple sensors[45] along the Indian coast for collection of various parameters. INCOIS planned to get the sensor data validated by carrying out in-situ sampling in association with academic/research institutes. The second component was forecasting the water quality parameters using high resolution location specific coastal models. Data generated through the sampling was planned to be used for validation and assimilation of the models so developed, to generate better water quality forecasts for coastal and estuarine waters.

Among the six locations, INCOIS planned to establish Automated Observatories at Kochi and Vishakhapatnam coast first. Each Observatory was planned to have real-time data transmission facility to help monitor the water quality round the clock. Budget of ₹25 crore was approved for the Coastal Monitoring component to be carried out by INCOIS and the entire budget was earmarked for the year 2019-20. First instalment of funds amounting to ₹17.28 crore was released in May 2019. Out of this, ₹15 crore was for procurement of Autonomous Coastal Observatories (buoy, sensor, communication, *etc.*).

While INCOIS received the funds in May 2019, it did not issue the Expression of Interest for procurement of the Autonomous Coastal Observatories until November 2019. Even after release of Expression of Interest, INCOIS took predominantly long time to publish the tender (August 2020) and placement of Purchase Order (July 2021) for a value of ₹14.74 crore**.** The Coastal Observatories were supplied in January 2022.

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[44] ***Okha, Goa/Karwar, Kochi, Chennai, Vishakapatnam and Digha.***

[45] ***For measuring Meteorological parameters (wind speed and direction, air temperature and pressure, relative humidity, rainfall, solar radiation); physical and water quality (temperature, salinity, dissolved oxygen, nutrients, chlorophyll, turbidity, pH), etc.***

INCOIS stated (December 2022) that the testing and acceptance was delayed due to the logistics involved, rough sea conditions and pandemic.

MoES stated (September 2023) that only two coastal monitoring buoys were decided to be established as per the new Expenditure Finance Committees. MoES further stated (December 2023) that such buoys are first of their kind in the world and needed to be specifically designed and custom built which led to some delays and that the coastal buoys were now deployed.

The reply of INCOIS/MoES is not acceptable, due to the fact that delays that occurred prior to pandemic period showed improper planning. The project was approved only in November 2018 despite the proposal being submitted in 2016. INCOIS also did not prepare any schedule for deployment of the buoys.

Further, INCOIS originally had the target of deploying six coastal monitoring buoys and apparently, the targets were brought down in the subsequent Expenditure Finance Committee, in alignment with the actual achievements.

Again, INCOIS could not deploy even the two out of the targeted six Autonomous Coastal Monitoring Buoys within the envisaged timelines. The buoys procured at a cost of ₹14.74 crore have been deployed only very recently in December 2023. Thus, collection of long-term data using the Coastal Observatories, which was expected to help assess the impact of climate change/anthropogenic activities on the coastal water quality and also validation of models, could not even commence as at the end of the project duration.

5.1.3.1 Sub-projects under Coastal Monitoring

INCOIS sanctioned six sub-projects for collection of parameters and validation of model output data. Audit observed that INCOIS sanctioned these sub-projects only in March 2020, though Ocean—Services, Modelling, Application, Resources and Technology project was approved as early as in November 2018. By the time INCOIS released the sub-projects, the pandemic period started. All the sub-projects have been closed as of March 2022. The details of the sub-projects and their status is appended as ***Annexure III***.

Audit observed from the closure reports of the sub-projects, that except in case of the sub-project handled by CSMCRI[46], Bhavnagar, activities other than time series data collection have not been carried out/completed. The shortfalls in the desired targets were mainly due to lack of sufficient data collection, which was attributed to restrictions imposed due to pandemic.

The details of sampling carried out by the five participating institutions[47] for the period April 2020 to March 2022 is given in ***Annexure IV***. Out of the five participating institutions,

[46] ***Central Salt and Marine and Chemical Research Institute, Bhavnagar - an autonomous body under Council for Scientific and Industrial Research (CSIR).***

[47] ***Out of six sub-projects, under one sub-project granted to University of Calcutta, no activities were carried out and the amount released was refunded.***

for one institution, the data collection was seasonal. The remaining four institutions had to carry out sampling data collection for a pre-defined number of stations for 24 months (April 2020 to March 2022).

Audit examination revealed that sample collection was not carried out for all the pre-defined number of stations for the entire 24 month duration. It was seen that in respect of National Institute of Oceanography, Goa, samples were collected for all stations only during 10 out of the 24 months targeted, indicating less than 50 *per cent* achievement. For National Institute of Oceanography, Kochi, the samples were collected for all stations only during one out of the 24 months targeted, indicating non-achievement of the project objectives. The participating institutions cited lack of funds as the reason for partial achievement.

INCOIS stated (December 2022) that funds for sub-projects have been released as and when sanctions were received from the MoES, as per the recommendations of Project Review Monitoring Committee and based on the periodic review of the progress. INCOIS added that despite the pandemic restrictions, the participating organisations carried out the collections.

MoES stated (September 2023) that data collection projects are continuing at Kochi and Visakhapatnam and coastal model has been set up for Kochi. It further stated (December 2023) that while the data collection from some of the projects was impacted due to the peak time of COVID 19 pandemic, the data is being used for model validation and testing.

The reply of INCOIS is not acceptable, since the funds were not released by INCOIS for the sub-projects in a timely manner. Further, the funds released was only 38 *per cent* of the funds sanctioned for the five institutions and the expenditure incurred by the five participating institutions constituted only 52 *per cent* of the funds released. Also, the fact remained that the data collection and setting up of models could not be effectively carried out during the tenure of the project.

Table 20: Details of Funds Sanctioned, Funds Released and Expenditure Incurred for Sub-Projects During the Period 2017-18 To 2021-22

Sl no.	Name of the Institution	Amount Sanctioned (₹)	Funds Released (₹)	Expenditure Incurred (₹)	Balance (₹)	Percentage of Fund released over Amount Sanctioned	Percentage of Expenditure incurred over Funds released
1	NIO, RC Goa	8161000	2981476	1735960	1245516	37%	58%
2	CSMCRI, Bhavnagar	8161000	2647511	1219760	1427751	32%	46%
3	NIO, RC Kochi	8161000	2928995	1534106	1394889	36%	52%

Sl no.	Name of the Institution	Amount Sanctioned (₹)	Funds Released (₹)	Expenditure Incurred (₹)	Balance (₹)	Percentage of Fund released over Amount Sanctioned	Percentage of Expenditure incurred over Funds released
4	NIO, RC, Vizag	7408000	2286000	1036752	1249248	31%	45%
5	XIM University, Harirajpur, Odisha	17931000	8114048	4277750	3836298	45%	53%
	Total	**49822000**	**18958030**	**9804328**	**9153702**	**38%**	**52%**

5.2 Forecast and Advisory Services

5.2.1 Ocean State Forecast

With the Arabian Sea to the west, Bay of Bengal to the east and the vast expanse of the Indian Ocean to the south, a wide range of marine activities dominate the maritime zone of India. Forecasting of oceanographic parameters (both surface and subsurface) at different time scales, is thus extremely important for a wide spectrum of users.

Figure 12: Map of India

Keeping this in mind, INCOIS established Indian Ocean Forecasting System, capable of predicting the surface and subsurface features of the Indian Ocean[48] reasonably well in advance (five to seven days).

INCOIS runs a suite of state-of-the-art numerical models, customised for predicting features within the Indian Ocean, to generate the Ocean State Forecast. To validate these models, INCOIS relies on in-situ data from observational platforms and satellite measurements. The dissemination of Ocean State Forecast occurs through various channels, including the official website, e-mails, mobile phone, TV, Radio and Display Boards. The user base spans a diverse spectrum, including fisherfolk, coastal communities, Indian Navy, Coast Guard, Maritime, Shipping and Energy Sectors, Oil and Offshore exploration industries, Ports, Disaster Management Agencies, Research Organisations, *etc.*

[48] ***Covering Bay of Bengal, Arabian Sea and the Indian Ocean.***

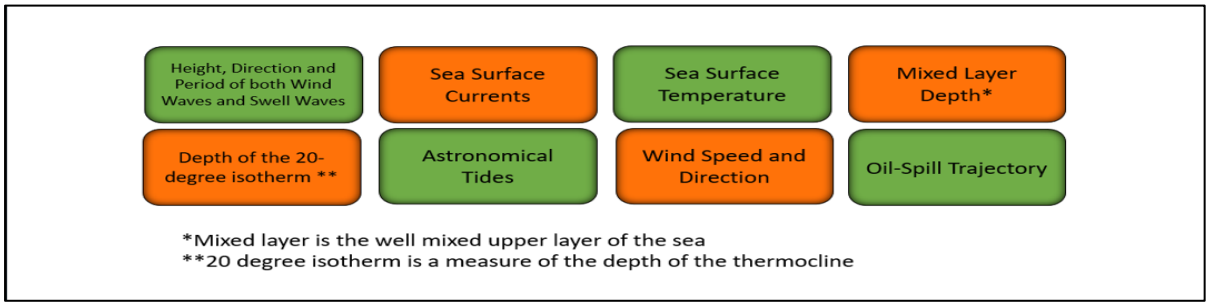

Figure 13: Forecasts provided by INCOIS

MoES funded INCOIS to carry out the Ocean State Forecast Services as one of the activities under the Ocean Advisory and Information Services, Computational Infrastructure and Communication Systems project, an ongoing initiative. From 2017 to 2022, the objectives encompassed dissemination of daily operational ocean state forecasts; sustain and improve the daily forecast, advisories and products; deliver impact-based forecasts and analysis products, validation efforts and real-time observational network maintenance through funded projects. The expenditure for the Ocean State Forecast component under the Ocean Advisory and Information Services, Computational Infrastructure and Communication Systems project during 2017-2022 amounted to ₹18.31 crore.

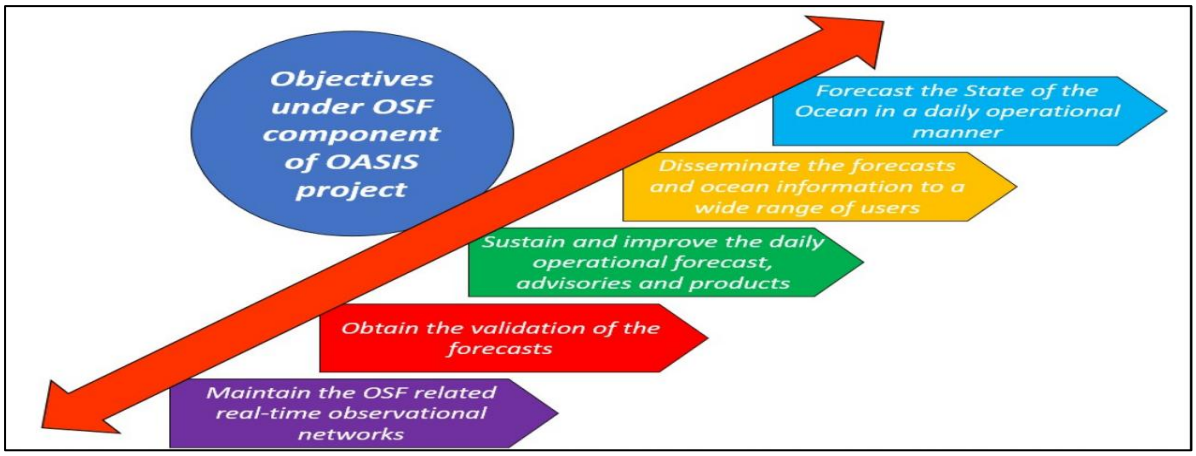

Figure14: Objectives under OSF component of OASIS project

5.2.1.1 Grant of sub-projects for deployment and maintenance of Wave Rider Buoys

During the period 2018-2022, INCOIS outsourced eleven sub-projects to various organisations under the Ocean State Forecast sub-component. These projects focused on deploying and maintaining the Wave Rider Buoys, collecting in-situ data for forecast validation, conducting awareness activities, user interaction workshops and research. The grantee organisations were expected to report the achievements against targets through progress reports and completion reports. The projects were monitored by the Project Monitoring Review Committee. An expenditure of ₹4.14 crore was incurred on these sub-projects. The details of the sub-projects are tabulated in ***Annexure V*****.** The audit observations in this regard are given hereunder:

i. Project Completion Reports in respect of seven out of the eleven projects were not on record. The expenditure incurred on these seven projects was ₹2.20 crore. The absence of Project Completion Reports from the grantee institutions indicates non-adherence to the stipulated guidelines and non-reporting of overall achievements against the targets, the reasons for shortfall and future recourses to the taken for redressing the issues. Thus, it could not be assured that the value for money invested was derived.

ii. INCOIS received Project Completion Report from the remaining four grantee organisations *viz.*, National Institute of Oceanography, Goa, M S Swaminathan Research Foundation, Central Institute of Fisheries Technology, Kochi and Kerala University for Fisheries and Ocean Studies. Audit examination revealed that:

a. National Institute of Oceanography maintained Wave Rider Buoys at nine locations[49]. It reported a number of instances of drifting of Wave Rider Buoys and inordinate delays in redeployment due to factors like boat unavailability and damage. As a result, all the Wave Rider Buoys were intermittently functional, leading to non-availability of continuous wave data at all the locations. Further, the Project Completion Report did not bring out the comparison of measured wave parameters with wave forecast outcomes, as required under the objectives, at least for the periods when data was available. Thus, no validation of the Wave Forecast happened during the period 2017-2022 at these nine locations.

[49] ***Veraval, Versova, Ratnagiri, Karwar, Kolachal, Tuticorin, Puduchery, Gangavaram and Gopalpur.***

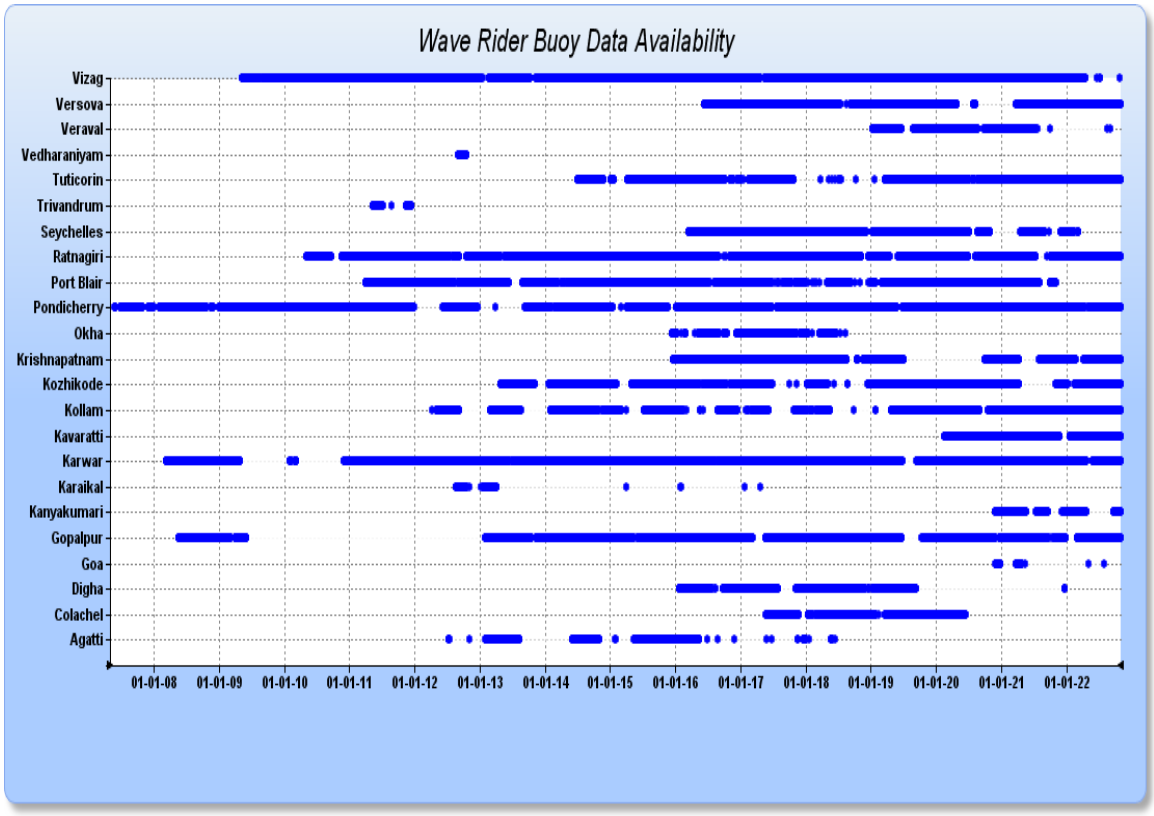

Figure 15: Wave Rider Buoy Data Availability Chart

b. Central Institute of Fisheries Technology had *inter alia,* the target of maintaining a Wave Rider Buoy off Gujarat Coast, dissemination of services and obtaining feedback from users. The Wave Rider Buoy deployed by Central Institute of Fisheries Technology at Veraval in January 2019 drifted thrice[50] and was redeployed each time after time lag. Further, there was Antenna damage which was attended in January 2021. The buoy again ceased transmission in July 2021 and was returned to INCOIS for repairs and spare parts replacement, but has not been redeployed, leaving the location without a Wave Rider Buoy since then.

c. The Department of Aquatic Environment and Management at Kerala University for Fisheries and Ocean Studies, Kochi, was granted a sub-project to maintain two Wave Rider Buoys, in addition to validation, dissemination, data collection from at least three major Kerala ports and studies on Sardine Fish Stock to aid INCOIS in refining Sardine prediction methodologies. The Department maintained two Wave Rider Buoys, one in Kozhikode and the other in Kollam. However, both experienced drifting[51] issues, requiring repeated redeployments[52].

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[50] ***June 2019, October 2019 and March 2020.***

[51] ***Kozhikode WRB Drifted thrice - 30 June 2019; 6 November 2019 and 19 February 2020. Kollam WRB deployed on 25 April 2018- drifted on 14 May 2019; Redeployed on 17 May 2019; Battery drained on 2 October 2019; Batteries replaced and redeployed on 11 October 2019.***

[52] ***WRBs were redeployed each time after intervals.***

The Project Completion Report submitted by the Department included charts depicting the forecast and observed wave heights at these two locations. Audit examination of these charts revealed variations between the forecast and actuals, indicating inaccuracies in the forecast. Audit examination also showed that data collection from at least three major fish ports in Kerala and the study on Sardine fish stock, crucial for enhancing INCOIS's prediction methodology, were not conducted.

The Principal Investigator reported in the Project Completion Report that the research component could not be completed due to difficulties in field work and lack of research personnel and that comprehensive feedback on the availability, periodicity and approximations of quantities of fish in the Potential Fishing Zone could not be analysed. The Principal Investigator also stressed the need for data collection to improve the predictability of the forecast and mentioned that presently, the location of fishing ground, species collected and quantity were being arbitrarily collected from catch observations and fishers at the fishing harbour and that based on such subjective estimates, the viability of Potential Fishing Zone advisories could not be assessed.

It was apparent from these reports that the project activities did not yield the desired results.

MoES stated (September 2023) that 10 out of the 11 Project Completion Reports were received. It added (December 2023) that necessary redundancies are built into the network design to overcome the inevitable data gaps. The above reply of MoES is not acceptable, since Project Completion Reports were not on record at the end of the project duration. INCOIS, as a funding agency, needed to have ensured that the grantee organisations prepared the Project Completion Reports in a time-bound manner, elaborating the overall achievements against the targets, the shortfalls in achievements, the constraints faced and future recourse to be taken. The contention of MoES that necessary redundancies are built into the network design to overcome the inevitable data gaps, is also not acceptable since INCOIS did not have any documentary evidence to this effect.

5.2.2 Marine Fisheries Advisory Services

Another flagship service rendered by INCOIS was Potential Fishing Zone advisories, providing information about areas where fish are likely to be found. Using data from various satellites, INCOIS provides these advisories to the fishermen on a daily basis, except during the periods of marine fishing ban imposed by the Government and during the adverse sea state conditions such as cyclones and high waves and cloudy days when satellite data coverage will be reduced.

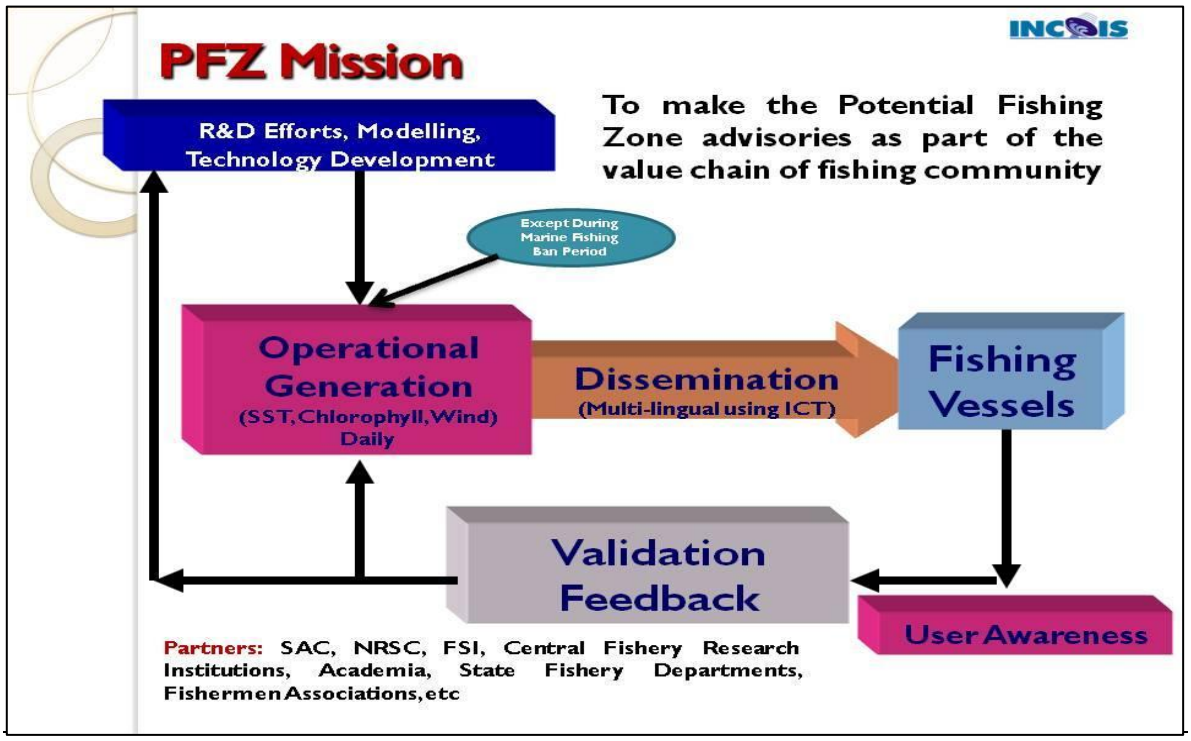


Figure 16: Process of issuing PFZ Advisories

INCOIS generates Potential Fishing Zone advisories for each of the 14 sectors in both map and text formats. INCOIS issues the Potential Fishing Zone advisories in the native language of each sector, with information on the major landing centres, bathymetry and the location of Potential Fishing Zone (latitude and longitude). Since the dynamic nature of the ocean can cause shifts in fishing zones, INCOIS also incorporates the information relating to wind speed and direction on the Potential Fishing Zone maps to guide fishermen on probable shifts in the Potential Fishing Zone.

INCOIS collaborates with various State Fisheries Departments, Private Organisations and Non-Government Organisations for capacity building, dissemination and feedback services. It uses various platforms[53] to disseminate the advisories. INCOIS provides both general Potential Fishing Zone advisories and species-specific fishery advisories.

MoES funded INCOIS to carry out the Marine Fisheries Advisory Services as one of the activities under the Ocean Advisory and Information Services, Computational Infrastructure and Communication Systems project as continuing scheme. During the period 2017-22, INCOIS had the objective to sustain and improve Potential Fishing Zone and Tuna Fishery Advisories; Develop Species Specific Fishery Advisories for other species like Hilsa, Oil Sardine; Improve Dissemination Mechanisms; and start new initiatives towards Ecosystem

[53] ***Such as Telephone/Fax, Internet, Display Boards, Mobile Applications, Short Messaging Services (SMS), Social Media Platforms, etc.***

based long-term Fishery Advisory Services. INCOIS spent an amount of ₹7.41 crore on this component during the period 2017-2022.

5.2.2.1 Potential Fishing Zone Forecast using Regional Ocean Modelling system

INCOIS provides Potential Fishing Zone advisories on a daily basis, in an operational mode, based on visual interpretation of satellite imagery depicting Sea Surface Temperature and Chlorophyll data, relying on physical and biological features observed in the imagery. Generating these advisories depended on clear satellite imagery, presenting a major challenge when cloud cover obstructed data acquisition. On such occasions of cloud cover, INCOIS was not able to provide advisories. In India, the monsoon period coincides with the peak fishing season thereby increasing the need for Potential Fishing Zone advisories even during cloudy days. The need for addressing this concern was identified as early as 2011-12.

Further, the Potential Fishing Zone advisories are derived based on same day satellite images which are valid only for the next 24 hours. Accurate forecasting of the Potential Fishing Zone advisories for the next 3-5 days was felt essential to aid the fishermen engaged in pelagic fishing activities in the deep sea which requires multi-day fishing.

Over the years, INCOIS made various attempts to overcome the cloud cover limitation and also to make Potential Fishing Zone advisory to forecast mode such as use of Global High-Resolution Sea Surface Temperature satellite data and use of Sea Surface Temperature data from geostationary satellites. However, these had limitations and INCOIS could not address the cloud cover issue.

To overcome this limitation, INCOIS developed a model set up - coupled physical-biogeochemical model in regional scale using Regional Ocean Modelling system[54] which was capable of adequately simulating the ocean biogeochemical state of the marine ecosystem. INCOIS generated the Potential Fishing Zone forecasts/advisories experimentally for two sectors, *viz.*, Gujarat and North Andhra Pradesh during October 2019. INCOIS carried out a study to validate the above model solution with in-situ data pertaining to the period 2010-2016. The model generated Potential Fishing Zone was also validated with Potential Fishing Zone derived from satellite data. The study report concluded that:

i. In most cases, the models overestimate the total length of all Potential Fishing Zones.

[54] ***Regional Ocean Modelling system is an Ocean General Circulation Model (OGCM), which is used to model the response of a regional ocean to physical forcings such as surface heat fluxes, winds, tides, etc., of the ocean to physical forcings such as heating or wind.***

ii. The model solutions were producing large scale ocean features better than the smaller scale features, indicating that the model set up experimented for the two sectors required improvements.

Audit examination showed that the experimental forecast have not yet been operationalised. INCOIS reported that the experimental forecasts have not yet been operationalised, pending detailed validation of the products covering all seasons, sectors and also field validation.

Apparently, neither the model was made operational for the above two sectors nor was it set up for other sectors. Further, no improvements were carried out to the existing model setup, since Regional Ocean Modelling system setup was proposed to be discontinued for operational use gradually, in view of the proposed Unified Modelling Framework.

Audit further observed that in December 2020, INCOIS had proposed the initiation of the process of setting up other models (such as Finite Volume Community Ocean Model, Modular Ocean Model 6) for replacing the above Regional Ocean Modelling system. It is a pertinent fact that these new models were yet to be configured and then tested/validated. Due to these reasons, INCOIS was still a long way from providing Potential Fishing Zone forecasts and was forced to continue providing only advisories that too based on satellite data, which had inherent limitations.

MoES replied (December 2023) that gaps in optical remote sensing data due to cloud cover is an inherent limitation world over. Models developed for such forecasting applications need to be validated extensively across different parameters, seasons and regions spanning wide temporal and spatial scales before it is operationalised. This process is currently underway and will be operationalised gradually.

5.2.2.2 Species Specific Fisheries Advisories

INCOIS realised that issuing general Potential Fishing Zone Advisories were insufficient, as the absence of species-specific advisory restricts the fishermen from selecting appropriate gear for targeted fishing, leading to over-exploitation of certain species and increased bycatch. To promote sustainable fishing practices and reduce bycatch by resorting to targeted fishing, species-specific advisories were essential. India has a diverse array of fish species (~2500) as per the National Fisheries Development Board. INCOIS commenced efforts to provide species-specific advisories during the X Plan Period with studies on Tuna. INCOIS has been issuing advisories for Tuna since November 2010 and it commenced studies on Hilsa and Oil Sardines during the XII Plan Period (2012-17). The work carried out by INCOIS towards issue of species-specific advisories and the Audit findings there upon are given below:

i. Tuna Advisories

INCOIS had the objective to sustain and improve the Potential Fishing Zone and Tuna Fishery Advisories during 2017-2022. INCOIS issued Yellow Fin Tuna Advisories to all the coastal states almost throughout the year[55]. The data from the Handbook of Fisheries Statistics: 2020[56], however, revealed that Yellow Fin Tuna landings happened only in Andhra Pradesh on the East Coast and Gujarat, Kerala and Lakshadweep on the West Coast in 2019-20. Audit examination showed that INCOIS issued Yellow Fin Tuna Advisories to all the coastal states during 2019-2020. Thus, the correctness of the Advisories issued by INCOIS to all the coastal states during 2019-2020 could not be corroborated with the above statistics.

Further, during the User Interaction Workshop (February 2022), fishermen from Tamil Nadu reported poor Tuna catches in the last two years and suggested INCOIS to conduct Potential Fishing Zone and Tuna Potential Fishing Zone validation studies along with them to strengthen the research on Tuna. INCOIS was also requested to provide exact fishing depth for tuna-specific advisories.

Considering the feedback received by INCOIS from the fishermen, the reliability of the Tuna Advisories also could not be confirmed. Audit findings further confirmed that INCOIS did not validate the Tuna Advisories, casting doubt on their accuracy.

MoES stated (September 2023) that the technique was developed only after validation of large amount of data. Tuna being a commercially viable species with very limited number of Tuna fishing vessels, it is difficult to get the actual catch information from the fishermen. Validation exercises of Tuna were indeed carried out in the prior years through projects and fishermen feedback.

The reply is to be viewed in the light of the fact that validations were not carried out even once during the last five years and the advisories could not be corroborated with statistics from the National agencies also while the user feedback was also not favourable.

ii. Hilsa Advisories

INCOIS initiated Hilsa studies with Jadavpur University from 2012 to 2017, by award of a project. It did not continue the collaboration with Jadavpur University after the sub-project ended in September 2018 (costing ₹0.83 crore). From 2018 to 2022, INCOIS sanctioned two projects, one to Vidyasagar University and the other to Andhra University and advised them repeatedly, to work in tandem and develop a unique sample collection and analysis methodology and submit consolidated completion report. The Universities, however, worked

[55] ***Excluding the ban Period and days of High Wave Alert.***
[56] ***Latest Handbook released by Department of Fisheries, Ministry of Fisheries, Animal Husbandry and Dairying, GOI.***

independently, without collaborating with each other. INCOIS reported to the Governing Council in August 2018 and March 2019 about the models and methodologies developed in collaboration with Vidyasagar University for Hilsa advisories and about ongoing validation and refinement, with plans for in-situ validation and operationalisation of Hilsa advisories in 2022-23.

Audit examination revealed that neither the model was validated nor operationalised, even on experimental basis. INCOIS is still pursuing the efforts towards development of methodologies for Hilsa advisories, through new projects sanctioned (August 2022) to both Andhra University and Vidyasagar University for the period 2022-2026.

iii. Oil Sardine – Collaboration with National Oceanic and Atmospheric Administration, USA

The MoU between National Oceanic and Atmospheric Administration and MoES signed in April 2008[57] provided for MoES to obtain support from National Oceanic and Atmospheric Administration towards survey design and statistical models for short-term prediction of the abundance and distribution of small pelagic fishes; refining Potential Fishing Zone advisory for species-specific forecasts. INCOIS developed a statistical forecast model for the Indian Oil Sardine landings in Kerala and tested it in collaboration with National Oceanic and Atmospheric Administration in February 2018. INCOIS planned to issue Experimental Indian Oil Sardine Forecast Bulletin for the Southwest coast in 2018-19. To validate these advisories, INCOIS planned fish data collection through (a) collaboration with National Oceanic and Atmospheric Administration scientists during cruise (b) correspond with Central Marine Fisheries Research Institute to collect fish catch data (c) collaborate with Kerala University of Fisheries and Ocean Studies by giving sub-project towards data collection from at least three major fish ports of Kerala and study on Sardine Prediction (d) develop Android App for collection of fish catch details directly from fishermen.

Audit examination revealed that INCOIS could not effectively carry out any of these activities, ultimately resulting in INCOIS not receiving fish catch data from any of the above mentioned sources. As regards the Android App, though INCOIS launched the App in May 2021 through Google Play Store, it was removed by May 2022, since INCOIS did not meet the changed requirements in the App policies. Audit examination also showed that even during the time when the App was available, INCOIS did not receive any fish catch feedback from the fishermen. Thus, INCOIS could not validate the experimental Oil Sardine advisories.

[57] ***MOU signed towards exchange of scientific resources, personnel and technical knowledge which support the improvement or development of Earth Observations and Earth Sciences for both parties. A Statement of Intent was also signed in August 2013 providing a framework for collaboration regarding research leading to improvements in forecast systems.***

Further, though INCOIS reported to the Governing Council that it would undertake joint cruises with Centre for Marine Living Resources and Ecology onboard Research Vessel for understanding the habitat of Oil Sardine during 2022-2023, it is yet to be undertaken.

MOES stated (September 2023) that development of habitat suitability models to develop species specific forecast involves huge amount of data collection and research that INCOIS has been undertaking for the past several years. It further added that Hilsa and Oil sardine forecast/outlook will be initiated on an experimental basis soon. MoES added (December 2023) that this is an R&D activity and efforts are continuing to refine the scientific methodology. Once successfully proven and validated, this will be made operational. Such short-term species-specific forecast are not available anywhere else in the world and India will be the first, once it is operationalised. MoES further stated that the development of techniques to derive general Potential Fishing Zone from satellite Sea Surface Temperature data took decades of R&D, spanning multiple scientific institutions across the country.

It is to be noted that providing potential fishing zone/species-specific advisories was one of the objectives proposed/approved for INCOIS even prior to XI Plan and MoES has been regularly funding this program. Thus, INCOIS needed to have collaborated effectively and built strong linkages with other scientific and research organisations to collect research data as well as fish catch data to validate its model outputs. While the efforts of MoES to develop models for short-term species-specific forecasts are appreciated it was also found that internationally, there are organisations that have been engaged in providing species specific forecast advisories. Further, INCOIS/MoES needed to employ modern technologies such as Artificial Intelligence and Machine Learning along with remote sensing data and advanced fisheries forecasting models to enhance their Potential Fishing Zone advisory services in order to aid sustainable fisheries.

5.2.2.3 Decision Support System Service for Mariculture Site Suitability

The Blue Economy encompasses all economic activities that directly or indirectly rely on the health and productivity of the oceans and coasts. It seeks to promote sustainable development while preserving marine ecosystems. The concept recognises that the ocean's resources are finite and should be managed responsibly to ensure their long-term viability.

Mariculture[58]/Aquaculture plays a pivotal role in the Blue Economy by providing a sustainable source of seafood and other marine products. It reduces pressure on wild fisheries, which are already overexploited in many regions. By adopting sustainable mariculture/aquaculture

[58] ***Mariculture, a specialised form of aquaculture is the farming of marine organisms for food and other products such as pharmaceuticals, food additives, jewellery (e.g., cultured pearls), nutraceuticals and cosmetics, either in the natural marine environment or in land or sea based enclosures, such as cages, ponds or raceways.***

practices, we can enhance food security, create employment opportunities and foster economic growth in coastal communities.

However, despite efforts by national research organisations such as Central Marine Fisheries Research Institute, to demonstrate the technology with model farms, Indian entrepreneurs are reluctant to venture into this field, due to lack of information on site-selection and technology. Thus, timely and reliable site-selection information and subsequent service as Decision Support System was found to be essential.

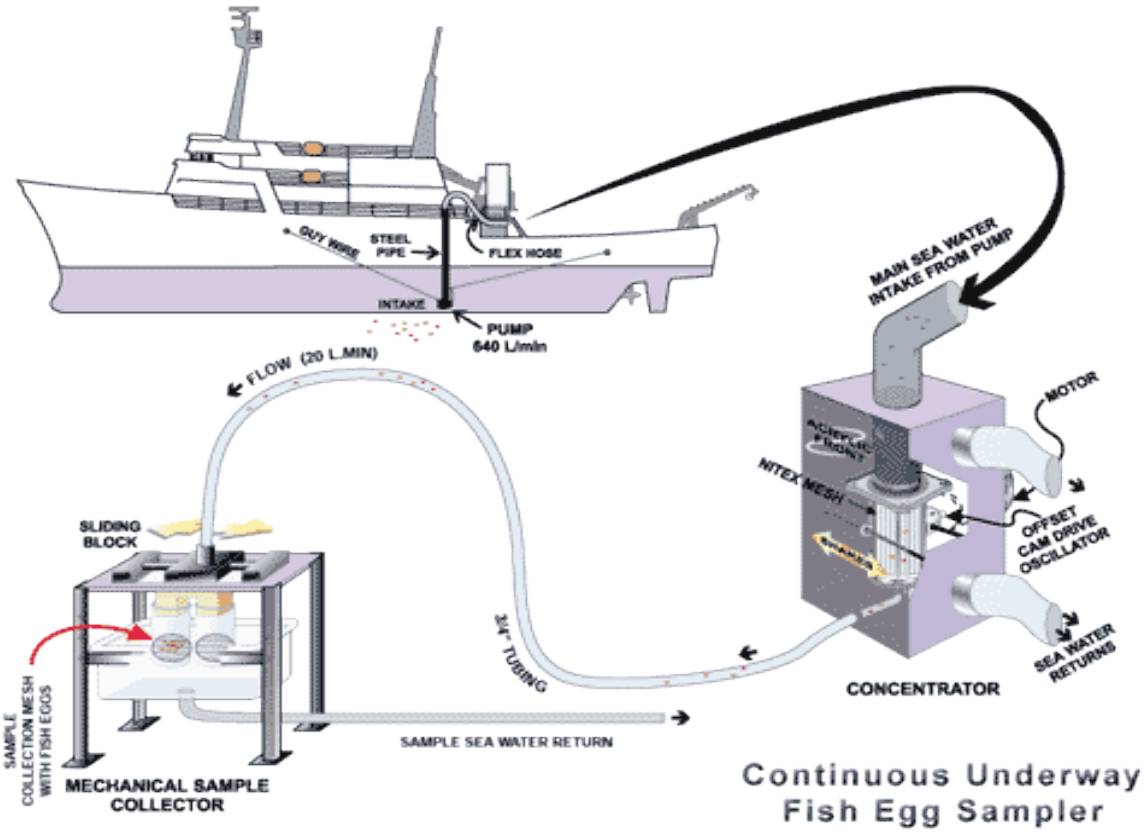
In order to address these issues, by highlighting the potential of mariculture industry in India and by demonstrating the possibility of a service, INCOIS conducted studies on Mariculture Site suitability during the XII Plan Period. Despite carrying out the studies in 2016-17 and envisaging to start the service during 2017, INCOIS did not roll out the service. INCOIS delayed the preparation of Manuscript and the Technical Report inordinately and submitted the same only in June 2022 after more than six years. INCOIS proposed to prepare Mariculture Site Suitability Atlas and subsequently refine it with higher spatio-temporal resolution and include more parameters. Audit examination showed that INCOIS did not carry out any work in this direction and the studies which were conducted during XII Plan Period were not brought to logical conclusion. MoES replied (March 2023) that this activity was not approved for the period 2017-2022, but INCOIS managed to conclude the work by making use of the project students.

It was apparent that due to non-continuation of the program, the findings of the studies did not benefit any user community and the studies were not brought to logical conclusion.

5.2.2.4 Introduction of Continuous Underway Fish Egg Sampler Technology

Continuous Underway Fish Egg Sampler system, is a methodology used to determine the location of fish eggs using acoustics. This would help map fish breeding grounds, essential for sustainable fisheries. Considering its potential use, INCOIS proposed to utilise this technology. It proposed to avail the acoustic training from National Oceanic and Atmospheric Administration Experts in September 2017, as part of the National Oceanic and Atmospheric Administration-MOES collaboration (MoU signed between MoES and National Oceanic and Atmospheric Administration in April 2008). INCOIS proposed to conduct this activity in collaboration with Centre for Marine Living Resources and Ecology (another constituent unit of MoES) during 2018-19.

Continuous Underway Fish Egg Sampler (CUFES) system



A methodology used to determine the location of fish eggs using acoustics. This would help map fish breeding grounds, essential for sustainable fisheries.

Figure 17: Illustration of CUFES

INCOIS was offered an opportunity to get hands-on training during the cruises along with Centre for Marine Living Resources and Ecology. But INCOIS scientists did not participate. It was decided by INCOIS that the acoustic and Continuous Underway Fish Egg Sampler expertise was to be with Centre for Marine Living Resources and Ecology. Hence, scientists from Centre for Marine Living Resources and Ecology were deputed for the training. Further, INCOIS decided (February 2020) not to participate in this activity and only provide inputs to Centre for Marine Living Resources and Ecology whenever required.

Inputs obtained by Audit from Centre for Marine Living Resources and Ecology showed that Centre for Marine Living Resources and Ecology on its part had obtained the Continuous Underway Fish Egg Sampler set up from National Oceanic and Atmospheric Administration and carried out only pilot operations on four cruises during 2019 and 2020. Centre for Marine Living Resources and Ecology is still in the process of identification of species of the fishes collected during these cruises. It reported that since fish eggs is a new topic and taxonomic identification keys were unavailable, efforts were on to develop them. Centre for Marine Living

Resources and Ecology added that more surveys were needed to identify the fish breeding grounds.

The flow of events indicated that after initiating the efforts, INCOIS disassociated itself with the program. Though Centre for Marine Living Resources and Ecology undertook the initiative, it could not execute the same in a time-bound manner and make the technology available for INCOIS for adoption in its Potential Fishing Zone Advisory services. As a result, utilisation of Continuous Underway Fish Egg Sampler technology for mapping fish breeding grounds to promote sustainable fisheries remained unachieved despite lapse of over four years.

MoES stated (September 2023) that since Centre for Marine Living Resources and Ecology had the fishery research vessel, resources and expertise on acoustics, it was decided that Centre for Marine Living Resources and Ecology would handle this activity and accordingly, Centre for Marine Living Resources and Ecology scientists were trained. Hence, the responsibility of INCOIS ceased to exist. MoES added (December 2023) that research work on fish eggs and larvae is mandate of Centre for Marine Living Resources and Ecology. It added that Continuous Underway Fish Egg Sampler is a complex equipment provided by National Oceanic and Atmospheric Administration, the use of which requires considerable expertise which National Oceanic and Atmospheric Administration has built over several decades, both for collection, preservation and taxonomic identification. MoES, however, agreed that it would ask Centre for Marine Living Resources and Ecology to continue this work.

The reply is not acceptable since both INCOIS and Centre for Marine Living Resources and Ecology are constituent units of the same Ministry and needed to have exploited the opportunity of availing the expertise available under the MoES-National Oceanic and Atmospheric Administration MOU. MoES needed to have ensured that both the organisations put in a coordinated effort so that the advantage of the technology is realised for ensuring sustainable fishing.

5.2.3 Wave/Storm surge/Swell surge forecast

Operational wave forecasting during tropical cyclones is of paramount importance as the associated extreme waves impact safe navigation and operations at sea and also greatly affect the coastal communities at the time of land fall. INCOIS had the target of developing models to provide the following services relating to wave forecasting during the period 2017-2020:

- Wave parameters
- Sea level projections
- Wave forecast system
- Swell surge/Kallakadal
- Storm surge early warning system

The target and current status of the development of these models are given in ***Annexure VI***. Audit examination showed that even as of September 2023, either the models could not be fully developed, or those that were developed required further refinements, with the result that these models could not be operationalised.

What is Kallakadal?

Flash-flood events that take place without any noticeable advance change in local winds or any other apparent signature in the coastal environment, with the result that the local population remains totally unaware of these flooding events until they actually occur. These occur specifically in the Kerala coast. These events are colloquially known as "Kallakadal" (swell surge). During Kallakadal events, the sea surges into the land and inundates vast areas. Swell surge forecast system is a system designed for the prediction of Swell Surge that occurs along the Indian coast.

Figure 18: Kallakadal in Kerala

Regarding swell surge forecast, where the achieved level of accuracy of forecasts was not matching up to the targeted level, MoES stated (March 2023) that improvement of accuracies was a continuous process that INCOIS was pursuing.

While acknowledging this fact, it is reiterated that the importance of providing accurate forecasts in the case of such disastrous events cannot be stressed enough.

As regards the model setup for forecast of wave parameters, MoES justified (March 2023) that it used the model set up for operationalisation of Small Vessel Advisory from February 2023. The reply is to be viewed in the light of the fact that after carrying out activities towards developing the model setup as well as data assimilation capabilities, the full potential has not been exploited. The model set up which was ready in March 2017, has been put to use only in February 2023, after a lapse of nearly six years, that too, only for one particular use, *viz.*, "Small Vessel Advisory". Even in the Small Vessel Advisory system, Audit observed that the advisory system was verified with a few real-life incidents from the past and INCOIS planned the refinement of the advisory system based upon regular feedback from the users. Audit examination showed that INCOIS was yet to obtain user feedback on Small Vessel Advisory service and carry out the refinements as planned.

No response has been received from MoES in respect of Sea level projections, Wave forecast system and Storm Surge Early Warning System.

5.2.4 Integrated Dissemination System

INCOIS has been providing its services in multiple languages through various communication methods such as telephone, fax, web, email, SMS, mobile apps, helplines, IVRS, cable TV

networks, electronic display boards, *etc.* These dissemination modes were in partnership with industry and NGOs. Installation of Display Boards at the specified locations (say fish landing centres or harbours) was one of the important modes of disseminating the advisories since these would facilitate the stakeholders to take precautions before venturing into the sea.

By 2014-15, INCOIS had installed 100 Electronic Display Boards. It proposed (2014-15) to commission 100 Digital Display Systems with improved features. While conveying the approval for this, the Technical and Financial Evaluation Committee suggested (February 2015) INCOIS to come up with an Integrated Dissemination System, to achieve mass dissemination through various modes in one single system, considering the technological advancements. INCOIS initiated action for procurement of Integrated Dissemination System in January 2016.

INCOIS issued Purchase Orders for (a) Design, Development, Installation and Maintenance of Integrated Dissemination System (b) Annual Maintenance Contract and (c) supply of 110 Integrated Receiver Decoders, between April and August 2016, totaling ₹1.91 crore. INCOIS decided (April 2016) to procure the requisite Servers and other Hardware for running the Integrated Dissemination System separately. The Integrated Dissemination System development and installation were to be completed by October 2016. The development, however, did not progress as planned.

The firm attributed the delay during the initial period of the project execution to INCOIS for non-readiness of the Servers and for non-finalisation of the third-party service provider. INCOIS disagreed with this contention of the firm. The project witnessed extensive correspondence, extensions and notices from both sides. Although both parties opted to resolve the matter amicably instead of pursuing arbitration, the issues remained unresolved even after multiple extensions.

The Integrated Dissemination System demonstration made by the firm were not cleared by the Project Evaluation Team of INCOIS. INCOIS granted extension until March 2022, but in June 2022, the firm cited unexpected challenges due to project delays, including outdated Application Programming Interfaces, devices and software standards. The firm informed INCOIS that it planned to rewrite components to align with current technology standards for project robustness. INCOIS did not grant further extensions, leading to a stalemate, with vendor ceasing to respond to the communications of INCOIS. Thus, INCOIS could not implement the Integrated Dissemination System even after seven years of effort.

INCOIS incurred an expenditure of ₹0.88 crore for procurement of Servers and Integrated Receiver Decoders. It is yet to release the payment to the firm for the Development of

Integrated Dissemination System (value of the order – ₹0.99 crore) and for the Third-Party Services availed through the Integrated Dissemination System Developer (value not known to INCOIS). Despite spending large volume of resources (time, manpower and money), INCOIS could not derive the anticipated benefits.

MoES stated (March 2023) that the delay in procurement of Servers was a technical delay and not procedural; the firm failed to provide consistent technical team, appropriate documentation and knowledge transfer, despite efforts from INCOIS side, thus leading to delay in project completion.

The fact remained that INCOIS could not succeed in bringing the firm on board to complete the project and the ultimate objective of mass dissemination through Integrated Dissemination System remained to be achieved.

5.3 Providing data generated from models to other organisations

In addition to utilising the model solutions for providing its mandated services, INCOIS also has the responsibility to provide such solutions to other organisations, such as IMD on day-to-day or seasonal basis, to enable them to issue forecasts/advisories. The models that were utilised for generating solutions for transfer to other organisations are discussed below.

5.3.1. INCOIS- Global Ocean Data Assimilation System

INCOIS provides analysed global Sea Surface Temperature on a day-to-day basis, to facilitate the initial conditions for ocean-atmospheric coupled models, specifically for the seasonal forecast of monsoon over India and Southeast Asia. INCOIS has been generating this data routinely by using Global Ocean Data Assimilation System model and transferring it to Indian Institute of Tropical Meteorology/IMD daily. During the period 2017-2022, INCOIS had the target of enhancement of the model resolution and the data assimilation scheme, to enable improvement in forecasts. To achieve this, INCOIS was working on improved model set up, INCOIS Global Ocean Analysis, with a more sophisticated assimilation method.

INCOIS could not complete the envisaged studies on improvement of models within the stipulated timelines. Audit analysis revealed that non-deployment of equipment as planned under the project (discussed in Para 5.1.1.2 above) deprived INCOIS of valuable data for improving the models. As a result, the ultimate objective of improving the forecasts was not achieved.

INCOIS stated (December 2022) that the INCOIS Global Ocean Analysis was in the final stage of implementation; that the model configuration was complete and the assimilation was being tested.

The reply proves that the improved model is not yet ready for operationalisation with the result that INCOIS continues to generate analysed Sea Surface Temperature with the old model setup even till date.

5.3.2 Hybrid Coordinate Ocean Model – Hurricane Weather Research and Forecasting model

Hybrid Coordinate Ocean Model is an open-source ocean general circulation modelling system. Hybrid Coordinate Ocean Model basin scale model was set up at INCOIS for ocean response to tropical cyclones, regional circulation, providing ocean currents to oil spill trajectory predictions and other applications like Search and Rescue at Sea. As scientific evidence shows

that ocean-atmosphere coupled[59] forecast systems can provide better hurricane/cyclone intensity forecasts, INCOIS took up the work of implementation of the regional version of Hybrid Coordinate Ocean Model to be coupled with the Weather Research and Forecasting[60] based hurricane model in 2017-18, as per the directions of Earth System Science Organisation and Research Advisory Committee.The outputs of this model, such as Sea Surface Temperature, were to be shared with IMD on operational basis, as these are very useful during cyclogenesis[61]. INCOIS developed the coupled model. It simulated successfully the Ockhi cyclone using the data from National Centers for Environmental Prediction[62]. In August 2018,

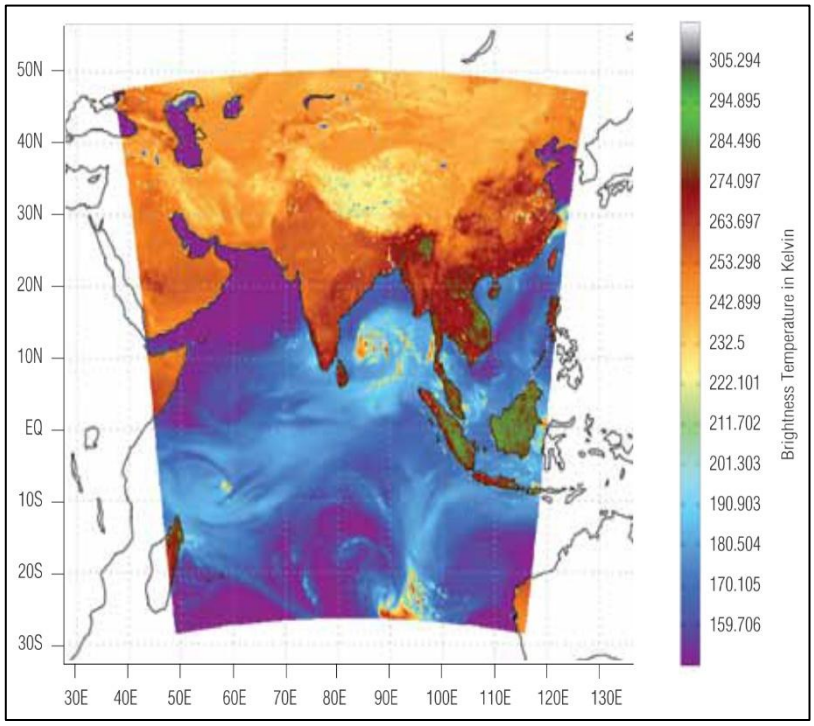


Figure 19: HWRF simulated Tropical Cyclone Phani in Bay of Bengal

[59] ***The coupling of models is a commonly used approach when addressing the complex interactions between different components of earth system. In climate research and forecasting activities, advanced models are needed, which consider regional and local air-sea interaction.***

[60] ***The Weather Research and Forecasting model is a numerical weather prediction framework designed for operational forecasting and atmospheric research needs.***

[61] ***The development or strengthening of an area of low pressure in the atmosphere, resulting in the formation of a cyclone.***

[62] ***The real ocean moves in response to forces. These forces include winds, tides, heating and cooling of the ocean surface and precipitation and evaporation. Much of the ocean's variability, especially in the top layers are wind driven, and hence realistic simulations require realistic wind to be used. The process by which these forces are applied to the ocean in ocean models is called forcing. In this instance, Hybrid Coordinate Ocean Model was forced with wind data from National Centers for Environmental Prediction, USA.***

INCOIS and IMD mutually decided to simulate Ockhi using data generated at IMD in place of National Centers for Environmental Prediction data and confirm the performance of the system and identify deficiencies, if any, in atmospheric or ocean components of the system. This was, however, not carried out since additional computer storage required for this was not available at INCOIS.

In addition to validating the model with more cyclone data, Research Advisory Committee in February 2019 suggested INCOIS to validate the models with satellite data. INCOIS did not carry out any of these validations suggested by the Research Advisory Committee but transferred the model to IMD. IMD began using it for forecasting of track and intensity of cyclones since March 2019.

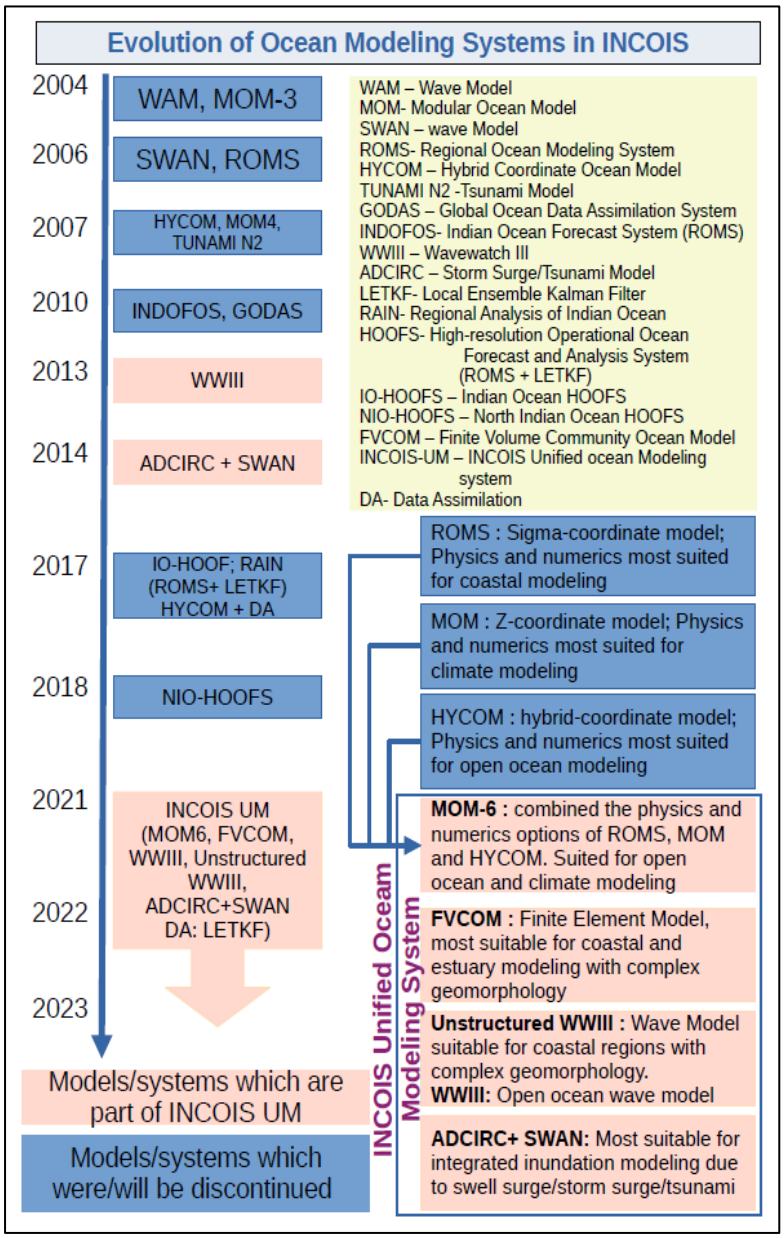


Figure 20: Evolution of models (Picture courtesy – INCOIS)

Audit examination showed that a study carried out on the performance of the coupled model was published in January 2021. The study reported that, while the model was advantageous for short-lived weaker storms, the performance of the model was not consistently maintained with longer lead time for intense and long-lived cyclones. The report also pointed out that the number of forecasts verified were less and that the intensity prediction skill was also less for the Hybrid Coordinate Ocean Model-Hurricane Weather Research and Forecasting Model[63].

[63] ***Hurricane Weather Research and Forecasting model is a type of Weather Research and Forecasting model and forecasts tropical cyclones. It has capability to address the intensity, structure and rainfall forecast problems.***

Audit also observed that IMD was releasing report every year in its website on the cyclonic disturbances over the North Indian Ocean during the year. A scrutiny of this report (for the year 2022) revealed that IMD was using a handful of model setups, including Hybrid Coordinate Ocean Model-Hurricane Weather Research and Forecasting for providing forecasts, implying that the accuracy levels of IMD forecasts cannot be attributed to the accuracy levels of Hybrid Coordinate Ocean Model-Hurricane Weather Research and Forecasting alone. Further, the report revealed that the error levels of the Hybrid Coordinate Ocean Model-Hurricane Weather Research and Forecasting model were quite high.

Thus, it is apparent that the coupled model transferred by INCOIS to IMD and being used by IMD for prediction of cyclone was not adequately validated and had inherent limitations.

5.3.3 Hybrid Coordinate Ocean Model-Data Assimilation

In order to develop the Hybrid Coordinate Ocean Model as a full-fledged operational forecasting system with Data Assimilation, necessity was felt to develop capability to assimilate satellite derived surface observations and vertical profile data (Argo data) to the model. The model products were expected to address the needs of offshore oil exploration platforms, fishermen community, shipping industry and Indian Navy. The basin scale model was also required for identification of the spread of effluents to ocean, nutrient dispersal and estimation of sediment transport along the coast, which would cater to the needs of ports and harbours and local tourism departments. The system was also expected to benefit Indian Ocean rim countries, where ocean modelling capability was limited.

For the purpose of data assimilation of satellite data as well as in-situ data for the Indian Ocean Hybrid Coordinate Ocean Model package, INCOIS placed the Work Order in January 2015 for ₹1.12 crore. The work was to be completed by January 2017. The model set up was to have capabilities to assimilate parameters such as Sea Surface Temperature, sub-surface Temperature/Salinity Profiles, *etc.* The vendor was required to transfer knowledge and train INCOIS personnel in the daily operations.

Audit observed that the work, which was to have been completed by January 2017, was finally completed only in March 2021, primarily because INCOIS High-Performance Computing, where the Indian Ocean Hybrid Coordinate Ocean Model was ported, stopped functioning. Due to this, the vendor was forced to redo the setup in the Aaditya High-Performance Computing at Indian Institute of Tropical Meteorology, which delayed the completion of work by nearly six months. Further, INCOIS continued to face network issues, particularly when data was needed to be transferred to local machines from the Aaditya High-Performance Computing for

further analysis. To overcome this, INCOIS had requested in-house High-Performance Computing from MoES which is still in the procurement stage.

Further, the Hybrid Coordinate Ocean Model- Data Assimilation system has capability to assimilate all data (both satellite and in-situ). However, due to non-availability of real time Satellite Sea Surface Salinity data, presently, only climatological salinity data was assimilated. The model setup was also assimilating the temperature and salinity profiles from Argo floats that are available in near real time. Evidently, non-availability of real time satellite Sea Surface Salinity data was a constraint, which affected the quality of model solutions.

Audit examination also showed that though the Hybrid Coordinate Ocean Model- Data Assimilation was ready by December 2020, INCOIS decided that the operational use of the above Hybrid Coordinate Ocean Model- Data Assimilation setup be discontinued gradually in view of its ongoing efforts to develop the Unified Modelling Framework. Thus, the Hybrid Coordinate Ocean Model- Data Assimilation which was developed at a cost of ₹1.12 crore, over a period of almost six years, was not put to use, rendering the expenditure incurred on it unfruitful. INCOIS also did not consider it prudent to keep using the above Hybrid Coordinate Ocean Model- Data Assimilation model at least until the unified modelling framework materialised and was made operational.

Introduction of New Unified Model Framework - A mission to develop a unified operational ocean forecast system

Over a period of time, INCOIS had developed/customised various models to simulate general circulation parameters in coastal, regional and global scales. This had introduced severe pressure on human capital, high performance computing resources, storage and analysis capabilities. As against this, operational ocean forecasting centers world-over use a finite set of models to cater to all their forecasting needs. Based on a study conducted in 2020, INCOIS decided that all possible resources available should be focused on implementing a unified ocean modelling and forecasting system that caters to its operational and research needs.

Accordingly, INCOIS decided (December 2020) that a new Unified Modelling framework be taken up with the objective of optimising the models and resources used in INCOIS for the operational ocean forecast/analysis activities and to make a seamless prediction system from global to regional domains. The new model setups are to be developed by 2025-26. As a result, certain existing model setups were decided to be discontinued gradually.

INCOIS also decided that the R&D would be stopped in the models that were to be discontinued in future. However, for providing Potential Fishing Zone forecasts and sea level projections, it was planned to continue very focused, but very limited, development of products and replace them with the new modelling framework when they were ready.

Further, while the Hybrid Coordinate Ocean Model- Data Assimilation has been decided to be discontinued for operational use, the models under the new Unified Ocean Modelling

Framework, are expected to be ready only by 2025-26. Due to this inconsistent situation, improvements to the models, envisaged as objectives of the Ocean Modelling, Data Assimilation and Process Specific Observations project for the period 2017-2022 could not fructify.

MoES replied (December 2023) that Ocean modelling is a complex activity that is developed over decades of work by contribution from global groups including INCOIS. Installation of models, testing, assimilation, validation and operationalisation for a service or scientific/process study is a continuous process. Different models are used for different purposes and as models with new capability are developed, the knowledge gained, *viz.*, parameterisations and mixing schemes, boundary conditions, forcings, *etc.*, from earlier models gets integrated into the newer ones. INCOIS has been following the global best practices and is in fact contributing its regional knowledge in modelling with the global community. The modelling framework and the trajectory of its development are continuously assessed by national and global experts in the domain. So, the changeover of one version to another or one model to another is need of the hour for better services.

The continuous evolutionary nature of developing models is appreciated in audit. However, it is reiterated that the specific targets/deliverables set for a particular year/project period needs to be achieved and cannot be rolled over indefinitely, so that the intended benefits are accrued in a timely manner.

5.4 Tsunami Early Warning Services

5.4.1 Functioning of the Indian Tsunami Early Warning Centre

Following the devastating 2004 under-sea earthquake and tsunami, MoES established the Indian Tsunami Early Warning Centre at INCOIS in October 2007. As part of the Early Warning System, a 17-station Real-Time Seismic Monitoring Network was made operational in October 2008 by IMD to detect large under-sea earthquakes that could trigger tsunamis. The Early Warning system also includes deployment of Open Ocean Tsunami Buoys with Bottom Pressure Recorders which provide advance warning about occurrence of tsunami and Coastal Tide Gauges to measure water level changes and confirm tsunami events.

The Indian Tsunami Early Warning Centre operates 24/7 and uses a scenario database and Decision Support System. It follows Standard Operating Procedures and communicates advisories to the stakeholders through various methods.

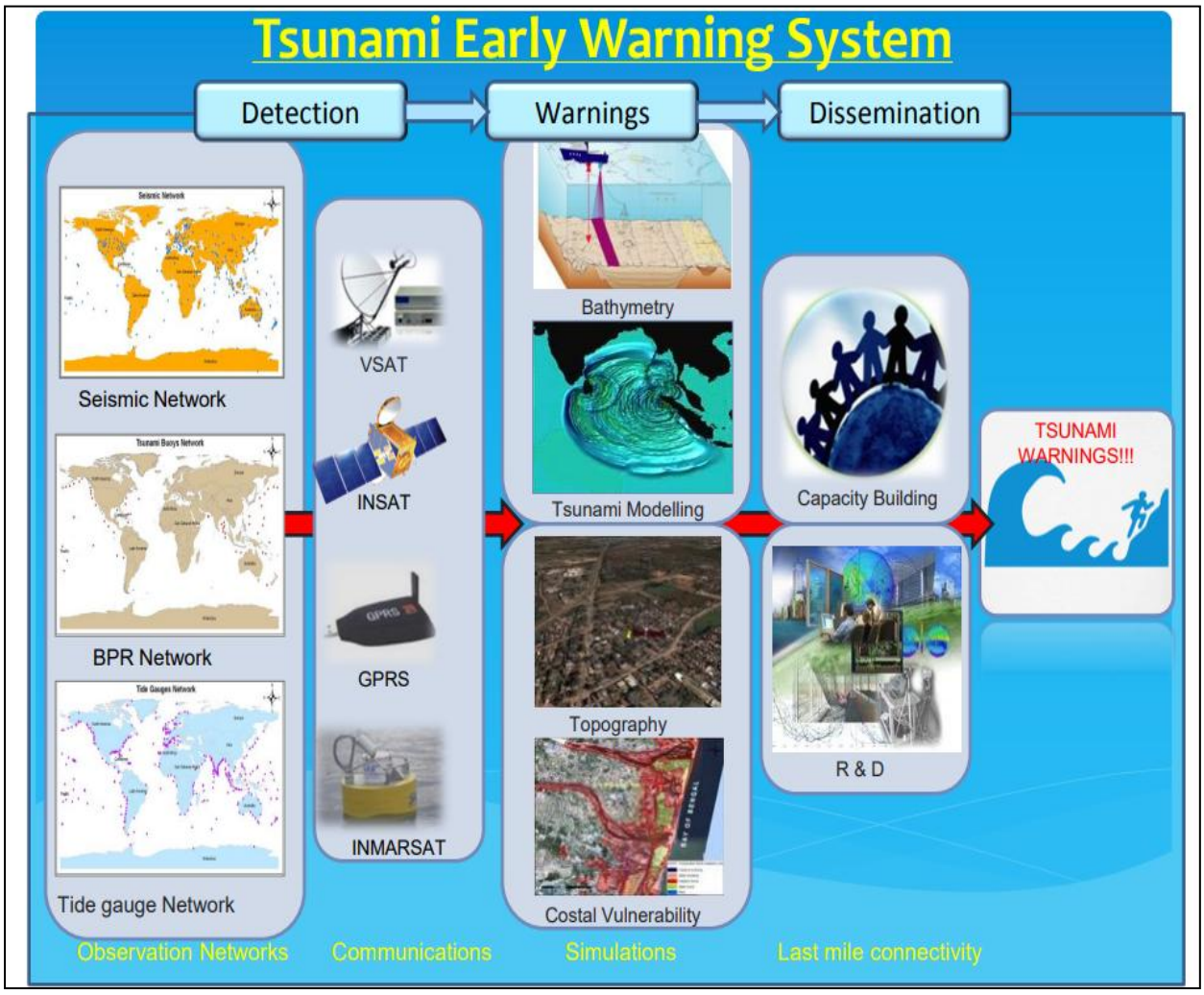


Figure 21: Functioning of Tsunami Early Warning System

5.4.1.1 Procurement, Deployment and Maintenance of Tsunami Buoys/Bottom Pressure Recorders

MoES constituted a Technical Committee (February 2011) with the purpose of planning, advising and executing various operational aspects related to the Tsunami Early Warning Network. This Committee decided (February 2011) the composition of the Tsunami Buoy Network. It recommended ideal network of seven Bottom Pressure Recorders (five locations in the Bay of Bengal and two in the Arabian Sea) and 36 Tide Gauge Stations. This network was to complement the 17 station Real-Time Seismic Monitoring Network that had been operational since 2008.

The development of indigenous Tsunami Buoy systems was commenced in 2005-06 by National Institute of Ocean Technology. Over the years, National Institute of Ocean Technology had been working on integrating the indigenously developed tsunami surface buoy with the imported subsurface Bottom Pressure Recorder unit. National Institute of Ocean Technology was also responsible for deploying, retrieving and maintaining these indigenously developed tsunami buoys.

While National Institute of Ocean Technology was working on indigenisation efforts, INCOIS imported the first set of three tsunami buoys in February 2010, followed by four more in November 2014. INCOIS entered into a Professional Service Agreement with the supplier to avail services for the deployment, retrieval and refurbishment of these buoys and incurred an expenditure of ₹48.84 crore until March 2022.

The Technical Committee decided (April 2013 and May 2015), that out of the seven tsunami buoys to be maintained in the network, five would be imported tsunami buoys managed by INCOIS and two would be Indian tsunami buoys developed and maintained by National Institute of Ocean Technology. These buoys were to be deployed at specific locations in the Bay of Bengal and Arabian Sea, with two imported buoys retained as spares for rotational replacement.

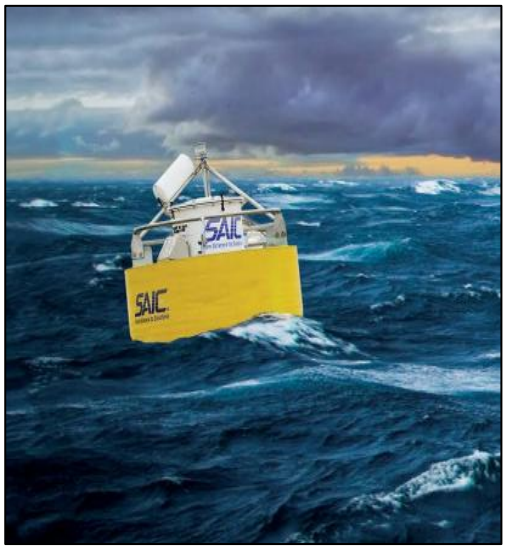


Figure 22: SAIC Tsunami buoy

Audit examination revealed that the optimal network of seven tsunami buoys suggested by the Technical Committee was never maintained during the period from 2017-18 onwards. The network consisted of six tsunami buoys (four imported and two Indian) in April 2017 and even this number could not be sustained. Data indicated that only two to three tsunami buoys were active most of the time during the years since 2018-19. By mid-December 2022, only one imported buoy in the Arabian Sea remained functional, while none of the Indian buoys were operational. Subsequently, as of July 2023, only two buoys, one imported buoy in the Arabian Sea and one Indian buoy in the Bay of Bengal, were active.

INCOIS and National Institute of Ocean Technology faced various challenges in maintaining the optimal tsunami buoy network. These included instances of vandalism, losses at sea, limited ship-time for deployment and maintenance, technical/technological challenges and limitations in Indian buoys. Added to this, the monopolistic position of the supplier increased the maintenance costs of the imported tsunami buoys. National Institute of Ocean Technology found that the endurance of Indian buoys was lesser when compared to the imported ones, since Indian buoys used INMARSAT communication that required more power as against the imported ones, that use Iridium communication.

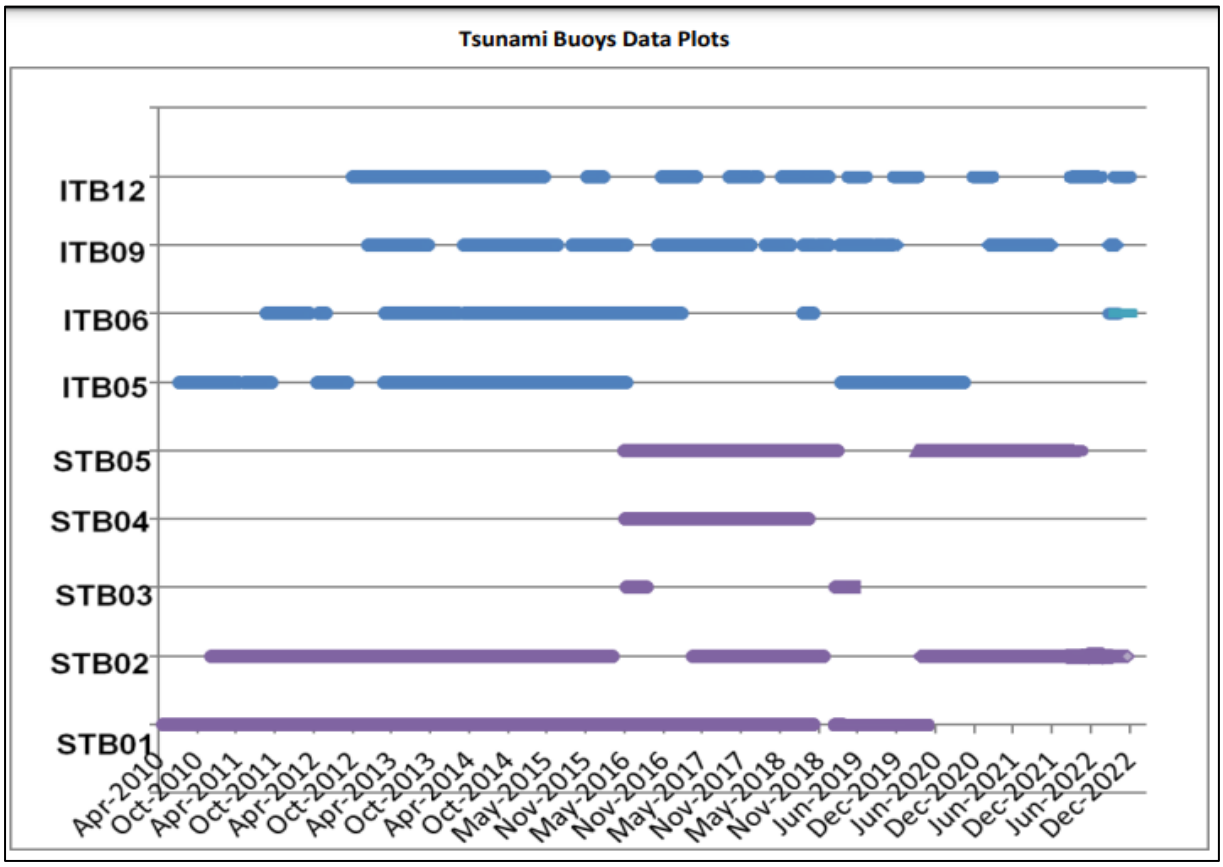


Figure 23: Data availability chart of Tsunami Buoys

The Technical Committee suggested various solutions to address these challenges. It advised changing deployment locations, increased surveillance, priority ship-time in fair weather period, alliance with other organisations for use of their vessels, special permission for using Iridium communication, upgradation/replacement of the old and obsolete Indian buoys, reaching out to ISRO for communication requirements in Indian Satellites. To resolve the issues with the imported buoys, the Technical Committee suggested gradual replacement of all imported buoys with Indian buoys; engagement of supplier team only for one more deployment during 2020-2021; National Institute of Ocean Technology and INCOIS teams to get themselves trained during such visit of supplier; future retrieval and deployment of imported buoys to be handled by INCOIS- National Institute of Ocean Technology team; rely on supplier only for refurbishment of the existing buoys till their lifetime. The Project Management Council of Ocean Observation Network project also reiterated the above suggestions and opined that INCOIS should handover the complete Tsunami Buoy Network to National Institute of Ocean Technology from 2023.

Audit examination showed that the issues could not be effectively resolved during the past 10-12 years. Vandalism persisted in spite of the communication with Coast Guard, ship-time paucity existed since priority allotment for deployment and maintenance of tsunami buoys could not be arranged, communication issues in the Indian buoys continued since use of Iridium

communication did not commence (though permission was received in 2021). The technical and technological issues in proving the endurance, reliability and sustenance of the Indian buoys remained unresolved. Further, Indian buoys became old and obsolete, requiring complete replacement.

As regards the imported buoys, the visit of the supplier team to carry out the maintenance cruise in association with National Institute of Ocean Technology and INCOIS scientists, could not materialise since March 2020 and thus, the imported tsunami buoys remained unattended. In the absence of the maintenance cruise, INCOIS- National Institute of Ocean Technology team could not get trained for future maintenance activities of the imported buoys.

Evidently, replacement of all imported buoys with Indian buoys, maintenance of imported buoys by INCOIS- National Institute of Ocean Technology team and taking over the entire Tsunami Buoy Network by National Institute of Ocean Technology, as suggested by the Committees, was not viable in the present situation and required more concerted and coordinated efforts.

Thus, the Tsunami Early Warning System, while crucial for disaster preparedness, has faced ongoing challenges in maintaining an effective buoy network. Addressing issues related to vandalism, ship-time, communication and the transition from imported buoys to indigenous ones remains a complex and pressing task. The lack of a consistently operational ideal Tsunami Buoy Network of seven buoys, as fixed by the Technical Committee, posed a risk of missing tsunami detection, emphasising the importance of resolving these issues promptly.

MoES responded (December 2023) that it is continuously working towards sustaining the network of tsunami buoys and other observing networks. Issues that are beyond control such as vandalism, ship-time, communications, contract agreement, *etc.* and more importantly COVID related restrictions have impacted observational networks both in India and globally. However, a few systems not working during intermittent periods of time will not degrade the accuracies of tsunami warning considerably, due to the inherent redundancies incorporated in the design of the end-to-end system. This is evident from the fact that there was never a false alarm on tsunami issued to the public.

The reply of MoES that it was making all out efforts to maintain the ideal Tsunami Buoy Network is appreciated, but the fact remained that only two to three buoys were maintained at any given point of time during the entire period from 2018-19 onwards. Further, the reply of MoES that all the issues that came in the way of maintaining ideal buoy network were beyond their control is not acceptable. It is a fact that COVID related constraints were unprecedented, but, for all other exigencies such as vandalism, ship-time, communication and contract

agreement, the Technical Committee, time and again, suggested solutions. Apparently, INCOIS/MoES could not resolve the issues by pooling resources and bringing in a coordinated effort. To cite an example, the Technical Committee advised INCOIS/National Institute of Ocean Technology to impress upon the Joint Scientific and Technical Advisory Committee to provide priority ship-time towards deployment and maintenance of tsunami buoys; it also advised National Institute of Ocean Technology/INCOIS to consider hiring of vessels or approach National Institute of Oceanography for utilisation of their vessel. But National Institute of Ocean Technology/INCOIS could not accomplish any of these suggestions. It was also to be noted that the Technical Committee's recommendation of a seven-buoy network was made after considering redundancy and also the essential need for Bottom Pressure Recorder data, to ensure timely detection of events. The claim of availability of in-built redundancies in the network cannot be accepted, since there were evidently no alternate functional Bottom Pressure Recorders present in the region. Further, the very purpose of Bottom Pressure Recorder is to detect tsunami in deep waters giving scope for an early warning before the tsunami wave reaches the coast. Thus, other instruments such as tide-gauges also cannot be considered as a redundancy for Bottom Pressure Recorders, since they can only facilitate confirmation of the arrival of the tsunami wave and track the wave height as it hits the shore. Further, non-issue of false alarm does not indicate that Bottom Pressure Recorder network was flawless.

Since Tsunami is “Race against Time”, the present position underscores the need for concerted and coordinated efforts to ensure optimal functioning of the network and critical importance of maintaining it, despite challenges, to be able to provide effective Tsunami Early Warning.

5.4.2 Establishment and functioning of Disaster Recovery site for Indian Tsunami Early Warning Centre

One of the activities proposed during the XII Plan Period was Technology Refreshment of the Indian Tsunami Early Warning Centre and Establishment of Disaster Recovery Site for the Indian Tsunami Early Warning Centre. The activity was taken up during XII Plan Period with an earmarked budget of ₹3.15 crore. The process, however, faced significant delays. The matter of setting up the Disaster Recovery site was taken up in the Technical Committee meeting only in May 2017. Further, though Governing Council had recommended in August 2017 setting up the Disaster Recovery Site at Indian Institute of Tropical Meteorology, Pune, INCOIS approached Indian Institute of Tropical Meteorology for formal approval of the Disaster Recovery site only in July 2018. INCOIS issued the Purchase Order for the Technology Refreshment of the Indian Tsunami Early Warning Centre and the setting up of the Disaster

Recovery site in October 2017 for a value of ₹2.75 crore (though the decision to this effect was made as early as November 2015).

Again, though the vendor proposed hardware and software solutions by March 2018, requesting timely procurement by July 2018 for an August 2018 integration, INCOIS completed the procurements only by May 2019.

The Disaster Recovery site was also not ready even by June 2019 (by which time major components were received for installation). Ultimately, the technology refreshment at the Data Centre and Disaster Recovery site was completed by December 2019, significantly delayed from the original 2012-2017 timeline.

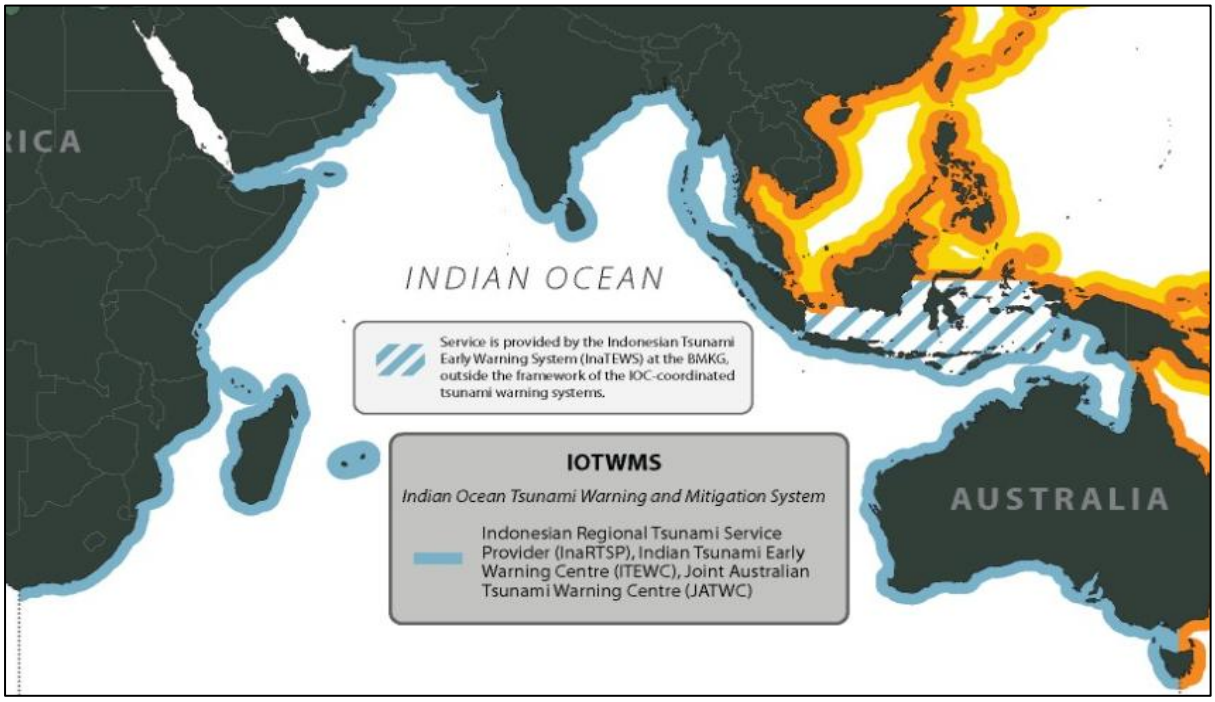


Figure 24: Area of responsibility in Indian Ocean Tsunami Warning and Mitigation System

Further, INCOIS set up a minimal Disaster Recovery site for Indian Tsunami Early Warning Centre at Indian Institute of Tropical Meteorology, Pune. The minimum required functional activities and subsystems for the proposed Disaster Recovery site were brought in consultation with the functional team.

Audit examination revealed that this Disaster Recovery site, managed by INCOIS, had the capability to receive data from international seismic and sea-level stations concurrently with the Data Centre site at INCOIS. However, it would not receive data from national seismic and sea-level stations if the Data Centre site is not operational. In the event of a Data Centre site failure, when the Disaster Recovery site needs to take over, it relies solely on data from the International Stations Database.

The drawback of this setup is that not all data from the country's networks, including seismic and sea level stations, is shared in the International Database. Out of the 17 national seismic

stations, data from only three selected stations is transmitted to the International Database. Similarly, of the 36 Tide Gauge stations, data from only eight is shared internationally. Although data from all the Bottom Pressure Recorders are shared, only two were functioning as of July 2023. The absence of data from local seismic and sea level stations compromises the effective functioning of the Disaster Recovery site. This is because Tsunami Service Providers responsible for local tsunami sources[64], rely on seismic data from nearby networks for initial assessments, with data from more distant networks used later to refine earthquake location and magnitude.

Additionally, there are data latency issues with most international stations, with seismic data latency of up to one minute and sea-level data latency of up to five minutes, provided the stations and communication channels are operational. This results in valuable time being lost.

MoES responded in March 2023 that the current Disaster Recovery site configuration was a conscious decision made by the Technical and Financial Evaluation Committee, considering functionality and cost.

The reply is to be viewed in the light of the fact that during an Indian Ocean tsunami event, when national stations are the first to detect local conditions, the Disaster Recovery site lacks this advantage, severely handicapping its effectiveness. Given the significant economic and social costs associated with tsunamis, it is essential to ensure the full functionality of the Disaster Recovery site for the benefit of coastal communities.

5.4.3 Key Performance Indicators of Indian Tsunami Early Warning Centre

In the Indian Ocean Region, INCOIS is one among the three[65] Tsunami Service Providers, with the responsibility to monitor seismic and sea level activity and issue accurate, timely tsunami threat information within the Intergovernmental Coordination Group Framework, to the National Tsunami Warning Centre/Tsunami Warning Focal Point of the country and other Tsunami Service Providers operating within the ocean basin. The Tsunami Service Providers agreed to transparent reporting of their performance against a range of predefined Key Performance Indicators. To facilitate effective communication, Tsunami Service Providers create various types of "Exchange Bulletins" and also issue Bulletin Notification and Cancellation Messages, as appropriate. National Tsunami Warning Centres rely on the tsunami forecasts furnished by Tsunami Service Providers to formulate public warnings and issue the same to the disaster management authorities, local administrations, *etc*. to ensure preparedness and safety.

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[64] ***Tsunamigenic zones that threaten the Indian Coast are the fault region off Sumatra, North Andaman, Car Nicobar in the Bay of Bengal and the Makran fault in the Arabian Sea.***

[65] ***The other two Tsunami Service Providers of Indian Ocean Region being Indonesian Regional Tsunami Service Provider and Australian Tsunami Warning Centre.***

Out of the 15 Key Performance Indicators, INCOIS reported on seven Key Performance Indicators. It did not report on other indicators, since they were not applicable in the absence of occurrence of tsunami. Out of the seven Key Performance Indicators reported, five related to reporting of occurrence of earthquakes; one related to performance in communications test; and only one Key Performance Indicator related to Tsunami bulletin[66]. Audit observed that INCOIS could not issue the bulletins within the targeted timeframe in three out of the last four years. Hence, INCOIS was not successful in achieving the timelines in respect of the above indicator, which is the core function of Tsunami Early Warning Centre.

Table 21: Key Performance Indicator – Elapsed time from earthquake to issuance of first threat assessment Bulletin

	2017-18	2018-19	2019-20	2020-21
Target in minutes	20	20	20	20
Indian Tsunami Early Warning Centre Performance in minutes	25	35	18	25

MoES in reply stated (March 2023) that INCOIS issued advisory at 25 minutes which is marked as near target and that other Tsunami Service Providers also performed near target; issue of tsunami threat assessment bulletin depends on the availability of source parameters which may differ for each Tsunami Service Provider based on their respective approach; detecting tsunamigenic earthquake[67] and providing advisories, i.e., Bulletin Type I, was given more priority. INCOIS assured that it was adopting new advancements in the technology to improve the timelines and services.

5.5 Conclusion

The goal of carrying out improvement of models for providing better forecasts for tropical cyclones, Potential Fishing Zone, storm/swell surge, *etc.*, fell short of attainment. Some of the models developed were still in the testing/validation stage. A few models which had been developed and tested had not been operationalised in view of the implementation of the Unified Modelling Framework.

INCOIS encountered setbacks in the timely procurement and deployment of observation platforms as planned under the projects, resulting in sub-optimal utilisation of these platforms for the execution of the projects. The objective of acquiring data and utilising the same for validation of the model/data assimilation for the purpose of development/improvement of the

[66] ***Elapsed time from issuing first tsunami threat assessment bulletin after earthquake.***

[67] ***While providing advisory of tsunamigenic earthquake, details of earthquake above a threshold value (above 6.5 Mw), which have the potential to cause tsunamis is given. Whereas in threat assessment bulletin, an initial forecast of tsunami threat – whether the potential for a tsunami to occur was present or not – is given.***

models also remained unmet. Time-series data crucial for quantifying the effects of anthropogenic activities could also not be acquired.

The execution of the projects by INCOIS was also hampered by inadequate computing facilities, manpower shortages and non-availability of ship-time. Thus, it could be concluded that the R&D projects carried out by INCOIS during the period 2017-22 could not achieve the ultimate objective of providing improved forecasts, thereby not benefiting the intended beneficiaries. Thus, the scientific and societal benefits remained to be achieved.

INCOIS did not ensure that the grantee institutions carried out the activities of maintenance of Wave Rider Buoys, validation of forecasts and alerts, dissemination and feedback effectively. INCOIS operationalised the Small Vessel Advisories, which was in great demand, after prolonged delay, but the utility of the same is still to be confirmed. INCOIS could not succeed in rendering Species-Specific Fisheries Advisories. INCOIS failed to collaborate with Central and State Government Organisations, which exclusively dealt with survey, collection, statistics and research on Fisheries in India, to get fish-catch data which was very much essential for validation of its advisories. The implementation of the Integrated Dissemination System remained unrealised.

INCOIS could not maintain the ideal Tsunami Buoy Network leading to risk of missing the timely detection of the occurrence of tsunami. Inadequate planning resulted in significant delays in establishment of the Disaster Recovery site and the minimal Disaster Recovery site eventually established, was operated with limited functionalities.

5.6. Recommendations

- ***In order to achieve improvements in advisories and forecasts, INCOIS may strive towards acquisition of adequate data essential for running the models and for model validation.***
- ***The data collection under the Mission Mode projects may be executed in a time-bound manner since this would have impact on the overall execution of the project.***
- ***INCOIS may ensure that the grantee organisations are provided sufficient funding in a timely manner to ensure that they execute their activities effectively.***
- ***INCOIS may build effective linkages with other organisations to get essential inputs towards validation and improvement of its services***
- ***INCOIS may strive to maintain ideal tsunami buoy network to alleviate the risk of missing timely detection of events.***

Chapter - VI

Sustainable Development Goals and Climate Change

Chapter VI: Sustainable Development Goals and Climate Change

MoES has been designated as the nodal ministry for achieving the goals and targets under SDG[68] 14 (Life Below Water) - To conserve and sustainably use the world's ocean, seas and marine resources. INCOIS plays a vital role in the UN Ocean Decade[69] initiated by UNESCO-Intergovernmental Oceanographic Commission. INCOIS is the nodal agency for the Tsunami Ready Programme in India, which aligns with SDG 11 – Make cities inclusive, safe, resilient and sustainable.

International policies for disaster risk reduction, sustainable development and climate adaptation are posing increasing emphasis on systemic risks. The need for holistic risk management was confirmed in the UN's Sendai Framework for Disaster Risk Reduction. Furthermore, multi-hazard risk management has been recognised as an important way to achieve the SDGs and Millennium Development Goals (MDG). INCOIS had taken up Multi-hazard vulnerability mapping of the entire coastline of India including the Andaman and Nicobar and Lakshadweep islands.

The Audit findings with regard to implementation of the SDG and Multi-hazard Vulnerability Mapping are discussed in this chapter.

6.1 Sustainable Development Goals

6.1.1. SDG-14 – Life Below Water

INCOIS was mapped by NITI Aayog in August 2018 for SDG sub-targets 14.3[70], 14.a[71] and 14.c[72]. Despite this designation, no dedicated organisational structure or specific funding was allocated to address these SDG goals. INCOIS was directed by MoES in April 2018 to initiate a programme on Ocean Acidification (SDG 14.3).

Earlier, under the Ocean Observation Network project, incorporation of pCO_2[73] sensors in two research vessels was one of the targets.

Figure 25: SDG Mapping

[68] ***Sustainable Development Goals.***
[69] ***United Nations Decade of Ocean Science for Sustainable Development 2021-2030.***
[70] ***Minimise and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels.***
[71] ***Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission criteria and guidelines on the transfer of marine technology in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small Island developing states and least developed countries.***
[72] ***Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as in Para 158 of "The Future We Want".***
[73] ***pCO_2 or partial pressure of CO_2 is an environmental indicator for ocean acidification.***

The need for pCO_2 observations was emphasised in the Project Advisory Council Meeting held in April 2022.

Audit examination showed that despite the above targets/recommendations, INCOIS neither initiated action towards procurement of pCO_2 sensors nor commenced any specific programme on ocean acidification.

MoES replied (December 2023) that data collected by INCOIS was useful for SDG 14, but it was not a mandatory programme of INCOIS.

The reply of MoES that it was not a mandatory programme of INCOIS is not acceptable since INCOIS was specifically mapped by NITI Aayog as nodal organization for certain SDG sub-targets. These national targets cannot be ignored and therefore it was imperative for INCOIS/MoES to direct their efforts towards achievement of the same.

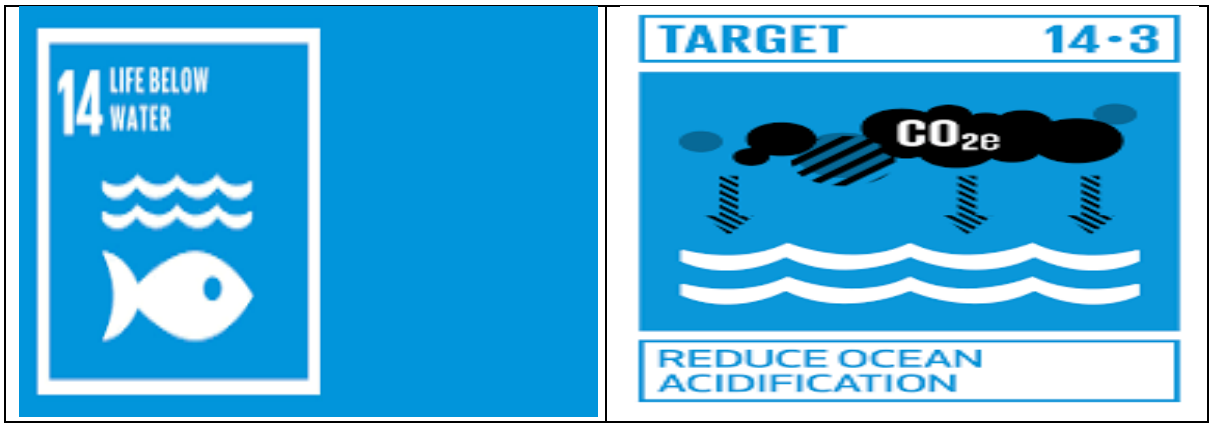

Figure 26: SDG 14: Life Below Water - Target 14.3: Reduce Ocean Acidification

6.1.2. Tsunami Ready Programme in India - achievement of SDG

MoES set up the Indian Tsunami Early Warning Centre at INCOIS for disaster preparedness. INCOIS has also been designated by UNESCO as a Tsunami Service Provider in the Indian Ocean region, as elaborated in para 5.4.

The "Tsunami Ready Program", initiated by UNESCO-Intergovernmental Oceanographic Commission, aims to enhance coastal communities' tsunami preparedness, minimising loss of life and property by meeting best-practice indicators set by the Inter-Governmental Coordination Group for Indian Ocean Tsunami Warning and Mitigation System of UNESCO-Intergovernmental Oceanographic Commission. It aligns with the Sendai Framework[74] for Disaster Risk Reduction 2015-2030 and SDG-11, focusing on urban resilience and disaster reduction. UNESCO-Intergovernmental Oceanographic Commission provides 12 assessment,

[74] ***The Sendai Framework for Disaster Risk Reduction 2015-2030 outlines seven clear targets and four priorities for action to prevent new and reduce existing disaster risks, such as understanding it, strengthening risk governance, investing in disaster reduction for resilience and enhancing preparedness. The Framework works in hand with the other 2030 Agenda agreements, such as the Paris Agreement on Climate Change and SDGs. It advocates for substantial reduction of disaster risk and losses and recognises that the State has the primary role to reduce disaster risk but that responsibility should be shared with other stakeholders.***

preparedness and response indicators, with communities meeting all 12 recognised as "Tsunami Ready". This recognition was renewable every four years.

India, chosen for a pilot project in 2017, implemented this programme in Odisha and Andaman and Nicobar Islands. A National Tsunami Ready Board, chaired by Director, INCOIS, was formed in May 2018 to oversee the program.

Audit observations on implementation of the programme in the selected States/UTs, are as follows:

The Tsunami Ready Programme faced challenges in its implementation.

i. Andaman and Nicobar Disaster Management Authority initially expressed interest but did not attend National Board meetings, despite their critical location near the subduction zone.
ii. In Odisha, while six coastal districts and 328 communities were identified, only two villages were recognised as “Tsunami Ready” by August 2020, constituting less than one *per cent* of the total.
iii. The National Board meetings in August 2018 and December 2019 discussed the need for villages in each coastal district to participate. INCOIS conducted online workshops for Odisha and Andhra Pradesh in 2021 but did not conduct any for other coastal states.
iv. Only three coastal states - Kerala, Andhra Pradesh and Andaman and Nicobar identified one district each for implementation of the programme.

The slow implementation of the Tsunami Ready Programme highlighted the need for effective coordination between Ministries and State/UT Governments to enhance Disaster Risk Reduction.

MoES stated (December 2023) that, INCOIS has been playing a very active role by chairing the National Tsunami Ready Board, promoting advocacy with state governments, organising training programmes, providing technical support in developing the Tsunami Ready indicators and coordinating with multiple national organisations and the UNESCO- Intergovernmental Oceanographic Commission. Though operating the technical warning system is the primary mandate of INCOIS, it has been doing its best within the scarce human resources to facilitate implementation of Tsunami Ready Program. Forcing other stakeholders who are responsible for the implementation is out of the scope of INCOIS.

While the role of INCOIS as Chairman of the National Tsunami Ready Board is appreciated, it is pertinent to note that only three meetings have been held from the time of constitution of the Board in May 2018. Also, there has been poor representation from the National/State Disaster Management Authorities in the Board meetings. The reply indicated a need for

intervention from the MoES, to bring in a co-ordinated approach involving other Central Ministries (like MHA) and respective governments of the coastal states, in order to achieve the overall objectives of the initiatives.

6.2 Multi-Hazard Vulnerability Mapping

Coastal areas are among the most important ecological and socio-economic environments on earth whose unique ecosystems provide a wide range of ecological services and natural products. Since the coasts are transitional areas and places of intense physical, ecological and social interactions, they are exposed to a range of natural and human hazards and have experienced a variety of environmental impacts at local, regional and global scales.

UN's Sendai Framework targets increasing the availability and access to multi-hazard early warning systems and disaster risk information and assessments that complements SDG 13 on combating climate change and its impacts.

INCOIS had taken up a project titled "Multi-hazard Vulnerability Mapping" during the period 2010-13, with a sanctioned budget of ₹48 crore. The project was extended several times up to 2020-2021. The original project (2010-13) aimed to create Multi-hazard Vulnerability maps for India's entire coastline, including islands, to aid in identification of most vulnerable and high-risk areas for prioritised action. The deliverables included 1:25000 scale Multi-hazard maps, an Atlas of Multi-hazard maps and Spatial Statistics to help disaster management. Further, the real-time coastal inundation models developed as part of the project were expected to help in improving the accuracy of tsunami warnings. The project also envisaged development of a visualisation software that would integrate the above information. During the period 2017-21**,** the deliverables under the project included; Completion of 3D GIS mapping for 3300 sq.km.; Upgradation of the Multi-hazard Vulnerability Mapping along the west coast using Airborne Laser Terrain Mapping data from National Remote Sensing Centre; Coastal risk assessment; Initiation of Airborne Laser Terrain Mapping of islands; Multi-hazard Vulnerability Maps atlas for Indian mainland with updated maps.

Audit examination showed that all the activities envisaged under the project have not been completed.

6.2.1 Generation of Multi-hazard Vulnerability Maps for the Indian coast

For multi-hazard vulnerability mapping, INCOIS acquired remote sensing/Geographic Information System (GIS) data in two phases from National Remote Sensing Centre. In Phase I, it received the Airborne Laser Terrain Mapping and Carto Digital Terrain Models'[75] data for

[75] ***Carto Digital Terrain Model refers to a digital representation of the earth's surface that captures the terrain elevation.***

the area from Kochi to Sundarbans between June 2007 to January 2016 and data relating to extraction of building heights for this area in May 2014. In Phase II, INCOIS received Airborne Laser Terrain Mapping and Carto Digital Terrain Models' data and data pertaining to extraction of buildings heights from Kochi (Kerala) to Narayan Sarovar (Gujarat) between June 2018 and March 2020.

Audit observed that based on the data obtained from National Remote Sensing Centre, INCOIS generated 1054 Multi-hazard Vulnerability maps from July 2013 to March 2022. Though Phase II was declared as completed in April 2021, Multi-hazard Vulnerability maps for the Andaman and Nicobar Islands were generated by March 2022 only. For Lakshadweep islands MHVM maps have not been generated yet.

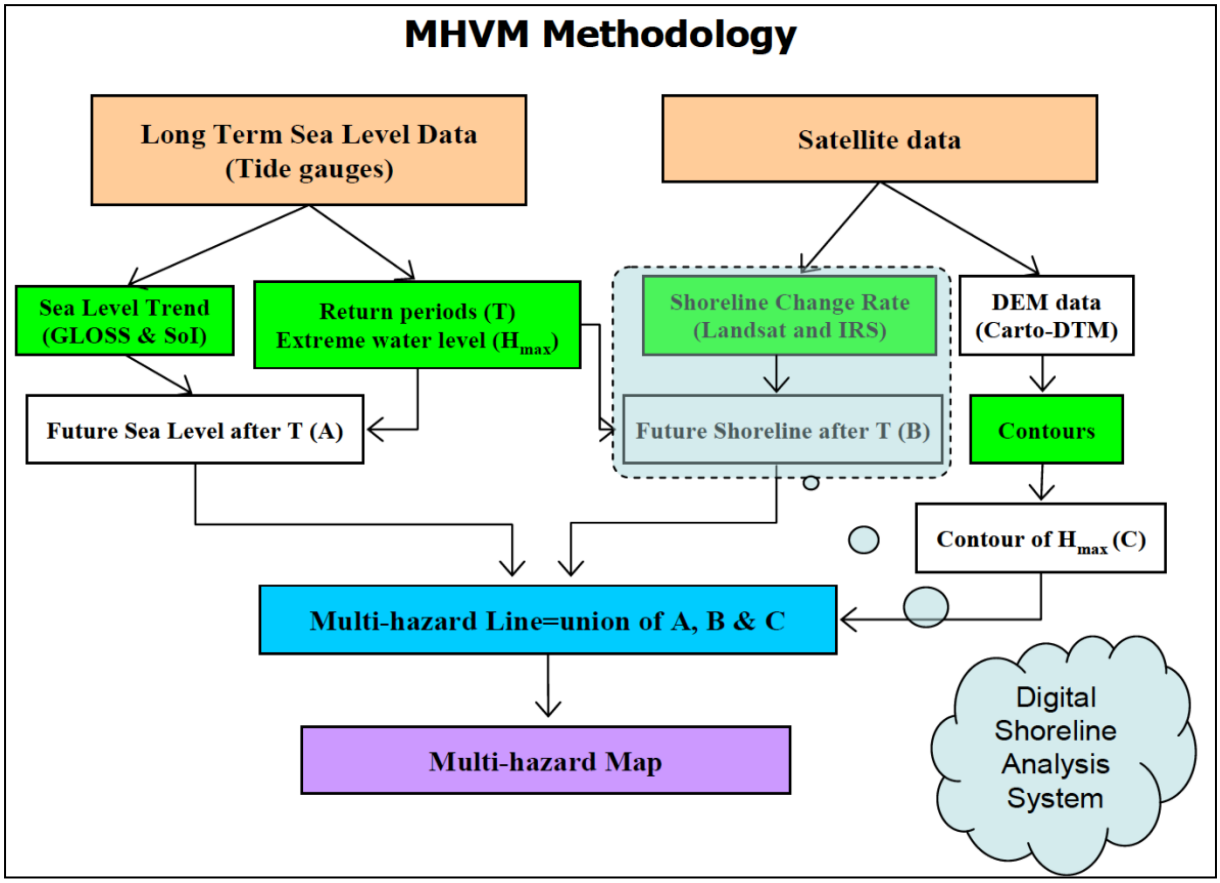

Figure 27: Flowchart describing the methodology to derive Multi-hazard Vulnerability maps

INCOIS justified the delay stating that the mapping of multi-hazard vulnerability for the entire Indian coast involved processing of large number of datasets pertaining to topography, shoreline change, sea level and other collateral information. Procurement of these input datasets from multiple sources took more time than expected.

MoES stated in March 2023 that blended bathymetry and topography for Lakshadweep has been generated.

However, the fact remains that Multi-hazard Vulnerability maps have not been prepared for one of the most vulnerable areas (Lakshadweep), despite the fact that INCOIS itself committed

in 2009-2010 that generation of Multi-hazard Vulnerability maps for Islands is to be initiated and Independent Review Committee also recommended the acquisition of Airborne Laser Terrain Mapping data for preparation of such maps in 2019**.**

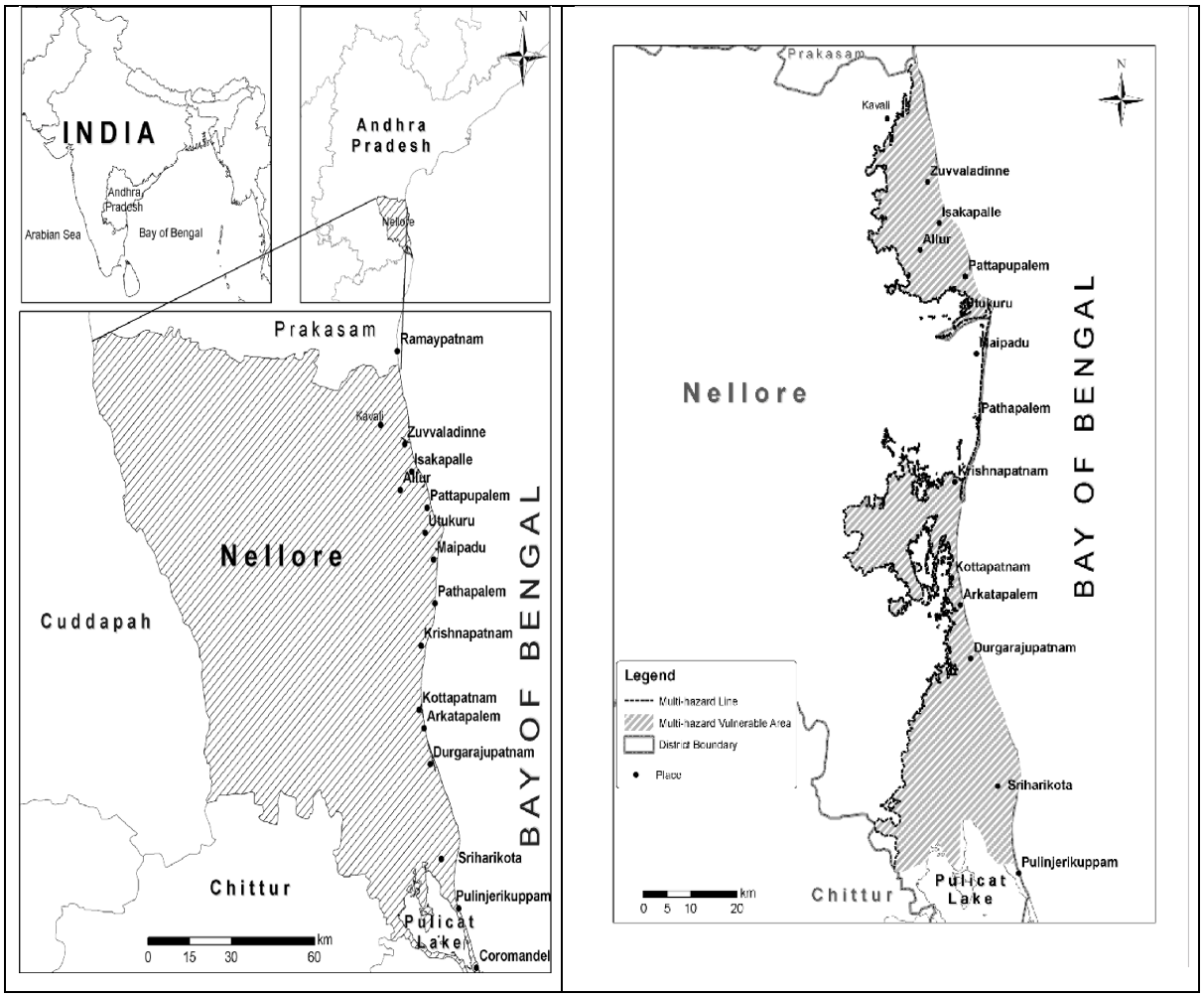

Figure 28: (a) Study Area – Nellore, (b) Multi-hazard Vulnerability Map of Nellore District

INCOIS prepared an Atlas comprising of the Multi-hazard Vulnerability maps generated by it with the available data and got it vetted by a Committee in September 2017. The Committee recommended publication of Versions 1.0 and 2.0 with modifications.

Audit found that INCOIS took over four years to implement these recommendations and readied the Atlas in March 2022, but again, it did not release it immediately. The Atlas was finally released in February 2023 after being pointed out by Audit. Some of the base data used for the Atlas released in February 2023 dated back to 2007, with some maps created as early as 2013 and made available to the stakeholders after more than ten years. Given the fact that nearly 33 *per cent* of the coastline is under varying degrees of erosion, there is every possibility that the shoreline would have changed from the time the maps were prepared. Thus, the utility of the Atlas for disaster management authorities is uncertain.

MoES stated (March 2023) that sharing of Multi-hazard Vulnerability Mapping through the web portal was in progress. MoES added (December 2023) that the Atlas was prepared with the most suitable datasets. In some cases where the changes are not dynamic, datasets being old does not impact the quality of the output maps.

The response fails to cover situations involving dynamic changes. Moreover, there is a considerable time lag of over fifteen years between the period of data sets and the release date of maps.

6.2.2 Setting up of real time coastal inundation models

The objective of an inundation forecast model was to provide an estimate of wave arrival time, wave height and likely coastal inundation area, immediately after a tsunami. When an event similar to the one of the pre-computed scenarios occurs, the available propagation information may be used to compute the last stage of the wave inundation. Bottom Pressure Recorders/Tsunami Buoys are instruments that provide the real-time data for the inundation model to perform. INCOIS maintained only two Bottom Pressure Recorders as against the seven (July 2023), affecting the model's efficiency in capturing tsunami genic events.

MoES responded (December 2023) that it is continuously working towards sustaining the Tsunami Buoy Network.

6.2.3 3D GIS maps for selected highly vulnerable areas

The major purpose of 3D GIS is to visualise and effectively communicate the inundation threat at sea level and to plan for evacuation routes. During the period 2010-2013, INCOIS proposed to construct 3D models for about 5000 sq.km.[76] of highly populated, economically important and vulnerable coastal regions, identified from the Multi-hazard Vulnerability Mapping. A tentative list of cities was generated, subject to finalisation of the locations based on the results of the Multi-hazard Vulnerability Mapping.

Originally, INCOIS proposed to cover cities from all the coastal states of the mainland as well as Andaman and Nicobar Islands and Lakshadweep islands. INCOIS placed a Purchase Order for 3D GIS mapping, starting with 500 sq.km. pilot area in May 2014, with a duration of five months up to October 2014. After successful pilot completion in September 2015, INCOIS awarded the remaining work in April 2016, with an initial deadline of October 2017.

[76] ***3300 sq.km. was proposed for the period 2017-2021, 5000 sq. km. was proposed for the period 2010-2013.***

The project was ultimately completed in February 2018, covering 4803 sq.kms., spanning area from Kochi to Puri. Vendor submitted to INCOIS the 3DML[77] data pertaining to all the areas between January 2017 and February 2018, for integration with the 3D VAS[78] application. INCOIS incurred an expenditure of ₹21.61 crore[79] and 3D GIS data integration into 3D VAS was completed by April 2018. Socio-economic data[80]was incorporated as attribute table.

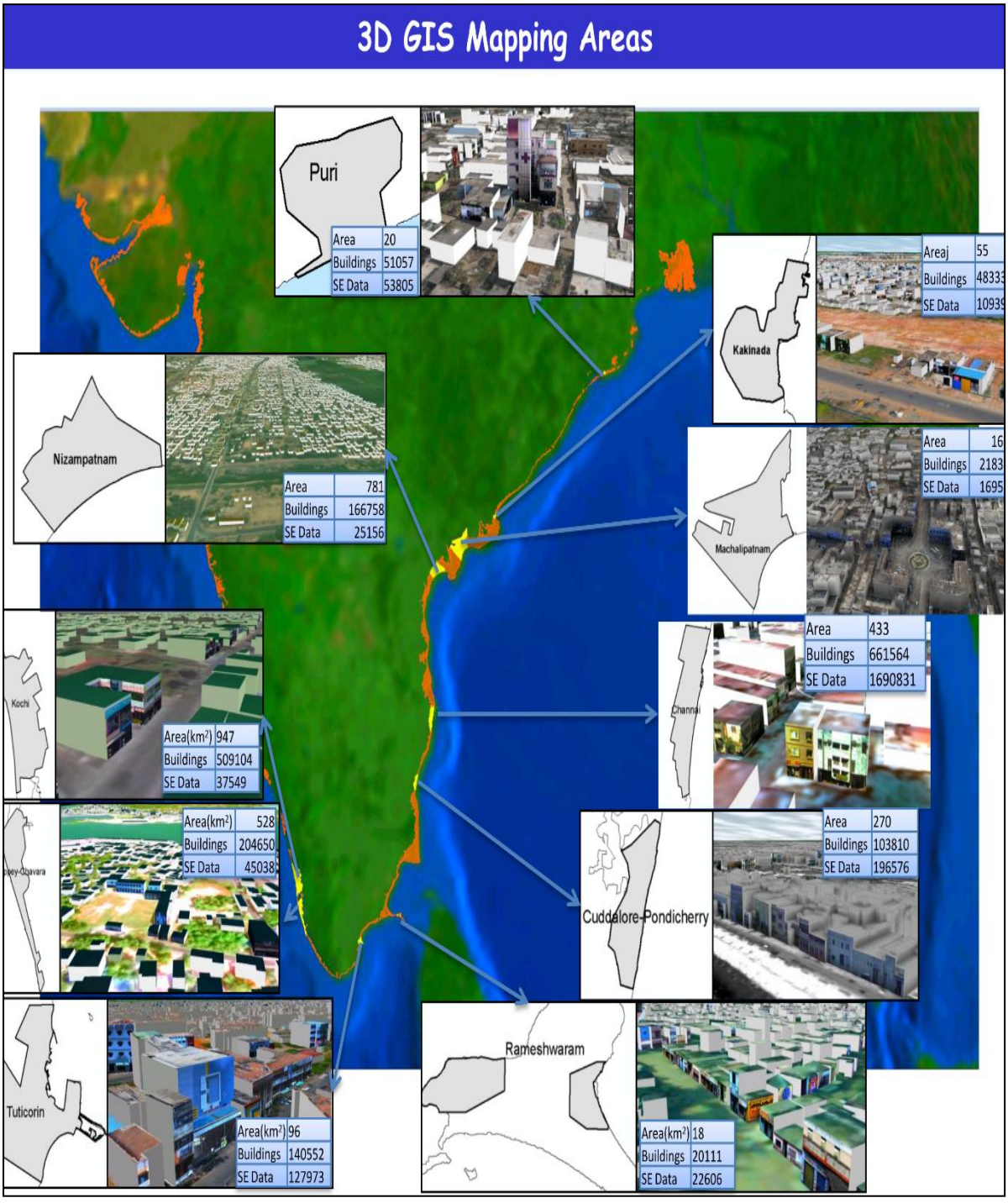

Figure 29: 3D GIS mapping

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[77] *3Dimensional Modelling Language is a format for creating three-dimensional websites by combining similar sized building blocks.*
[78] *3D VAS application software has capability to display, analyse and disseminate the outputs generated.*
[79] *Payment for Phase I was ₹ 2.48 crore and for Phase II was ₹ 19.13 crore.*
[80] *Useful for estimating the building level risk assessment on the tsunami water level derived from model simulation.*

Audit observed that INCOIS has not yet identified the highly vulnerable coasts of the West Coast (from Kochi to Gujarat), Andaman and Nicobar and Lakshadweep Islands.

MoES stated in March 2023 that there was currently no proposal for carrying out 3D GIS mapping for other areas.

Thus, 3D GIS mapping of nine cities/contiguous areas between Puri and Kochi have only been completed, as against the proposal to cover all the coastal states and the two islands.

6.2.4 Integrated Software for display and analysis

INCOIS proposed (November 2011) to develop a 3D GIS enabled, 3D VAS application software, to meet the scientific requirements of the project. Accordingly, it placed a work order in January 2015, for ₹2.43 crore. All the activities[81] envisaged in the work order were stipulated to be completed by January 2016. INCOIS granted extension up to May 2016, considering the complexity involved. The firm deployed the Production version of the application software at INCOIS in May 2016 and in July 2016 it was decided to make the application operational.

Audit observed that though preparation of 3D VAS application depended on the 3D GIS data, by the time the 3D VAS application was declared operational in July 2016, INCOIS possessed 3D GIS maps only to an extent of 500 sq.kms. relating to the pilot area[82].

While vendor gave system architecture and hardware requirements in July 2015 and the Technical Committee formed for this purpose approved the purchase of hardware in September 2015, the work order for workstations for porting the 3D VAS application was placed only in October 2016 and the items received in January 2017, six months after the application software was declared as go-live.

Apparently, the project faced significant delays at multiple stages, including data receipt, procurement, work completion and hardware acquisition. Despite an initial 2010-2013 timeline, after over 12 years, some of the key deliverables remain unachieved i.e., (i) Preparation of Multi-hazard Vulnerability maps for Lakshadweep islands and (ii) Preparation of 3D GIS maps for West coast regions beyond Kochi, for East coast beyond Puri, Andaman and Nicobar Islands and Lakshadweep islands.

[81] ***System Analysis and System Architecture, Application Software Development, Data Integration and Operationalisation.***

[82] ***Pilot area of 500 sq. kms was ready by September 2015. For rest of the areas, work order was issued in April 2016 and completed in February 2018.***

6.3 Conclusion

There was neither an organisational setup established at INCOIS to address the needs of SDG, nor any funds allotted specifically for this purpose though INCOIS was specifically mapped for certain targets. Despite the fact that INCOIS was directed to carry out programme on Ocean Acidification, this was yet to be carried out.

INCOIS could not establish coordination among the various State and Central agencies to improve coastal community's preparedness for tsunami emergencies.

Atlas comprising Multi-hazard Vulnerability maps prepared as early as 2013, was released in 2023. Some of the base data used for preparation of the Atlas was as old as 2007. INCOIS has not yet identified the highly vulnerable coasts of the west coast (from Kochi to Gujarat), Andaman and Nicobar and Lakshadweep Islands. INCOIS also did not have any plans for preparation of 3D GIS maps for the same. Additionally, for Lakshadweep Islands, not only 3D GIS maps but even Multi-hazard Vulnerability maps have not been prepared.

6.4 Recommendations

- ***INCOIS/MoES may formulate the research programmes/activities targeting the achievement of Sustainable Development Goals.***
- ***INCOIS may establish coordination among the various State and Central agencies to improve coastal community's preparedness for Tsunami emergencies.***
- ***INCOIS may prepare Multi-hazard Vulnerability maps for Lakshadweep Islands. INCOIS may also carry out vulnerability studies for the West coast (from Kochi to Gujarat), Andaman and Nicobar and Lakshadweep Islands for preparation of 3D GIS maps.***

New Delhi
Dated: 25 April 2025

(Dr. Kavita Prasad)
Director General of Audit, Central Expenditure
Environment and Scientific Departments

Countersigned

New Delhi
Dated: 07 May 2025

(K. Sanjay Murthy)
Comptroller and Auditor General of India

Annexures

Annexure I
(Refer Para 4.1)
Details of Data Holdings at INCOIS (as of 31st July 2022)

Sl. No.	Platform	Parameter	No. of Platforms	Years of data availability
1.	Met Buoys (National Institute of Ocean Technology)	Met-Ocean parameters	56 (Distinct Named buoys)	1997 – present (in Variable time intervals)
2.	OMNI Buoys (National Institute of Ocean Technology)	Met-Ocean parameters	12 buoys	2010 – present (in Variable time intervals)
3.	XBT[83]	Temperature	7593 profiles	1990 – 2020
4.	XCTD[84]	Temperature and Salinity	940 profiles	2009 – 2020
5.	Argo	Temperature, Salinity, Dissolved Oxygen, Chlorophyll, Backscattering	494	2002 – Present
6.	Tide gauges	Sea Level	37 stations	2010 – present
7.	Drifters	SST, Air Pressure	440 (23 – INCOIS Argos 4 – Wave drifters of INCOIS, 413 – NIO)	1991 – present
8.	ADCP[85]	Currents	41 (32 distinct Coastal Region, nine in Equatorial Region)	2003 – 2022
9.	RCM[86]	Currents	Distinct seven stations in Equatorial Region	2000 – 2021
10.	Wave Rider Buoys	Wave Parameters	23 stations	2007 – Present
11.	AWS[87]	Met parameters	42	2009 – present
12.	Ship Mounted Wave Height Meter	Wave parameters	1	2010 – 2020
13.	Tsunami Buoys	Sea Level	17 buoy locations	2011 – present
14.	Coastal HF Radar	Currents	5 Pairs	2008 – present
15.	COMAPS[88]	Bio Geo Chem Phy Parameters	88 stations	1989 – 2012
16.	UCTD[89]	Temperature and Salinity	2	2013
17.	Microstructure Profiler	Turbulence measuring suite	2	2015
18.	LADCP[90]	Currents	1	2018

[83] ***Expendable Bathy Thermograph.***
[84] ***Expendable Conductivity-Temperature-Depth.***
[85] ***Acoustic Doppler Current Profiler.***
[86] ***Residual Current Monitoring.***
[87] ***Automatic Weather Station.***
[88] ***Coastal Ocean Monitoring and Prediction System.***
[89] ***Underway Conductivity Temperature and Depth.***
[90] ***Lowered Acoustic Doppler Current Profiler.***

Annexure II
(Refer Para 5.1.1.1)
Implementation of Sub-Projects carried out under Ocean Modelling Data Assimilation and Process Specific Observations Project

Sl. No.	Project Title	Organisation	Output generated	Remarks	Total Expenditure ₹
1	Significance of wave-current and tide-wave interaction at various coastal locations of India.	IIT, Bombay	The model for the designated domains (Krishna-Godavari domain, Gulf of Kutch and Khambhat, Hooghly-Mahanadi) transferred to INCOIS in March 2021.	Under the new modelling framework, INCOIS envisages making use of WAVEWATCH III for wave simulations and hence the models provided by the PI were not operationalised.	20.73 lakh
2	The impact of atmospheric aerosols and pollution on the Bay of Bengal Marine ecosystem.	IIT, Kharagpur	The coupled WRF-Chem + ROMS biogeochemistry model incorporating the atmospheric chemistry transferred to INCOIS in December 2021.	Under the new modelling framework, INCOIS envisages to make use of a different ocean-atmosphere coupled system and hence this model was not operationalised.	31.87 lakh
3	A coupled physical – ecosystem model based on MOM5-COBALT for the Indian Ocean.	CUSAT, Kerala	Model simulations were carried out for nutrients such as nitrate, phosphate, silicate, *etc.* More in-situ observation data sets were required so as to thoroughly validate the nutrient simulation from the model. The ecosystem model which has been set up includes phytoplankton and zooplankton. Efforts were made to simulate up to zooplankton. However, it lacked proper validation of model-simulated zooplankton because of non-availability of observation on zooplankton data.	Manuscript prepared based on the major findings was ready for submission in a high impact journal. The model set up and technical description had been completed and transferred to INCOIS in April 2021.	19.65 lakh
4	Natural and human-induced hypoxia and its consequences in the coastal waters off Kochi.	KUFOS, Kerala	Field visits were carried out during the period December 2018 to March 2021. There were breaks in field visits due to the COVID-19 pandemic and extreme sea conditions during the southwest monsoon.	The data collected under the project had been transferred to INCOIS in July 2021. The PI has been analysing data generated under this project in collaboration with INCOIS scientists which resulted in a recent publication.	30.996 lakh Unspent Balance 1.82 lakh

Sl. No.	Project Title	Organisation	Output generated	Remarks	Total Expenditure ₹
5	Influence of anticyclonic eddies on Oxygen Minimum Zone in the Bay of Bengal.	NIO, Visakhapatnam	Two cruises were conducted for sampling of parameters and nutrients. The data collected under this project has been transferred to INCOIS. Based on all the samples collected in the Bay of Bengal, an Atlas for dissolved organic nitrogen was prepared.	Atlas is yet to be released.	44.52 lakh
6	Ship-based measurement of resolution surface turbulent air-sea fluxes of heat, moisture and momentum from the Indian Ocean/Arabian Sea.	NIO, Goa	There was discontinuity in sample collection due to failure of sensors, COVID pandemic. The data collection started in December 2020 and was accomplished in two legs. The raw and processed data were submitted to INCOIS in July 2021.	There was discontinuity in sample collection due to failure of sensors, COVID pandemic.	39.99 lakh
7	Development and implementation of river discharge and biogeochemical module for the global climate model set-up of INCOIS.	IISc, Bangalore	The MOM global model was provided by INCOIS to the concerned PI to build the river discharge module, which was developed and handed over to INCOIS in March 2021. The module was now integrated into the INCOIS global model and was being tested.	The biogeochemical module was not implemented due to INCOIS moving over to the Unified modelling framework.	95.52 lakh
8	Quality control of HF radar surface currents for investigation of sub-mesoscale coastal processes and its use for assimilation in the INCOIS model.	IIT, Bhubaneswar	(a) The PI came up with a data filling algorithm for HF Radar surface current data and the algorithm had been transferred to INCOIS. These surface current data was supposed to be assimilated in operational RAIN which was able to assimilate temperature and salinity profiles and sea surface temperature observations. (b)Further, IIT Bhubaneswar had transferred the quality-controlled HF-R current data for the Odisha, Andhra Pradesh and Tamil Nadu coast from 2015 to 2018, the methodology used to	(a) Under modelling framework, Data Assimilation system would be developed for global and regional MOM6 during 2023-25. Once the data assimilation scheme was properly tuned, INCOIS would be able to directly assimilate quality controlled HF-R data into this setup. (b) INCOIS will assimilate these quality controlled data once the data assimilation scheme with MOM6 was ready for assimilating currents.	16.12 lakh

Sl. No.	Project Title	Organisation	Output generated	Remarks	Total Expenditure ₹
			process the above datasets, the gap filled and flagged data to INCOIS in March 2021.		
9	Dynamics of Mesoscale and sub-mesoscale processes in the Indian Ocean using Modular Ocean Model.	IIT, Bombay	The Project Monitoring Committee recommended closure of the project with immediate effect and to submit a new project to pursue the unaddressed objectives of the project. However, no new proposal was submitted by the PI.		15.96 lakh
Total Expenditure					**315.356 lakh**

Annexure III
(Refer Para 5.1.3.1)
Coastal Monitoring Sub-projects[91]

Sl. No.	Name of the participating institution	Objective	Achievement	Percentage of success	Justification
1.	NIO, RC, Vizag	Maintenance of buoy based autonomous observatory off Visakhapatnam.	Autonomous observatory which was procured in January 2022 is not deployed yet.	0 *per cent*	---
		Time-series sampling at the buoy location, with monthly frequency, measuring the essential parameters.	Sampling was conducted between September 2020 and March 2021. Due to lack of funds observations were not conducted.	10 *per cent*	Due to lack of funds in both boat hire and consumables.
		Time-series measurements of atmospheric aerosol composition.	Aerosol samples were collected and analysed between April 2020 and April 2021.	50 *per cent*	---
2.	NIO, RC, Goa	Maintenance of buoy based autonomous observatory off Goa.	Nil	0	---
		Time-series sampling at the buoy location, with monthly frequency.	Partial	62.5	Severe lack of funding (only ₹29.82 Lakh out of the sanctioned amount of ₹81.61 lakh).
		To assess the response of foraminifera and juveniles such as Oyster larvae to changing pH conditions in seawater.	Nil	0	---
		To delineate changes in chlorophyll, CDOM and pathogens under changing physicochemical parameters.	Partial (Chlorophyll and CDOM)	58 *per cent* and 42 *per cent* respectively	---
		To observe long-term changes in plankton community under changing nutrient stoichiometry.	Nil	0	---
		To assess the influence of changing physicochemical parameters on macro-faunal distribution and diversity.	Nil	0	---

[91] ***Out of six sub-projects, under one sub-project granted to University of Calcutta, no activities were carried out and the amount released was refunded.***

Sl. No.	Name of the participating institution	Objective	Achievement	Percentage of success	Justification
		To assess seasonal and long-term changes in the fish community at the buoy location.	Nil	0	---
		To understand the mechanisms driving the oxygen variability off Goa.	Nil	0	---
3.	CSMCRI, Bhavnagar	Maintenance of buoy based autonomous observatory off Veraval/Diu, Gujarat.	Location is finalised in consultation with the Diu fisheries Department.	The buoy is yet to be installed by INCOIS	---
		Time-series sampling at the buoy location, with monthly frequency, measuring the essential parameters.	Monthly marine sampling at Diu coast were performed in 07 different stations, which includes the proposed Buoy location. The samples were analysed with respect to selected physico-chemical parameters as well as biological parameters.	100 *per cent*	---
		Understanding the fluctuation of physico-chemical parameters in the coastal water and their relation to spread of pathogenic genes, multiple antibiotic resistance trait, factor responsible for spread of antibiotic resistant traits are need to be studied in details.	Characterisation of pathogenic traits and antibiotic resistance are under progress.	70 *per cent*	Due to non-availability of funds, the proposed objectives were not fulfilled.
		Regular monitoring of one selected popular beach near sampling location to fulfil our initiative to make Blue Flag beach in future.	Ghoghla beach is declared as a blue flag beach in October 2020. Therefore we have monitored the health of Somnath beach, Veraval.	100 *per cent*	---
4.	NIO, RC, Kochi	Maintenance of buoy based autonomous observatory off Kochi.	The monthly observation started at the proposed buoy location. Test deployment of the buoy in the estuarine region was conducted on 3 March 2022. Sensor validation with in-situ measurements of the various parameters has been carried out. We are expecting buoy deployment in April 2022.	Not mentioned	---
		Time-series sampling at the buoy location, with monthly frequency, measuring the essential parameters.	Monthly sampling started from August2020 onwards; Due to COVID-19 and the lockdown scenario, we could not sample from April, May, June, July in 2020	Not mentioned	---

Sl. No.	Name of the participating institution	Objective	Achievement	Percentage of success	Justification
			and April, May in 2021 the lack of fund availability, August sampling is not conducted.		
		To establish a water quality model to nowcast and forecast coastal environment off Kochi.	FVCOM model for Off Kochi has been set up for simulating hydrodynamic conditions. Temperature and salinity validation of the model has been carried out. We expect collaborative work with the INCOIS modelling team as per the directions received during the protocol meeting.	Not mentioned	---
		Intra-seasonal to inter-annual physical forcing and their relative importance to the biogeochemical variability in the off-Kochi.	The in-situ and satellite data of the biological production unveils that the shelf off Kochi was always productive up to a distance of 15-20 km from the inlet irrespective of season, which can be augmented by the influence of the estuarine system.	Not mentioned	---
5.	XIM University, Harirajpur, Odisha	In situ measurements of physical (Temperature, Salinity), optical (apparent optical properties, phytoplankton, detritus and CDOM absorption coefficient) and biogeochemical (phytoplankton pigment, TA, DO, BOD, COD, macro-nutrients, DIC, DOC, PIC, POC, TOC, E. coli, Total Coliform, trace metals) parameters, simultaneously at upstream, downstream and near coastal waters, covering complete tidal cycle, during pre-monsoon, monsoon and post-monsoon season.	In-situ physical, optical and biogeochemical parameters were collected simultaneously at upstream, downstream and near coastal waters of Mahanadi estuary in Post – monsoon covering full tidal cycle and during monsoon covering half tidal cycle. Data were analysed and submitted to INCOIS.	70 *per cent*	---
		To discern influence of tide and river runoff on seasonal hydro-chemical budget in Mahanadi estuary.	The hydro-chemical budgeting has been initiated which will be submitted for potential publication.	70 *per cent*	---

Sl. No.	Name of the participating institution	Objective	Achievement	Percentage of success	Justification
		To identify trophic status of Mahanadi estuary at seasonal scale.	The trophic state index of Mahanadi estuary has been computed which will be further refined to make it ready for publication.	70 *per cent*	Due to shortage of funds.

Annexure IV
(Refer Para 5.1.3.1)
Coastal Monitoring
Details of sampling carried out by the participating institutions for the period April 2020 to March 2022

Sl. No.	Name of the institution	No. of stations	Total no. of months in which samples to be collected	No. of months in which sample collected for all stations	Percentage of months in which samples collected for all stations	No. of months in which no samples collected	Percentage of months in which no samples collected
1.	CSMCRI[92], Bhavnagar	7	24	21	87.50	3	12.5
2.	NIO, RC[93], Goa	4	24	10	41.67	9	37.5
3.	NIO, RC, Kochi	6	24	1	4.17	12	50
4.	NIO, RC, Vizag	5	24	Data not available	---	Data not available	---
5.	XIM[94], Odisha[95]	3	Seasonal	1	---	1	---

[92] *Central Salt and Marine Chemicals Research Institute.*
[93] *National Institute of Oceanography, Regional Centre.*
[94] *Xaviers Institute of Management.*
[95] *Only seasonal data was to be collected.*

Annexure V
(Refer Para 5.2.1.1)
Details of sub-projects granted under Ocean State Forecast

Sl.No.	Name of the project	Organisation	Objectives	Amount released ₹ in lakh	Expenditure incurred ₹ in lakh	Duration of the project	Audit observations
1	Real Time Wave Data Collection from selected Coastal Indian locations.	CSIR-NIO	To carry out measurements of directional waves at selected shallow water locations; To compare the measured wave parameters with the wave forecast results; To study the wave spectral characteristics; To identify the theoretical wave spectra for different wave conditions.	62.81	61.99	01.04.2018-31.03.2022	Project Completion Report for the period 2018-2022 submitted in May 2022. The PI reported the maintenance of the Wave Rider Buoys deployed at nine locations Veraval, Versova, Ratnagiri, Karwar, Kolachal, Tuticorin, Puduchery, Gangavaram, Gopalpur. There were a number of instances of WRBs getting drifted and inordinate delays in redeployment. All the WRBs were non-functional for long intermittent spells. There were delays in redeployment due to reasons such as non-availability of boat, damages, *etc.* with the result that continuous Wave. Data was not available for predominantly long spells at all the locations. The report did not bring out the comparison between the measured wave parameters with the wave forecast results at least for the periods when there was data, though this was one of the main objectives of the project. Thus, no validation of the Wave Forecast happened during the period 2017-2022 at these locations.
2	Dissemination Validation of OSF and PFZ Services	Dept. Of Studies in	Validation, Dissemination and organisation of awareness	26.27	26.47	01.04.2018-31.03.2022	In the PMRC Meeting held in March 2021, the project was graded 6/10. Project completion report for the period 2018-2022

Sl.No.	Name of the project	Organisation	Objectives	Amount released ₹ in lakh	Expenditure incurred ₹ in lakh	Duration of the project	Audit observations
	off Uttara Karnataka for study of fisheries and economic development of fisher folks.	Marine Biology, Karnataka University	meetings related to OSF and MFAS in Karnataka region; Conduct user interaction meetings and collecting user feedback on OSF and MFAS; Assist for wave rider operations off Karnataka.				elaborating the achievements against the targets was not available.
3	Wave Rider Buoy (WRB) programme for the West Bengal coast collection of in situ data, its dissemination and utilisation for the coastal population.	Institute of Business Management National Council of Education Bengal (IBMNCE), Kolkata	Maintain the Wave Rider Buoy off Digha; Analysis of the WRB data; Monitoring the methods of dissemination, collection of feedback on OSF and MFAS services and further improvements; Validation of OSF model outputs against the WRB data obtained for further improvements of the daily OSF and PFZ forecasts being received; Conducting User Interaction, Outreach and Capacity Building programmes; Collecting and documenting the local folklore, indigenous technology used by fishermen; Submission of analysed WRB data to INCOIS.	24.04	24.38	01.04.2018-31.03.2021	During the PMRC meeting held in March 2021, the committee graded the project as 5.5/10. It advised the PI to submit the final project completion report along with Audited UC and SOE. Committee suggested INCOIS to make the arrangements for the transport of equipment and other project material available with the project either to INCOIS or to any other appropriate nearby centre connected to INCOIS. Project Completion Report, Utilisation Certificate and Statement of Expenditure were not available.

Sl.No.	Name of the project	Organisation	Objectives	Amount released ₹ in lakh	Expenditure incurred ₹ in lakh	Duration of the project	Audit observations
4	Wave Rider Buoys in Puducherry, Tuticorin and Colachel coast, Documentation of ITK, Capacity Building and Validation of INCOIS Services in Tamil Nadu and Andhra Pradesh.	Fish For All-Research and Training Centre, MSSRF	Validation and dissemination of OSF and MFAS services in TN and Pondicherry; Monitoring the WRB; Assess the potential of OSF and MFAS services and its impact on fishing by carrying out studies; Capacity Building, Awareness Campaign, user interactions and dissemination of knowledge to utilise the forecast services.	59.28	59.86	01.04.2018-31.03.2022	At the end of the project duration, MSSRF furnished Project Technical Report. While giving the details of works carried out, MSSRF reported that in spite of the utility and benefits, there were some concerns and issues which need to be addressed to realize the benefits to its full potential. It also advised that before launching the future forecast models, there was a need for incorporating fishermen's knowledge, which would facilitate development of an integrated forecast system and improve accuracy.
5	Location specific ocean state forecast off Andhra Pradesh coast.	Centre for Studies on Bay of Bengal, Andhra University, Visakhapatnam	Validation, Dissemination and organising awareness meetings on OSF and MFAS; User Interaction and Awareness Meetings and collecting Feedback on OSF and MFAS; Assist WRB operations off Krishnapatnam and Vishakhapatnam.	90.21	89.49	01.04.2018-31.03.2022	Project Completion Report, Utilisation Certificate and Statement of Expenditure for the period 2018-2022 detailing the achievements against the targets was not made available.
6	Deployment and Data Collection of the Directional Wave Rider Buoy off Gopalpur Coast on East Coast of India.	Chilika Development Authority, Bhubaneshwar	Validation, Dissemination and Organising awareness meetings related to OSF and MFAS in Odisha region; User Interaction Meetings and collecting user feedback on OSF and MFAS; Assist for WRB at Gopalpur	25.44	26.54	01.04.2018-31.03.2022	Project Completion Report, Utilization Certificate and Statement of Expenditure for the period 2018-2022 detailing the achievements against the targets were not available.

Sl.No.	Name of the project	Organisation	Objectives	Amount released ₹ in lakh	Expenditure incurred ₹ in lakh	Duration of the project	Audit observations
7	Validation and dissemination of ocean state forecast advisories along Gujarat coast.	ICAR-Central Institute of Fisheries Technology Kochi	To conduct research on jelly fish; Disseminate OSF and MFAS advisories and feedback collection along Gujarat coast; To assist operation of WRB off Gujarat Coast.	21.87	21.32	01.04.2018-31.03.2022	Project Completion Report submitted. WRB deployed at Veraval on 11.1.2019, drifted thrice (June 2019, October 2019, March 2020). Redeployment delayed due to lockdown. Deployed in October 2020. Next, Antenna damage occurred. This was repaired in January 2021. Buoy stopped transmission on 13th July 2021. Buoy found in vandalised state and could not be used due to lack of spare parts and repairs. Brought back to INCOIS Hyderabad for repairs and replacement of spare parts. No WRB at Veraval since then. User Workshops and awareness meetings conducted. But no feedback about the utility of the services collected and documented.
8	Socio-economic betterment and development by scientific approach to the Ocean state Forecast (OSF) through wave rider buoy (WRB) parameters and PFZ.	G.M.Vedak College of Science, Maharashtra	Validate, Disseminate and organise awareness meetings on OSF and MFAS in entire Maharashtra Coastal Region; Conduct User Interaction Meetings and collecting user Feedback on OSF and MFAS; Assist for WRB operations off Ratnagiri.	24.89	24.91	01.04.2018-31.03.2022	Project Completion Report, Utilisation Certificate and Statement of Expenditure detailing the achievements against the targets were not available.
9	Synergistic applications of earth observation data-microwave SAR, IR and visual data for the validation of ocean state	Nansen Environmental Research Centre (India), Kochi	To conduct methodologies on validation/fine tuning of OSF forecast of wave, current, SST, wind, *etc*. using data supplied from INCOIS, SAR data and data collected using own instruments.	11.52	11.37	01.04.2018-31.03.2021	Project Completion Report, Utilization Certificate and Statement of Expenditure were not available.

Sl.No.	Name of the project	Organisation	Objectives	Amount released ₹ in lakh	Expenditure incurred ₹ in lakh	Duration of the project	Audit observations
	forecast for North Kerala.						
10	Establishment of Wave Observation at two locations off Kerala coast; Verification and Dissemination of forecasts, advisories and user interaction workshops.	Dept. Of Aquatic Environment Management, KUFOS, Kochi	Validation, dissemination of advisories/forecasts and organising awareness services on OSF and MFAS in entire Kerala Coastal region; Conduct User Interaction Meetings and collect use feedback; Maintenance of WRB off Kozhikode and a new location off Kerala Coast; Data Collection from at least three major fish ports of Kerala and study on Sardine Fish stock to help INCOIS to develop and fine tune the methodology for Sardine prediction.	50.20	50.09	01.04.2018-31.03.2022	Project Completion Report submitted. Two WRBs were maintained – one at Kozhikode and another at Kollam. Kozhikode WRB – Drifted thrice (30/6/2019; 6/11/2019; 19.2.2020). Redeployed each time after intervals. Kollam WRB - Deployed on 25/4/2018; Drifted on 14.5.2019; Redeployed 17.5.2019; Battery Drained – 2/10/2019; New Batteries replaced and redeployed 11/10/2019. Report projected Forecasted and observed Wave heights at Kozhikode and Kollam – Variations seen. The PI reported in the PCR that research components could not be completed due to the difficulties of field work and lack of research work force. Comprehensive feedback on the availability, periodicity and approximations of quantities of fish in the PFZ has not been analysed. PI proposed to initiate citizen Science mechanism to record exact fishing ground, specifies and quantity of fish obtained. PI also stated that the need for data collection to improve the predictability of the forecast was realised. PI also mentioned that the location of the fishing ground, species collected and quantity are arbitrarily collected from catch observations and fishers at the fishing harbour and that viability of the

Sl.No.	Name of the project	Organisation	Objectives	Amount released ₹ in lakh	Expenditure incurred ₹ in lakh	Duration of the project	Audit observations
							PFZ advisories based on such subjective estimates could not be assessed. Data collection from at least three major fish ports of Kerala and study on sardine fish stock which will help INCOIS to develop and fine tune the methodology of sardine prediction not conducted. Consolidated UC and SoE not available.
11	OSF and MFAS dissemination in the Lakshadweep coast, in-situ data collection and ground truth validation of PFZ data in Lakshadweep islands.	Department of Fisheries, UT of Lakshadweep	To assess the variability in environmental variables and refine the tuna specific advisory based on the tagged data available from INCOIS on Yellow Fin Tuna resources in coordination with INCOIS Scientists; To collect Tuna Fishery data ITK knowledge in Tuna fishery and validation of Tuna fishery advisories; To validate and refine the Tuna Advisory provided by INCOIS. Validation, dissemination of fishery advisories and organising awareness Meetings. Conduct interaction meetings and collect user feedback. Assist WRB operation off Kavaratti and data collection.	17.13	17.26	01.04.2018-31.03.2022	During the PMRC held in April 2019, the PI was advised to collect skipjack tuna data and work jointly with INCOIS for the development of skipjack tuna advisories wherein appropriate tagging data could be used. Subsequently, in the PMRC held in March 2021, the PI was advised to complete and close the project by March 2021 and submit the Project Completion Report by May 2021. There was, however, no Project Completion Report, Audited UC and SOE.

Annexure VI
(Refer para 5.2.3)
Target and current status of the models developed by INCOIS

Sl.No.	Name of the service and target	Current status	Remarks
1.	**Wave parameters – Wavewatch – SWAN** Development of customised state-of-the-art numerical ocean models Wavewatch III and SWAN for generating operational ocean forecasts in the coastal waters around the country as well as for the open ocean was an objective during the period 2017-20.	INCOIS configured this setup by April 2019 and also generated forecasts on experimental basis using this model setup. However, it did not validate the results and fine-tune the model set up for releasing it for operational purposes.	Further, INCOIS decided (December 2020) not to proceed with this model set up since it planned to adopt a new modelling framework, thus rendering entire efforts futile.
2.	**Sea level projections-** INCOIS reported to IRC in 2019 that configuration and hindcast simulations of high-resolution global model and Indian Ocean model were completed for making sea level projections in the context of global warming. INCOIS also reported that it was continuing its studies for operationalising it for generating future sea level projections.	The model was still under development.	It was apparent that INCOIS could not operationalise the model setup despite lapse of four years from the time of its commitment and thus the intended benefits could not be derived.
3.	**Wave forecast system – Simulating Waves Nearshore Model (SWAN) – ADvanced CIRCulation (ADCIRC)** I) For the years 2017-2020, INCOIS had the target of setting up SWAN + ADCIRC wave forecast system for three locations – one location each year, as deliverable for the years 2017-2020. (ii) As per the Outcome Output Monitoring Framework (OOMF), for the year 2018-19, setting up of high-resolution SWAN-ADCIRC based wave forecast for three coastal states was the target and for the period 2020-2024, the deliverables were setting up	By April 2019, ADCIRC- SWAN configuration for wave forecast had been setup for three regions in the east coast, *viz.*, north Tamil Nadu coast, Chandipur and Visakhapatnam and one region in the west coast, *viz.*, Kerala. INCOIS configured the forecast system for only one coastal region - Pondicherry coast.	Only the forecast system for Kerala coast has been operationalised till date. INCOIS was still in the process of configuring the high-resolution wave forecast system. Thus, it was apparent that the targets as identified in the OOMF are yet to be achieved.

Sl.No.	Name of the service and target	Current status	Remarks
	high resolution wave forecast system for more locations.		
4.	**(d) Swell surge – SWAN – ADCIRC** Setting up a swell surge forecast system was a deliverable for the years 2017-20.	Swell surge forecasting system using ADCIRC was inaugurated in February 2020**.** INCOIS claimed that the system would predict Kallakadal and warnings would be given to the authorities concerned at least 2-3 days in advance, which would help the local authorities for contingency planning and to reduce damage. Using this system, alerts/warnings were provided to Kerala coast for the 138 swell surge events that met the operational threshold. Further efforts were underway to expand the system for Karnataka, Goa, Maharashtra and West Bengal coasts.	The present level of accuracy of the forecasting system for Kerala coast was less than the target – for Root Mean Square Error (RMSE) the present level of accuracy was 0.25 against the target of 0.15 and for Period the present level of accuracy was two seconds as against the target of one second. This indicated that the system needs to be fine-tuned.
5.	Implementation and operationalisation of ADCIRC + SWAN Coupled model as part of the enhancement of the current storm surge early warning system was a deliverable for the years 2017-2020.	By April 2019, INCOIS had configured and tested the same for historical events.	INCOIS, however, could not operationalise the model setup even after more than three years of target date, as the model setup was still undergoing improvements.

Abbreviations

Abbreviations

1.	ACROSS	Atmospheric and Climate Research – Modelling Observing Systems and Services
2.	ADCIRC	Advanced Circulation Model
3.	ADCP	Acoustic Doppler Current Profiler
4.	ADMT	Argo Data Management Team
5.	ALTM	Airborne Laser Terrain Mapping
6.	AO	Administrative Order
7.	API	Application Programming Interface
8.	AWS	Automatic Weather Station
9.	BPR	Bottom Pressure Recorder
10.	Cert-In	Indian Computer Emergency Response Team
11.	CIFT	Central Institute of Fisheries Technology
12.	CMFRI	Central Marine Fisheries Research Institute
13.	CMLRE	Centre for Marine Living Resources and Ecology
14.	CISO/CSO	Chief Information Security Officer/Chief Security Officer
15.	DDS	Digital Display System
16.	DOM	Deep Ocean Mission
17.	DTM	Digital Terrain Models
18.	ECFS	Eddy Covariance Flux System
19.	EDB	Electronic Display Board
20.	EFAS	Ecosystem-based long term Fishery Advisory Services
21.	ECMWF	European Centre for Medium Range Weather Forecasting
22.	EFC	Expenditure Finance Committee
23.	ESSO	Earth System Science Organisation
24.	GC	Governing Council
25.	GDP	Global Drifter Program
26.	GHRSST	Global High-Resolution Sea Surface Temperature
27.	GIGW	Guidelines for Indian Government Websites
28.	GODAS	Global Ocean Data Assimilation System
29.	HOOFS	High-resolution Operational Ocean Forecast and re-analysis System
30.	HPC	High Performance Computing
31.	HYCOM	The Hybrid Coordinate Ocean Model
32.	HWRF	Hurricane Weather Research and Forecast Model
33.	IAST	International Argo Steering Team
34.	IDS	Integrated Dissemination System
35.	IGOA	INCOIS Global Ocean Analysis
36.	IITM	Indian Institute of Tropical Meteorology
37.	IMD	India Meteorological Department
38.	INCOIS	Indian National Centre for Ocean Information Services
39.	INDOFOS	Indian Ocean Forecasting System
40.	IndOOS	Indian Ocean Observing System
41.	IOCDEP	Intergovernmental Oceanographic Commission Oceanographic Data Exchange Policy
42.	IODE/IOC	International Oceanographic Data and Information Exchange/ Intergovernmental Oceanographic Commission
43.	IRC	Independent Review Committee
44.	IRD	Integrated Receiver Decoder
45.	ITB	Indian Tsunami Buoy
46.	ITCOOcean	International Training Centre for Operational Oceanography

47.	ITEWC	Indian Tsunami Early Warning Centre
48.	JSTAC	Joint Scientific and Technical Advisory Committee
49.	KPI	Key Performance Indicators
50.	KUFOS	Kerala University of Fisheries and Ocean Studies
51.	LADCP	Lowered Acoustic Doppler Current Profiler
52.	MAS	Mariculture Site Suitability
53.	MDG	Millennium Development Goals
54.	MFAS	Marine Fisheries Advisory Services
55.	MHVM	Multi Hazard Vulnerability Mapping
56.	MM	Monsoon Mission
57.	MODIS	Moderate Resolution Imaging Spectroradiometer
58.	MoES	Ministry of Earth and Science
59.	MoF	Ministry of Finance
60.	MOM	Modular Ocean Model
61.	MoU	Memorandum of Understanding
62.	NCIIPC	National Critical Information Infrastructure Protection Centre
63.	NCMWRF	National Centre for Medium Range Weather Forecasting
64.	NCS	National Centre for Seismology
65.	NIO	National Institute of Oceanography
66.	NIOT	National Institute of Ocean Technology
67.	NOAA	National Oceanic and Atmospheric Administration
68.	NODC	National Oceanographic Data Centre
69.	NRSC	National Remote Sensing Centre
70.	NTWC	National Tsunami Warning Centre
71.	OASIS	Ocean Advisory and Information Services, Computational Infrastructure and Communication Systems
72.	O-IAS	Ocean Information and Advisory Services
73.	OMAS	Ocean Modelling and Advisory Services
74.	O-MASCOT	Ocean-Modelling, Data Assimilation and Process Specific Observations
75.	OMI	Operational and Maintenance of INCOIS
76.	OON	Ocean Observations Network
77.	OSF	Ocean State Forecast
78.	O-SMART	Ocean Services, Modelling, Applications, Resources and Technology
79.	PB	Petabyte
80.	PCR	Project Completion Report
81.	PET	Project Evaluation Team
82.	PF	Petaflop
83.	PFZ	Potential Fishing Zone
84.	PMC	Project Management Council, Project Monitoring Committee
85.	PMRC	Project Monitoring Review Committee
86.	POGO	Partnership for Observation of the Global Ocean
87.	QMS	Quality Management System
88.	RAC	Research Advisory Committee
89.	RCM	Residual Current Monitoring
90.	REACHOUT	Research, Education, Training and Outreach
91.	RIMES	Regional Integrated Multi Hazard Early Warning System
92.	ROMS	Regional Ocean Modelling System
93.	RTSMN	Real-Time Seismic Monitoring Network
94.	SCOR	Scientific Community on Oceanic Research
95.	SDG	Sustainable Development Goals

96.	SFC	Standing Finance Committee
97.	SIBER	Sustained Indian Ocean Biogeochemistry and Ecosystem Research
98.	SST	Sea surface Temperature
99.	STB	SAIC Tsunami Buoy
100.	SWAN	Simulating Waves Nearshore Model
101.	SVA	Small Vessel Advisory
102.	TF	Teraflop
103.	TSP	Tsunami Service Provider
104.	TUNAMI N2	Tohoku University's Numerical Analysis Model for Investigation of Near-field Tsunamis
105.	UCTD	Underway Conductivity Temperature and Depth
106.	UNESCO	United Nations Educational, Scientific and Cultural Organisation
107.	VMP	Vertical Microstructure Profiler
108.	VSAT	Very Small Aperture Terminal
109.	WHOI	Woods Hole Oceanographic Institute
110.	WMO	World Meteorological Organisation
111.	WRB	Wave Rider Buoy
112.	WWIII	Wavewatch III
113.	XBT/XCTD	Expendable Bathythermograph/Expendable Conductivity-Temperature Depth
114.	3DGIS	3-Dimensional Geographic Information System