# FORMAT FOR EFC/SFC MEMORANDUM FOR APPRAISAL OF SCHEMES

## 1. Scheme Outline

1.1 Title of the scheme:

**Ocean Observation Network (OON), (INCOIS and NIOT components)**

1.2 Sponsoring Agency (Ministry/Department/ Autonomous Body or undertaking):
**Ministry of Earth Sciences (MoES)**

1.3 Total Cost of the proposed scheme:

| | |
|---|---|
| **INCOIS components (**Argo floats, Drifters, XBT/XCTD, Coastal ADCP moorings, Equatorial current meter Array, Wave rider buoys network, AWS onboard research vessels and Wave measurements onboard ships, Bay of Bengal Observatory, Tsunami Buoys (BPR), Tide Gauges) | |
| **For 3 years (2017-18 to 2019-20)** | **124.11 Crores** |
| | |
| **NIOT components -1** (Moored Ocean Observation Network) | |
| **For 3 years (2017-18 to 2019-20)** | **120.00 Crores** |
| | |
| **NIOT components-2** (Deployment and Maintenance of HF Radars) | |
| **For 3 years (2017-18 to 2019-20)** | **36.84 Crores** |
| | |
| **Total** | **280.95 Crores** |

**1.4 Proposed duration of the scheme: 3 Years**

3 years; April 2017 – March 2020.

**1.5 Nature of the scheme: Central Sector scheme/ Centrally Sponsored Scheme:**
Central Sector Scheme

**1.6 For central schemes, sub-schemes/components, if any, may be mentioned. For centrally sponsored schemes, central and state components, if any, may be mentioned.**
Not applicable

**1.7 Whether a new/a continuing scheme? In case of continuing scheme, whether old scheme was evaluated and what were main findings:**
It is a continuous Scheme. Old scheme was evaluated thoroughly and recommended for continuation by Independent Review Committee (IRC) constituted by Ministry of Earth Sciences (MoES). The main finding with INCOIS-OON component is that all the observation schemes proposed are to be continued.

For NIOT-OON component-1 the main finding is that buoy network should be continued. CalVal collaborative program with ISRO should also be continued. It was opined that technology demonstration should include more of indigenization efforts.

For NIOT-OON component-2 the main finding is that the radar network should be well maintained and continued.

**1.8 Whether in principle approval is required? If yes has been obtained:**

Recommendation for continuation of project is obtained from Independent Review Committee constituted by MoES and IRC report/recommendations are accepted by competent authority. The report along with the minutes is attached along with the SFC.

**1.9 Whether a Concept paper or a detailed paper has been prepared and stake holders consulted? In case of new centrally Sponsored scheme, whether the state governments have been consulted?**

Not applicable as this is continuing program and accordingly a SFC is prepared and submitted.

**1.10 Which existing schemes/ sub-schemes are being dropped, merged or rationalised?**

Tide gauge network and Tsunami monitoring buoys (or Bottom Pressure Recorder; BPR) which are part of OIAS during XII FYP is now merged with INCOIS component of OON.

**1.11 Is there an overlap with an existing scheme/sub-scheme? If so, how duplication of effort and wastage of resources are being availed:**

No overlap with any existing schemes/sub-schemes.

**1.12 In case of an umbrella scheme (program) give the details of scheme and sub-schemes under along with the proposed outlay component-wise.**

No, it is not an umbrella scheme.

Note: It may kindly be noted that the word scheme here is used in a generic sense. It includes programs, schemes and sub-schemes, which depend on need can be appraised and approved as stand-alone coast centres.

## 2 Outcomes and Deliverables

### 2.1a Stated aims and objectives of the schemes proposed under INCOIS OON components:

Considering the importance of ocean observations in terms of understanding the ocean environment and to utilize them for operational oceanography, a large number of observation platforms were deployed and maintained by INCOIS through Ministry of Earth Sciences (MoES) funding under the project Ocean Observation Network (OON) in the coastal and interior ocean areas of the Indian Ocean. These observational platforms have facilitated to acquire real-time *in-situ* oceanographic and near-surface meteorological data. While designing OON programme, it was also considered the existing Indian Ocean Observing System (IndOOS), which is a regional contribution to the Global Ocean Observing System (GOOS), an international collaborative effort led by the Intergovernmental Oceanographic Commission (UNESCO-IOC) to establish ocean observation and collect real time oceanographic data of the world's oceans. The different platform under OON includes the Argo floats, Expendable bathythermograph/expendable conductivity temperature depth (XBTs/XCTDs), satellite-tracked surface drifting buoys (drifters), Bay of Bengal Observatory, ship-board Automated weather stations (AWSs), Acoustic Doppler Current Profiler (ADCP) network along Indian coast, current meter array in the equatorial Indian Ocean, wave rider buoys (WRBs), sea level gauges (or Tide Gauges) along the Indian Coast, open ocean tsunami monitoring buoys (or Bottom Pressure Recorder (BPR)) etc. These *in-situ* observation networks succeeded in providing near/real-time oceanic and meteorological data in different spatio-temporal scales and they have been significantly utilized to address and answer key scientific question and issues and it eventually led to better operational system development and improvement. Today, OON is emerged as one of the strongest pillars of operational oceanography in India, which have direct and indirect effect to various spectra of society.

The **objectives of INCOIS-OON** components are defined as follows:

**Objecitive-1)** To establish a wide range of ocean observing networks for acquisition of marine meteorological and oceanographic data from offshore and coastal Indian Sea, Viz., Argo floats, expendable bathythermograph/expendable conductivity temperature depth (XBTs/XCTDs), satellite-tracked surface drifting buoys (drifters), Bay of Bengal observatory, ship-board Automated Weather Stations (AWSs), equatorial current meter array, open ocean Tsunami monitoring buoys (or Bottom Pressure Recorder; BPR), coastal Acoustic Doppler Current Profiler (ADCP) network, wave rider buoys (WRBs) and sea level gauges (or Tide Gauges) network.

**Objective-2)** To set up a real-time and delayed mode coastal and offshore observational system for understanding the boundary currents and to facilitate data assimilation and real time validation of operational nowcast/forecast of ocean variables in and around Indian Sea.

**Objective-3)** To cater the ocean observational need of both operational (real and near real-time) and to understanding (mainly delayed mode or process studies).

**Objective-4)** To conduct R&D projects, Capacity Building, Education & Training and inter institutional project.

The progress, achievement, and data utilization of each platform during last five years (XII plan) under OON is highlighted in (Independent review committee report). Considering the importance of OON to operational services and to answer key scientific questions, **it is imperative to not only maintain the existing network but also expand the existing network by more deployment and incorporation of additional sensors in the existing platforms.** Some of these new sensor technology and operations (e.g., direct covariance flux measurements and $pCO_2$ measurements) are new to the Indian scientific community. Hence, it is imperative to get training on deployment, data collection, data quality control procedure and data analysis technique from the developers, manufacturer and expertise in the respective filed in order to execute successful missions.

**2.1b Stated aims and objectives of the schemes proposed under NIOT OON component-1:**

Under the Ocean Observation Network (OON) programme of ESSO MoES, the Ocean observation systems (OOS) group of NIOT is entrusted to undertake the activities on Moored Ocean Observation Network. Established in 1996, with the objectives to operate, maintain and develop moored buoy observational network in the Indian seas. The buoy network comprises of Met Ocean (Deep ocean and Coastal), Tsunami, and CalVal buoy systems. These moored Data Buoys are offshore floating platforms, fitted with meteorological and oceanographic sensors, moored at strategic locations to observe in situ met ocean data and water level data at regular intervals. The observed data are then transmitted through satellite along with location reference to the state-of-the-art mission control centre facility at NIOT, Chennai. Data sets are disseminated in near real time to INCOIS and are being posted in GTS. Data sets are used for operational forecast by IMD through NCMRWF and by INCOIS for Ocean State Forecast. Data from tsunami buoys are used by INCOIS for tsunami early warning application. Data are also used for research, satellite data validation and ocean modeling applications. Timely planning and execution of cruises will augment seamless real-time data input to INCOIS, the nodal agency under ESSO MoES for ocean data repository, which will then be disseminated to end user agencies for developing and validating models that aid timely promulgation of extreme weather, cyclone and tsunami warning to the countrymen. Globally, India is well recognized for sustenance of these activities.

The **objective of** Moored Ocean Observation Network **- MOON**(NIOT component-1) can be defined as:

**Objecitive-1)** To maintain Moored Ocean Observation Network comprising of met-ocean, CALVAL and tsunami buoy for data collection and to disseminate data to INCOIS and to support RAMA programme under the Indo-US collaboration transferred from INCOIS.

**Objecitive-2)** Ocean observational tools proto type technology development

**Objecitive-3)** To conduct collaborative R&D projects, capacity building with national and international institutes / Organizations.

**2.1c Stated aims and objectives of the schemes proposed under NIOT OON component-2:**

The main objective under the HF Radar program is installation and maintenance of Coastal HF radar Network along the Indian coast including Islands. This includes:

**Objecitive-1)** Procurement, installation and operation of new HF radar system (3 pairs), which includes site selection, land acquisition and getting permission, procurement of new HF radar systems, installation at site and validation of data.

**Objecitive-2)** Upgradation of existing HF radar (5 pairs).

**Objecitive-3)** Operation and maintenance of existing HF radar network (8 pairs), which includes preventive maintenance and breakdown maintenance.

**2.2 Indicate year-wise deliverable in tabular formation**

2.2a INCOIS Components of OON:

<table>
<tr><td colspan="3">Individual platforms (targets or deliverable) under future observation network during 2017-2020 (INCOIS component)</td></tr>
<tr><td>SI. No.</td><td>Platforms (or targets) under OON (INCOIS-Component)</td><td>Plan for 2017-20<br>(Year-wise deployment plan has been summarized for the platforms 4,5,6 and 7)</td></tr>
<tr><td>1.</td><td>Argo floats*</td><td>2017-2020: Deploy of 50 Argo floats/per year (33 Argo with Temperature and salinity sensor and 17 Argo with enhanced biogeochemical sensors).</td></tr>
<tr><td>2.</td><td>Drifters*</td><td>2017-2020: Deploy 50 drifters/per year.</td></tr>
<tr><td>3.</td><td>XBT/XCTD*</td><td>2017-2020: Maintain 3 - 5 XBTs/XCTDs lines**<br>Kochi-Lakshadweep.<br>Chennai-Port Blair and Port Blair-Kolkata.<br>Mumbai – Mauritius and Chennai – Singapore transects.<br>**subject to availability of cargo/passenger ship.</td></tr>
<tr><td>4</td><td>Coastal ADCP moorings</td><td>2017-20: Deploy and maintain existing coastal ADCP mooring (18 mooring) along the coast of India.
<table>
<tr><td>Year</td><td>2017-18</td><td>18-19</td><td>19-20</td></tr>
<tr><td>New</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Total</td><td>18</td><td>18</td><td>18</td></tr>
</table></td></tr>
<tr><td>5.</td><td>Equatorial current meter Array</td><td>2017-20: Deploy and maintain 2 mooring in the equatorial Indian Ocean.</td></tr>
<tr><td>6.</td><td>Wave rider buoys network</td><td>2017-2020: Maintain existing 15 WRB network along the Indian coast and 1 WRB at Seychelles. Deploy 3 new WRB along the coast of India and 4 in the Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) countries. (Total 18 WRB along Indian coast and 5 in RIMES countries.)
<table>
<tr><td>Year</td><td>2017-18</td><td>18-19</td><td>19-20</td></tr>
<tr><td>New</td><td>3</td><td>2</td><td>2</td></tr>
<tr><td>Total</td><td>19</td><td>21</td><td>23</td></tr>
</table></td></tr>
<tr><td>7.</td><td>AWS onboard research vessels and Wave measurements onboard ships</td><td>2017-20: Maintain existing 34 AWS network and deploy 5 new AWS. Incorporate $pCO_2$ sensors in 2 research vessels (Total 39 AWS and 2 $pCO_2$ sensors).
<table>
<tr><td>Year</td><td>2017-18</td><td>18-19</td><td>19-20</td></tr>
<tr><td>New</td><td>0</td><td>5 AWS + 2 $pCO_2$</td><td>0</td></tr>
<tr><td>Total</td><td>34 AWS</td><td>39 AWS + 2 $pCO_2$</td><td>39 AWS +2 $pCO_2$</td></tr>
</table></td></tr>
<tr><td>8.</td><td>Bay of Bengal Observatory</td><td>2017-2020: Enhance two OMNI mooring (one in the Bay of Bengal and one in Arabian Sea with Biogeochemical sensors).<br>Maintain a mooring in the northern BoB with sub-surface temperature, salinity, current, direct covariance flux measurements sensors ASIMET sensors and ocean turbulence sensors.
<table>
<tr><td>Year</td><td>2017-18</td><td>18-19</td><td>19-20</td></tr>
<tr><td>New</td><td>0</td><td>1</td><td>2</td></tr>
<tr><td>Total</td><td>0</td><td>1</td><td>2</td></tr>
</table></td></tr>
</table>

| | | |
|---|---|---|
| 9. | Tsunami Buoys (BPR) | **2017-2020:** Service and maintain the existing network of 5 STB systems with the help OEM (M/s SAIC). |
| 10. | Tide gauges | **2017-20:** Up-gradation and maintenance of the existing 36 tide gauges. |
| ***Argo floats, satellite based drifters and XBT/XCTD's are expendable instruments and hence not recoverable. However, data from these instruments are transmitted in real time to onboard or inland ground stations through satellite communication until it is abandoned.** | | |

2.2b Component-1 of NIOT OON (Moored Ocean Observation Network (MOON)):

| **Individual platforms (targets or deliverable) under future observation network during 2017-2020 (NIOT component-1)** | | |
|---|---|---|
| **SI. No.** | **Platforms (or targets) under OON (NIOT-Component)** | **Plan for 2017-20** ***(Year-wise deployment plan has been summarized)*** |
| 1 | To maintain Moored Ocean Observation Network comprising of met-ocean, CALVAL and tsunami buoy for data collection and to disseminate data to INCOIS and to support RAMA programme under the Indo-US collaboration to be transferred from INCOIS. | **2017-20:** Deploy and maintain Met Ocean, tsunami and CALVAL moorings in Indian Seas<br><br>2017-18: 19; 18-19: 19; 19-20: 19 |
| 2 | Ocean observational tools proto type technology development | **2017-20:** Develop cutting edge proto type technology systems, autonomous devices for ocean observation and exploration. |
| 3 | To conduct collaborative R&D projects, capacity building with national and international Institutes/ Organizations. | **2017-20:** To collaborate on R&D projects, capacity building both at national and international level to evolve robust observational systems. |

Moored buoy systems deployed at sea left unattended to collect data in real time, and are moored with anchor. These are located far away from shore and cannot be physically monitored at site. Vandalism affected the buoy programme, which was also reported globally. Project Review Board recommended such buoy systems are tobe treated as consumable.

2.2c Component-2 of NIOT OON (HF Radars)

| | **Individual platforms (targets or deliverable) under future observation network during 2017-2020 (NIOT component-2)** | | | |
|---|---|---|---|---|
| **Sl.No** | **Components** | **2017-18** | **2018-19** | **2019-20** |
| 1 | Upgradation of existing 5 pairs of HF radar | x | | |
| 2 | Operation, Maintenance, spares and AMC Existing 5 pair of HF radar | x | x | x |
| 3 | Procurement of new systems 3 pairs | x | x | |
| 4 | Site selection, preparation and Installations of proposed New systems (3 pairs) | x | | |
| 5 | Operation, Maintenance, spares and AMC (new 3 pairs of HF radar) | | | |
| 6 | Site clearance, frequency clearance etc. | x | x | |
| 7 | Installation at sites | | x | x |
| 8 | Operation and maintenance(new systems | | x | x |

| | | | | |
|---|---|---|---|---|
| | - 3 pairs) | | | |
| 9 | Data analysis and reports | x | x | x |

**2.3 Indicate outcomes of the schemes in the form of measurable indices which can be used to evaluate the proposal periodically. Baseline data or survey against which such outcome bench marked also should be mentioned.**
For INCOIS-OON component it is as indicated in item 2.2a.

For NIOT-OON components the outcomes of the schemes can be evaluated as per the targets and activity (servicing, deployments and maintenance) mentioned against each platforms of OON (NIOT Component-1 and Component -2) in the items 2.2b and 2.2c respectively.

**2.4 Indicate other schemes/sub- schemes being undertaken by the Ministries/Departments which has significant outcome overlap with the proposed scheme. What converges framework have been evolved to consolidate out comes and save public resources**

There is no overlap between any of the components of OON and programme of other MoES institute.

**3. Target Beneficiaries**

**3.1 If the scheme is specific to any location, area and segment of population, please give the details and basis for selection.**

Not applicable

**3.2 Please bring out specific interventions directed in favour of social groups, namely SC, ST, differently abled, minorities and other vulnerable groups.**

Not applicable

**3.3 Please bring out special interventions if any, in northeast, Himalayan, LWE, Island territories and other backword areas**

Not applicable

**3.4 In case of beneficiary oriented schemes, indicate the mechanism for identification of target beneficiaries and the linkage with Addhaar/ UID numbers**
Not applicable

**3.5 Whether possible, the mode of delivery should involve the Panchayat Raj institutions and Urban local bodies. Whether this is indented, the preparedness and ability of the local bodies for executing the proposal may also be examined**

Not applicable.

**4. Cost Analysis**

4.1a Cost estimate for the Scheme duration: both year-wise, component-wise, segregated into non-recurring (capital) and recurring (revenue) expenses for INCOIS components.

| **Outlay (Rs. Crores) of INCOIS component of OON for 2017 - 2020** |
|---|

| | 2017-18 | 18-19 | 19-20 | 3 Years 2017-20 |
|---|---|---|---|---|
| Salaries (8 SB/15 1PA-INCOIS/2 Office Assistant/2 Lab Assistant) | 1.76 | 2.19 | 2.36 | 6.31 |
| Domestic Travel Expenses | 0.88 | 0.69 | 0.76 | 2.33 |
| Foreign Travel Expenses | 0.14 | 0.14 | 0.14 | 0.42 |
| Office Expenses | 0.08 | 0.08 | 0.08 | 0.24 |
| Publications | 0.04 | 0.15 | 0.15 | 0.34 |
| Other administrative expenses | 2.61 | 3.45 | 3.24 | 9.3 |
| Supplies and Materials | 6.89 | 10.7 | 13.66 | 31.25 |
| Advertising and publicity | 0 | 0 | 0 | 0 |
| Minor works | 0.1 | 0.1 | 0.01 | 0.21 |
| Professional Services | 0.35 | 0.14 | 0.11 | 0.6 |
| Total (Revenue) | 12.85 | 17.64 | 20.51 | 51 |
| **Machinery and Equipment** | **22.68** | **31.51** | **18.92** | 73.11* |
| Major works | 0 | 0 | 0 | 0 |
| Total (capital) | 22.68 | 31.51 | 18.92 | 73.11 |
| **Total (Revenue + Capital)** | **35.53** | **49.14** | **39.43** | 124.11 |

* For details of the proposed platforms kindly refer to section 2.2a INCOIS component of OON.

4.1b Cost estimate for the Scheme duration: both year-wise, component-wise, segregated into non-recurring (capital) and recurring (revenue) expenses for NIOT components.

| **Outlay (Rs. Crores) of NIOT Component-1 of OON for2017 - 2020** | | | | |
|---|---|---|---|---|
| | 2017-18 | 2018-19 | 2019-20 | 3 years 2017-2020 |
| **Recurring** | | | | |
| Professional Services, inter institutional R&D projects (National & International), O&M, AMCs, Cruise related expenses, Satellite usage, Refurbishment, Calibration of sensors, repairs, boat/vessel hiring, contingencies | 18.00 | 20.11 | 22.54 | 60.65 |
| Travel Expenses (Domestic & Foreign) Administrative & Office Expensesl Publications, Advertising and publicity, Training, Awareness, International Conference/ seminars/workshop, Minor works | 9.24 | 10.33 | 12.57 | 32.14 |
| Salaries & Manpower | 2.76 | 3.06 | 3.39 | 9.21 |
| **Total (Revenue)** | **30.00** | **33.50** | **38.50** | **102.00** |
| **Non Recurring** | | | | |

| | | | | |
|---|---|---|---|---|
| Machinery and Equipment<br>Major works, Building-Civil and Augmentation of data centre, Ocean observational tools proto type technology development | 5.00 | 6.50 | 6.50 | 18.00 |
| **Total (Capital)** | **5.00** | **6.50** | **6.50** | **18.00** |
| **Total (Revenue + Capital)** | **35.00** | **40.00** | **45.00** | **120.00** |

4.1c Component-2 of NIOT (Deployment and Maintenance of HF Radars)

| Sl.No. | **Description** | **2017-18** | **2018-19** | **2019-20** | **3 years (2017 - 20)** |
|---|---|---|---|---|---|
| 1 | Salaries | 0.9 | 0.99 | 1.09 | 2.98 |
| 2 | Domestic Travel Expenses | 0.4 | 0.4 | 0.5 | 1.3 |
| 3 | Foreign Travel Expenses | 0.05 | 0.1 | 0.05 | 0.2 |
| 4 | Office Expenses | 0.1 | 0.1 | 0.1 | 0.3 |
| 5 | Publications | 0.04 | 0.05 | 0.05 | 0.14 |
| 6 | Other Administrative Expenses | 0.1 | 0.15 | 0.15 | 0.4 |
| 7 | Supplies & Materials | 1.5 | 4.65 | 6.45 | 12.6 |
| 8 | Advertising & Publicity | 0.15 | 0.24 | 0.18 | 0.57 |
| 9 | Minor Works | 0.7 | 1.35 | 1.15 | 3.2 |
| 10 | Professional Services | 0.4 | 0.5 | 0.5 | 1.4 |
| 11 | **Total (Revenue)** | **4.34** | **8.53** | **10.22** | **23.09** |
| 12 | Machinery & Equipment | 0 | 6 | 5 | 11 |
| 13 | Major Works | 0.25 | 1.5 | 1 | 2.75 |
| 14 | **Total (Capital)** | 0.25 | 7.5 | 6 | 13.75 |
| 15 | **Total (Revenue + capital)** | **4.59** | **16.03** | **16.22** | **36.84** |

**4.2 The basis of these cost estimates along with the reference dates for normative coasting**

As per current market prices and current salaries of temporary scientific staff.

**4.3 In case of land is to be acquired, the details of coast of land coast of rehabilitation/Resettlement, if any**

Land acquisition is not required.

**4.4 In case of pre-investment activate or pilot studies are being carried out, how much has been spent on this.**

Not applicable

**4.5 In the case of the scheme involves playout subsidy, the year wise and component wise expected out go may be indicated**

Not applicable

**4.6 In case committed liabilities are created, who will or has agreed to bear the legacy burden? In case assets are created, arrangements for their maintenance and upkeep?**

Not created.

**5 Scheme Financing**

**5.1 Indicate the source of finance for the scheme: budget support, extra-budgetary sources, external aid, state share etc.**

It is central budget support scheme of Ministry of Earth Sciences, Government of India.

**5.2 If external sources are intended, the sponsoring agency may indicate, as also whether such funds have been tied up?**

Not applicable

**5.3 Indicate the components of the coast that will be shared by the state governments, local bodies, user beneficiaries or private parties?**

Not applicable

**6 Approvals and Clearances**

Requirement of mandatory approvals and clearances from various local, state and national bodies and their availability may be indicated in a tabular form (land acquisition, environment, forestry, wildlife etc.)
Not applicable

**7 Human Resources**

7.1 Indicate the administrative structure for implementing the scheme. Usually creation of new structures, entities etc should be avoided.

The administrative structure in INCOIS will be utilised for implementing the scheme.

**7.2 Manpower requirement, if any. In the case posts, permanent or temporary, are intended to be created, a separate proposal may be sent on file to personal division of department of expenditure (such proposals may be sent only after the main proposal is recommended by the appraisal body)**

7.2a Manpower requirement under OON (INCOIS)

| Year | Requirement in each year | | Cumulative strength | |
|---|---|---|---|---|
| | Scientists/ Project scientists | Research Fellows/ Project Assistants | Scientists/ Project scientists | Research Fellows/ Project Assistants |
| 2017-18 | 4-Sc(B)/P.Sc(B) | 3-RF/2-PA | 4-Sc(B)/P.Sc(B) | 3-RF/2-PA |
| 2018-19 | 3-Sc(B)/P.Sc(B) | 3-RF/6-PA | 7-Sc(B)/P.Sc(B) | 3-RF/8-PA |
| 2019-20 | - | - | 7-Sc(B)/P.Sc(B) | 3-RF/8-PA |
| | | **Total** | **07** | **11** |
| *The 3 RFs are for Argo, Drifters and Bay of Bengal Observatory programs of INCOIS. The other manpower projected* | | | | |

*here is only for those platforms which will be maintained by INCOIS. The manpower for outsourcing/Externally Funded projects (e.g., NIO) is not included here. However, it is projected in total budget (4.1).*

The recruitment of project scientists and research fellows will be done every six months whenever vacancy arises during the project period.

7.2b Manpower requirement under OON (NIOT Component-1 for MOON)

First column indicates the name of the post as per regular mode. Second column give the no. of regular staff required. Third column gives the no of project staff required.

| **Sl. No.** | **Name of the Post** | **No. of regular staff required** | **No. of Project staff required** |
|---|---|---|---|
| 1. | Scientist - C | 2 | 3 |
| 2. | Scientist - B | 8 | 9 |
| 3. | Scientific Asst. | 8 | 9 |
| 4. | Sr. Research Fellow | - | 3 |
| 5. | Junior Assistant | 2 | 7 |
| 6. | Sr.Executive | - | 2 |
| 7. | Executive | - | 1 |
| 8. | Technician | | 3 |
| | **TOTAL** | **20** | **37** |

7.2c Manpower requirement under OON (NIOT Component-2for HF Radars)

| Year | Requirement in each year | | Cumulative strength | |
|---|---|---|---|---|
| | Scientists/ Project scientists | Research Fellows/ Project Assistants | Scientists/ Project scientists | Research Fellows/ Project Assistants |
| 2017-18 | 2-Sc 'C' (Reg)<br>2-Sc 'C' (Proj)<br>3-Sc 'B' (Reg)<br>5-Sc 'B' (Proj) | 2-Sci Asst<br>2-Proj. Asst | 2-Sc 'C' (Reg)<br>2-Sc 'C' (Proj)<br>3-Sc 'B' (Reg)<br>5-Sc 'B' (Proj) | 2-Sci Asst<br>2-Proj. Asst |
| 2018-19 | - | - | 12 | 04 |
| 2019-20 | - | - | 12 | 04 |
| | | **Total** | **12** | **04** |

**7.3 In case outsourcing of services on hiring of consultants is intended, brief details of the same may be provided.**

Not required.

**8. Monitoring and Evaluation**

8.1 Please indicate the monitoring framework for the scheme and the arrangements for statutory and social audit (if any)

The Project Management Council (PMC) constituted by MoES will monitor the progress of the project. Besides, the progress of the projects as a part of INCOIS/NIOT activities will be monitored by Research Advisory Committee (RAC) of INCOIS/NIOT under the Chairmanship of an eminent Scientist, Governing Council of

INCOIS/NIOT under the Chairmanship of Secretary, MoES and Finance Committee of INCOIS/NIOT under the Chairmanship of Financial Advisor, MoES.

**8.2 Please indicate the arrangements of third party/independent evaluation? Please note that evaluation is necessary for extension of schemes from one period to another.**

IRCs will be formed for evaluation of projects.

**9. Comments of Finance advisor, Niti Aayog, department of expenditure and other ministries/Department may be summarised in tabular form along with how they are being internalised and used to improve this proposal.**

**10 Approval sought**

Please attach an executive summary along with the concept/detailed paper outlining the main elements and overall architecture of proposed scheme.

**10.a Executive summary of INCOIS component of OON**

The primary objective of Ocean Observation Network (OON), (INCOIS component) is to establish and maintain various *in-situ* observation platforms, such as, Argo floats, satellite-tracked surface drifting buoys (drifters), expendable bathythermograph/expendable conductivity temperature depth (XBTs/XCTDs), ship-board Automated weather stations (AWSs), equatorial current meter array, open ocean tsunami monitoring buoys (or Bottom Pressure Recorder (BPR)), coastal Acoustic Doppler Current Profiler (ADCP) network and coastal wave rider buoys (WRBs) network and coastal sea level gauges (or Tide Gauges) network, to collect near surface marine meteorological and oceanographic (physical and biogeochemical) data in the Indian Ocean. In the last one and half decade, these *in-situ* observation networks succeeded in providing real-time oceanic and meteorological data in different spatio-temporal scales and these data sets have been extensively used for answering key scientific questions. This eventually led to operational systems development and resulted in significant improvement in the existing systems. Considering the importance of OON to support various operational system developments such as data assimilation in the ocean general circulation models and Atmospheric General Circulation Models, validation of ocean hindcast/forecast model outputs, development and improvements of ocean model parameterization schemes, validation of satellite derived parameter and improvement of satellite based retrieval algorithms and to facilitate research studies for better understanding and enhance our knowledge on present climate, it is proposed to maintain the existing network and expansion of the existing network by more deployment and incorporation of additional sensors in the existing platforms.

**10.b Executive summary of NIOT component-1 of OON**

Tropical Indian Ocean plays key roles in modulating Indian Summer Monsoon rainfall, weather and climate of India. Experiments provide evidence that the Indian Ocean warming in the last decades is of paramount importance in driving the monsoon rainfall and droughts which in turn impacts the livelihoods of millions of people and the economy. It is well known that one of the starting mechanisms of monsoon is the thermal contrast between land and ocean and sea surface temperature and moisture are crucial factors for its evolution and intensity. It is found further that the progressive warming of the tropical Indian Ocean is a principal contributor for many oceanographic phenomena and to understand them more genetically, due importance need to be given for continuous ocean observations.

Though the challenges in continuously observing the vast open oceans have been harmonized by buoy based in-situ observations, it is imperative that the observations need to be continued to genetically understand the ocean phenomena, builds expertise and to evolve robust warning system possible for the nation.The physical, chemical and biological processes within the oceanic system are distributed and long-term observations, both surface and sub-surface, in real time will help to evolve models which can simulate the weather predictions in a more realistic way.

Moreover, the data collected by these observational networks can also be used to support various operationalservices and it will be very beneficial for various stake holders involved in weather and ocean state forecast, advisory services, seafarers, search and rescue operations, offshore industries, maritime transport, Navy, Coast Guard, Disaster Management Agencies, public health and safety, for better preparedness, mitigation and many other sectors of the society.

Support to RAMA (Research Moored Array for African – Asian – Australian Monsoon Analysis and prediction) buoy programme which was carried out by MoES INCOIS in collaboration between NOAA-PMEL, USA and MoES-India, under 12th Five year plan will be taken over by MoES NIOT under NIOT Component-1 as recommended by Project Monitoring Council (PMC) and Independent Review Committee (IRC). This project will enhance knowledge on Ocean-atmosphere interactions and its connections with Asian Monsoon.

The NIOT Component-1 activities are periodically monitored by the Project Management Council, Project Review Board, and Scientific Advisory Committee and have also been evaluated by Independent Review Committee for extension of the scheme. Newer observation techniques, proto type development and cutting edge technology systems have to be implemented to strengthen, enhance and effectively utilize buoy based observations and collaboration with national/international institute/organizations. Globally, India is well recognized for the sustenance of this buoy programme.

It is a continuing programme being implemented as approved by the Ministry in the Administrative Orders of XII Five Year Plan (AO No: MoES/36/OOIS/OON/2012 dated 31.08.2012).

Sustenance of buoy network involves assured financial commitments in procuring quality sensors which are proven, and has acclamation and acceptance from both national and international Scientists. It also calls for additional and trained man power, allotted ship time to operate the programme. Timely planning and execution of cruises will augment seamless real-time data input to INCOIS, the nodal agency under ESSO MoES for ocean data repository, which will then be disseminated to end user agencies for developing and validating models that aid timely promulgation of extreme weather, cyclone and tsunami warning to the countrymen and there-by providing support to the society. The support to Indo-US programme in Bay of Bengal is continued under the Ministry's Monsoon mission programme.

NIOT is representing data Buoy cooperation panel of JCOMM and annual country subscription is sent to WMO Geneva every year. NIOT has signed cooperation agreement with WHOI USA and JAMSTEC Japan and would take up joint program and capacity building exercise visit to respective institution abroad.Under the capacity building exerciseStudent Autonomous Underwater Vehicle Competition is being organized by NIOT and winning team is deputed to participate in the International AUVSI Competition at San Diego, USA.

**10.c Executive summary of NIOT component-2 of OON (HF Radar)**

The purpose of HF radar to establish wide range of ocean observing network for acquisition of oceanographic data from offshore and coastal ocean of Indian seas. Set up a real-time mode coastal and offshore measurement for understanding the surface current to facilitate data assimilation in and around Indian seas. It is proposed to install and maintain 5 pairs (10 Nos.) of HF radar systems along Indian coast including Islands for surface current and wave measurement during XII five year plans.

Currently, a small portion of Indian coast was covered with HF Radar system. This surface current data set has been used for the validation of numerical model, rescue operation, oil spill model in limited places. However, the present coverage is not sufficient for said objective and hence it is proposed to increase the spatial coverage of Indian coast with increased HF radar installation.

At present, the surface current measurement being carried out along Indian coast at 10 locations (5 pairs) and working successfully with near real time data has been transferred from observation locations to central station (NIOT and INCOIS). Though the technology is sound there are some limitations within the system. The ranges of the data get hampered during calm sea condition and interference from ionosphere and other noises. The filling of the gaps in the data should be considered as a need of the hour, and proper statistical tools should be used for same.

The government institutes and research organizations were utilized the HF radar data for offshore projects and nearshore research purposes. Apart from the NIOT and INCOIS various Indian organizations like the Indian Institute of Technology - Chennai, Mumbai, Khargapur and Bhubaneswar, Indira Gandhi Centre for Atomic Research-Kalpakkam, Anna University - Coastal Zone Management Studies, NIO- Goa, SAC - Ahmedabad, NODPAC- Kochi, NPOL – Kochi, Andhra and Annamalai University - Chidambaram institutes are utilizing HF radar data for their academic and research proposes. Various research thesis produced by M. Tech and Ph. D. students from the different organizations using Hf radar current and wave data.

Only a mere percentage of the Indian coast is covered by HF radar networks, in order to cope up with the societal and scientific demand, the program may be continued. At present, 300km along the East coast, 100km at Andaman and Gulf of Khambhat has covered using HF radar surface current measurement. In order to cover entire Indian coastline for various applications, the new systems (5 – 40 MHz) has to be installed at selected sites depending on the user requirements.

There are 6 Nos. (3 pairs) of new HF Radar installation proposed. 2 pairs is proposed to be installed in East coast and 1 pair in West coast of India, selected based on ADCP mooring plan i.e. every 3 Degree at 8 locations along the Indian coast.

The demonstration of the HF radar technology in the coastal zone targets not only scientific research, but also search and rescue, pollution control, the offshore oil and gas sector, the renewable energy sector and additional end users such as the fishing industry. These radars provide a lot of useful data for various applications.

Typical users are:

- Meteorological institutes coastal management (erosion, flooding, pollution, etc.)
- Port authorities & harbour management, Oil & gas industries
- Oceanographic researchers, Vessel traffic services and ship tracking
- Renewable energy providers (wind farm planning and management)
- Component for tsunami warning systems
- Coast Guard search and rescue
- Hazardous Material spills Response
- Waste water system management of Water quality Monitoring
- Fisheries Management

**Annexure-I**

## I. Detailed justification for each component under INCOIS-component Ocean Observation Network

### Objective

It is well known fact that the tropical Indian Ocean plays a key role on the modulation of weather and climate of India, which in turn influence livelihoods of millions of people and Indian economy. The strong sensitivity of the livelihood of the Indian society and growth of Indian economy to weather and climate highlights the importance of accurate weather and climate predictions. The physical, chemical and biological processes within the oceanic system are distributed into various spatio-temporal scales (few centimeters to 1000 kilometers and seconds to years) and are in constant interactions with the overlying atmosphere. In order to make forecast of oceanic and atmospheric conditions through ocean, atmosphere and coupled models, it is imperative to understand these process and model them. Hence, it is important to monitor the ocean state in real-time, for both the surface and the interior ocean, through establishment of a continuous and long-term system of ocean observations to characterize and understand the underlying dynamics and physics at various spatio-temporal scales. Moreover, the data collected by these observation networks can also be used to support various operational system developments and services and it will be very beneficial for various stake holders involved in ocean state forecast and advisories services, seafaring peoples, public health and safety, search and rescue operations, offshore mining and oil industries, maritime transport, marine ecosystem and marine living resources management and assessment, navy and coast guard, disaster management agencies for better preparedness and mitigation, tourism industry and many other sectors of the economy.

However, just over one and half decade ago, Indian Ocean was under-sampled and poorly understood compared to other tropical oceans. However, during past one and half decade there were systematic and focused efforts to monitor ocean state in the Indian Ocean region. Considering the importance of ocean observations in terms of understanding the ocean environment and to utilize them for operational oceanography, a large number of observation platforms were deployed and maintained by INCOIS through Ministry of Earth Sciences (MoES) funding under the project Ocean Observation Network (OON) in the coastal and interior ocean areas of the Indian Ocean. These observational platforms have facilitated to acquire real-time *in-situ* oceanographic and near-surface meteorological data. While designing OON programme, it was also considered the existing Indian Ocean Observing System (IndOOS), which is a regional contribution to the Global Ocean Observing System (GOOS), an international collaborative effort led by the Intergovernmental Oceanographic Commission (UNESCO-IOC) to establish ocean observation and collect real time oceanographic data of the world's oceans. The different platform under OON includes the Argo floats, Expendable bathythermograph/expendable conductivity temperature depth (XBTs/XCTDs), satellite-tracked surface drifting buoys (drifters), Bay of Bengal Observatory, ship-board Automated weather stations (AWSs), Acoustic Doppler Current Profiler (ADCP) network along Indian coast, current meter array in the equatorial Indian Ocean, wave rider buoys (WRBs), sea level gauges (or Tide Gauges) along the Indian Coast, open ocean tsunami monitoring buoys (or Bottom Pressure Recorder (BPR)) etc.

These *in-situ* observation networks succeeded in providing near/real-time oceanic and meteorological data in different spatio-temporal scales and they have been significantly utilized to address and answer key scientific question and issues and it eventually led to better operational system development and improvement. The information collected from these observation platforms provided valuable insight on spatio-temporal variability of thermo-haline structure and its impact on air-sea interaction process in the Indian Ocean region and depicts how these processes modulate the Indian Summer Monsoon rainfall, which has significant influence on Indian economy and livelihood of millions of people. The data collected under OON is used for assimilation of ocean surface and sub-surface data into ocean general circulation models to improve the initial estimation of ocean state. Currently various agencies in India (IITM and IMD) are utilizing these ocean analysis products to initialize their coupled ocean-atmospheric models, which is used for seasonal monsoon forecasts and represents the backbone of 'National Monsoon Mission' by MoES. The *in-situ* data collected under OON has been extensively used for validation of simulated ocean parameters from Hindcast/Forecasts ocean models to understand ocean model's abilities and limitations and fine-tune them for optimal performance, which in turn led to improved forecasting systems. Moreover, the scientific knowledge acquired and development of ocean forecasting system through OON led to early warning for ocean-related hazards, such as, Tsunami waves, storm surge, high wave alerts associated with tropical cyclones and high wind events, prediction of tropical cyclone track and intensity. Hence, these efforts provided better opportunities for disaster management agencies for better preparedness and mitigation to reduce loss of life and property damage. Today, OON is emerged as one of the strongest pillars of operational oceanography in India, which have direct and indirect effect to various spectra of society.

The primary **objective of OON** can be defined as "***to establish and maintain various in-situ observation platforms, such as, Argo floats, expendable bathythermograph/expendable conductivity temperature depth (XBTs/XCTDs), satellite-tracked surface drifting buoys (drifters), Bay of Bengal observatory, ship-board Automated Weather Stations (AWSs), equatorial current meter array, open ocean Tsunami monitoring buoys (or Bottom Pressure Recorder; BPR), coastal Acoustic Doppler Current Profiler (ADCP) network, wave rider buoys (WRBs) and sea level gauges (or Tide Gauges) network, to collect high quality marine meteorological and oceanographic data in the Indian Ocean to support operational systems development and facilitate research studies.***"

The progress, achievement, and data utilization of each platform during last five years (XII plan) under OON is highlighted in annexure-II (Independent review committee report). Considering the importance of OON to operational services and to answer key scientific questions, **it is imperative to not only maintain the existing network but also expand the existing network by more deployment and incorporation of**

**additional sensors in the existing platforms.** Detailed plans with justification for each platform are summarized below.

**1. Argo profiling floats**

The Argo program is a collaborative partnership of more than 30 nations under Global Ocean Observing System (GOOS) to provide a unique opportunity to map the ocean hydrography. Sustaining the Argo float array is important to monitor the thermohaline field of the upper ocean for seasonal, annual and decadal time scale. As per India's commitment to international ocean community, we are committed to deploy at least 40 Argo floats per year in the Indian Ocean. The number of floats in the north Indian Ocean has to be sustained such that at least one float is available in a 3x3 degree grid box or even higher. Moreover, a major part of temperature and salinity data from Argo observation network goes as input to ocean data assimilation system at INCOIS, which provides the initial conditions to ocean-atmosphere coupled models used for the monsoon prediction. Moreover, the availability of long term data record of ocean temperature and salinity from Argo can be used for spatio variability of trends in heat and freshwater storage and the role of ocean circulation on climate variability.

In the recent past, the demand for Argo floats with biogeochemical sensors (Bio-Argo floats) increased significantly due to ongoing research and ecosystem model development. One of the key advantages of Bio-Argo floats measurements is their ability to provide subsurface information of these parameters, which was previously only possible through ships. However, ship-borne observations have significant bias towards areas that are more easily sampled. The importance of physical and dynamical forcing on the upper ocean biogeochemical processes is well recognized and linked to the state of the total marine ecosystem. Last couple of years, INCOIS has deployed quite a few Bio-Argo floats in the Indian Ocean region, which provided unprecedented datasets to understand the response of biogeochemical parameter to physical and dynamical process and it facilitated to extend our knowledge that were achieved through satellite ocean colour measurements to subsurface levels. Moreover, such data sets are valuable source for the diagnostic validation of marine ecosystem model output and assimilation of biogeochemical parameter in the marine ecosystem models, which is one of the important future modelling goals of INCOIS. Ultimately, it will lead to improvement in the ecosystem model simulation and it will definitely lead to better marine fisheries advisory services. This clearly emphasizes the need for long term systematic and focused effort to collect biogeochemical parameter in the Indian Ocean. At present the biogeochemical measurements in the Indian Ocean region are very sparse and only way to improve this significantly is through the deployment of automatic profiling floats likes Argo. Hence, it is proposed to deploy more Argo floats equipped with biogeochemical sensors (e.g., Chlorophyll, Dissolved Oxygen, Nitrate, pH, PAR, $pCO_2$ and acoustic sensors).

The present Argo float density map shows the inadequacy to map the entire Indian Ocean; there are still many data sparse regions (e.g., 5°S to 20°S in the Indian Ocean). Moreover, the current Argo density in the north

Indian Ocean is insufficient to resolve the spatio-temporal evolution of Intraseasonal variability of biogeochemical and physical parameter in the equatorial Indian Ocean, Arabian Sea and Bay of Bengal. Hence, it is proposed to enhance float coverage near the equatorial belt, Arabian Sea, and Bay of Bengal for the improved estimation of intraseasonal variability. Such efforts are already implemented in the other region of Globe. Hence, from 2017 onwards, it is planned to deploy 50 floats per year in order to increase the data density and also to complement our other ongoing ocean observation programs. Presently, the ratio of the normal T-S Argo to Bio-Argo (Argo with enhanced bio-geo capabilities) is roughly 3:1. It is proposed to increase this ratio to 3:2 from 2017 onwards, such as, 33 Argo with Temperature and salinity sensor and 17 Argo with enhanced biogeochemical sensors. Moreover, the increased Argo density will be useful for the improvement in the ocean re-analysis products generated for operational purposes.

**2. Drifting buoys**

Primary objective of satellite-tracked drifting buoys programme is to maintain a 5x5 degree array of satellite-tracked surface drifting buoys to measure sea surface temperature and air pressure. The standard design uses a holey-sock drogue at 15m depth to follow mixed-layer currents. We can derive the surface velocity distribution through tracking drifter positions. In addition to standard temperature and pressure sensor, drifter can be equipped with salinity, wind and chlorophyll sensors. Moreover, recently drifter data has been used to extract the unprecedented details about ocean turbulence at the sub-mesoscale (100 m-10 km). Such processes are extremely important for tracer transport and dispersion, such as fresh water from the Bengal delta, and energy transfer from the meso-scale (~10-100km) to micro-scale (1-100m). Satellites and mooring arrays do not have the required resolution to observe and characterize the behaviour of the turbulent flows at these scales. The solution is surface drifters. Data collected from drifter with appropriate deployment strategy, such as, releasing a drifter in pairs and possibly triplets, will enable us to measure relative spreading rates which are governed by the turbulence. Such studies will help us to characterize the scale dependent kinetic energy distribution and relative dispersion/diffusivity. At present Drifter network in the Indian Ocean region are very sparse. To deploy and maintain 50 drifters in a year in the Arabian Sea and the Bay of Bengal for a decade will be the remarkable dataset of sub-mesoscale observations. Moreover, these data can be used for validation of satellite based temperature/salinity measurements and ocean data assimilation. During 2017-26, it is proposed to increase the yearly deployment of drifting buoys in the Indian Ocean to 50 from the present 30, with few drifters with C-T chains to collect upper ocean thermohaline structure. Further, it is important to make the quality of data such as the drogues are attached through the observation period and the accuracy of GPS is the best possible. Moreover, it is proposed to use indigenously developed drifter with INSAT communication from 2017 onwards. Transmission of drifter data using INSAT may help us to enhance the sampling rate and it will enable us to resolve diurnal variability with reasonable good temporal resolution.

**3. XBT/XCTD**

XBT surveys along selected shipping lanes in the seas around India using the ships of opportunity (cargo ships) have been conducted since 1990. At preset XBT/XCTD contributions to total temperature profiles in the Indian Ocean are very small as compared to the Argo floats density in the Indian Ocean. However, XBT/XCTD lines can provide different information of ocean temperature and salinity state, which cannot be measured by Argo. First of all, the XBT/XCTD can provide temperature and salinity structure with high spatial resolution and it can enable to monitor three dimensional structure of eddy field in the ocean. However, as reported by earlier studies, root mean square nearest-neighbour distance of Argo float locations is approximately 170 km, with actual nearest-neighbour separations between two lonely float is varying from 1 km to 780 km. Compared with other instruments, XBT operations are relatively easy and can be operated even when the ship is steaming at high speeds under any weather conditions. In addition XBTs/XCTDs produce profiles of cost effective temperature and salinity. The long term repeated XBT/XCTD lines along same route can provide important hydrographic features of ocean. Moreover, real-time communication from these systems can provide valuable data source for data assimilation system.

During 2017-22, it is proposed to maintain 5 XBT/XCTD lines in the Indian Ocean (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 transects.). Further, collection of sea surface water samples for the analysis of salinity along these 5 transects is also proposed. The advantage of Kochi-Lakshadweep transects is  it passes through Argo float sparse region. As far as hydrographic point of view, the Kochi-Lakshadweep line covers mini-warm pool region in the south eastern Arabian Sea, which is believed to instrumental for onset Indian summer monsoon onset on the west coast of India. Moreover, temperature and salinity data collected by XBT/XCTD along with coastal ADCP and HF-RADAR network can provide useful data source to understand the long term trend and variability of meridional heat and fresh water by west India coastal current. Further, Kochi-Lakshadweep transects covers the upwelling zone in the west coast of India, which have significant influence on fisheries in that region, will also facilitate long term trends in the temperature structure in that region. Port Blair-Kolkata, Chennai-Port Blair, and Chennai–Singapore transects covers northern, central and southern Bay of Bengal and it facilitate meridional variability of heat and salt transport and meridional overturning circulation in the Bay of Bengal. Mumbai – Mauritius XBT lines (IX08) is part of IndOOS and it is important to maintain. Mumbai – Mauritius covers western part of Indian Ocean and it passes through thermocline ridge, an important region for the Indian Ocean zonal mode (a dominant interannual model in tropical climate), where the Argo floats is very sparse due to its unique current structure.  Necessary step should be taken for the transmission of these data in real time to shore via INSAT communication to improve ocean forecast.

**4. Coastal ADCP mooring network**

With funding from INCOIS and CSIR, particularly for ship time, the coastal ADCP mooring network along Indian Coast (in shelf and slope) has expanded from 10 moorings during the XI Plan to 18 moorings during XII plan. The data from these ADCP moorings are not available in real time, but have permitted a hitherto unprecedented description of the variability of the observed currents off the Indian east and west coasts and the development of a theoretical framework for the shelf circulation. Moreover, these data are invaluable for improving our understanding of the circulation, and are therefore an asset in building a viable forecasting system. Hence, it is essential to continue this programme. Shelf moorings have proven difficult to maintain owing to trawling and trawling extends deeper each year and it is likely that we may not be able to deploy the shelf moorings beyond a few more years. Hence, in future the coastal ADCP mooring network would be restricted to the slope moorings majority of location, but the connection between the slope and shelf currents makes them useful in spite of this limitation. Moreover, for the future, it is proposed to expand the network to ensure a slope mooring every 2.5-3 degrees of the Indian coast to measure current in the entire water column (approximately 4 ADCP in each mooring). Furtherr, it is proposed to deploy ADCP or current-meter moorings on the shelf over shorter durations to map the shelf currents; these deployments will be less frequent and should be tied to the need, but they are equally critical for improving our ability to simulate the near-shore currents. Hence, it is proposed to make simultaneous time-series measurements of ocean current profiles by deploying and maintaining 20-24 ADCP moorings on the shelf and slope off the coast of India.

In conjunction with modelling systems, this network of long-term ADCP moorings, HF radars, and short-term shelf moorings would form the backbone of a forecasting system for the Indian EEZ. Given the cost of the *Sagarmala* project being executed by the Indian government, such an observing system will pay back the investment made on it if the modelling systems are able to capture the variability of the near-shore currents and the associated transport of sediments and pollutants. These moorings are also important for the goal of linking the PFZ (potential fishery zones) programme with the ocean forecasting system: INCOIS has such a goal and so does CSIR-NIO via its TRIMFish (Trans-disciplinary Research for improved Forecasts of Indian Marine Fisheries) proposal.

**5. Equatorial Current meter array**

With funding from INCOIS and CSIR (particularly for ship time) a network of current mooring has been maintained in the equatorial Indian Ocean at 93°E, 83°E and 76°E. Each mooring has one upward looking 75 kHz ADCPs at 350 m (to measure current from surface to 350 m) and recording current meters (RCMs) and temperature/temperature and salinity sensors at 3 levels of nominal depths of 1000 m, 2000 m and 4000 m. This observation programme was initiated by the Department of Ocean Development (DOD), Government of India in 1997 and in 2002 the responsibility of executing the project was given to the National Institute of Oceanography (NIO), Goa, through INCOIS funding.

At present almost 20 years of data is available from this mooring and it has provided valuable new insights about the circulation characteristics in the equatorial Indian Ocean in different temporal scales. One of the highlight of this three mooring is the presence of deep sea current measurements, which cannot be measured by the any other existing observation network in the Indian Ocean. The long term measurements of deep sea current measurements along with temperature and salinity measurements can provide valuable insight on deep ocean circulation, warming trend and water mass chrematistics in the context of global warming and climate change scenario. Maintenance of 93°E mooring is logistically very difficult and it was not in operation from late 2014 onwards. Hence, it is proposed to maintain at least two mooring in future.

**6. Wave Rider Buoy networks**

INCOIS maintains a network of 15 wave rider buoys around Indian coastline and 1 in Seychelles during XII plan. The Wave Rider Buoy **(**WRB) data has been used significantly to understand the spatio-temporal variability of wave characteristics along the Indian Coastal lines. Moreover, the data from this platform has been extensively used for validation of simulated wave parameters from ocean model and fine-tune the model for optimal performance, which in turn lead to improved operational wave forecast model. Further, WRB data has been comprehensively used for near-real time evolution of operational wave forecast, particularly during high wave alert period, to increase user confidence. At present, WRB is an important component operational wave forecasting system at INCOIS. During 2017-22, it is proposed to increase the wave rider buoy network to 19 numbers along the Indian coast based on operational requirements of ocean state forecast project. During XII plan, INCOIS has operationalized the Ocean state forecast and warning services to Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) member countries such as Seychelles, Maldives and Sri Lanka and planning to extent to other Indian Ocean countries through RIMES. In this context INCOIS will be deploy 4 Wave rider buoys in the coastal waters of RIMES member countries. However, it is worth mentioning here that, the implementation of WRB network to RIMES countries required inter-country collaborative programmes in Ministry/Government levels.

The diagnostic validation of ocean wave model simulation in the Indian Ocean coastal region shows that significant factor of errors are primarily associated with southern ocean swells. Though significant wave height measurements are available from altimeter, other wave parameters that are important for validation and fine-tune the operational wave models is unavailable from altimeter. Moreover, scarcity of *in-situ* observations of wave characteristics in the southern ocean hinder accurate validation of wave model simulation and fine tune the operational wave forecast model. Expansion of WRB network into off islands in the RIMES member countries in the southern Indian Ocean will help in tracking southern ocean swells especially during the swell surge events and validation and fine tuning of operational wave forecast models. Moreover, past studies have shown that there is an increasing trend of wave activity in the southern Indian Ocean and it has significant impact on north Indian

Ocean. However, similar kind of studies in the north Indian Ocean is not yet performed in detail. Long term WRB measurements in the southern Indian Ocean and north Indian Ocean facilitate us to understand the trend of wave characteristics in these regions.

**7. Marine meteorological and oceanographic parameters onboard Ships/Rigs (Automatic Weather Stations and wave parameters)**

INCOIS Real Time Automatic Weather Stations (IRAWS) measures near surface met-ocean parameters that are operational onboard vessels. IRAWS Systems are equipped with satellite (INSAT) based real time data acquisition and data is being reported at INCOIS for operational and research applications. Real time data collected from the IRAWS systems has been used extensively for the validation of ocean state forecast products and it is useful for data assimilation in Numerical Weather predication models. In future, expansion of the IRAWS network shall lead to more data collection in different parts of the Indian Ocean and will help us to improve bias corrected ocean model forcing fields. The met-ocean parameter collected through these systems will be adequate for generation of climatology of radiative, turbulent and momentum flux in the Indian Ocean region. Since all these datasets collected through this network are pushed to GTS (Global Tele-communication System), it shall be assimilated to all global and regional forecast models, which are operational at different parts of the world. Hence, it is proposed to continue this program through maintenance of the existing AWS network and further enhance the network by addition of 15 new IRAWS. Moreover, it is also envisaged to incorporation of pCO2 sensor in 4 research vessels to understand how ocean carbon uptake feedback to global climate system. Moreover it facilitates to identify the oceanographic region for net source (e.g., Arabian Sea) and sink (e.g., Bay of Bengal) to atmospheric $CO_2$ (Please refer section 2.1.8 more detailed description of objective of biogeochemical measurements). It will help us to predict the behaviour of ocean carbon cycle in future and develop strategies for mitigation and adaption for this climate change.

**8. Bay of Bengal observatory**

Last few years, INCOIS has maintained a mooring in the Northern Bay of Bengal ($18^0$N, $90^0$E), also known as Bay of Bengal Observatory. The present system can measure only subsurface temperature, salinity and current at few discrete depths. Nevertheless, data from this mooring helped us to understand the evolution of thermohaline structure in the northern Bay of Bengal, one of the freshest regions in the tropics. Earlier studies have shown that, the distribution of summer monsoon rainfall over the Indian region is linked to the variation of the convection over the northern Bay of Bengal, which exhibit significant oscillation in different temporal scales varies from diurnal to seasonal. But one major disadvantage of existing mooring in the northern BoB is the absence of concurrent near-surface meteorological observations along with subsurface observations, which hamper our efforts to study the air-sea coupling at diurnal to seasonal time scales. In 2017-22, it is proposed to enhance the Bay of Bengal observatory by adding high frequency measurements of surface-met variables, few diffusivity sensors on the mooring line (one in the mixing layer and other well below the mixed layer)**,** and vertical profile of currents using ADCP in addition to existing subsurface temperature and salinity measurements. These data sets will provide a useful repository for to understand the air-sea interaction process in this region and it will eventually lead to improvement in accurate representation of physical processes in the ocean models.

Even though steady progress made in ocean models, simulated ocean model field is not free from errors. These model errors depend on both intrinsic parameterizations (e.g., resolution, subgrid scale parameterizations, turbulent closure scheme) and external data required to run the model (atmospheric forcing, initial conditions, open boundary conditions, and bathymetry). As far as atmospheric forcing errors concerned, it is important to represents of turbulent heat and momentum flux in to the ocean models accurately. At present turbulent heat and momentum flux in the ocean model has been prescribed by bulk aerodynamic formula and which is not free from uncertainty. Eddy covariance is the method to measure the vertical flux of heat, water and momentum. However, direct measurement of turbulent fluxes of sensible heat, latent heat and momentum over Indian Ocean with eddy covariance systems are still rare. Hence, process-based understanding of ocean-atmosphere interactions remains very limited. Moreover, the direct covariance measurements of sensible heat, latent heat, and momentum fluxes provide better estimation of the scaling parameters in the bulk aerodynamic formula, which may eventually lead to the improvement in ocean model simulation. Moreover, understanding physical processes that control turbulent fluxes of heat and momentum, over ocean surfaces is critical in quantifying their influences on local, regional, and global climate. Hence, it is proposed to equip the Bay of Bengal observatory with direct co-variance flux suite (DCFS), to measure invaluable direct turbulent flux dataset. This data set will be useful source to improve air-sea fluxes algorithm through fine tuning of the flux parameterizations and which in turn will lead to improvement in the ocean general circulation simulation. Our strategy involves placing a DCFS system along with high accuracy ASIMET system in a mooring in the Bay of Bengal. The DCFS system will provide direct measurements of turbulent fluxes and ASIMET provides high accuracy meteorological and oceanographic data required for deriving the fluxes. This will allow us to get the best bulk flux model available by comparing DCFS flux data with mooring fluxes from different bulk models. Our strategy should be to see how well we can tune the parameters to get the best data from the bulk model. In the first three year, INCOIS will mainly concentrate on covariance flux measurements and quality control procedure and from fourth year onwards, INCOIS will look to data analysis.

It is well known that, the Indian Ocean plays an active role in the global carbon cycle. In terms of the global carbon system, the Indian Ocean accounts for nearly one fifth of the global oceanic uptake of atmospheric $CO_2$. As reported by earlier studies, ocean uptake of $CO_2$, is primarily related to atmospheric $CO_2$ concentrations, i.e., $CO_2$, will diffuse into the water until the equilibrium between partial pressures across the air-water interface. In general different oceanographic region is considered as net source (e.g., Arabian Sea) and sink (e.g., Bay of Bengal) to atmospheric $CO_2$. Due to scarcity of biogeochemical data in the Indian Ocean region (though some observation were exist which are primarily collected during short scientific cruise) our understanding/interpretations about biogeochemical cycle in Indian Ocean may not be free from bias. For example, recent studies using data from coastal sites in the Bay of Bengal show that coastal regions are huge source of $CO_2$ to the atmosphere than what was assumed earlier. If we consider these new findings, our present understanding about biogeochemical cycle in the Indian Ocean should be re-examined. It clearly emphasise the need for long term systematic and focused effort to collect biogeochemical parameter in the Indian Ocean.

Hence, it is proposed to enhance the Bay of Bengal mooring with chlorophyll, $pCO_2$ and pH measurements. Biogeochemical data from these proposed mooring along with autonomous platforms like Argo and glider will provide unprecedented data to understand the modulation of biogeochemical parameters in the context of physical and dynamical variability in different temporal scale (diurnal-intraseasonal-seasonal-interannual-decadal). Moreover, these time series measurements of biogeochemical parameter will facilitate us to validate the marine ecosystem model, which is currently under development stage in India (e.g., INCOIS). Ultimately it will lead to the improvement in the simulation of ecosystem and eventually will have better PFZ advisory services. Moreover, this data set can be used to test parameterizations of carbon cycle processes used in ocean biogeochemical models and its improvement. Long term time series observations of biogeochemical measurements will provide an opportunity to understand the diurnal, intraseasonal, seasonal, interannual and decadal variability of biogeochemical parameter, such as, what are the processes control gas exchange in the Tropical Indian Ocean region and how its behaviour will change in warming environment. Moreover, high frequency observations of these biogeochemical parameters at a given point in a space will provide a unique opportunity to monitor how short-term variability and its impact on biogeochemical parameter. Further, long term observation from this mooring will facilitate us to understand how ocean carbon uptake feedback to global climate system. It will help us to predict the behaviour of ocean carbon cycle in future and develop strategies for mitigation and adaptation for climate change. Moreover, the $pCO_2$ observation along with pH will help us to understand ocean acidification rate at different temporal scale and its impact on phytoplankton growth, the lowest level food web, which has significant impact on top level predictors such as fish.

**9. Tsunami monitoring buoys (or Bottom Pressure Recorder) and Tide gauge network**

Sea level monitoring network of Tide gauges and Tsunami monitoring buoys (or Bottom Pressure Recorder (BPR)) are crucial component of tsunami warning system, which measures the changes in the water level in real-time with high accuracy in coastal and open ocean region respectively to confirm the generation of tsunami waves and monitor its progress and it is important near-real time evaluation of the tsunami advisories. The real-time sea level data helps to avoid false alarms and unnecessary public evacuations for all major events. Moreover, the real time tide gauges and tsunami buoys data can be useful to detect Tsunami source through the sea level data inversion techniques.

INCOIS has established a network of state-of-the-art 31 tidal gauge stations, of which 21 stations equipped with Radar, Pressure and Shaft Encoder sensors and 10 stations equipped with RADAR sensor, along strategic locations of the Indian coastline. Moreover, 5 new tide gauges are planned to establish by January, 2017. In addition to proposed usage of these networks, tide gauge data can also be useful to understand coastal wave dynamics in the Indian Ocean in various spatio-temporal scales along with HF radar and coastal ADCP network. Moreover, long term data from these tide gauge network can provide spatial and temporal variability of sea level rising trend along the coast of India, which is central issue in climate change research and it have significant environmental and socioeconomic impact along the Indian Coastal belt. Further, tide gauge data set has been significantly utilized for validation of the tsunami/storm surge model output. In future it is proposed to up-gradation and maintenance of the existing 36 tide gauges.

INCOIS has established and maintained a network of 5 Tsunami buoys close to the tsunamigenic source regions in the Bay of Bengal (4 number) and the Arabian Sea (1 number). As per a technical expert committee suggestion, it is imperative to maintain a network of 7 Tsunami buoy in the north Indian Ocean. As of now, in addition to 5 INCOIS BPR, NIOT is maintaining 2 indigenous Tsunami buoys in the north Indian Ocean. In addition to detect and identify the Tsunami waves, BPR data can also be used for various research purposes and significant insights can be derived. For instance, the data from BPR can be used for the validation of open ocean tides from ocean model outputs which can be used later for removing tides from satellite altimeter. Apart from that, BPR data can provide valuable insights about regional mass variability induced by local/remote wind forcing/pressure variability in various spatio-temporal scales. Which includes identifying of non-isostatic variability in pressure, detection of fast moving barotropic waves, identifying resonating basins and also it can be used to study the potential vorticity dynamics between Earth-ocean-atmosphere systems. Moreover, it can also be used to monitor the global mass variability induced by glacier ice melt. Hence, in future it is proposed to service and maintain the existing network of 5 STB systems (INCOIS-component) in the Indian Ocean.

**10. Capacity building**

Some of the sensors technology and operations mentioned in the above list (e.g., direct covariance flux measurements and $pCO_2$ measurements) are new to the Indian scientific community. Hence, it is imperative to get training on deployment, data collection, data quality control procedure and data analysis technique from the developers, manufacturer and expertise in the respective filed in order to execute successful missions. Hence, it is proposed to send the INCOIS scientists for training to appropriate institutes (both Indian and foreign) as part of capacity building.

**II. Detailed justification for each component under NIOT Component-1 (Moored Ocean Observation Network (MOON))**

**Objective:**

1. ***To maintain Moored Ocean Observation Network comprising of met-ocean, CALVAL and tsunami buoy for data collection and to support RAMA programme under the Indo-US collaboration to be transferred from INCOIS and to disseminate data to INCOIS:***

Under the Moored Ocean Observation Network (MOON) programme of ESSO MoES, the Ocean observation systems (OOS) group of NIOT will undertake activities with the objectives to operate, maintain and develop moored ocean observational network in the Indian seas. The buoy network will comprise of Met Ocean (Deep sea and Coastal), Tsunami, and CalVal buoy systems. The observed data will be transmitted through satellite along with location reference to the state-of-the-art mission control centre facility at NIOT followed by dissemination to INCOIS in near real time. Data sets are used for operational forecast by IMD through NCMRWF and by INCOIS for Ocean State Forecast. Data from tsunami buoys are used by INCOIS for tsunami early warning application. Data are also posted in GTS through INCOIS and used for research, satellite data validation and ocean modelling applications. Support to RAMA programme under Indo-US collaboration will be taken up by NIOT to carry out study on Ocean-atmosphere interactions and its connections.

**2 Ocean observational tools proto type technology development:**

The development of Data Acquisition System (DAS) has repressed technology dependency and proven to be cost competitive. Seven variant of DAS conceived, designed and devised by the group and presently in operational mode. Development of low power system for these variants is underway. Ocean science is becoming the beneficiary of a host of powerful emergent technologies driven by many communities that are entirely external to the world of ocean research—they include, but are not limited to, nanotechnology, biotechnology, information technology, computational modeling, imaging technologies, and robotics. More powerful yet will be the progressive convergence of these enabling capabilities as they are adapted to conduct sophisticated remote marine operations in novel ways by combining innovative technologies into appropriate investigative or experimental systems. OOS has forayed into development of AquaBots a Robofish device that bio-mimic marine fish which will be used for explorative ocean observation. Development of Variable Buoyancy of Aquatic Gliders is underway and the objective of this development is to device autonomous ocean observational systems.

**3** ***To conduct collaborative R&D projects, capacity building with national and international institutes / Organizations*.**

The programme's steady and sustained efforts towards accomplishing the goals have paved way to collaborate with international agencies like NDBC, NOAA, PMEL–USA, reputed organizations which include SCRIPPS, Seabird, JCOMM, JAMSTEC, etc and multinational Universities. OOS has also transformed, and expanded its observational capabilities and one such calibration/validation exercise CALVAL is being carried out in collaboration with SAC-ISRO, Ahmedabad to vicariously calibrate the sensors onboard ISRO's OCEANSAT-2 satellite using controlled and instrumented site over the ocean. A pair of buoy systems, MET and OPTICAL, consisting of fully automated hyper spectral radiometers, Fluorometer, and meteorological sensors, have been realized and deployed in deep ocean site at Kavaratti in Lakshadweep, Arabian Sea, for pre-programmed in-situ data collection and transmission via INSAT-3C satellite. The buoy of described configuration is capable of measuring in-water optical and biological parameters in an unattended manner for long-term time series with less vertical tilt. CALVAL Met Buoy system data is transmitted via INSAT communication.In Bay of Bengal due to change in scientific methodology different approach is planned and will be executed in consultation with Science Experts. Support to RAMA (Research Moored Array for African – Asian – Australian Monsoon Analysis and prediction) buoy programme in collaboration with NOAA-PMEL, USA will henceforth be carried out under NIOT Component-1for studying Ocean-atmosphere interactions and its connections with Asian Monsoon.

**III. Detailed justification for each component under NIOT Component-2 (HF Radar Network)**

Coastal HF radar networks are the back bone for providing such invaluable coastal data on a near real time basis. The deliverable products from the HF radar network are

- Ocean Surface current Atlas for the whole Indian coast
- Surface current prediction from observation
- Wind direction along the coast
- Near Shore ocean wave parameters (height, period and directions)
- Linking HF radar storm surge wave data with Indian Meteorological Department (IMD) to provide better prediction and Transferring information to the public
- Surf zone, sediment transport, tourist (Rip current & surf swimmers)
- Tsunami Monitoring
- More over the surface current vectors available can be utilized for eddy detection and tracking as eddies are ubiquitous in ocean they play a major role in the heat mass transfer in the ocean