GOVERNMENT OF INDIA

TWELFTH FIVE YEAR PLAN

(2012-17)

WORKING GROUP DOCUMENT

Earth System Science Organisation (ESSO)

Ministry of Earth Sciences

October 2011

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PREFACE

The Earth behaves as a single inter-linked system. The energy and material transfer within and across different sub-systems, viz., atmosphere, ocean, cryosphere, geosphere, and biosphere are complex. The understanding of such interactions can lead to improved prediction of weather, climate and hazards for societal, economic and environmental benefits. According to a recent survey, the net economic benefit of various services being rendered by the Earth System Science Organization (ESSO) can contribute from 0.4 to 1.2 per cent of GDP.

During the XI plan period (2007-2012), the major focus was on the observation systems for improving services related to oceanic, geological and atmospheric hazards, and improving short-term forecasts. Some of the major highlights were setting up of the state-of-the-art tsunami warning system, two desalination plants in the Lakshadweep Islands, centre for climate change research, advanced training school for earth system science and climate change, third polar station at the Larsmann Hills in Antarctica, high performance computing facility, first scientific expedition to the North Pole, successful testing of remotely operable vehicle and soil tester beyond 5000m. Various services were augmented/improved such as agro-meteorology for farmers, fog forecast for aviation, weather and air quality forecasting for Delhi, seasonal forecast of monsoon, cyclone forecast, ocean state forecasting, potential fishing zone advisories, ornamental fishery, coastal water quality, etc. The preparation of our additional claim of Exclusive Economic Zone (EEZ) under Legal Continental Shelf Program based on scientific data of 31,000 line km was highly acclaimed. This was possible due to availability of high quality atmospheric/oceanic observations and high computing resources, their assimilation in models and integration and collaboration among various units of ESSO.

The focus during the XII plan would be on discovering new phenomena, exploring sea bed and polar regions, understanding of various earth processes and their interaction, developing earth system science model and application of knowledge for improving/developing services for societal benefits. The major task would be to develop climate services in view of climate change and variability. Apart from continuing many operational programs related to observations of atmosphere, ocean, snow and ice and land surface and services related to weather and hazards. The major missions planned are related to monsoon, earthquake, mountain meteorology, cloud physics, ocean exploration, acquisition of observing platforms, such as aircrafts and ships, and augmenting observing systems.

The development of program for the XIIth Plan largely depends on inputs from four Group of Expert Committees in Ocean Science, Atmospheric Sciences, Information and Services, Technology, Solid Earth and Cryosphere Studies to develop Vision and Prospective Plan for 10 years. I would like to thank all the members of three committees, particularly the Chairpersons viz., Dr. P.S. Goel Former Secretary, MoES, Dr. Harsh Gupta Former Secretary, DOD, Dr. J. Srinivasan, Professor IISc, Bangalore and Dr. S.R. Shetye, Director, NIO, Goa for providing their valuable time and advice towards preparation of these documents.

The Working Group and Sub-groups led by Dr. J. Srinivasan, Prof. V.K. Gaur, and Dr. A.K. Singhvi, for atmospheric, ocean, cryosphere and geosciences, respectively, constituted by the Planning Commission in April 2011, had deliberated extensively. The outcome of these meetings have culminated into the formulation of the draft proposals for XII Plan period enumerated in this report. I sincerely thank all the Members of the Working Group for their contributions and guidance in shaping the course of the ESSO for the next five years and beyond. The effort of the officers and scientists of the ESSO in preparing this Report is commendable.

Dr. Shailesh Nayak
Chairman, Working Group
Ministry of Earth Sciences

Date: September, 2011
Place: New Delhi

Executive Summary

1. Introduction

The Ministry of Earth Sciences (MoES) was established by the Government of India in 2006 to address holistically various aspects relating to earth processes for understanding the variability of earth system and for improving forecast of the weather, climate and hazards The Earth System Science Organization (ESSO) works as an executive arm of the MoES for implementing its policies and programmes. The Planning Commission has constituted a Working Group for MoES to develop proposals for the 12th Plan, vide Order NO.12016/3/2011-S&T dated 18.04.2011 (Annexure). The Working Group had two meetings, and had deliberated various issues extensively in line with the approach to 12th Plan exercise suggested by Planning Commission. The Working Group finally has given consent to the draft 12th Plan proposals of the Ministry.

This document describes the salient achievements during the 11th Plan period (2007-12), the proposed plan for the 12th Plan (2012-17), and financial outlay.

2. Achievements during 11th Plan (2007-12):

2.1 Atmospheric Science, Technology and Services: The meteorological services have significant impact on society in general.

The upgradation of weather forecasting capabilities to an optimum level was one of the major priority programs launched during 11th Plan. It has four components, viz., atmospheric observation network; strengthening of computing facilities, data integration and product generation and dissemination of information. The activities related to computing, integration and product generation and dissemination have been completed. The argumentation of observational network is progressing. IMD now has a network of automatic weather stations, Doppler Weather Radars (DWR), state-of-the-art upper air systems etc. These observations are now being used to run its global and regional numerical prediction models on High Performance Computing Systems (HPC). It has improved forecasting capabilities for high impact weather events like cyclones, severe thunderstorm, heavy rainfall and floods in a significant manner. A Web-interfaced National Satellite Data Centre was established for archiving all satellite data available till date and serving near real time value added products.

A complete end-to-end forecasting system that includes acquisition of data from various observing systems, linkage to a central data processing system, their utilization in the numerical models, providing a state-of-the-art IT based environment to all forecasters across the country has been installed. This involves integration of all observations and overlaying them on model outputs and synoptic charts along with proper visualization and customized dissemination of weather forecast to the end users.

A set of four High Performance Computing systems (HPCS), one each at INCOIS, IITM, IMD, and NCMRWF have been installed for global data processing, assimilation and numerical weather prediction (NWP) for weather and ocean state forecasting services. The combined strength of HPC in the ESSO is about 125 TeraFlops, which has significantly improved coupled atmospheric–ocean modelling capability.

With the commissioning of HPCs, Global Forecast System (GFS T382/L64) having spatial resolution of 35 km was made operational at IMD, incorporating Grid Point Statistical Interpolation (GSI) scheme for global data assimilation for the generation of global scale forecasts up to 7 days in advance. At NCMRWF, continuous efforts are on to enhance the accuracy and reliability of the forecasts by increasing resolution, improving physical processes, data assimilation, optimizing use of satellite and DWR data, coupling land, ocean and atmosphere, ensemble forecasting along with extensive verification and validation. The horizontal resolution of the Global Forecast System (GFS) was increased from T254L64 (50km) to T382L64 (~35km) along with assimilation of direct satellite radiances which was subsequently made operational at IMD. Experimental runs with higher resolution (T574L64(22km) GFS and unified model (N512L70(25Km) with 4D VAR assimilation) models are underway.

Meso-scale forecast system WRF (ARW) with 3DVAR data assimilation is being operated daily twice, at 27 km, 9 km and 3 km horizontal resolutions for the forecast up to 3 days in advance using initial and boundary conditions from the GFS T382/L64 system. Global model assimilation utilizing 4D VAR is being done on experimental basis for WRF model for generating regional scale data assimilation.

The Numerical Weather Prediction (NWP) products from mesoscale model WRF were supplied to BARC at 9km resolution for the four nuclear sites namely Trombay, Kalpakkam, Kaiga and Narora for their Indian Real time Online Decision Support System for Offsite Nuclear Emergency (IRODOS).

In an effort to take care of the uncertainties in the initial conditions, model dynamics and model physics, Multi Model Ensemble (MME) forecasting project for providing rainfall forecasts during the monsoon season has been developed. District Level Quantitative five-days weather forecasts based on MME system are being generated in support of rendering district scale Agro-Meteorological Advisory Service (AAS) of India during the current five year plan.

Polar WRF is implemented to provide day-to-day short range (48 hours) weather forecast for the Maitri region in the Antarctica. NCMRWF was regularly providing NWP guidance from its global and regional analysis and forecast products in support of first ever South Pole Expedition.

A new state of the art Climate Forecast System (CFS) based on coupled ocean-land-atmosphere model, was setup at IITM and numerous sensitivity experiments were carried out to test the model skill in predicting the Indian Summer monsoon rainfall on seasonal time. This model was used to provide experimental forecast assessment of the Indian Summer monsoon seasonal mean rainfall and its distribution in March 2010. Similarly, prediction of active/break spells of the Indian summer monsoon is implemented in IMD through collaboration with IITM.

The introduction of NWP in operational forecasting has been a major shift in practice, which has enhanced forecast capabilities across different time scales ranging from a few hours to a month.

a) Agro-Meteorological Advisory Services (AAS): Based on the weekly forecast of weather comprising maximum and minimum temperature, rainfall, cloud cover and surface humidity, advisories for farmers have been developed in association with

State Agricultural Universities and Indian Council for Agricultural Research (ICAR) Krishi Vignan Kendras (KVKs). These services are available in 539 districts of the country currently. Through this service, farmers receive crop-specific advisories with regard to the time of sowing of weather-sensitive high yield variety of seeds, need-based application of fertilizer, pesticides, insecticides, efficient irrigation and harvest. The services are made available through web, radio, TV, newspaper, and mobile. Currently over 25.0 lakhs farmers have subscribed for receiving this information through mobile in vernacular languages.

b) Aviation services: The aviation services includes a continuous watch of meteorological conditions over Flight Information Regions (FIR) and prepare Significant Meteorological Charts for hazardous en-route weather phenomena, such as, thunderstorms, tropical cyclones, turbulence, volcanic ash, etc., which may affect the safety of aircraft operations. Fog forecasting accuracy is 85-90 percent for the Delhi airport

c) Hydrological service: Based on real time daily rainfall data, weekly district-wise, sub-division wise and state wise/season wise rainfall distribution summaries are prepared in the form of rainfall tables and maps. These are useful to the agricultural scientists, planners and decision makers. Quantitative Precipitation Forecasts were supplied to the Central Water Commission for flood forecasting purposes.

d) Environmental Service: The network for Air Pollution Monitoring stations provide data on long-term changes in composition of trace gases of the atmosphere. These observations provide reliable long-term observations of the chemical composition of the atmosphere and related parameters in order to improve understanding of atmospheric chemistry.

e) Metropolitan Weather and Air Quality Forecast System: Site-specific weather and air-quality forecast system was put in place with indigenous capability for the National Capital Region during Common Wealth Games (CWG) 2010. Hourly updates to different air quality and weather parameters at the venues and other locations were provided to the organizers. This service is now connected into Metro service.

f) Sports including Adventure Sports: Customized forecast for mountaineering expeditions were issued with constant interaction with expedition teams and coordination with their headquarters.

g) Data Services**:** Observational data of past and present are provided to researchers, Government agencies and private parties on demand. Real-time data is made available to all stakeholders through dedicated channels and web-based systems.

2.2 Disaster Early Warning Support

2.2.1 Tsunami Warning System: A state-of the-art tsunami warning system was set up in October 2007 as outlined in the Prime Minister's twenty-six thrust areas. The system comprises a network of seismic stations including international stations to compute earthquake parameters, simulated scenarios of travel time and run-up heights at 1800 coastal locations in the Indian Ocean, observing platforms for sea level variations, both in deep sea and coast, robust communication and

dissemination system, data centre and decision support system. In last three years, many earthquakes larger than 7- magnitude, which can cause tsunami, did occur. In all such cases necessary advisories were provided to all concerned within 10 minutes of the occurrence of earthquake. This system is recognized as the Regional Tsunami Service Provider (RTSP) for the Indian Ocean region.

Earthquake Monitoring, Prediction and Mitigation: A real-time seismic monitoring network has been put in place which allows significant earthquakes being auto-located and first information sent within 15 minutes. A suite of Multi-Parametric Geophysical Observatories (MPGOs) have been set up at Ghuttu, Shillong and Koyna to monitor various earthquake precursory phenomenon such as, seismicity patterns, crustal deformations, gravity anomalies, electrical resistivity changes, electromagnetic perturbations, water level changes, geo-hydrochemical changes, Radon and Helium anomalies, thermal anomalies, etc. The microzonation of Guwahati, Sikkim and Bangalore on 1:25000 scale, and Delhi on 1:50,000 scale has been completed.

Cyclone Prediction: The low pressure areas depressions and cyclones are routinely monitored using satellite, DWR and AWS data in real time. The average operational forecast error for 24 hours track forecast is about 140 km and landfall is 80 km. However, continuous efforts are underway to improve the forecasts further.

Storm Surge: Present technique of predicting only residual storm surge requires improvement in order to forecast total water level envelope (TWLE) occurring as a result of the combined effect of the interaction of storm surge with tides, wind waves, and several other factors.

Vulnerability Maps: The work on research areas such as (i) Multi-hazard Vulnerability, (ii) Real-time tsunami inundation modeling, as well as (iii) 3-D GIS have been initiated. The Coastal Vulnerability Index (CVI) maps at 1:100000 scale for the entire coastline of India including Andaman & Nicobar and Lakshadweep Islands have been completed.

Climate Change Science: A dedicated Centre for Climate Change Research (CCCR) to address various scientific issues including impacts on sectors like health, agriculture and water has been set up in IITM, Pune along with necessary manpower, computing, physical infrastructure under the global and regional climate change programme. Major efforts of the climate change research include 100-year simulation of the CFS model to test CFS model suitability to predict variability of the Indian Summer Monsoon; annual Seasonal Monsoon Simulation Experiment; and a focused and well-defined roadmap for contributing to the Assessment Report-5 (AR5) of the Intergovernmental Panel on Climate Change (IPCC).

Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX): An instrumented air-craft was chartered during monsoon period to conduct CAIPEEX during 2009-11. This national experiment is being carried out in three phases. Phase I and Phase II of the CAIPEEX have been conducted successfully in the monsoon season of 2009 and 2010, respectively. Phase III will be conducted in the monsoon season of 2011. All the national institutions and universities working in the area of aerosol observations, cloud physics and cloud-modeling participated in this experiment. First time an exhaustive data of cloud microphysics and vertical profiles of aerosol have been collected. The data have been quality controlled and made available to the Indian Scientific community within one month of completion of

the experiment. The experiment opened a new era in the observational field of the atmospheric sciences in India.

Solar dimming continues unabated over the Indian region. From 1981–2006, the rate of dimming is found to be twice as large during cloudy conditions (~12 W/m^2/decade) compared to that during clear sky conditions (~6 W/m^2/decade). The clear sky dimming cannot be fully attributed to increasing aerosol density and concentration changes.

Detailed special monsoon reports, High resolution daily gridded rainfall data (1°x1°) & (0.5°x0.5°), high-resolution daily-gridded temperature data (1°x1°), high-resolution gridded terrestrial climate of India, and climatological summaries for districts and states are produced.

Towards human resource development in the field of earth system science, a state of-the-art Advanced Training School was established at Pune in 2010.

2.3 Ocean Survey, Resources and Technology

Delineation of the outer limits of the Extended Continental Shelf: The first partial submission for an extended continental shelf (~ 0.6 million sq. km) under the provision of article 76 was made to the UN Commission on the Limits of the Continental Shelf on the 11th May 2009. A second partial submission for another part of the extended shelf (~ 0.6 million sq km), under the provisions of the Statement of Understanding, has also been finalized and provided to the MEA for filing before the CLCS. A National Marine Geophysical Data Centre has been established with state-of-the-art archival and retrieval facilities of the geo-scientific data in a structured database

Comprehensive Swath Bathymetric Survey of EEZ: About 5,73,000 sq km (~30%) of the deep-water regions of the EEZ beyond 500 m water depth, and 14,300 sq.km off Goa, Bombay High, Karnataka and Cuddore have been completed.

Polymetallic Nodules Programme: India has exploration contract with the International Seabed Authority (ISBA) in 75,000 sq km area in the Central Indian Ocean. A total area of 7900 sq km was identified for potential mine site based on detailed chemical analysis, interpretation of the collected samples into the Central Indian Ocean. A 3-Dimensional hydrodynamic sediment plume model was developed as a part of Environmental Impact Assessment Studies. An integrated mining system consisting of crawler, collector and crusher and a Remotely Operable Artificial nodule laying system were developed and tested at 500 m water depth. The research carried out in the field of extractive metallurgy include to optimize recovery of various metals.

Seabed Minerals: Under Cobalt crust programme, multibeam map has been generated for the Afanasiy-Nikitin Seamounts in equatorial Indian Ocean covering an area of around 40000 sq. km for the potential Cobalt-crust resource. Reconnaissance sampling has yielded few crust samples containing cobalt 0.5 to 0.65 %.

A possible source of a hydrothermal vent in an area over the slow spreading Carlsberg Ridge (CR) was located based on acquisition, analysis and interpretation

of high-resolution geophysical data, deep CTD observations, water column, deep-tow, TV-grab and seabed sampling.

Gas Hydrates exploration: Multi-channel seismic data indicated two promising sites of 100 km x 100 km and surveyed in detail in the Krishna-Godavari (KG) and the Mahanadi basins. A remotely operated Autonomous Coring System (ACS) has been developed to retrieve approximately 30 m sediment core, and store in magazine at the seabed in deep sea operation [3000 m]. An exploratory tool (ROV) with necessary sensor is developed and an exploration trial at gas hydrate site is completed.

Integrated Ocean Drilling Programme (IODP): A Science Plan addressing the scientific issues pertaining to the seas around India which calls for deep-ocean drilling was developed.

Under the MoU with IODP, five scientists from the leading geoscientific institutions in the country participated in IODP Pacific Equatorial Age Transect Expedition 321, JOIDES Bering Sea 323, CHIKYU Nankai Trough Japan 322, MSP (Europe) GBR 325, and JOIDES Wilkes Land 318

Launch of a Technology Demonstration Vessel- Sagar Nidhi: An ice-class vessel of 5050 tones, equipped for launching and testing various marine equipments including ROV, AUV and manned Submersible was acquired in December 2007. This vessel is capable of conducting multi-disciplinary studies in the sea continuously for 45 days with 30 scientists onboard.

Deep-sea Technology Development: An instrument to measure sea bed soil properties in-situ, at a depth of 5200 m has been developed. The deep water trials of ROSUB (remotely operable vehicle) were conducted successfully at a depth of 5300 m in April 2010. The complete hardware and software for the instrumentation and control system were developed indigenously.

Low Temperature Thermal Desalination (LTTD): The LTTD technology was demonstrated using waste heat from the North Chennai Power Plant and produced fresh water. The capacity of the plant is 1 lakh liter per day (lpd). A LTTD barge-mounted plant of 1 million litre per day was successfully demonstrated off Chennai (Tamilnadu) in April, 2007. 2 desalination plants of 1 lakh liter capacity, one each at Minicoy and Agatti of the Lakshadweep Islands, have been set up.

Development of integrated deep sea mining system: Design and development of Underwater Mining System with Manganese Nodule Collector and Crushing Systems completed. Testing and qualification of underwater mining system with collector and crushing systems was done in Angria Bank (off coast of Malvan) at 500 m depth after laying artificial nodules during September–October 2010. A remotely operable in-situ soil testing equipment was developed and tested successfully at 5200m water depth.

Realization, installation and commissioning of Hyperbaric Test Facility (simulating 9000 m of Ocean Depth) and Testing of Deep-sea Equipment and Components, and Hydrotransport Test Facility, Underwater Vehicle Test Pond and other Facilities like Winch Test Facility, Hydraulic Valve Test Facility have been developed.

Marine sensors, electronics & ocean acoustics:

A broadband transceiver designed and developed for new generation P17 platforms and transferred the technology to BEL. An automated ambient noise measurement system for time series measurements has been developed and deployed in three locations. Acoustic Test Facility (ATF) has been upgraded for increasing the frequency range from 100 kHz to 300 kHz. Tsunami surface buoy and an bottom pressure recorder have been developed and tested at more than 800 m water depth. An Autonomous Underwater Profiling Drifter (AUPD) has been indigenously developed and demonstrated. Patents have been filed based on the above developments.

Offshore structures: Optimization of structural design for wave forces to withstand high wave-loads is carried out. The design of sumps for drawing warm water and cold deep sea water is optimized. A suction pump capable of 2 bar suction (differential) has been developed and validation of various individual components is completed.

Ocean Energy: A Backward Bent Ducted Buoy with power module and instrumentation has been designed, developed and successfully tested in the sea for three weeks.

2.4 Polar Science

Antarctic Expeditions: Four Indian Scientific expeditions to Antarctica (27 to 30) were successfully undertaken during 2007-11, while the next (31st) expedition is planned to be launched during October–November 2011. In the course-of the winter and summer seasons of 2007-11, scientific data collection pertaining to projects in the disciplines of earth science, glaciology, atmospheric sciences, biology, environmental sciences, engineering and communication, besides the logistic tasks critical to the expeditions were accomplished.

South Pole Scientific Expedition:

For the first time, India launched a scientific expedition to the South Pole on 13th November 2010 from *Maitri*. The 8-member team collected valuable atmospheric aerosol data and several short ice cores in the course of its transect from the Schiramcher Oasis to the South Pole The team reached the South Pole on 22nd November, 2010. and on completion of all the scientific tasks, returned to '*Maitri'* on 1st December, 2010.

Arctic Expedition: India embarked upon the Arctic research by launching First Indian scientific expedition to Arctic - in the first week of August 2007 using the international research facility at Ny-Alesund in the Spitsbergen Island of Norway. Subsequently India has been sending scientific teams every summer and winter for carrying out studies in the Arctic, primarily in the fields of glaciology, hydrochemistry, microbiology, and atmospheric sciences.

Southern Ocean Studies: Five multidisciplinary cruises in the Southern Ocean for a better understanding of the oceanographic processes were undertaken. The focus areas of study during these expeditions were oceanography and hydrography (during the 2009 Expedition), biogeochemistry and paleo-climatology (2010) and plankton dynamics (2011).

Polar Environmental Studies: Comprehensive Environmental Evaluation (CEE) of the New Indian Research Station at Larsemann Hills, Antarctica was carried out and was presented at the XXX ATCM (2007), New Delhi.

Polar Remote Sensing: An enhanced digital elevation model (DEM) of the Larsemann Hills region, (on the eastern boundary of Antarctica) was generated synergistically by using highly accurate ground-based GPS measurements, satellite-derived laser altimetry (GLAS/ ICESat) and Radarsat Antarctic Mapping Project (RAMP) DEM-based point elevation data. A DEM is essential to model the ice elevation change and address the ice mass balance.

2.5 Ocean Science and Services

Ocean Observing System: During the period, significant progress has been made in the ocean observing systems, with a mix of in-situ platforms and satellite systems and concomitant capabilities in retrieval of data. Moored data buoys with subsurface sensors up to 500m depth, besides surface sensors, were deployed in Bay of Bengal and continuous measurements have been made. Argo floats, drifters, current meters, wave-rider buoys, HF radars, etc. have been deployed to capture changes in time at specific locations or along ship tracts.

Ocean Modelling: The capability to run various global and regional models, viz., HyCOM, MOM4, CUPOM, ROMS which has significantly improved ocean forecasting services was established. Indian Ocean Forecasting System (INDOFS), first of its kind in the country and developed indigenously was made operational in January 2010.

Ocean Services: A unique system of Fishery Advisories based on identification of potential fishing zones (PFZ) using remote sensing technology has now reached to 90% of fishermen. In addition to PFZ maps, advisories on Tuna species based on satellite derived SST, Chlorophyll, water clarity and model based mixed layer depth, has been operationalized. In January 2009, Indian Ocean Forecasting System (INDOFOS) was launched integrating existing forecasts of ocean wave and the surface and subsurface parameters of the Indian Ocean. The system, at present, provides forecast on the wave heights, wave direction, sea surface temperature (SST), surface currents, mixed layer depth (MLD) and depth of 20^{o}C isotherm up to 5-7 days in advance. Currently, these forecasts are provided on a spatial resolution of 25x25 km and 12.5x12.5 km grids.

The recent study of National Centre for Economics and Applied Research stated that the total annual net economic benefit due to the scientific identification of PFZs based on satellite information is estimated to lie in the range of Rs. 34,000 to 50,000 crores.

Coral reef maps have been prepared for Gulf of Kutch, Gulf of Mannar, Lakshadweep, and Andaman and Nicobar Islands. Considering thermal stress as an indicator, coral health bulletins are issued bi-weekly indicating the hot spot composites (early signs of bleaching), and degree of heating weeks (DHWs) as an indicator to intensity of bleaching.

All data relating to ocean science are being archived at INCOIS which includes voluminous and heterogeneous data sets from the in-situ and remote sensing ocean observing systems, in real time. This centre has been designated as the National

Oceanographic Data Centre (NODC) by the International Oceanographic Data and Information Exchange (IODE) Programme of Intergovernmental Oceanographic Commission (IOC).

An automatic data processing chain (ADPC) has been set up to generate ocean color products using MODIS – Aqua data. The data products are being generated at near real-time (NRT) for India, Sri Lanka, Iran, Kenya, Maldives, Oman, Tanzania and Thailand and are disseminated via a web-server. As a spin-off, a value added product known as bloom indices (BI) has been also generated with live MODIS – Aqua data.

2.6 Coastal and Marine Ecology

Assessment of Environment and Productivity Patterns of Indian EEZ: An 'Atlas on Environment and Productivity Patterns of Indian EEZ' providing comprehensive information on the physical, chemical and biological features of the Indian EEZ covering the various seasons of a year has been prepared. Satellite derived Chlorophyll a data is used in conjunction with in situ data on chl-a, primary productivity, secondary productivity and benthic productivity to generate the fishery potential of the Indian EEZ. The estimated figure of 4.32 million tons of fish is more robust and reliable.

Harmful Algal Blooms (HABs): A number of harmful algal blooms have been reported in various coastal waters of India. Efforts are underway to monitor the spatial and temporal variations of blooms using Ocean Colour Monitor sensors available on board both Indian and foreign satellites.

Census of Marine Life (CoML): The Census of Marine Life (CoML), begun in the year 2000, is a scientific worldwide Census campaign to assess and explain the diversity, distribution, and abundance of marine life. IndOBIS currently has record of 48,422 species.

Island Development activities: Ornamental fish culture was established in 2009 in the Agatti Island of Lakshadweep. Other activities such as live-bait culture, pearl culture, biodiversity studies, etc. of Lakshadweep has been taken up. Black-pearl production in the Andaman Islands has been strengthened by imparting training to local people on nucleus implantation. Mass culture of micro-algae in photobioreactor at Kavaratti Islands, Lakshadweep utilizing deep ocean water upwelled by the Low Temperature Thermal Desalination plant for extraction of biochemicals has been initiated. A viable technology for fattening lobsters and mud crabs in cages was successfully developed and disseminated to select beneficiaries in the Gulf of Mannar in Tamil Nadu and Andaman Islands.

Marine Biotechnology: The understanding of barotolerant deepsea microbes to a considerable extent but under ambient atmospheric pressure and temperature has been developed. Significant work on the production of nutraceuticals like lutein from marine microalgae has been done. A prototype plasma pulse technology for biofouling control in pipelines and on plate heat exchanger surfaces, is under development.

Coastal Ocean Monitoring and Prediction System: Extensive monitoring of marine pollution along the coastal waters was continued at 76 locations and it has been found that the disposal of untreated sewage from towns, cities and villages cause

decrease of dissolved oxygen and increase of nitrate and pathogenic bacteria in the sea close to the shore. The data collected revealed that pollution problems are confined up to 1 km in the sea except at Mumbai where the pollution problem prevails up to 3 km in the sea. Model to predict the movement of oil during oil spills has been developed for the coasts of Mumbai and Chennai.

Shoreline Management: Coastal erosion along the coast of Gopalpur (Orissa), Muthalapozhy, Vadanapally and Trissur (Kerala), Devbagh, Pavindurve and Kundapur kodi (Karnataka) and Gangavaram (Andhra) have been studied with extensive oceanographic data to provide solutions to the respective states. Field studies are being carried out at Pondicherry, Ennore and Shriharikota to characterize and work out possible engineering solution to stabilize the coastline.

Ecosystem modelling: Hydrodynamic modelling of Chilika and Kochi backwaters completed.

Drugs from the Sea: A programme is being implemented to harness the bioactive principles from the marine biota for human therapeutic purposes with participation of several research labs and Universities. Over 2,000 extracts of marine samples were screened for wide spectrum bioactivity. More than hundred hits have been identified, which need revalidation from repeat collection, and follow-up. Four products are being developed for clinical usage and are in different stages of development.

2.7 Outreach Activities

In order to propagate and bring awareness about the programmes and achievements among the public, students and user communities, Earth Day is celebrated on the 22nd of April every year since 2008 across the country. Special publication covering Earth and environment related articles by noted scientists were published in Geography and You (English) and Bhugol Aur Aap (Hindi). Indian team (4 students) bagged four bronze medals in Olympiad 2009 and one Silver Medal and three Bronze medals at the Olympiad 2010. About 500 seminar/conference/training events were supported in area of Earth system sciences to provide platform to scientists, engineers, and technologists.

2.8 R & D in Earth system Science

Focused research in earth, polar, ocean and atmospheric sciences were supported. In order to augment capacity building, MoES Chair Professors were established. Several academic programmes like MTech/PhD have been initiated. Specialized Labs were set up as National facility for use by various researchers and Institutes.

Nine Ocean and Atmospheric Science & Technology Cells (OASTC) are currently operational with well defined areas of research, viz. Marine biology at Annamalai University, Marine microbiology at Goa University, Marine coastal ecology at Berhampur, Marine coastal ecology at Bhavnagar University, Beach Placers at Tamil University, Marine geology and geophysics at Mangalore University, Coastal marine culture systems at Andhra University, Marine benthos at Cochin University of science and technology, and Ocean engineering and underwater robotics, IIT, Kharagpur.

To increase visibility of research outputs emanating from the ESSO-MoES funded projects, an open access digital repository has been set up. The repository is hosted

and maintained by INCOIS, Hyderabad. Research outputs/papers emanating from ministry funded projects are uploaded in the repository which are accessible worldwide through internet. A consortium of MoES institutes was set up for providing online access to full text database—*Science Direct* and abstracting and indexing database -*SCOPUS*.

3. STRATEGIES FOR THE 12TH FIVE YEAR PLAN

The ESSO has excelled in many areas of the earth system science, especially providing services to society. The major focus of the 12th Plan proposals has been to carry out research on discovering new phenophena, exploring unchartered areas especially sea-bed and Antarctica, understanding earth processes, and developing new services as well as improving existing services for societal, environmental and economical benefits. Four Expert Committees on Atmospheric Science and Services, Ocean Science and Services, Cyrosphere/Geoscience, and Technology constituted in 2009 provided a long-term strategy and perspective plan. A background document prepared on these inputs. The Working Group set up by the Planning commission has extensively deliberated on this document along with approach to the 12th Plan suggested by Planning Commission, and recommended programmes for the 12th Plan. These programmes have been grouped into following major schemes.

i) Atmospheric Observation System
ii) Atmospheric Processes, Modelling and Services
iii) Climate Change Research
iv) Airborne Platforms for Atmospheric Research
v) Ocean Observations
vi) Ocean Science and Services
vii) Ocean Survey and Mineral Resources
viii) Ocean Technology
ix) Ocean Research Vessels
x) Polar Science and Cryosphere
xi) Marine Geoscienctific studies
xii) Seismological Research
xiii) High Performance Computing (HPC) for Earth System Science Research
xiv) Research, Education, Training & Outreach, Earth Enterprise

3.1 Atmospheric & Climate Science & Services

The meteorological services have significant impact on society in general and on every spheres of life in particular both financially and socially. Improved and reliable forecast of weather and climate requires integration of observations of earth system using very-high-resolution dynamical models (e.g. coupled ocean-atmosphere-biosphere-cryosphere models). Intensive monitoring of various weather systems through different platform based observing systems including satellites provide not only the necessary information about current systems, their effective assimilation in numerical models provides important guidance for accurate forecasts. Thus, a combined approach involving land, ocean and atmospheric processes hold the key to improve the forecasts at various temporal and spatial ranges.

Atmospheric Observation System: The modernization plan aims in commissioning of state-of-the-art observing systems throughout the country. The phase II of the modernization will thus focus on the augmentation of the existing infrastructure established during the phase I of the modernization in terms of observing systems and integrating the same with the rest of the network. Additional AWS, ARS, DWR, upper air, wind profiler, etc. will be deployed. New observations are required, some of which are given below:

Ground-based radiometers providing temperature and humidity profiles and complementing the sonde observations to be developed with priority. Global Positioning System (GPS)-based columnar (integrated) water vapour measurement to be implemented, initially for every 100 km, to be enhanced suitably in a phased manner. Troprosphiric stratospheric (ST) Radars, established on a 500x500 km grid to provide continuous data as inputs for accurate weather modeling. Boundary layer wind profilers covering the height range of 0.1 to 4 km can operate at relatively high frequencies (915-1300 mHz) and hence be small and inexpensive enough to cover the country initially approximately on a 200x200 km grid, on a 100x100 km grid in the medium term and eventually on 50x50km Grid.

The instrumentation for atmospheric observation are Runway Visibility Recorder (RVR) imported with few indigenization efforts like Doppler Weather Radar by ISRO, NAL, etc. There is need to have a separate institute for Atmospheric Technologies. The Atmospheric Technology Institute will conduct and coordinate development of instruments, calibrate instruments including satellite-based, and provide overall technology support to atmospheric sciences. In addition, it will support development of atmospheric services through appropriate technology support.

It is also proposed to have instrumented aircraft for atmospheric research. INSAT 3D, Meghatropique, Oceansat-II scatterometer and many other international mission data will be appropriately utilized. A cal-val site for calibrating satellite-based to be developed.

The observations in Himalayan region are sparse. **I**t is necessary to expand both, surface as well as upper-air networks for real-time collection of data and dissemination of weather forecasts & warnings for the entire Himalayan region. It is proposed to have dedicated forecasting centers with a much focused objective of integrating and improving the weather related services.

It is necessary to set-up/identify an institution to design and develop prototype technology related to measurement of atmospheric parameters. It can be developed on lines of National Institute of Ocean Technology.

Atmospheric Processes, Modeling and Services: Coupled Ocean-atmospheric models will be the main tool used for seasonal/extended range, and short & medium range forecasting and prediction of future climate in the next 10 years. However, the skill of these models need to be improved. Necessary experiments will be undertaken and efforts will be focused to formulate an Indian Ocean-Atmosphere coupled model. Earth system model will be developed based on climate forecast system, to understand the impact of climate change on regional monsoon and various eco systems.

During the past decade, statistical models have done marginally better than dynamical models in the prediction of seasonal mean rainfall. There is a need to look for new statistical models for improving the forecast of seasonal mean rainfall.

District-level agromet advisory is provided to about 540 districts of the country. There is need to further improve these services through generating weather forecast at a smaller scale than district, and for extending the temporal range. The new concept of establishing the Gramin Krishi Mausam Sewa in the country under the 12th Five Year Plan has been taken up. The main objective is to improvise the existing District level Agromet Advisory Services (AAS) to deliver crop and location specific AAS to farmers at block level with village level advisory.

Aviation services are important for safe air operations. The upgradation of facilities of about 100 airports in the country is to be taken up. Metropolitan air quality and weather service providing real-time weather as well as nowcasting of weather and air quality in all metro cities as well be initiated.

Monsoon forecasting is very crucial for Indian economy. It is essential to work out a modeling framework and put it in use to predict monsoon weather and climate in India on different time scales ranging from short and medium range to seasonal mean. A working partnership will be built up between the Academic R & D Organizations and the operational agencies to improve the monsoon forecast skill. Under this mission the computational facilities will be made available to academic institutes that will be participating in the national mission. This needs to add the infrastructure beyond the medium range needs.

The efficiency with which clouds produce rain at the surface varies greatly. The understanding of these processes is very essential for rain enhancement programmes. Action has been initiated to develop cloud physics lab at Mahabaleswar to understand interactions of cloud with aerosols, and to investigate precipitation [processes, classify clouds and estimate rain rate. The research activities will continue during 12th Plan.

Global warming will lead to increase in the intensity of cyclones in the tropics. Hence, it is essential to develop models to improve the prediction of track and intensity of cyclones. Improvement to the cyclone track and landfall forecasts is expected due to recent technological advancements in respect of space-based (advanced satellite sensors - IR and Microwave; scatterometry/altimetry) and land-ocean based (Automatic Weather Station (AWS) Network; Data Buoys; High-speed wind recorders (HWR) Network; Automatic Rain Gauge (ARG) Network; Doppler Weather Radar (DWR) Network; Coastal Tide Gauge (CTG) Network observational systems. These observations are to be assimilated in improved models to improve cyclone forecast.

Severe weather, such as cyclones, heavy rains, storms, floods, heat and cold waves, etc. cause huge damages. It is proposed to develop improved prediction skills.

Climate Change Research: The seasonal monsoon prediction of the Indian Summer monsoon rainfall is very important. The development of seasonal and intra-seasonal prediction of monsoon through coupled model is to be taken up. The impact of climate change on various regions of India needs to be documented. Information available with regard to changes in temperature, rainfall, the sea level rise of about 1.8 mm/year during last 100 years has been documented. The

development of high resolution climate model for projection of regional climate change is undertaken. The understanding of various processes is vital. We also need to develop climate services for this region based on the projections developed through high-resolution regional models, and down-scaling of global models. The utility of geo-engineering schemes to mitigate global warming has to be explored. There is need to develop expertise in India to evaluate the benefits and risks of these schemes.

Water is one of the most vital elements for our sustenance on this planet. The inextricably linked surface water, soil moisture, and groundwater constitute a single resource replenished every year by the excess of rainfall over evapo-transpiration characterized by its spatial and temporal variability. It would be important to understand the changing water cycle from the perspective of water cycle drivers and mechanisms, land surface- and subsurface-water interactions, the water cycle-anthropogenic interface, and the society/ social factors. The research projects would be taken up to enhance our understanding of the changing water cycle.

Another important aspect is to understand the mechanism of ocean CO_2 sequestration techniques, and establishing feasible CO_2 capture technology from industrial technology.

A comprehensive knowledge of the carbon cycle-sources, sinks and bio-geochemical interactions is essential to have robust estimates of GHG fluxes. A state-of-the-art Earth System model to be developed to provide input to the 5^{th} IPCC assessment. A state-of-the-art GHG measurement network and analysis centre is to be set up.

The sea level is rising at 1.8 mm/year. It was observed that the rate of increase is now 3 mm/year. It is hence necessary to study the impact of sea level rise on coasts and response of shoreline to be modeled. Possible remedial and adaptive measures are to be planned.

Rich coral colonies and coastal terraces along the Indian coastal regions (Tamil Nadu) as well as the Andaman and Nicobar Islands and the Lakshadweep Islands offer outstanding records of sea level fluctuations. Oxygen isotope and minor elements analyses of these corals would help reconstruction of paleo-sea-surface temperature and salinity records for the Indian region and also interpret the climate and tectonic aspects of coastal evolution.

The primary objective of this initiative will be to extend our understanding of the natural climate variability that took place in our Earth's history during the past 20 Kyr especially during the Holocene (past 10,000 years) and to compare it with those from the short instrumental records of the last millennium. Accurate and high precision quantitative estimates of climate variability can now be obtained from paleo-proxies including tree rings, cave deposits carbonate fossil shell from marine records, lake deposits, ice cores, and geochemical and sedimentologic recorders. These proxies store the evidence of repeated large and regionally extensive changes in atmospheric and oceanic temperatures throughout the past 20 Kyr.

Airborne Platform for Atmospheric Research: Aircraft observations are required to observe upper air phenomena, especially cloud and aerosol. There is a need for simultaneous measurements of aerosols and cloud microphysics for studying the cloud aerosol interaction. This can be done only by the airborne platform. A wealth

of atmospheric, aerosol and cloud microphysics data will be generated which will be useful to validate the convection and cloud schemes, and for improving the model physics. The proposed program will be useful in air pollution assessment and associated impacts over India (health, visibility, climate), hydrological and water resources studies, and enhancement of research infrastructure (human resources and technology).

3.2 Ocean Survey, Science, Technology and Services

Ocean Observations: Indispensable to any forecasting system is an observational system that provides the data needed to build and validate models and provides data that are available in near-real-time for assimilation into models. The Indian Ocean observation system has been designed comprising sub-surface moorings, surface moorings with ADCPs, current meters, AWSs and water-level recorders, wave-rider buoy, HF radar, current-meter, buoys equipped with sensors for sea surface temperature (SST), surface air pressure, winds, and surface currents, Bottom-pressure recorders (BPRs) and Ship-borne observational programme. This system will be maintained and augmented. Gliders will be deployed. Indigenous development of many platforms will be undertaken.

Bio-geochemical observations are key to understand productivity changes in the ocean. Time-series stations would be set up for bio-geochemical and ecological research. The other aspect is measure the distribution of key trace elements and quantify fluxes.

Ocean Science and Services

A forecast of the oceanic conditions in the Indian EEZ depicted by such phenomena and variables as waves (significant wave height, seas, and swells), currents (both tidal and wind-forced), temperature and salinity, and biogeochemical variables is of great interest. Our ability to make such forecasts depends on the current state of the science underlying such forecasts. The existing system of the ocean forecasting will be strengthened by improving spatial and temporal scales. The PFZ forecasts will be sustained and improved.

Tsunami warning system has been established in October 2007. It has been now declared as Regional Tsunami Warning System, and will provide advisories to all Indian Ocean rim countries. This activity has to be sustained.

The long-term measurements of bio-optical properties in the Indian coastal waters are required for ocean colour research. This will facilitate productivity studies of the ocean and ultimately fishery potential. Ocean modelling will facilitate studies of ocean processes and provide inputs on heat and mass transfer. This will help to understand thermodynamics of the Indian Ocean.

A programme like COMAPS which provides current status of health of our coastal status of health of our coastal waters along with prediction of future trends of pollution needs to be continued to ensure proper management of pollution in the coastal waters. This is vital to preserve marine biodiversity and also to sustain the fish production. The key components would be monitoring and prediction with associated aspects of data quality exercise, database and application of GIS in understanding the spatial distribution of pollutants. Habitat-specific water quality criteria will be developed.

The coastal and marine ecosystems are very productive. Ecosystem models for selective coastal and marine habitats will be developed to predict productivity in the changing environment.

The study of living resources include assessment of deep sea fishery resources, marine benthos and technology to harvest marine resources. Harmful algal blooms affect fishery resources, and to be modeled.

The Census of Marine Life (CoML), begun in the year 2000, is a scientific worldwide census campaign to assess and explain the diversity, distribution, and abundance of marine life. These layers drawn baselines for measuring changes of marine life after natural changes and human actions. The development of DNA fingerprints of all the species found in the Indian waters will be accomplished. Huge number of samples of sea life are likely to be accessed and maintained under the centre of marine life. A marine museum as part of the Oceanarium Complex at Kochi is proposed to be set up.

The Intergovernmental Oceanographic Commission has recognized Centre for Marine Living Resources and Ecology (CMLRE), Kochi as the Ocean Bio-geographic Information System (OBIS) node for Indian Ocean. The OBIS is an International website dedicated to the representation of the species diversity and abundance in world oceans in a 5°x5° grid resolution. The IndOBIS at present hold 48422 records. As per this mandate, the need to to document the species diversity of the Indian Ocean in 2^0x 2^0 grid resolution and provide details on species abundance, shifts in species distribution, if any, and correlate these with environmental data.

The Drug and Bio-chemical Research Centre will be set up at the Centre for Marine Living Resources & Ecology. This centre is expected to help collection of deep-sea organisms are known to be the potential candidates for extraction of bioactive compounds. The major activities will include following:

(i) Provide extracts from deep-sea organisms to continue with our search for production of news drugs.
(ii) Develop novel compounds / products with market demand and transfer the technology to entrepreneurs.
(iii) Develop culture techniques for deep-sea microbes and explore the possibility of using them in various fermentation technologies.
(iv) Undertake DNA manipulation on microbes with a view to produce desired molecules on a commercial scale.

Non-conventional fishery is to be studied with major objectives being assessment of deep-sea fishery resources in the Indian EEZ (200-1500 m depth), assessment of myctophid resources in the Arabian Sea, assessment of tuna resources in the Central Indian Ocean, and the Southern Ocean Krill programme. Climate change is expected to affect upwelling patterns, surface circulation, regional shifts in fishery, variations in primary production and secondary production (microbial loop becoming stronger) and changes in the distributional patterns of marine species; all of which have a profound effect on our marine ecosystems. MLR technologies are to be developed for islanders and include commercialisation of ornamentals, black-lip and pearl culture, live feed culture for supporting tuna fishery, technologies for hatchery products of commercially important gastropod species and for protection & conservation of natural resources of the island ecosystem.

Microbial Oceanography is a new discipline that draws insights from the basic sciences of marine microbiology, marine ecology and oceanography to understand the role that microorganisms play in biogeochemical dynamics of natural marine ecosystems. Evolutionary dynamics, biological processes, marine biogeochemical cycles and ocean & atmospheric chemistry are critical to understanding the environment and human activities in it. Microbial oceanography has developed by studying these linkages with new techniques such as genomic studies of microbial communities *en masse*, *in situ* ocean monitoring systems, Earth-orbiting satellites for planetary productivity estimates, etc. Microbial oceanography involves understanding sea microbes from genomes to biomes, thereby coupling biosystems to ecosystems.

Integrated Coastal and Marine Area Management project will be converted into a dedicated Coastal Research Centre continuing research on coastal zone and to address related issues. The programmes proposed to be undertaken are

(i) Development of Ecosystem models for management of the coastal and estuarine resources
(ii) Development of seawater quality criteria for chemicals based on modern bioassay methods
(iii) Coastal Ocean Monitoring and Prediction System
(iv) Vulnerability Assessment of Coastal areas of India

Ocean Survey and Mineral Resources: India has large EEZ of 2.0 million sq km. The first requirement is seabed survey to understand topography and possibility of mineral occurrences. This survey is to be continued and extended to the continental shelf around India. The ferro-manganese deposits such as nodule,s cobalt crusts as well as hydrothermal sulfides are important for future needs. The exploration work need to be continued.

Gas hydrate has potential for future energy resource. Quantification of gas hydrate reserves using multi-channel seismic data for the Krishna-Godavari and Mahanadi basins to be continued.

High-resolution Secondary Ionization Mass Spectrometry to take up advanced research in isotope geo-chemistry and geo-chronology pertaining to earth, atmospheric and oceanic sciences.

Ocean Technology: In view of the fast depletion of fossil fuels, renewable and non-renewable energy sources from the ocean are to be captured and converted to usable form. The objective is to develop technology for energy and fresh water from alternate sources like Waves, Thermal Energy, Ocean currents, Algal fuels, Gas hydrates, etc. Development of turbines and other equipment for harnessing renewable energy and fresh water are under progress. The key priority areas include 10 MLD floating desalination plant. The deliverables would be the pilot plant technology development for recovery of Gas Hydrates and Floating large capacity offshore desalination plant.

Ocean is a large depository of the resources like minerals. However reliable technologies and vehicles, suitable for deep water environment, are required for exploring and harnessing these resources. The objective is to develop and

demonstrate technologies for exploration and harnessing deep ocean resources. The sea mining machine with collector and crusher has been developed and demonstrated at 500 metre water depth. Also undertaken are the design and development of offshore structures to aid these technologies. Development and demonstration of underwater vehicles, and mining system for deep sea mineral resources. The development of Manned submersible, Polar ROV and technology for sequestration of CO_2 would be taken up during 12th Five Year Plan

The goal is to develop country wide coastal zone characterization, shoreline management and development of engineering techniques for coastal protection. Technical criteria atlas for coastal engineering design parameters is being developed. Demonstration of shoreline management techniques are being carried out at few locations.

It is necessary to develop technology for mass culture of specific bacteria, identification of bio-molecules and ballast water management systems.

Sea-front facility is required to prototype system development, testing and calibration of marine systems.

Ocean Research Vessels

FORV *Sagar Sampada* and ORV *Sagar Kanya* were commissioned in 1984 and have been the major platform for marine living resources and oceanographic studies undertaken in the last 27 years in India. With the increasing demand for coverage of vast areas of oceans, it is necessary to plan for new vessels, as the lead time to commission a vessel is around 4 to 5 years. Proposed new vessels will be >100m OAL, Ice-class, with speed of 20 knots and fitted with winches and systems for exploration of living resources up to 5000m depths. *Sagar Sampada* had the limitation of undertaking these studies only up to 1000 – 1500m depths. These vessels will be acquired.

3.3 Polar Science and Cryosphere

Changes in the cryosphere can also impact global climate through changing albedo, thawing of permafrost and attendant release of greenhouse gases, changes in sea level, etc. Indian research activities of the cryosphere are concentrated in three major regions: (1) Antarctic region (2) Arctic region and (3) Himalayan region.

Antarctic Expeditions: Since Antarctica account for nearly 91% of the global cryosphere, and it is the least understood of all regions, it is necessary to continue to explore the continent to study cryospheric processes and climate records from this region. Our knowledge of the functioning of Antarctica within the global system and the spatial and temporal complexity of Antarctic climate is still poor, which is largely due to the limited and the short period of observational and instrumental data on climatic variables. Fundamental questions that remain in this approach include:

(a) How typical of Antarctic climatic history are the few decades?
(b) Has Antarctica experienced a typical spatial climate pattern over the last few centuries to thousands of years, as suggested for other regions of the globe?

One of the most crucial requirements of climate change study in Antarctica is the availability of ice core-based proxy records that are long enough (representing at least the last millennium) for decoding the natural and modern variability with at least annual to seasonal time resolution. As a rational approach to our study in Antarctica, it is essential to carry out integrated studies in spatially distinct regions in the following major aspects:

a) Ice dynamics and modelling
b) Monitoring the modern accumulation changes and mass balance of glaciers and ice sheets.
c) Biogeochemical process measurements in snow/ice
d) Proxy based reconstruction of the climate variability of the last millennium

The Third station at the Larsemann Hills will be commissioned.

Replacement of Maitri Station: *Maitri* station was built in 1987-88. It has withstood vagaries of harsh climate and outlived its postulated active life. A team of experts has recommended that it is an outdated structure that has outlived its useful life and is barely able to cater to the present scientific need and shall be a retarding factor for future growth of science. It is therefore planned to rebuilt the Maitri station incorporating the modern energy conservation systems i.e. CHP units and integrated power generation through wind energy and solar power, a waste conservation and waste disposal strategy through appropriate redesign of wastewater treatment and disposal system capable to recycle treated water to meet environmental protocol, integration of summer camp modules with necessary facilities to act as separate residential units and updating the laboratories facilities along with keeping provision for additional rooms and facilities for unforeseen activities in immediate future.

Polar Remote Sensing: Antarctica is a barometer of climate change. A 0.5°C warming has taken place at the peninsular Antarctica and there has been disintegration of ice shelves in that region. The southern ocean has warmed by >0.3°C, as a result of which the peripheral continental ice is getting eroded thereby, giving rise to a tipping point for the ice sheets. It is proposed to monitor the surface topography of the ice sheet and glacier. Seasonal and interannual monitoring will help to identify areas that are prone to faster melting than the other regions in the Indian Antarctic sector.

Hydrodynamics of the Indian sector of coastal Antarctica: The Antarctic Coastal Current is the southernmost current in the world. It is an important component of the very active air-sea exchange in this area that leads to deep convection and production of deep ocean water masses. The Antarctic Coastal Current is barotropic, banded at many points with countercurrents and is mainly driven mainly by east winds south of 66°S. The coastal hydrodynamics in the vicinity of Antarctica is also as a result of freezing in austral winter and melting of sea ice in austral summer. Melting releases fresh and nutrient rich water, while freezing process rejects brine. These processes promote thermohaline circulations and in presence of strong winds facilitate convective mixing and deepening of mixed layer and warming of the subsurface layer due to convective circulation. Synergetic use of ARGO floats and hydrographic data sets supplemented by satellite-based altimetry products will help compute geostrophic transport, quantify water masses mixing, frontal meandering and mixing, etc. This data set will be combined with other historical CTD casts (ARGO floats, WOCE, climatology, Good Hope XBT line, etc) to compare

interannual variations in the transport of ACC fronts and coastal Antarctic fronts, and water masses characterization in relation to melt water from continent.

The report of the IPCC (2007) clearly indicates that the Arctic ice cover is shrinking dramatically, more so in the summer. Therefore, large amount of efforts are required from the scientific community not only to unlock the hidden information in the region, but also to predict the possible implications on its future. One important research area for the Indian scientific efforts would be to study the modern biogeochemical cycling in the snow packs and sea ice to identify the possible triggers in the seemingly less understood, but crucial linkage in the controlling mechanisms in the response of the ice cover to the warming trend.

It is proposed to establish a long-term multi-institutional program of the physical and biogeochemical parameters that characterize the Kongsfjorden system through deployment of an ocean-atmosphere mooring at a suitable location in the fjord.

The Southern Ocean is the most important region on the earth surface with reference to material cycling. This region absorbs, for instance, huge amounts of atmospheric carbon dioxide at the surface and transports it to the deep ocean. Systematic and sustained oceanographic and atmospheric data collection is called for to understand the biogeochemical cycling, especially from the Indian Ocean sector of the Southern Ocean, where such data is lacking, to understand the role of climate change if any, in modulating the absorption capacity of CO_2.

Himalayan Region: Despite the long history of glaciological studies in Himalaya, our understanding of the Himalayan cryosphere is very limited. The terrain and altitude-related logistic constraints to undertake large scale studies in this region have led to several knowledge gaps in this region. The Indian Himalaya has more than 9000 glaciers of varying sizes. We need to have long-term and independently-corroborated quantitative data on the multiple variables like environmental, biogeochemical and ecosystem variability during the modern times as well as in the past for most of the glaciers.

An Ice-class vessel will be constructed and commissioned for polar and southern ocean operations.

Geo science Studies

The solid earth is an essential component of the Earth system. Lithospheric processes such as volcanism and orogenic uplift can strongly affect the global climate over the long-term through energy transfers within and between the various parts of the climate system. It also controls such catastrophic events as earthquakes, landslides, tsunamis and volcanic eruptions. On much shorter time scales, physical and chemical processes affect such characteristics of the soil as moisture availability and run-off, and the amounts of greenhouse gases and aerosols in the atmosphere and oceans. Understanding the discrete events that shape the various components of the solid earth and from them building a complete picture of our planet's dynamics, requires knowledge at local, regional and global scales.

Earthquake Research: The aim of the programme is to provide thrust to the earthquake- related studies and to generate inputs for earthquake disasters mitigation. Efforts are also being made towards generation of long-term, comprehensive multi-parametric geophysical observations in seismically active

areas. Their comprehensive analysis may help in establishing possible relationship between various earthquake precursory phenomenon and the earthquake generation processes. The following process-based studies will be taken up:

i) Deep crustal studies across the Indian continental margin and the interior.
ii) Paleo-seismological studies and kinematics of the Himalayan region.
iii) Andaman subduction zone.
iv) Active faults of India.

Knowledge of the composition and spatial variability of the lithosphere as well as of the deformational and magmatic processes affecting it and of its interaction with the underlying asthenosphere is fundamental to our understanding of the Earth system at all scales. Similarly, the dynamic processes of the Earth interior shape the Earth's surface through plate tectonics, giving rise to mountains ranges, oil-rich sedimentary basins and mineral–rich crust.

Considering the immense volume of geoscientific data gathered by research organisations from the continental margin over the years as well as the excellent dataset available from the continental interior, an integrated offshore-onshore endeavor aimed at investigating the nature, origin and evolution of the continental lithosphere is proposed as a national initiative over the next decade. This program aims at reconciling the constraints from available geophysical and geological data along a series of transects across the Indian peninsula into a consistent model of the Indian lithosphere.

Deep bore holes investigations in Koyna – Warna region:

The Koyna dam located near the west coast of India is the most significant site for Reservoir Triggered Seismicity (RTS) globally. The earthquake of magnitude 6.3 was occurred in Koyna on 11th December 1967. Over the past 43 years, more than 20 earthquakes of magnitude 5 and several thousand small earthquakes have occurred in the same region. The seismicity is confined to a small area of 20 km x 20 km.

Considering the importance of deep borehole investigations, it is proposed to undertake a suite of observations in deep borehole(s) in the area of persistent and focused seismicity. The observations will include stress regime, pore fluid pressure and its variations, heat flow and its variation, orientation of faults, study of chemical properties of fluids, before, during and after earthquake. The proposed boreholes will also facilitate i) observation and analysis of data, generated through the operation of borehole for 4-5 year of time, when it is anticipated that a few earthquakes of magnitude ~3 would occur in the immediate vicinity of borehole, ii) continuous observation to study the data in the far and near field of the earthquake and temporal variation with respect to occurrence of earthquake and iii) development of a model of RTS mechanism.

Deep borehole investigations in the Koyna region would allow direct characterization of the underlying fault geometry, and measurements of rock physical properties, fluid composition, pore fluid chemistry, heat flow, and in-situ stress to name a few, which may ultimately lead to better understanding of stable continental region earthquakes in general, and Reservoir Triggered Seismicity in particular.

The deep borehole investigations will also provide insight into Deccan volcanism and Mass Extinction; Thermal structure and state of stress in the lithosphere; Geothermal potential of the West Coast Belt as well as Geothermal Record of Climate Change in the region.

Marine Geo-scientific Studies:

Study of largest Geoid low: Geoid is an equi-potential surface of the earth's gravity field that best fits the global mean sea level in a least squared sense. Recent gravity models and satellite based observations show that geoid are caused due to subsurface density heterogeneities. Positive long wavelength geoid anomalies are generally concentrated over subduction zones and are understood to have been caused due to responses of deep subducted materials. However, there is no univocal proposal to explain the sources of geoid lows. One such geoid low, the largest one, is centered around the south of India. Some researchers think that it is caused due to the depression in the Core-Mantle boundary, while others propose density heterogeneities in the upper mantle. It has also been proposed that it is produced due relict of earlier subduction. All the studies are, however, in agreement that it is a deep-seated earth structure. Seismological observations from the deep in the Indian Ocean are thus needed to understand this deep-seated, globally debated earth structure. Two kind of seismic arrays will be deployed along with global seismic network (like IRIS): one along of measurements could be along a EW line, along this line of 2500 to 3000 km, OBO can be deployed as every 100-200 km. The OBOs in the eastern part can also provide additional information about the Andaman-Sumatra subduction zone.

Deep-sea drilling in the Arabian Sea basin through the Integrated Ocean Drilling Program: The Himalaya and Tibet represent the most dramatic examples of mountain building in the recent geologic past, and no topographic feature on the Earth perturbs the atmosphere and affects the climate as much as the Himalayan-Tibetan Plateau. The influence of this landform on the climate of South Asia is cited as a prime example of climate-tectonic interactions. Thus basins surrounding the Himalaya – the Arabian Sea and Bay of Bengal- are excellent repositories for studying the relationship between tectonics and climate. Sediments in these basins which are brought by rivers draining through the world's highest terrain record the history of the world's most spectacular continental collision zone.

The integrated Ocean Drilling Programme provides the opportunity to explore these sediment records and reconstruct the history of climatic variations and rate of erosion. The sedimentation records from the Indus and Bengal Fans, both of which can be obtained from IODP cores, should present erosional histories of different parts of the Himalaya. Thus the Indus Fan should serve as an important repository of the information on the uplift history of western Himalaya.

The scientific proposal "Deep sea drilling in the Arabian Sea: Discovering the tectono-climatic unknowns" will be taken up.

Geo Technologies: India has large support system for geo-services through research institutions like NGRI and service organizations like GSI. GSI has one of the largest pools of geo scientists in the world, however the country has no mechanism to address instrumentation and engineering for this science and service function and every equipment is imported. The large country with so much economic interest in stakes, like mining, Coal gasification, exploration of resources like

geothermal energy, including instrumentation for geo-sciences, cannot and should not remain dependent forever. Appreciating this need, an institute for Geo-technologies, integrating of all the scientific and operational bodies and taking new initiatives on merit like finding geo-technology solutions to serious problem like global warming needs to be set up.

High Performance Computer - Up gradation, Maintenance and Data Centre: With the increasing scope of research activities, the computational demand has increased manifold over the years for undertaking various climate related problems that involve running of coupled models for hundreds of years and utilizing data from the global land, ocean and atmosphere. This will help to study dynamics and predictability of muti-decadal monsoon oscillation. In addition, ensemble modelling is required for these studies that are computationally exhaustive. It would involve assessing component models, namely, models of the atmosphere and the ocean, coupling strategy, assessment of bias of the coupled model, data assimilation, development of forecast strategy, etc. to be carried out to study the dynamics and predictability of monsoon multi-decadal oscillation. Following are the major activities that involve a large number crunching capability will be carried out at Centre for Climate Change Research (CCCR): Seasonal Prediction of Monsoon, Extended Range Prediction of Active/Break Spells, National Monsoon Mission, Program for Advanced Training in Earth System Science and Climate, and activities of CCCR. A high priority has been assigned to the development of climate models for more reliable projection of climate change in the 21st century - with a special focus on the behaviour (frequency and intensity) of extreme events (heat waves, cold spells, severe thunder storms, tropical cyclones, storm surges, severe storms, droughts, etc.) in the near future. Both the development of a coupled modeling strategy as well as to generate a large ensemble of future climate change scenarios using a suite of global and high resolution regional climate models involve a large number crunching capability. This will require a very high performance computing facility with peak performance of at least 3 PF.

3.4 Human Resources Development

Research, Training and Education: The hands on training will be beneficial in capacity building of trained manpower. The Centre for Advanced Training (CAT) will also be upgraded by providing world class teaching courses and good hostel facilities to serve for the region. Its courses have been recently modernized to suit present day requirements of all operational staff. Facilities have to be built to provide necessary infrastructure.

The growing dependence of mankind on the ocean for food, energy and recreation demands nowcasting and forecasting the behaviour of oceans. The nowcasting and forecasting of oceans in turn demands the systematic integration of long-term routine measurements of the seas, oceans and marine atmosphere and rapid interpretations and dissemination of information to end users. The main objective is to set up an Institute for Operational Oceanography for training and capacity building in operational oceanography. The proposed training centre in operational oceanography mainly envisages the capacity development on how to make measurements using in situ and satellite platforms, how to obtain the data in real time, how to process and use the data in modelling, how to make the nowcast and forecasts and how to disseminate them to the end users at shortest possible time. Construction of faculty blocks, state-of–art class rooms, and service buildings and an international standard hostel and guest house to accommodate the trainees and

guest faculty. The major outcome would be operationalisation of permanent facility for the Institute for Operational Oceanography.

It is proposed to support Human Resource Development through establishment of MoES Chair/Professorship in IITs and IISERs; initiation of academic programmes at IITs and IISERs; Opening of Centers of excellence in universities. Focused research in areas of National importance through integration of multi-institutional and multi-disciplinary scientific expertise will be encouraged. Thrust on indigenous capability will be given through support of joint activities. Scientific and technical cooperation with national and international scientific groups in earth system science will continue.

3.5 Exploration for hydrothermal sulphide deposits on the Central Indian Ridge.

This is a Central Scheme. The project has been recommended for implementation in-principle by the Inter-Ministerial Group, as a follow-up action of the decision by the Committee of Secretaries (CoS). Supporting science and technology for exploration and exploitation of ocean resources (living and non-living), ensuring their sustainable development and utilization is one of the mandated activities of the Ministry of Earth Sciences. This is a major national initiative which focuses on the study of seafloor hydrothermal systems at mid-ocean ridges with emphasis on the survey and exploration for hydrothermal sulphide deposits on the central Indian Ridge (CIR) in the Indian Ocean. Modern seafloor hydrothermal systems, with their black/ white smokers issuing hot metal rich vent fluids from mafic or felsic volcanic rocks can be considered as modern analogs for the formation of volcanic-hosted massive sulphide (VMS) deposits The discovery of such systems in the deep oceanic realm along the mid-ocean ridges has kindled a lot of interest primarily on account of the high concentration of base metals (Cu and Zn) and many noble metals (Au, Ag, Pd, Pt) in them. Apart from their economic potential, perhaps the most striking feature of sea-floor hydrothermal vents is their dense biologic communities. Biologically, vents are among the most productive ecosystems on Earth. Sulfide from hydrothermal fluids provides the energy to drive these productive systems. The discoveries are therefore also significant from a scientific point, especially as some of them, such as the carbonate tower at the Lost City hydrothermal field on the Mid-Atlantic Ridge (MAR), have provided new insights in the role of hydrogen and methane generation and in understanding the link between serpentinisation and evolution of biological communities. The basic paradigm of hydrothermal activity involves sub-seafloor convective circulation of seawater through permeable rocks mainly driven by the upper mantle heat sources. In spreading centres, prevailing kinematics favor rigorous churning of water and downward propagation supplement the circulation of hydrothermal fluid manifold. Thus spreading centres are very much conducive to host the world's best hydrothermal sulphide sites. The Indian Ocean ridge system, which is part of the 65,000 km-long global ridge system, consists of mainly four ridges-Carlsberg Ridge (CR), Central Indian Ridge (CIR), Southeast Indian Ridge (SEIR) and Southwest Indian Ridge (SWIR).

Objectives of the study

- Acquistion of Research and Survey Vessel and Exploration for potential sites of hydrothermal multi-metal sulphide mineralization in the central Indian Ocean Ridge

- To make India's submission for initiating exploration activities on the active hydrothermal vents in the central Indian Ridge for polymetallic sulphides.
- Identification of locales of hydrothermal sulphide deposition in the central Indian Ridge, including determination of the resource potential.
- Initiation of associated scientific research in the frontier areas of hydrothermal mineralization including the tectonic environment, host-rock composition, role of biological organism and development of geological models for seafloor hydrothermal systems.

Implementation
National Centre for Antarctic and Ocean Research (NCAOR), Goa, an autonomous body under the MoES is being entrusted with the responsibility of implementation of the programme in its entirety on behalf of the Ministry with the active co-operation and participation of all national geoscientific institutes. A Steering Committee headed by Secretary, MoES and comprising of representatives from Ministries of External Affairs, and Defence would be constituted to monitor the progress of activities under this programme.

3.6 Earth Enterprise:
The purpose of the above Enterprise is providing data/technologies on commercial basis developed by the autonomous bodies/attached and subordinate offices under the administrative control of the Ministry. There has been phenomenal increase in the sectoral applications of weather and climate products as well ocean technologies and related products, resulting in an unprecedented demand for reliable and timely supply of products and information. The traditional demand in sectors such as aviation, shipping, agriculture, petroleum, coastal marine and fisheries community, etc. has been supplemented by new sectors such as tourism, power, adventure & sports, defence, industries, transport other than aviation/shipping, etc. In the absence of a commercial organization to offer such data to the user groups, there is often an information gap with the users, denying access to such data readily. Sometimes the users are not even aware that such data is being generated as there is no marketing effort undertaken by the government departments who generate the data. Thus, optimum commercialization has not been possible so far.

The income of the proposed corporation would be applied for providing short term services of higher level of skilled scientists/professionals for supporting state of art technologies that are currently being installed by IMD, NCMRWF, IITM, NIOT, INCOIS and NCAOR. The kind of support staff needed for such technologies is not readily available at government salaries. Further, the income of the Corporation would be applied to commercial and aggressive R&D activity that may not readily fall in the domain of Government laboratories. It may also be mentioned that the institutions under the Ministry are already generating revenue to the extent of `. 23.30 crore per year.

Keeping in view the above, it is proposed to set up a public sector undertaking, namely, the Earth Systems Enterprise under the Companies Act under the administrative control of the Ministry with the equity capital of `.10.00 crores. The equity amount shall be provided from time to time from the budgetary allocation of the Ministry. Initially, it is proposed to release a sum up to Rs.5.00 crores during the Financial Year 2012-13. The remaining part of equity shall be released later depending upon the requirements of the proposed corporation during the Plan.

3.4 Financial Requirement for XII Five Year Plan (2012-17)

The following schemes will be operated which has component of continuing program and new programmes.

No	Name of Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
1.	Atmospheric observation System	367	457	617	342	372	2155
2.	Atmospheric Processes, Modelling & Services	207	530	257	200	190	1384
3.	Climate Change Research	212	217	230	201	195	1055
4.	Airborne Platforms	70	200	250	80	100	700
5.	Ocean Observations	80	90	110	100	106	486
6.	Ocean Science & Services	193	307	307	232	226	1265
7.	Ocean Survey &Mineral/Hydrothermal Sulfides	**254**	**380**	**374**	**376**	**365**	**1749**
8.	Ocean Technology	324	370	323	282	248	1547
9.	Ocean Research Vessels	124	415	518	249	177	1483
10.	Polar Science & Cryosphere	586	679	531	377	255	2428
11.	Seismological Research	108	194	247	296	264	1109
12.	Geoscientific Studies	15	79	46	21	13	174
13.	High Performance Computing (HPC)	150	150	200	200	200	900
14.	Research, Education, Training and Outreach Earth Enterprise/IT	**277**	**560**	**469**	**292**	**251**	**1849**
	Total	**2967**	**4628**	**4479**	**3248**	**2962**	**18284**

INTRODUCTION

The Earth System Science Organization (ESSO) addresses holistically various aspects relating to earth system processes for improving forecast of weather, climate and natural hazards. The ESSO is also responsible for development of technology towards the exploration and exploitation of marine resources in a sustainable way. The activities include weather forecasting, weather advisories specific to agriculture, aviation, shipping, sports, etc, monsoon, disasters (cyclone, earthquake, tsunami, sea level rise), polar science, living and non-living resources (fishery advisory, poly-metallic nodules, gas hydrates, freshwater etc), coastal and marine ecosystems and climate change. Satellite based, airborne and in-situ atmospheric, ocean and lithosphere observing systems have been deployed and continuously augmented. ESSO is organized and managed by the ESO Council.

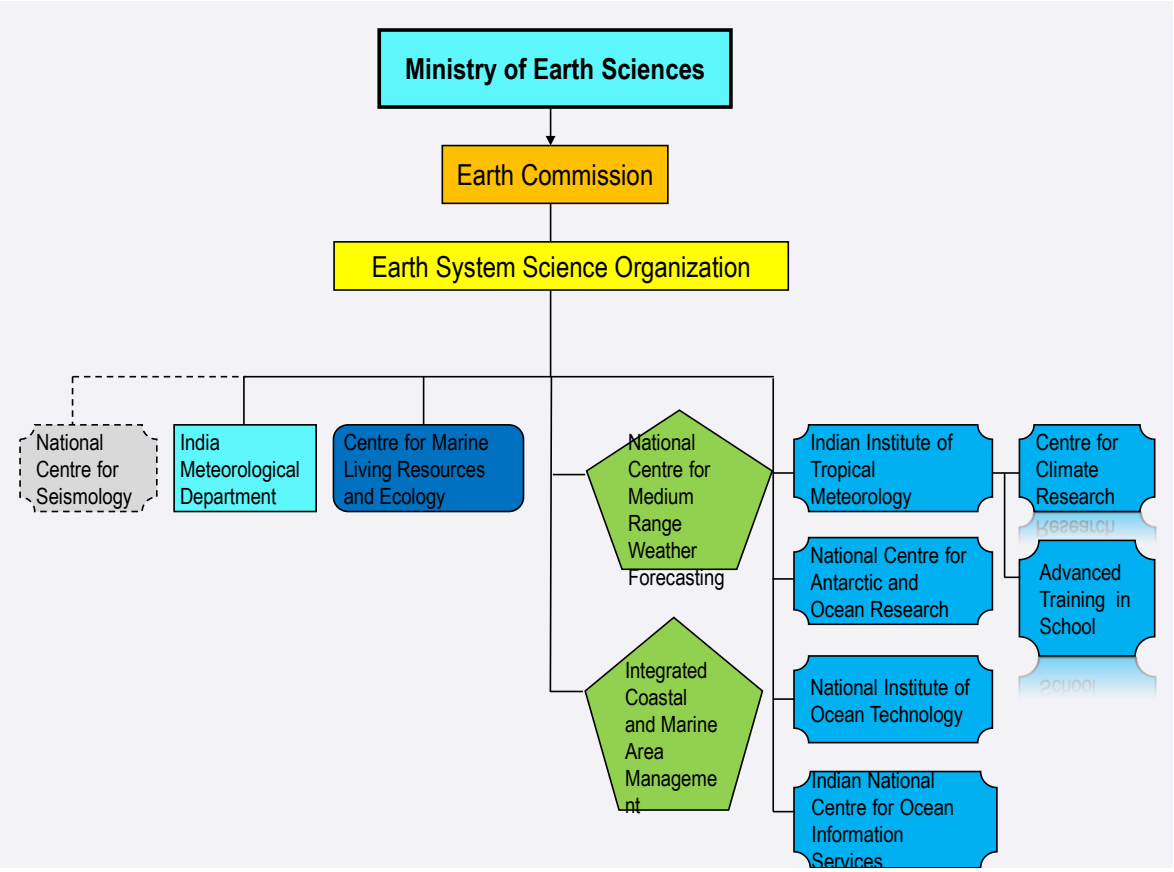
The vision of the ESO is to excel in knowledge and technology enterprise for the earth system science realm. The earth system studies in India has three major components:

- Provide scientific and technical support for both basic and applied research in earth system sciences as a whole comprising atmosphere, hydrosphere, cryosphere and geosphere, with particular reference to the Indian sub-continent and the surrounding oceans as well as the polar regions.

- Provide the Nation with the best possible services in forecasting monsoon and weather/climate parameters, ocean state, early warnings to natural disasters like storm surge, earthquakes, tsunamis, etc. through well integrated programs.

- Conduct scientific survey and develop technology for exploration and exploitation of ocean resources (living and non-living), ensuring their sustainable utilization.

ESSO pursues these goals through its Centres, viz. India Meteorological Department (IMD), National Centre for Medium Range Weather Forecasting (NCMRWF), Indian Institute of Tropical Meteorology (IITM), National Centre for Antarctic and Ocean Research (NCAOR), National Institute of Ocean Technology (NIOT), Indian National Centre for Ocean Information Services (INCOIS), Centre for Marine Living Resources (CMLRE) and Integrated Coastal and Marine Area Management (ICMAM), as detailed in the organization chart below.



Working Group of the Ministry of Earth Sciences:

The Steering Committee on Science and Technology for the formulation of Twelfth Five Year Plan, during its first meeting held on 5th April, 2011 under the Chairmanship of Dr. K. Kasturirangan, Member (Science), Planning Commission has decided to constitute a Working Group for the Ministry of Earth Sciences. The Terms of Reference of the Working Group are given below:

(i) To review and assess the performance and role of the Department at the end of the Eleventh Five Year Plan. Identify priorities of the Department for the Twelfth Five Year Plan and suggest measures including policy initiatives for enabling India to emerge as a major global technological power b 2025.

(ii) To suggest plan programmes for the Department by adopting a ZBB approach and keeping in view the priorities and goals for the Twelfth Five Year Plan as well as the agenda for the Decade of Innovations during 2010-20.

(iii) To define deliverables as well as goals for the Department for the Twelfth Five Year Plan period as well as Annual Plans, both in terms of tangible and non-tangible outputs and formulate guidelines for deployment of resources for relating inputs to the specified goals.

(iv) To suggest an optimum outlay for the Department, comprising on-going commitment and new programmes proposed to be undertaken.

The suggestions/ corrective measures recommended by Planning Commission during the Mid-Term Appraisal of the plan programmes of the Ministry have been deliberated by the Working Group constituted by Planning Commission for

formulation of the 12th plan proposals. Efforts have been made to focus more on regional and local-specific forecasts and over a greater time horizon for the benefit of farmers and more emphasis has been given on modeling for long, medium and short term weather forecasting while formulating the 12th plan programmes.

The 12th plan Working Group of Ministry of Earth Sciences has also deliberated the issue of deriving maximum benefits from the research funding, greater emphasis has been laid on the creation of appropriate institutional framework cutting across departments and other kinds of organizational mechanisms.

Regarding the replacement of two Research Vessels ORV Sagar Kanya and FORV Sagar Sampada which are more than 25 years old, replacement of these platforms has been included as a part of the 12th plan programmes to provide support for various oceanographic and atmospheric research.

As suggested during mid-term appraisal, an integrated programme for island development through S & T intervention would be under technology development programme for island community.

Programmes have been formulated for IITs & IISERs forms part of 12th plan proposal of the Ministry to meet the emerging requirements of various multi-disciplinary manpower under R&D programmes of ocean and atmospheric sciences in future.

In order to meet human resources of multi-disciplinary nature for providing wide range of services in the field of ocean, atmospheric, climate and seismological services, advanced Training School has already been established at Pune and the first batch of 20 scientists are presently undergoing training. The ultimate aim is to increase the number of scientist to 40 for providing the required services.

Regarding effective implementation of various schemes being formulated during the 12th plan, appropriate action has already been initiated for expediting the process for getting the approvals at an early date as suggested at Mid-Term Appraisal stage.

2. ACHIEVEMENTS OF THE 11TH FIVE YEAR PLAN (2007-2012)

The Earth System Science Organization (ESSO) through its units has made significant contributions in the field of weather forecasting, weather advisories specific to agriculture, aviation, shipping, sports, monsoon, disasters (cyclone, earthquake, tsunami, sea level rise), polar science, living and non-living resources (fishery advisory, poly-metallic nodules, gas hydrates, freshwater, etc), coastal and marine ecosystems and climate change. Satellite-based, airborne and in-situ atmospheric, ocean and lithosphere observing systems have been deployed and continuously augmented. The major achievements are given below:

2.1 Atmospheric Science, Technology and Services

The meteorological services have significant impact on society in general. Public/private/government sectors demand for accurate prediction of weather and climate at various temporal and spatial scales is increasing due to possible impacts of global climate variability and change. Improved and reliable forecast of weather and climate requires high-resolution dynamical models (e.g. coupled ocean-atmosphere-biosphere-cryosphere models). Thus, a combined approach involving land, ocean and atmospheric processes hold the key to improve the forecasts of various temporal and spatial ranges. On the other hand, intensive monitoring of various weather systems through different platform based observing systems including satellites provide not only the necessary information about current weather systems, their effective assimilation in numerical models provide important guidance for accurate forecasts. ESSO has taken positive steps to implement comprehensive developmental programs in these lines involving all its constituent units.

The upgradation of weather forecasting capabilities to a sufficient level is one of the major priority programs launched during 11th Plan. It has four components, viz., atmospheric observation network; strengthening of computing facilities, data integration and product generation and dissemination of information. The activities related to computing, integration and product generation and dissemination have been completed. The argumentation of observational network is progressing. IMD now has a network of automatic weather stations, Doppler Weather Radars (DWR), state-of-the-art upper air systems etc. These observations are now being used to run its global and regional numerical prediction models on High Performance Computing Systems (HPC). It has improved forecasting capabilities for high impact weather events like cyclones, severe thunderstorm, heavy rainfall and floods in a significant manner.

Operational weather services have been greatly benefited by successful completion of the 'Varsamana' project, which has integrated observations, communication, analyses, forecasting and dissemination into a single system accessible across the country under the phase-I of the IMDs modernization plan.

2.1.1 Atmospheric Observational Networks:

Details of the augmentation of atmospheric observation network under Modernization of IMD Phase-I (Table-I), is continuing. Five DWRs have been commissioned, each at Hyderabad, New Delhi, Nagpur, Patna and Mumbai, and products are regularly available to the users on Web. The Delhi DWR has also been demonstratively used for building now-casting system in support of the Common Wealth Games (CWG 10) through generating site specific weather forecasts on hourly scale. The GPS sonde has improved the quality of upper air observations

over India. At the same time, a new variant of indigenously developed upper air sounding system based on GPS has been successfully tested by IMD. Action is underway to produce the same for operational induction in a limited scale facilitating for robust performance evaluation.

Table 2.1: Status of Atmospheric Observation Network.

Sensor	Target	Up to July 2011	Existing prior to moder-nization	Total	Data receipt
AWS	550	411	125	522	503
ARG	1350	364	-	364	314
GPS-S	10	10	1	11	11
DWR	13	2	5	7	7
Pilot Balloon	70	65	-	-	65

An instrumented air-craft was chartered during monsoon period to conduct cloud aerosol-interaction experiment during 2009-11. A Web-interfaced National Satellite Data Centre was established for archiving all satellite data available till date and serving near real time value added products. The new satellite INSAT 3D is to be launched in the near future. The ground segment required to process its data has already been established and is being currently tested for the existing Indian satellites, Kalpana-1/INSAT-3A. The new system will substantially augment Indian capability to foreshadow high impact weather occurrences.

Satellite product broadcast services were upgraded with Digital Meteorological Data Dissemination (DMDD) systems being installed at 37 locations in India and neighbouring SAARC countries of Nepal, Male and Sri Lanka. 353 coastal Digital Cyclone Warning Disssemination Stations (DCWDS) continued to operate with the support of fail-safe satellite communication. Its migration to DTH mode has already been prototyped for deployment.

A significant development was a bilateral agreement between EUMETSAT and IMD to receive data of all European satellites. Other areas of development during this period included Integrated Precipitable Water Vapour using GPS satellites data and installation of data receiving systems from NOAA/MODIS/Metop polar orbiting satellites.

2.1.2 Atmospheric Modeling & Research

Data Integration and Computing Facilities: A complete end-to-end forecasting system that includes acquisition of data from various observing systems, linkage to a central data processing system, their utilization in the numerical models, providing a state-of-the-art IT based environment to all forecasters across the country has been installed. This involves integration of all observations and overlaying them on

model outputs and synoptic charts along with proper visualization and customized dissemination of weather forecast to the end users.

During the first phase of the modernization of IMD, along with the commissioning of state-of-the-art observing systems, application module “SYNERGIEe” has been installed at 34 forecasting offices all over India. These have the capability to visualize multiple layers of observation and forecast overlayed on each other, thus providing to the forecaster the capability to assimilate terabytes of information before issuing weather forecast. A Public Weather Service System(PWS) ‘METEOFACTORY ’ enables the forecaster to generate required customized presentation for the automatic delivery of products to the visual and print media viz. newspaper, TV, farmers, shipping, etc. The Central Information Processing System (CIPS) with a super-computer at the back-end has given a paradigm shift from Observation Network Management towards integrated information processing systems providing fully customized services to the user community. It is equipped with state-of-the-art hardware and software to handle, manage, store, process and archive all data and forecast products used in operational weather forecasting. It consists of seven sub-systems comprising data acquisition, data policy management, data centre, tpolicy management, task centre, backup policy management . The CIPS Data Centre provides flexibility to ingest any kind of meteorological data like satellite, radar, etc. with regard to the assessment of current weather and prognosis for the future.

A set of four High Performance Computing systems (HPCS), one each at INCOIS, IITM, IMD, and NCMRWF have been installed for global data processing, assimilation and numerical weather prediction (NWP) for weather and ocean state forecasting services. The combined strength of HPCS in ESSO is about 125 TeraFlops, which has significantly improved coupled atmospheric–ocean modelling capability. High End Servers at 10 centres namely, RMC Delhi, Kolkata, Chennai, Mumbai, MC Chandigarh, Ahmedabad, Nagpur, Bhubaneswar, Bangalore and Hyderabad were commissioned.

Weather Modeling Framework: With the commissioning of HPCs, Global Forecast System (GFS T382/L64) having spatial resolution of 35 km was made operational at IMD, incorporating Grid Point Statistical Interpolation (GSI) scheme forglobal data assimilation for the generation of global scale forecasts up to 7 days in advance. At NCMRWF, continuous efforts are on to enhance the accuracy and reliability of the forecasts by increasing resolution, improving physical processes, data assimilation, optimizing use of satellite and DWR data , coupling land, ocean and atmosphere, ensemble forecasting along with extensive verification and validation. The horizontal resolution of the Global Forecast System (GFS) was increased from T254L64 (50km) to T382L64 (~35km) along with assimilation of direct satellite radiances which was subsequently made operational at IMD. Experimental runs with higher resolution (T574L64(22km) GFS and unified model (N512L70(25Km) with 4D VAR assimilation) models are underway. It is planned to make the high resolution system operational after extensive evaluation and verification studies.

Meso-scale forecast system WRF (ARW) with 3DVAR data assimilation is being operated daily twice, at 27 km, 9 km and 3 km horizontal resolutions for the forecast up to 3 days in advance using initial and boundary conditions from the GFS T382/L64 system. At regional centres as mentioned above, very-high-resolution mesoscale models (WRF at 3 km resolution) are made operational to generate high resolution regional scale forecasts. Typical customization of NWP-based forecast

products is carried out in support improving cyclone warning service. Doppler weather and mesoscale WRF-model-based Nowcast system was exclusively for the national Capital of Delhi to generate site specific hourly scale weather forecasts. Global model assimilation utilizing 4D VAR is being done on experimental basis for WRF model for generating regional scale data assimilation.

In an effort o take care of the uncertainties in the initial conditions, model dynamics and model physics, Multi Model Ensemble (MME) forecasting project for providing rainfall forecasts during the monsoon season has been developed. Rainfall forecast data from 4 global models of India and outside India, i.e. NCMRWF, NCEP,USA, UKMO,UK and JMA, Japan for the summer monsoon period were used to train the MME algorithm coefficients. MME forecasts of rainfall in short and medium range were made available for operational real time use for the Indian region. District Level Quantitative five-days weather forecasts based on MME system are being generated in support of rendering district scale Agro-Meteorological Advisory Service (AAS) of India during the current five year plan.

Polar WRF is implemented to provide day-to-day short range (48 hours) weather forecast for the Maitri region in the Antarctica. All these NWP products are routinely made available on the IMD web site (www.imd.gov.in) in support of Antarctic Expedition. NCMRWF was regularly providing NWP guidance from its global and regional analysis and forecast products in support of first ever South Pole Expedition.

A new state-of-the-art Climate Forecast System (CFS) based on coupled ocean-land-atmosphere model, was setup at IITM and numerous sensitivity experiments were carried out to test the model skill in predicting the Indian Summer monsoon rainfall on seasonal time Further, the model horizontal resolution is increased from T62 (~ 200km) to T126 (~ 110 km) that resulted in better reproduction of spatial distribution of monsoon rainfall over India. This effort led to the utilization of coupled model framework to provide experimental forecast assessment of the Indian Summer monsoon seasonal mean rainfall and its distribution since March 2010. Similarly, prediction of active/break spells of the Indian summer monsoon is implemented in IMD through collaboration with IITM.

The Numerical Weather Prediction (NWP) products from mesoscale model WRF were supplied to BARC at 9km resolution for the four nuclear sites namely Trombay, Kalpakkam, Kaiga and Narora for their Indian Real time Online Decision Support System for Offsite Nuclear Emergency (IRODOS).

2.1.3 Weather and Climate Services:

The introduction of NWP in operational forecasting has been a major shift in practice, which has enhanced forecast capabilities across different time scales ranging from a few hours to a month. Extensive use of web-based dissemination has evoked tremendous public response and has proved to be very effective. Priority has been given to supply the required information to the targeted user and to streamline connectivity with disaster management authorities.

General Forecasting Services: Due to its unique geo-climatic conditions the Indian subcontinent experiences a variety of weather systems with two monsoons and cyclone seasons. It is also exposed to a number of natural hazards like floods, droughts, heat waves, cold waves, thunderstorms, cloud burst, landslides,

avalanches, cyclones etc. The challenges lie in improving forecast skill in face of such extreme variability so as to prevent/minimize loss of life and damages to property. The number of user agencies and diversified demands from various sectors of economy on rendering weather based services are continuously increasing. Besides the traditional users, such as disaster managers; air traffic services and maritime transportation operators, other sectors like energy, agriculture, environment, tourism or leisure sports, require reliable and most representative information on current and future weather. In addition, the forecasters have to cope with ever increasing data volume, notably emanating from NWP models; meteorological satellites and radars, etc. They have also to process them faster while supplying more customized information in a quantitative manner.

IMD is carrying out 24x7 weather surveillance and employing dedicated telecom systems in a fail-safe mode for issuing warnings of hazardous weather. Specialized Meteorological information to various sectors is also being issued. Weather capsules for Doordarshan and other TV channels are being prepared and disseminated as per the adapted operational procedures and protocols.

Agro-Meteorological Advisory Services (AAS): Based on the weekly forecast of weather comprising maximum and minimum temperature, rainfall, cloud cover and surface humidity, advisories for farmers have been developed in association with State Agricultural Universities and ICARs Krishi Vignan Kendras (KVKs). These services are available in 539 districts of the country currently. Through this service, farmers receive crop-specific advisories with regard to the time of sowing of weather-sensitive high yield variety of seeds, need-based application of fertilizer, pesticides, insecticides, efficient irrigation and harvest. The services are made available through web, radio, TV, newspaper, and mobile. Currently over 25.0 lakhs farmers have subscribed for receiving this information through mobile in vernacular languages.

Aviation services: The needs of aviation services are catered through a network of four Meteorological Watch Offices (MWO) functioning at the four major international airports at Chennai, Kolkata, Mumbai and New Delhi, 18 Aerodrome Meteorological Offices (AMO) (inclusive of the four MWOs) and 51 Aeronautical Meteorological Stations (AMS). The responsibility of the four MWOs is to maintain a continuous watch of meteorological conditions over their respective Flight Information Regions (FIR) and prepare SIGMETs (Significant Meteorological Charts) for hazardous en-route weather phenomena, such as, thunderstorms, tropical cyclones, turbulence, volcanic ash, etc., which may affect the safety of aircraft operations. AMOs maintains watch over their aerodromes; prepare forecasts, warnings, current weather observations and other relevant information for flights operating from their aerodromes and their associated aeronautical meteorological stations. AMSs mainly supply current weather observations. Their forecasting needs are met by the associated AMO. Monitoring system of the weather and visibility conditions within the airport area (especially visibility over runways) has been taken up through the commissioning of state-of-the-art Automatic Weather Observation Systems (AWOSs) with a continuous monitoring of Runway Visibility Range (RVR). The real time RVR conditions, measured at Delhi airport, are uploaded to the IMDs web portal in Delhi during the winter months along with the crucial fog forecast products. The accuracy of fog forecasting was 94% and 86% for December and January months during 2009-10, respectively. A frame work of dynamical-statistical models for forecasting the changing visibility conditions for the airports of north India has been firmed up.

Hydrological service: Based on real time daily rainfall data, weekly district-wise, sub-division wise and state wise/season wise rainfall distribution summaries are prepared in the form of rainfall tables and maps. District-wise and subdivision-wise rainfall statistics provide important information useful to the agricultural scientists, planners and decision makers. The inputs on rainfall to the Central Water Commission (CWC) through ten Flood Meteorological Offices (FMOs) established in different parts of India for operation Flood Forecasting. Flood, QPF (Quantitative Precipitation Forecast) were issued by FMOs and supplied to the Central Water Commission for flood forecasting purposes. A MOS technique is being developed for QPF in a pilot mode on the Mahanadi basin. Design storm studies were conducted to evaluate intense storm estimates (rainfall magnitude and time distribution) for various river catchments/ projects in the country, for use as main input for design engineers in finalising design flood for hydraulic structures, irrigation projects, dams, etc. on various rivers.

Environmental Service: The network for Air Pollution Monitoring stations have been set up at Allahabad, Jodhpur, Kodaikanal, Minicoy, Mohanbari, Nagpur, Port Blair, Pune, Srinagar and Visakhapatnam to collect rain samples for chemical analyses and measurement of atmospheric turbidity with the objective of documenting the long-term changes in composition of trace gases of the atmosphere. These observations provide reliable long-term observations of the chemical composition of the atmosphere and related parameters in order to improve understanding of atmospheric chemistry. Specific services pertaining to environment are rendered to the Ministry of Environment and Forests and other Government agencies in the assessment of likely air pollution impacts arising from thermal power generation, industries and mining activities. Atmospheric diffusion models developed for carrying out air quality impacts of multiple sources located in different climatic and geographical conditions are being utilized for setting up of industries, environmental impact assessment and adoption of air pollution control strategies.

Metropolitan Weather and Air Quality Forecast System: Site-specific weather and air-quality forecast system, was put in place in a record time with indigenous capability for the National Capital Region during CWG 2010. 35 Automatic weather stations (11 of which were equipped with air quality measurements) were installed in the NCR of Delhi including those at the Games venues. Hourly updates to different air quality and weather parameters at the venues and other locations were provided to the organizers. A set of NWP models from global to very high-resolution sub-regional models was used for the forecasts. An uniquely designed nowcast system were made operational for the first time in India for providing the site specific forecasts for next three hours. Considering the success of the project, the facility would be extended to other Metro cities of India.

Sports including Adventure Sports: Customized forecast for mountaineering expeditions were issued with constant interaction with expedition teams and coordination with their headquarters. The forecast bulletin for mountain expeditions for Mt. Dhaulagiri to the Army Adventure Wing and for Mt. Everest to the Nehru Institute of Mountaineering was issued. Meteograms for the Mount Satopanth, the Mount Stok Kangri, the Mount Chaukhamba and the Mount Shivling as requested by the Army Adventure Wing were provided.

Data Services: Observational data of past and present are provided to researchers, Government agencies and private parties on demand in accordance with a stated policy. Real-time data, which is of vital importance to aviation and transport sector,

is made available through dedicated channels and web-based systems. The data is also shared freely with the international weather services through WMO. During this plan period the electronic dissemination modes have been utilized more predominantly with experiments being done with utilizing mobile SMS services.

2.2 Disaster Early Warning Support

2.2.1 Tsunami Warning System:

A state-of the-art tsunami warning system was set up in October 2007 as outlined in the Prime Minister's twenty-six thrust areas. The system comprises a network of seismic stations including international stations to compute earthquake parameters, simulated scenarios of travel time and run-up heights at 1800 coastal locations in the Indian Ocean, observing platforms for sea level variations, both in deep sea and coast, robust communication and dissemination system, data centre and decision support system. In last three years, many earthquakes larger than 7- magnitude, which can cause tsunami, did occur. In all such cases necessary advisories were provided to all concerned within 10 minutes of the occurrence of earthquake. This system is recognized as the Regional Tsunami Service Provider (RTSP) for the Indian Ocean region that provides services to the countries in the Indian Ocean.

2.2.2 Earthquake Monitoring, Prediction and Mitigation:

Earthquake Monitoring: A real-time seismic monitoring network consisting of seventeen broad-band stations for monitoring of earthquakes is set up to estimate earthquake parameters within shortest possible time. Significant earthquakes are being auto-located and first information is sent within 15 minutes using both Indian and global seismic stations configured in the network. A 20-station VSAT-based seismic telemetry network is established for real time monitoring and reporting of seismic activity in the northeastern region of India. Facilities have also been created for scanning, vector digitization and systematic archival of seismic analog charts of historical importance in electronic form.

Earthquake Pre-cursor Studies: During the last two decades, India has been affected by moderate to large magnitude earthquakes not only in the Himalayan region, but also in the Peninsular Shield region. National Program on Earthquake Precursors (NPEP) was launched to adopt an integrated approach of generation, assimilation and analyses of a variety of earthquake precursory phenomena in critical seismotectonic environments in the country in a comprehensive manner. As part of this, a suite of Multi-Parametric Geophysical Observatories (MPGOs) have been set up at Ghuttu, Shillong and Koyna to monitor various earthquake precursory phenomenon such as, seismicity patterns, crustal deformations, gravity anomalies, electrical resistivity changes, electromagnetic perturbations, water level changes, geo-hydrochemical changes, Radon and Helium anomalies and thermal anomalies, etc. Preliminary analyses of these data sets have provided useful leads on the ongoing tectonic processes in the Koyna-Warna region, which has helped in issuing short-term forecasts of earthquakes in this region. In Ghuttu, various geophysical data series are being analysed for probable identification of precursory signals.

Micro-zonation studies: Microzonation is a multi-disciplinary and multi-institutional effort, which has direct application in disaster mitigation and management, urban development, planning, design and construction, and risk assessment to existing

life and property, defence installations, heavy industry and public utilities and services, etc. During the last few years' efforts have been made to take up microzonation studies for Delhi, Guwahati, Sikkim and Bangalore. The microzonation of Guwahati, Sikkim and Bangalore on 1:25000 scale, and Delhi on 1:50,000 scale has been completed.

2.2.3 Cyclone Prediction:

The low pressure areas depressions and cyclones are routinely monitored using satellite, DWR and AWS data in real time. There has been significant improvement in the forecasting of cyclones track, movement and intensity during the past four years which has been achieved primarily due to implementation of high-resolution models and augmentation of capability to acquire and analyze all available atmospheric and ocean data. The average operational forecast error for 24 hours track forecast is about 140 km and landfall is 80 km. However, continuous efforts are underway to improve the forecasts further. This can be achieved through improved scientific understanding, enhanced observation network, generation of in-situ observations from the cyclone core and environment along with improved modeling techniques through collaborative research

2.2.4 Storm Surge:

The destruction due to storm surge flooding is a serious concern along the coastal regions of the countries around the North Indian Ocean. Thus, provision of precise prediction and warning of storm surges is of great interest in the region. IMD uses the Nomograms and IIT-Delhi model for location specific storm surge prediction. The model predicts surges with reasonable accuracy. IMD needs to improve both storm surge model as well as meso-scale NWP model to further enhance storm surge forecasting capability in the region. Present technique predicting only residual storm surge requires improvement in order to forecast total water level envelope (TWLE) occurring as a result of the combined effect of the interaction of storm surge with tides, wind waves, and several other factors.

2.2.5 Forecast Demonstration Project:

The Forecast Demonstration Projects seek to enhance scientific understanding in key areas through special observational campaigns coupled with intense modeling efforts so that new/ improved operational forecasting techniques can be evolved. Three areas considered are cyclonic storms, fog and thunderstorms because they are the major sources of damaging hazard potentials. The FDPs are benefited from the recent Modernization drive that raised the basic observational level to a suitable standard.

There has been an improvement in initial values and position of the tropical cyclone utilizing 3-DVAR data assimilation system of conventional and non-conventional data sets over data sparse oceanic region. The vortex re-location and initialization including simulation of track and intensity of tropical cyclones have been generated through multi-scale model super ensemble forecasting system.

2.2.6 Vulnerability Maps:

The work on research areas such as: (i) Multi-hazard Vulnerability (iii) Real-time tsunami inundation modeling as well as (iii) 3-D GIS have been initiated. The broad

scientific methodologies have been established. A pilot project on 3 D GIS was undertaken for the coastal stretch between Cuddalore and Nagapattinam. Tsunami hazard maps using tsunami propagation models and CARTOSAT derived coastal topography have been prepared for the coast of Tamil Nadu, Orissa and Andhra Pradesh on 1:25000 scale. Preparation of similar maps for the coasts of the Andaman & Nicobar, Kerala and West Bengal are in progress and shall be completed by 2012. Preparation of 1:5000 scale tsunami hazard maps for the coast of Orissa using ALTM data has been initiated and will be completed by the end of 11th plan.

The CVI maps at 1:100000 scale for the entire coastline of India including Andaman & Nicobar and Lakshadweep Islands have been completed.

2.6 Climate Change Science

A dedicated Centre for Climate Change Research (CCCR) to address various scientific issues including impacts on sectors like health, agriculture and water has been set up in IITM, Pune along with necessary manpower, computing, physical infrastructure under the global and regional climate change programme. Major efforts of the climate change research include

(i) Two sets of 100-year simulation of the CFS model in a coupled ocean-atmosphere model having 2°and 1° grid scale have been produced. These simulations are being used to test CFS model suitability to predict variability of the Indian Summer Monsoon.

(ii) Annual Seasonal Monsoon Simulation Experiment has been launched in a Hind-cast mode over a period of 29-Years starting CFS Model with 1st May data fields to run up to 31st October for successive years during 1981-2009.

(iii) Forecast Mode Experimental Runs are being carried out starting with the 1st day data fields of successive 8-month period (March – October, 2010). The coupled-model output of monsoon rainfall with that of the long-range forecast (LRF) statistical models are being compared.

(iv) A focused and well-defined roadmap for contributing to the Assessment Report-5 (AR5) of the Intergovernmental Panel on Climate Change (IPCC) is chalked out.

Hadley Centre Coupled Ocean-Atmospheric Climate Model version 3 (Had CM3) is being examined to select potential ensemble member fields, among the 17, which have most closely reproduced the observed summer monsoon climate variables. Six among the 17-ensemble runs of QUMP experiment are found to be reproducing mean summer monsoon climate reasonably well and these fields are used to drive the Regional Climate Model (RCM) – PRECIS to generate 50Km grid scale under A1B Scenario (Medium Emissions) runs over South Asia continuously for the period 1961-2100.

Under the aegis of the Indian Network of Climate Change Assessment (INCCA), a Report, entitled Climate Change & India: A 4X4 Assessment – A Sectoral and Regional Assessment of Impact of Climate Change in 2030s, has been released by the Government during November, 2010. Studies were undertaken in four climate sensitive regions of the country, viz. Himalayan Region, Western Ghats, North Eastern Region, Coastal Areas, assessed impacts in the four sectors viz. agriculture, water, forests and health, have been analysed using RCM fields generated in India.

2.3.1 Monsoon Variability:

Extended Range Predictability of Monsoon Intra-seasonal Variability (Active/ Break Monsoon Spells) is being investigated. It is found that the potential predictability of both active and break spells have undergone a rapid increase during the recent three decades. Role of stratiform rainfall in modifying the northward propagation of monsoon intra-seasonal oscillation is studied. An analysis of daily rainfall over India during 1951-2007 reveals an increased duration and frequency of monsoon breaks over the subcontinent. While noting that the increasing trend of break monsoon condition is consistently related to changes in large sale monsoon circulation and vertically integrated moisture transport, the findings point to the role of sea surface temperature (SST) warming trend (0.015°C per year) in the tropical eastern Indian Ocean in inducing anomalous changes favorable for the increased propensity of monsoon breaks.

Understanding the links between the variation of the Indian monsoon and the variation of the atmospheric convection over the equatorial Indian Ocean with the analysis of the observations is crucial for the evolving circulation changes. In the first three weeks of June 2009, there were no northward propagations across the Bay. Also, no low pressure systems were generated over the head Bay and naturally, the westward propagation of such systems across the Indian monsoon zone, which is characteristic of the onset phase of the monsoon, did not occur. Consequently, there was a massive deficit of (48%) in the all India rainfall in June 2009. The El Nino induced Indian Ocean winter warming is significant in the following winter and spring and persists for the summer as well.

The basin scale deep warming in the west is associated with the local IOD forcing rather than the remote El Nino forcing. Indian Ocean warming induced anomalous climatic effects in Asia, Africa and NW Pacific.

2.3.2 Solar Dimming:

In contrast to most of the world where solar dimming has changed over to solar brightening since late eighties, dimming continues unabated over the Indian region. From 1981–2006, the rate of dimming is found to be twice as large during cloudy conditions (~12 W/m^2/decade) compared to that during clear sky conditions (~6 W/m^2/decade). The clear sky dimming cannot be fully attributed to increasing aerosol density and concentration changes.

2.3.3 Increase in Air Temperature:

The near-term future (i.e., end of 21st century) would witness substantial increases in both day and night temperatures and increase in frequency and intensity of extremes. Temperature changes are likely to trigger abrupt responses in agricultural productivity and human mortality. Also there is a potential for a modest increase in seasonal mean monsoon rainfall with possible increase in frequency and intensity of extreme rain events.

2.3.4 Climate Services and Climate data Centre:

The climate products that include real-time climate monitoring and publication of Climate Diagnostics Bulletins for the Indian region and reporting of major anomalous

climate events were generated and supplied to researchers. Detailed special monsoon reports, High resolution daily gridded rainfall data (1°x1°) & (0.5°x0.5°), high-resolution daily-gridded temperature data (1°x1°), high-resolution gridded terrestrial climate of India, and climatological summaries for districts and states are produced.

2.3.5 Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX): An instrumented air-craft was chartered during monsoon period to conduct CAIPEEX during 2009-11. This national experiment is being carried out in three phases. Phase I and Phase II of the CAIPEEX have been conducted successfully in the monsoon season of 2009 and 2010, respectively. Phase III will be conducted in the monsoon season of 2011. All the national institutions and universities working in the area of aerosol observations, cloud physics and cloud-modeling participated in this experiment. First time an exhaustive data of cloud microphysics and vertical profiles of aerosol have been collected. The data have been quality controlled and made available to the Indian Scientific community within one month of completion of the experiment. The experiment opened a new era in the observational field of the atmospheric sciences in India.

2.3.6 Advanced Training School: Towards human resource development in the field of earth system science, a state of-the-art Advanced Training School was established at Pune in 2010. The first batch of 20-trainees were inducted, and the course was launched on August 8, 2011.

2.7 Ocean Survey, Resources and Technology

2.4.1 Delineation of the outer limits of the Extended Continental Shelf:

Under the UN Convention on the Law of the Sea, every coastal Nation has sovereign rights to a continental shelf up to 200 nautical miles from its coastal baselines, (or out to a maritime boundary with an adjacent or opposite coastal State). This limit has now been extended up to 350 nautical miles, if certain criteria are met. A major multi-institutional national programme of collecting, processing, analyzing and documenting the requisite scientific and technical information for delineating the outer limits of the continental shelf in the Arabian Sea and the Bay of Bengal including the western offshore areas of the Andaman-Nicobar Islands has been completed.

The first partial submission for an extended continental shelf (~ 0.6 million sq km) under the provision of article 76 was made to the UN Commission on the Limits of the Continental Shelf on the 11th May 2009. On the 16 August 2010, a six-member delegation led by Secretary, MoES made a formal presentation of India's submission before the Commission on the Limits of the Continental Shelf at the UN Headquarters, New York. A second partial submission for another part of the extended shelf (~ 0.6 million sq km), under the provisions of the Statement of Understanding, has also been finalized and provided to the MEA for filing before the CLCS.

A National Marine Geophysical Data Centre has been established with state-of-the-art archival and retrieval facilities of the geoscientific data in a structured database. This datacenter won the 2010 Computer Society of India-Nihilent e-Governance Award under Project - G2G Category.

2.4.2 Comprehensive Swath Bathymetric Survey of EEZ:

Swath bathymetric mapping of the entire EEZ has been undertaken. ~5,73,000 sq km (~30%) of the deep-water regions of the EEZ beyond 500 m water depth has been completed. Some of the significant observations include the presence of channel-levée systems between Ninety Degree East Ridge and the Andaman Trench, two Seamounts off Lakshadweep and pockmarks on the seabed off-Goa. About 14,300 sq.km, off Goa, Bombay High, Karnataka and Cuddore have been completed.

2.4.3 Polymetallic Nodules Programme:

India has exploration contract with the International Seabed Authority in 75,000 sq.km area in the Central Indian Ocean. A total area of 7900sq. km was identified for potential mine site based on detailed chemical analysis, interpretation of the collected samples into the Central Indian Ocean. A 3-Dimensional hydrodynamic sediment plume model was developed as a part of Environmental Impact Assessment Studies. An integrated mining system consisting of crawler, collector and crusher and a Remotely Operable Artificial nodule laying system were developed and tested at 512 m water depth. The research carried out in the field of extractive metallurgy include, viz. optimization of direct smelting on 4 kg scale, optimization of reduction roasting with the Talcher coal as redundant, preparation of Electrolytic Manganese Dioxide (EMD) from manganese cake, Ammonia Recovery from Ammonium Sulphate by electrochemical splitting, High Pressure Acid Leaching of Manganese Nodule, etc. India has been elected as Member of Council in investor's category of the International Seabed Authority (ISA) for a period of 5 years beginning 2009.

2.4.4 Seabed Minerals:

Under Cobalt crust programme, multibeam map has been generated for the Afanasiy-Nikitin Seamounts in equatorial Indian Ocean covering an area of around 40000 sq. km for the potential Cobalt-crust resource. Reconnaissance sampling has yielded few crust samples which indicate Co-enriched crust occurrence in the northern and southern plateau region. This region is at ~3200 m water depth and covers area of ~20000 sq. km. The initial reconnaissance sampling has yielded a few crust samples containing cobalt up to 0.5 % and the average cobalt in northern region of the area surveyed is 0.65%.

Acquisition, analysis and interpretation of high-resolution geophysical data, deep CTD observations, water column, deep-tow, TV-grab and seabed sampling and the results suggest a possible source of hydrothermal vent in the vicinity due to the presence of a large plume in an area over the slow spreading Carlsberg Ridge (CR). The mapping of the rift valley and seabed sampling has been carried out.

2.4.5 Gas Hydrates exploration:

Gas hydrates with their abundant resource potential is emerging as a potential fuel resource. The preliminary assessment of geological condition and limited available seismic data suggests high possibility of occurrence of large quantity of gas hydrates within the EEZ of India. The multi-channel seismic data collected by various organisations has been evaluated and based on the data, two promising sites of 100 km x 100 km were identified and surveyed in detail in the Krishna-Godavari (KG)

and the Mahanadi basins. A total of 6660 line km of coarse grid data (with line spacing of 8 to 12 km) and 1067 km of fine grid seismic reflection data (with line spacing of 500 m) was acquired. In addition, 48 deployments of the Ocean Bottom seismometer were carried out with acquisition of 1055 line km of seismic refraction data. The seismic data is expected to provide the sediment profiles revealing signatures of gas hydrates. A remotely operated Autonomous Coring System (ACS) has been developed, equipped with tool handling system and cam gate assembly to drill each section of about 3 m [approximately 100m sediment core], retrieve the sample, and store in magazine at the seabed in deep sea operation [3000 m]. An exploratory tool (ROV) with necessary sensor is developed and an exploration trial at gas hydrate site is completed. Further, acquisition of high resolution sparker data has been carried out in the KG Basin.

2.4.6 Integrated Ocean Drilling Programme (IODP):

A National Committee of Experts has been constituted under the chairmanship of Director, NCAOR, with distinguished scientists from various national institutions and organizations, as members to guide this activity. A Science Plan addressing the scientific issues pertaining to the seas around India which calls for deep-ocean drilling was developed.

Under the MoU with IODP, a total of five scientists from some of the leading geoscientific institutions in the country participated in the following IODP activities during 2009-10:

- IODP Pacific Equatorial Age Transect Expedition 321
- JOIDES Bering Sea 323
- CHIKYU Nankai Trough Japan 322
- MSP (Europe) GBR 325
- JOIDES Wilkes Land 318

Action has also been initiated to nominate three more scientists to participate in the forthcoming IODP drilling activities during 2011-12.

2.4.7 Launch of a Technology Demonstration Vessel- Sagar Nidhi:

This is an ice-class vessel of 5050 tones, equipped for launching and testing various marine equipments including ROV, AUV and manned Submersible. This multi-purpose vessel was acquired in December 2007. The vessel is equipped with the state-of-the art facility, to shallow water survey, and acts as a supply and support platform for the various coastal and deep ocean activities. This vessel is capable of conducting multi-disciplinary studies in the sea continuously for 45 days with 30 scientists onboard.

2.4.8 Deep-sea Technology Development:

India has been working to harness ocean mineral resources. In view of this, collaboration with the Russian scientists have developed and tested an instrument to measure sea bed soil properties in-situ, at a depth of 5200 m. The deep water trials of ROSUB (remotely operable vehicle) were conducted successfully at a depth of 5289 m in April 2010. The complete hardware and software for the instrumentation and control system were developed by the Indian scientists.

2.4.9 Low Temperature Thermal Desalination (LTTD):

The LTTD technology was also demonstrated using waste heat from the North Chennai Power Plant and produced fresh water. The capacity of the plant is 1 lakh liter per day (lpd). A LTTD barge-mounted plant of 1 million litre per day was successfully demonstrated off Chennai (Tamilnadu) in April, 2007. The Kavaratti plant has been working since May 2005. Besides, 2 more desalination plants of 1 lakh liter capactity, one each at Minicoy and Agatti of the Lakshadweep Islands, have been set up. Currently, Public-Private Partnerships are being explored for further development of the technology for up-scaling to capacities of the order of 10 million lpd offshore plant.

2.4.10 Development of integrated deep sea mining system:

Design and development of Underwater Mining System with Manganese Nodule Collector and Crushing Systems completed. Testing and qualification of underwater mining system with collector and crushing systems was done in Angria Bank (off coast of Malvan) at 512 m depth after laying artificial nodules during September–October 2010. A remotely operable in-situ soil testing equipment was developed and tested successfully at 5200m water depth. Realization, installation and commissioning of Hyperbaric Test Facility (simulating 9000 m of Ocean Depth) and Testing of Deep-sea Equipment and Components, and Hydrotransport Test Facility, Underwater Vehicle Test Pond and other Facilities like Winch Test Facility, Hydraulic Valve Test Facility have been developed. Indigenization development of 10 new products and devices for Deep-sea Mining like Subsea Motors, Transformers, Thrusters, Load Cells, Depth Sensors, etc. have been completed.

2.4.11 Marine sensors, electronics & ocean acoustics:

Electronic support facilities such as Helium leak detector, EMI/EMC analyser, Shock and Vibration analyser, Environmental chamber, and corrosion test facility have been established. Non-off-the-shelf underwater components like 250 kW motor, fibre optic connector have been developed in association with Indian industry. Wide band 3-90kHz light weight transducer technology, a wide band 2-16, 2kW single element transmitter suitable for sub-bottom profiling and long range under water communications, and CYMBAL transducer elements and arrays have been developed. Designed and developed a broadband transceiver for new generation P17 platforms and transferred the technology to BEL. An automated ambient noise measurement system for time series measurements has been developed and deployed in three locations. . Acoustic Test Facility (ATF) has been upgraded for increasing the frequency range from 100 kHz to 300 kHz. Tsunami surface buoy and an bottom pressure recorder have been developed and tested at more than 800 m water depth. An Autonomous Underwater Profiling Drifter (AUPD) has been indigenously developed and demonstrated. Patents have been filed based on the above developments.

2.4.12 Technical Criteria Atlas:

The program of Technical Criteria Atlas was formulated with an aim of characterizing the shoreline using observations at select locations and modeling with numerical simulation. Study of the component (Tide, wave and currents) was to produce a database/atlas of engineering parameters like extreme value statistics with different return periods.

The development of High-resolution coastal wave model is in final stages with validation carried out with field observation at two locations. Validation at more locations are in progress. Preparatory work completed for tide model with secondary data. Model setup completed using ADCIRC package for west coast. Routines for data handling, QC and validation for data of High Frequency Radar for coastal surface current completed

2.4.13 Offshore structures

Rising oil prices, increased environmental awareness and energy security issues are driving the rapid development of renewable energy technologies and dependence on offshore resources. There is increasing need of floating plants, design of the platform, riser pipe and its attachment from the point of dynamic interaction among them due to the action of waves, currents and wind. Optimization of structural design for wave forces to withstand high wave-loads is carried out. Also the design of sumps for drawing warm water and cold deep sea water for small islands is optimized. A suction pump capable of 2 bar suction (differential) has been developed and validation of various individual components is completed.

Accordingly, the analysis, design, model studies and testing of fixed and floating offshore platforms, moorings, anchors such as SUCTION PILE ANCHORS, material studies for cold water pipes and interface design and testing of riser connections to floating bodies and identification of suitable configuration for the fixed and floating offshore platforms for supporting wind turbines are being carried out.

2.4.14 Ocean Energy

A Backward Bent Ducted Buoy with power module and instrumentation has been designed, developed and successfully tested in the sea for three weeks.

2.8 Polar Science

2.5.1 Antarctic Expeditions:

Four Indian Scientific expeditions to Antarctica (27 to 30) were successfully undertaken during 2007-11, while the next (31st) expedition is planned to be launched during October–November 2011. In the course-of the winter and summer seasons of 2007-11, scientific data collection pertaining to projects in the disciplines of earth science, glaciology, atmospheric sciences, biology, environmental sciences, engineering and communication, besides the logistic tasks critical to the expeditions were accomplished.

Some of the highlights of the work carried out in Antarctica are as follows:

- A digital Ionosonde System with two cross Delta antennas were installed at the Maitri station to study short and long-term variation of Ionosphere and magnetospheric-ionospheric coupling between high and low latitudes during space weather events.
- A magnetic observatory was operated at the Maitri station for monitoring variation in the Earth's magnetic field. Monitoring the variation in the Earth's magnetic field was taken up to understand storm–substorm relationship, the global signature in the atmospheric electrical parameters, the decline in total

magnetic field 'F' observed in the southern hemisphere, especially over Antarctica continent; and the ionospheric TEC, scintillation and tropospheric water vapor content.

- Geological mapping between 2^0 to 3^0 east longitudes in Gjelsvikfjella was carried out utilising the Norwegian station Troll (S. Lat. 72^0 0' 7" & E. Long. 2^0 32' 2") as a base. Two maps "Geological map of Orwin Range, cDML, East Antarctica" and "Geomorohological map of Schirmacher Oasis, East Antarctica" were published.
- Microbiological studies carried out on fresh snow deposits in the coastal Antarctica reveal the crucial role of bacteria in the air-snow biogeochemical cycling in this region. Glaciochemical and microbiological study of snow from the coastal Larsemann Hills, East Antarctica reveal that elevated nutrient concentrations in ice cap snow are responsible for the observed high bromide concentration in snow related to the enhanced growth of microalgae in snow and subsequent production of bromo-carbons. Twelve new species of bacteria were reported from the Polar region during 2008-2011. Two genes namely t-RNA modification GTPase and aspratate aminotransferase were identified as the genes required for survival of bacteria at low temperature. A number of lipases and proteases active at low temperatures and useful for the biotechnology industry were also identified.
- Delineation of the Land-Ice-Sea (LIS) interface (Hinge-line) around the Schirmacher Oasis, central Dronning Maud Land (cDML) was carried out.
- A major multidisciplinary study to understand the late Quaternary climatic conditions of the East Antarctica was initiated utilising sedimentological, palynological, and geochemical proxy indicators in the lake sediments of the Schirmacher Oasis. Satellite-based DEM for the Larsemann Hills has been generated for mass balance studies.

2.5.2 South Pole Scientific Expedition:

For the first time, India launched a scientific expedition to the South Pole on 13th November 2010 from Maitri. The 8-member team collected valuable atmospheric aerosol data and several short ice cores in the course of its transect from the Schiramcher Oasis to the South Pole The team reached the South Pole on 22nd November, 2010. and on completion of all the scientific tasks, returned to 'Maitri' on 1st December 2010.

2.5.3 Arctic Expedition:

India embarked upon the Arctic research by launching First Indian scientific expedition to Arctic **-** in the first week of August 2007 using the international research facility at Ny-Alesund in the Spitsbergen Island of Norway. Subsequently India has been sending scientific teams every summer and winter for carrying out studies in the Arctic, primarily in the fields of glaciology, hydrochemistry, microbiology, and atmospheric sciences. A station building "HIMADRI" with accommodation and work space for a total of 8 scientists, was formally inaugurated on the 1st July 2008. A web-based portal showcasing the various scientific activities of India in the Arctic has been developed. An MoU was signed between NCAOR and NPI for collaborative scientific endeavors in the fields of glaciology, microbiology, geology and atmospheric sciences. India was unanimously elected as a member of the Ny-Ålesund Science Managers Committee (NySMAC).It has also been invited as an Observer in the International Arctic Science Committee.

2.5.4 Southern Ocean Studies:

Five multidisciplinary cruises in the Southern Ocean for a better understanding of the oceanographic processes were undertaken.

The focus areas of study during these expeditions were Oceanography and Hydrography (during the 2009 Expedition), biogeochemistry and paleo-climatology (2010) and plankton dynamics (2011). Some of the salient results of the studies carried out during these expeditions are as below:

- An anomalous warming trend observed in the Subtropical Front in 2011.
- Spatial and temporal variations in the northern and southern branches of the Polar Front
- Observed variations in chlorophyll distribution on account of different types of food web operating at different levels within the PF
- High grazing pressure by copepods and salps on phytoplankton community responsible for lowered chlorophyll a conc.
- Nutrients especially nitrate and silicates show increasing trend towards southern latitude.
- Secondary production pattern and diversity show marked difference in different fronts and zones
- Air sea fluxes of sensible and latent heat estimated from the Indian sector of southern ocean for the first time using in-situ observations.
- Strong surface winds blowing over southern latitudes facilitate increased air-sea transfer of fluxes in the study area.

2.5.5 R&D in Polar Regions:

Polar Biological Studies: Study of bacterial diversity and adaptability in snow and ice from the Larsemann Hill and the Schirmacher Oasis, Antarctica have been taken up. About 105 discrete bacterial colonies were isolated and purified. To understand the adaptability to cold environment the isolates were subjected to growth at 40°C. Twenty six isolates from the Schirmacher Oasis and 50 isolates from the Larsemann Hills area showed growth at 40°C. The protein profiling of the isolates were carried out in the range of 14.4 Kda to 97.4 Kda. Based on the similarity of the protein profile 55 isolates were short-listed and were subjected to 16 S rDNA analysis. The isolates were predominated by *Bacillus flexus, B. thuringiensis, B. cereus* and *B. aryabhattai*.

A first report on the isolation of *Cellulosimicrobium cellulans* bacteria in the snow deposits of the Larsemann Hills with physiological traits that were markedly different from that of the mesophilic *C. cellulans* type strain reveal that this genus could be more cosmopolitan than hitherto thought of and is capable of living in extreme cold environments. Carbon utilization studies demonstrated that *C. cellulans* preferred complex carbon substrates over simple ones, suggesting that it could play a potential role in carbon uptake in snow.

Biogeochemical and microbiological study of snow from the coastal Larsemann Hills (East Antarctica) reveal that elevated nutrient concentrations in ice cap snow seems to enhance the growth of microalgae in snow and the subsequent production of bromo-carbons leading to high bromide concentration in snow. The activated Br in the Antarctic atmosphere would react with ozone leading to BrO enhancement with subsequent DMS oxidation and production of sulphur aerosols. Since BrO based DMS oxidation is much faster than OH/NO3 pathway, elevated bromide in the

Antarctica could contribute more towards the formation of cloud condensation nuclei (CCN) at the expense of ozone.

Polar Environmental Studies: Comprehensive Environmental Evaluation (CEE) of the New Indian Research Station at Larsemann Hills, Antarctica was carried out and was presented at the XXX ATCM (2007), New Delhi.

Polar Remote Sensing: An enhanced digital elevation model (DEM) of the Larsemann Hills region, (on the eastern boundary of Antarctica) was generated synergistically by using highly accurate ground-based GPS measurements, satellite-derived laser altimetry (GLAS/ ICESat) and Radarsat Antarctic Mapping Project (RAMP) DEM-based point elevation data. A DEM is essential to model the ice elevation change and address the ice mass balance.

Link between Tropical Indian Ocean Processes, Indian Ocean Dipole (IOD) and Sea-ice was carried out at the Lamont Doherty Earth Observatory, Columbia in Feb to April 2010 under the SCAR Fellowship scheme. Most remarkable correlations were obtained when the ice concentration anomalies lags Dipole mode index (DMI) by 2 years and when the ice concentration anomalies leads the DMI by one year. The reasons for these correlations are being investigated.

2.5.6 Establishment of the Third Indian Antarctic research Base:

A new permanent Indian Base in the Larsemann Hills, Antarctica, was approved at the XXX Antarctic Treaty Consultative Meeting in Delhi, during April 2007. A Comprehensive Impact Assessment study was carried out, employing prediction models, i.e Industrial Source Complex-Short Term (ISCST3) for air quality, Noise Prediction Model (Predictor 7810) for noise environment and CORMIX 6, model for dilution and dispersion study of wastewater discharge into sea. Additional data and important information on station design and initial environmental reference have been incorporated in the final CEE report including discussions on baseline data.

A conceptual design of the station was obtained through Global Expressions of Interest solicited during the year 2006-07 for innovative ideas and a consultant architectural firm was appointed. The pre-construction activities commenced during the austral summer of 2009-10, when the most critical task of putting in place the infrastructure necessary for the construction of the station was achieved successfully. All the heavy earthmoving / construction material and cargo, ranging from 5 to 47 metric tons were transported from ship to shore either by the two helicopters or by vehicles over the fast ice. A 250 m long road from landing site up to the helipad was also carved out. The Phase-I construction activities of the station comprises piling for the foundation for the main station building and erection of garage sump and walls, construction of helipad using pre- cast concrete elements, construction of foundation of fuel farm using pre- cast concrete elements, laying of pipeline for fuel, fresh and waste water, Site survey and foundation piling for the planned Satellite Ground station etc have been completed. The Phase-II construction activities are scheduled to commence during the austral summer of 2011.

2.5.7 Acquisition of Ice-class Research Vessel:

Acquisition of Ice-class Research Vessel with state-of-the art scientific equipments/ instrumentation has been approved at the total allocation of Rs. 490 cr. which is

scheduled to be completed by March 2013. A Consultant has been appointed for developing conceptual design and supervision. A Global Expression of Interest has been floated for selecting the ship yards for construction of the PRV..

2.9 Ocean Science and Services

2.6.1 Ocean Observing System:

A comprehensive ocean observation network program had been launched for the understanding of structure and dynamics of ocean, improving the predictability of ocean and climate, for the sustainable development of coastal ecosystem and for the generation of ocean information and advisory services. The ocean observing systems, currently in operation can be broadly classified as (i) in-situ observation systems that capture the changes in time at specific locations or along the ship tracks, (ii) the satellite-based remote sensing systems that capture the spatial and temporal variations, synoptically, as ramified at the surface and sub-surface. During the period, significant progress has been made in the ocean observing systems, with a mix of in-situ platforms and satellite systems and concomitant capabilities in retrieval of data. Moored data buoys with subsurface sensors up to 500m depth, besides surface sensors, were deployed in Bay of Bengal and continuous measurements have been made. Also data buoys and tsunami buoys are developed indigenously. The details of deployment against planned so far in the plan period are as follows:

Type of Platform	Target for XI Plan	Commissioned till July 2011	Data received during Jan 2011
Argo Float	200	158	78*
Drifters	50	66	22*
Moored Buoys	12	19	17
Expandable Bathy-Thermograph(XBT)/Expandable Current Temperature Depth (XCTD)	1000	1004	895
Tide Gauges	45	25	27
High Frequency(HF) Radars	10	10	10
Current Meter Array	10	7	#
Acoustic Doppler Current Profiler(ADCP)	12	12	#
Tsunami Buoys	12	7	3
Wave Rider Buoy	8	6	6

*The remaining floats/drifters have completed their life time and as such no data can be received from them.
The data is retrieved on yearly basis. No data received during the month.

2.6.2 Ocean Modelling

The capability to run various global and regional models, viz., HyCOM, MOM4, CUPOM, ROMS which has significantly improved ocean forecasting services was established. Indian Ocean Forecasting System (INDOFS), first of its kind in the

country and developed indigenously was made operational in January 2010. The core of the INDOFS is the state-of-art ocean general circulation model (OGCM), Regional Ocean Modeling System (ROMS), developed and distributed as open source code by the Rugters University, New Jersey, USA. The model is customized to simulate the observed Indian Ocean features realistically by making appropriate changes in the model parameters and source code. At present, the model is forced with the 5-day forecast data of surface wind fields and atmospheric fluxes from the atmospheric model of National Centre for Medium Range Forecast (NCMRWF), New Delhi. Accordingly, the INDOFS also forecasts the oceanographic features for 5 days. The INDOFS gives the forecasts on sea surface currents, sea surface temperature, mixed layer depth and the depth of the 20 degree isotherm as an indicator of the depth of thermocline. The forecasts are also being validated on a continual basis. A focused research and development approach will continue to support the INDOFS to meet the requirements of various users.

2.6.3 Ocean Services

i) Potential Fishing Zones (PFZ) Advisories: A unique system of Fishery Advisories based on identification of potential fishing zones (PFZ) using remote sensing technology has been made operational. The PFZ advisories prepared in local languages and local measurement units are disseminated to over 225 nodes, thrice a week through innovative and novel initiatives such as Electronic Display Boards and Information Kiosks at the fishing harbors, radio, print media, emails and web sites supplementing fax and telephone and mobile. 97 electronic display boards were installed in selected coastal areas for the dissemination of information on PFZ and Ocean State Forecast. The electronic display board (EDB) communicates with the server in INCOIS and automatically obtains the necessary information (PFZ advisories and ocean state forecast) relevant to the location where it is installed.

In addition to PFZ maps, in November 2010 INCOIS also operationalised advisories on Tuna species based on satellite derived SST, Chlorophyll, water clarity and model based mixed layer depth.

ii) Ocean State Forecasting: In January 2009, Indian Ocean Forecasting System (INDOFOS) was launched integrating existing forecasts of ocean wave and the surface and subsurface parameters of the Indian Ocean. The system, at present, provides forecast on wave heights, wave direction, sea surface temperature (SST), surface currents, mixed layer depth (MLD) and depth of 20^{o}C isotherm up to 5-7 days in advance. This system is operational since January 2010. The beneficiaries of INDOFOS are: traditional and mechanized fishermen, the maritime boards, Indian Navy, Coast Guard, shipping companies and oil and natural gas industries, energy industries and academia.

Currently, the wave forecasts are provided on a spatial resolution of 25x25 km grids and the other parameters (SST, MLD, etc.) on 1/8°x1/8° grid (ie. ~ 13 km resolution). In addition to providing the forecasts on aforementioned parameters, INCOIS has also set up operational tidal predictions (tidal elevation) at 137 major and minor ports along the Indian region during XI plan. Another useful service, named ‘high wave alert’ started during the XI plan is found to be highly useful for the coastal community

The achievements of PFZ and Ocean State Forecast programmes are highlighted in the recent study of National Centre for Economics and Applied Research revealed that ~90% fishermen in Tamil Nadu and 64% fishermen in the eastern states, Andhra Pradesh and Orissa, are aware of and are utilizing these advisories together with the

ocean state information generated and provided by INCOIS. The study further stated that the total annual net economic benefit due to the scientific identification of PFZs based on satellite information is estimated to lie in the range of Rs. 34,000 to 50,000 crores.

iii) Coral reef maps: Coastal reef maps have been prepared for all coral reef regions. Considering thermal stress as an indicator, coral health bulletins are issued bi-weekly indicating the hot spot composites (early signs of bleaching), and degree of heating weeks (DHWs) as an indicator to intensity of bleaching. Time series of satellite observations also is provided. Currently, this service covers the coral environs of Gulf of Kutch, Gulf of Mannar, Lakshadweep, and Andaman and Nicobar Islands.

Ocean Data Management and Dissemination: All data relating to ocean science are being archived at INCOIS which includes voluminous and heterogeneous data sets from the in-situ and remote sensing ocean observing systems, in real time. This centre has been designated as the National Oceanographic Data Centre (NODC) by the International Oceanographic Data and Information Exchange (IODE) Programme of Intergovernmental Oceanographic Commission (IOC). The Ocean Data and Information System (ODIS) is one such system that provides data and information on physical, chemical and biological parameters of oceans on various spatial and temporal domains. It is an end-to-end ocean data management system, developed by adopting the advances in the field of information and communication technology. Currently, the INCOIS archive contains more than 140000 salinity and temperature profiles. The data sets available includes data from Argo floats, moored buoys, drifting buoys, XBTs, current meters, buoys, tide gauges, bottom pressure recorders, coastal radars, wave rider buoys, autonomous weather stations, etc. The databank holds ~17,00,000 records. The remote sensing data include NOAA AVHRR, MODIS (Terra and Aqua), Oceansat-1, altimeter, TMI, Quikscat, SeaWifs, etc. In addition to the data received in real-time from various ocean observing systems, the data centre also downloads and archives the data from model outputs, reanalysis data sets and the satellite data products for the Indian Ocean region. The satellite data is of the order of ~ 5 TB. The Live Access Server (LAS) installed at INCOIS is widely used by the oceanographic community for data selection, visualization and the generation of on-the-fly graphics.

2.6.4 Ocean Color Research:

The activity of operational generation of the ocean color satellite data products (chlorophyll, SST, Kd-490 and TSM) aligns to the global initiative known as Chlorophyll Global Integration Network (ChloroGIN) project. An automatic data processing chain (ADPC) has been set up to generate ocean color products using MODIS – Aqua data. The data products are being generated at near real-time (NRT) for the following Indian Ocean Region countries: India, Sri Lanka, Iran, Kenya, Maldives, Oman, Tanzania and Thailand and are disseminated via a web-server. As a spin-off, a value added product known as bloom indices (BI) has been also generated with live MODIS – Aqua data.

The SATCORE program has been found to be highly beneficial to the scientific community involved in operational as well as research activities in ocean color. The SATCORE program aims to deliver an in situ data-base of bio-optical properties of in-water constituents like: chlorophyll, CDOM, and TSM in the Indian coastal waters. The information on bio-optical properties will be used in the validation of existing algorithms as well as the development of new algorithms in optically complex coastal

waters and to develop a comprehensive ocean color atlas of the region for baseline purpose. The new or improved algorithms for the retrieval of chlorophyll will also help in improving Potential Fishing Zone (PFZ) advisory services.

2.7 Coastal and Marine Ecology

2.7.1 Assessment of Environment and Productivity Patterns of Indian EEZ

An 'Atlas on Environment and Productivity Patterns of Indian EEZ' was prepared. This atlas provides comprehensive information on the physical, chemical and biological features of the Indian EEZ covering the various seasons of a year. Satellite derived Chlorophyll a data is used in conjunction with in situ data on chl-a, primary productivity, secondary productivity and benthic productivity to generate the fishery potential of the Indian EEZ. The estimated figure of 4.32 million tons of fish is more robust and reliable as the estimates are made separately for each ecosystem in the Indian EEZ and covering the various seasons of a year. Reliable transfer efficiencies ranging from 5 to 32% have been used in the model.

2.7.2 Harmful Algal Blooms (HABs)

Commonly occurring Harmful Algal Blooms in the Indian EEZ are due to species belonging to the genera of *Trichodesmium, Noctiluca, Gymnodinium, Gonyaulax, Cochlodinium* and *Chattonella*. Recurrence of extensive multi-species algal blooms on an annual basis along the Northern sector of the Arabian Sea during late winter monsoon (February) and early fall inter-monsoon (March-April) and their impacts on the biogeochemical cycles and the fishery of this sector are being investigated under the National HAB programme. A number of harmful algal blooms have been reported in various coastal waters of India such as *Noctiluca* bloom off Kochi (30 km area)-(10-18 Sep 08), *Noctiluca* bloom (20 km wide) off Goa. (3-5 Oct 08), bloom of *Gonyaulax sp*. off Manglore (8-10 Oct 08). Efforts are underway to monitor the spatial and temporal variations of blooms using Ocean Colour Monitor sensors available on board both Indian and foreign satellites. *Trichodesmium erythraeum* bloom with straw yellow discolouration of the surface water spread over an area of 25 km^2 was observed off Goa (May 2010) during the spring inter monsoon period. Surface chlorophyll a concentration and cell density of the bloom area was 12 mg m^{-3} and 2.93x106 filaments L-1, respectively. The occurrence of the nutrient depleted Arabian Sea High Saline Water (ASHSW) is expected to be the causative factor for the blooming of *Trichodesmium* species. It is well known that *Trichodesmium* can fix atmospheric nitrogen and hence occurrence of *Trichodesmium* blooms along the southwest coast during spring inter monsoon can be an adaptation to recycle nitrates to the ocean. *Asterionella japonica* bloom was observed off Kochi during summer monsoon period (June, 2010) with cell density 5.5x 106 cells L-1. Greenish surface water discolouration was observed in the bloom area. The depletion of nitrate and increased concentration of phosphate is expected to favour the bloom of this pennate diatom.

2.7.3 Census of Marine Life (CoML)

The Census of Marine Life (CoML), begun in the year 2000, is a scientific worldwide Census campaign to assess and explain the diversity, distribution, and abundance of marine life. India started survey in the Indian Ocean in 2010, to begin the census of life in oceans. The census will be userful for measuring changes of marine life after natural changes and human actions. IndOBIS currently has record of 48,422 species.

2.7.4 Island Development activities

Ornamental fish culture was established in 2009 Kavaratti to commercialize in the Agatti Island of Lakshadweep. Other activities such as live-bait culture, pearl culture, biodiversity studies, etc. of Lakshadweep has been taken up. Black-pearl production in the Andaman Islands has been strengthened by imparting training to local people on nucleus implantation. Development, deployment and testing of open sea cage for open sea cage farming of fin fishes in mainland and A&N Islands has been undertaken. Mass culture of micro-algae in photobioreactor at Kavaratti Islands, Lakshadweep utilizing deep ocean water upwelled by the Low Temperature Thermal Desalination plant for extraction of biochemicals. Has been initiated.

2.7.5 Technology for fattening of Lobsters and mud crabs

A viable technology for fattening lobsters and mud crabs in cages was successfully developed and disseminated to select beneficiaries in the Gulf of Mannar in Tamil Nadu and Andaman Islands. There has been a substantial improvement in earnings of coastal fishermen due to implementation of this scheme. The technology for seaweed culture and lobster fattening and crab fattening have been extended to over 100 women beneficiaries in the Gulf of Mannar and 25 women beneficiaries in the Andaman & Nicobar Islands.

2.7.6 Marine Biotechnology:

The understanding of barotolerant deepsea microbes to a considerable extent but under ambient atmospheric pressure and temperature has been developed. Significant work on the production of nutraceuticals like lutein from marine microalgae has been done. A prototype plasma pulse technology for biofouling control in pipelines and on plate heat exchanger surfaces, is under development.

2.7.7 Coastal Ocean Monitoring and Prediction System:

Extensive monitoring of marine pollution along the coastal waters was continued at 76 locations and it has been found that the disposal of untreated sewage from towns, cities and villages cause decrease of dissolved oxygen and increase of nitrate and pathogenic bacteria in the sea close to the shore. The data collected revealed that pollution problems are confined up to 1 km in the sea except at Mumbai where the pollution problem prevails up to 3 km in the sea. Model to predict the movement of oil during oil spills has been developed for the coasts of Mumbai and Chennai. Works to develop similar models for the coasts of Goa, Kerala and Visakhapatnam have been undertaken.

2.7.8 Shoreline Management

Under the programme on Shoreline management, problems of coastal erosion along the coast of Gopalpur (Orissa), Muthalapozhy, Vadanapally and Trissur (Kerala), Devbagh, Pavindurve and Kundapur kodi (Karnataka) and Gangavaram (Andhra) have been studied with extensive oceanographic data to provide solutions to the respective states. Field studies are being carried out at Pondicherry, Ennore and Shriharikota to characterize and work out possible engineering solution to stabilize the coastline.

2.7.9 Ecosystem modelling:

Under the programme on Ecosystem modelling, hydrodynamic modelling of Chilika and Kochi backwaters completed. Field investigations for ecosystem modelling for Sundarbans has been inititated. Water quality criteria for copper, cadmium and mercury have been determined and are referred to the Central Pollution Control Board. Over 20 training programmes on hazard mapping, satellite oceanography, and marine pollution have been conducted.

2.7.10 Drugs from the Sea

A programme is being implemented to harness the bioactive principles from the marine biota for human therapeutic purposes with participation of several research labs and Universities. Over 2,000 extracts of marine samples were screened for wide spectrum bioactivity including anti-diabetic, anti-hyperlipidemic, anti-malarial, anti-leishmanial, anti-bacterial, anti-fungal, anti-filarial, anti-trypanosomal, anti-HIV, anti-cancer, anti-osteoporosis, anti-tubercular, and neurobehavioral effects of marine samples. More than hundred hits have been identified, which need revalidation from repeat collection, and follow-up.

- The Phase-I Clinical Trial of CDR-134-D123 (An aqueous ethanolic extract of *Xylocarpus Granatum* (an indig neous epicarp, obtained from the tidal forests) for anti-diabetic property has been completed successfully. Compiled data has been submitted to Dept of AYUSH for fast track marketing permission as Natural Product / Herbal Medicine. This compound has been licensed to M/s. TVC Shy Shop so as to develop the drug on herbal mode through AYUSH for faster track marketing. Inclusion of *Xylocarpus Granatum* in extra Pharmacopeia is under active consideration at AYUSH Ministry.

- DCGI has permitted to initiate Phase-I Clinical trial of CDR134F194 (*Xylocarpus Granatum,* enriched fraction from the epicarp) having anti-hyperglycaemic and anti-dyslipidemic activities.

- Monkey toxicity and genotoxicity studies have been completed with CDR-267-F018 (enriched fraction prepared from the fruits of *Xylocarpus molluccensis*), an anti-dyslipidemic and anti-hyperglycemic fraction, exhibiting no significant adverse effects.

Further, another novel compound was discovered by the Indian Institute of Chemical Technology, Hyderabad, and US patent has been granted jointly between CSIR and the Ministry on “Beta carboline derived Guanidine alkaloids, *Trichenduramine*” and derivatives (2-20), from a sponge (*Synoicum mactoglossum*). These compounds are useful as Glucosidase inhibitors for the treatment of diabetic conditions, including but not limited to postprandial hyperglycemia and macro-vascular complications of diabetes mellitus.

The Advanced Centre for Treatment, Research and Education Centre (ACTREC), Mumbai is screening the marine samples for anti-cancer properties. National Institute of Ocean Technology is screening for anti-microbial bioactive molecules and Madras University is bio-evaluating for anti-HIV compounds.

2.8 Outreach Activities

In order to propagate and bring awareness about the programmes and achievements among the public, students and user communities, Earth Day was celebrated on the 22nd of April every year since 2008 across the country in 300 centres, where competitions were held amongst students of various categories and cash prizes were given. The best entries from each of the schools are further selected for national level prizes given on the Earth Sciences Foundation Day. Popular talks, society involvement in cleaning the environment, plantation, cycle rallies also formed part of Earth Day celebrations. Special publication covering Earth and environment related articles by noted scientists were published in Geography and You (English) and Bhugol Aur Aap (Hindi). Specific programmes aimed at green awareness and large scale plantation by school students were organized in Raipur district and Haridwar with co-participation of State Governments. The film "Science Safari" in regional television channels in local languages on various activities of earth system science and technology, produced by the National Geography channel was telecast many a times, besides publishing articles in popular magazines "Frontline", "Namaskar", "Outlook", and "Shrishti" (in English and Hindi), "Bhugol aur Aap" in Hindi, which are being distributed to various central schools. The participation of Indian students in the International Earth Science Olympiad was supported. Indian team (4 students) bagged four bronze medals in Olympiad 2009 and one Silver Medal and three Bronze medals at the Olympiad 2010. About 500 seminar/conference/training events were supported in area of Earth system sciences to provide platform to scientists, engineers, and technologists. The beneficiaries were Indian Institute of Technology, CSIR labs, Colleges, Universities, Professional bodies, Non-Governmental and Government agencies/organizations, etc.

2.9 R & D in Earth system Science

To encourage focused research activities towards improving the various services of the country in earth, polar ocean and atmospheric sciences for the societal benefit, 15 projects, were supported. In order to augment capacity building in the field of Earth sciences, MoES Chair Professors (IIT Delhi, NGRI Hyderabad, IIT Kanpur & IIT Kharagpur) and MoES outstanding Young Faculty (IIT Delhi, IIT Kharagpur) were established.

Several academic programmes like MTech/PhD (IIT Delhi, IISc Bangalore, IIT Chennai) have been initiated. Specialized Labs (Laser Diamond Anvil Cell at IISER Kolkata, Accelerator Mass Spectrometry (AMS) measurement facility at IUAC, UGC, Delhi; Raman Spectrometer for oil exploration using fluid inclusion methods at CESS, Trivandrum were set up as National facility for use by various researchers and Institutes.

To encourage indigenous capability through Joint developmental work, MoES is providing 50% funding for carrying out research in mesoscale modeling and biofuel from microalgae (NMITLI (CSIR)) and Computational Aspects of Numerical Weather Prediction (CDAC, DIT).

MoES also undertakes developmental work under international collaborations so as to bring Indian meteorological services at par with other developed countries. MoUs have been signed with United Kingdom Meteorological Office (UK), NoAA(USA), Natural Environmental Research Council (UK), Korean Meteorological Administration (Republic of Korea) KMA for exchange of technical knowledge,

resources for weather and climate forecast; earth observations and earth sciences; changing water cycle; and earth science & services, respectively.

A detailed study of the Agromet Advisory Service and the Fishery Service was carried out in order to assess the impact and the economic benefits of the services

Following nine OASTCs (Ocean and Atmospheric Science & Technology Cell) are currently operational with well defined areas of research:

1. Marine biology at Annamalai University,
2. Marine microbiology at Goa University,
3. Marine coastal ecology at Berhampur
4. Marine coastal ecology at Bhavnagar University
5. Beach Placers at Tamil University
6. Marine geology and geophysics at Mangalore University
7. Coastal marine culture systems at Andhra University
8. Marine benthos at Cochin University of science and technology, and
9. Ocean engineering and underwater robotics, IIT, Kharagpur.

A total of 103 projects have been completed and around 70 projects are ongoing at the Centres. 111 Ph.Ds, 13 M.Phils and 5 MS degrees were awarded. 204 papers have been published in peer reviewed journals. A 6-member evaluation committee under the chairmanship of Dr. A.E. Muthunayagam, Ex-Secretary, and Department of Ocean Development was constituted to evaluate the performance of the OASTCs since inception. The committee has submitted its report containing suggestions for expanding the scope of the programme and improving the productivity and output of the Centres. It is also proposed to open new OASTCs.

To increase visibility of research outputs emanating from the MoES funded projects, an open access digital repository has been set up. The repository is hosted and maintained by INCOIS, Hyderabad. Research outputs/papers emanating from ministry funded projects are uploaded in the repository which are accessible worldwide through internet.

A consortium of MoES institutes was set up for providing online access to full text database—*Science Direct* and abstracting and indexing database—*SCOPUS*.

3. Proposals for XII Five Year Plan (Continuing and New programs)

The Earth System Science Organization (ESSO) addresses holistically various aspects relating to earth system processes for improving forecast of the weather, climate and natural hazards. The ESSO is also responsible for development of technology towards the exploration and exploitation of marine resources. The major areas include weather forecasting, weather advisories specific to agriculture, aviation, shipping, sports, monsoon, disasters (cyclone, earthquake, tsunami, sea level rise), polar science, living (fishing advisory) and non-living resources (poly-metallic nodules, sulphide and Co-crust minerals, gas hydrates, freshwater, etc), coastal and marine ecosystems and climate change. Satellite-based, airborne and in-situ atmospheric, ocean and lithosphere observing systems have been deployed and continuously augmented.

The proposals of the Ministry's XII Five Year Plan, primarily encompass both ongoing programs and new initiatives, in 4 major areas of earth sciences viz., Atmospheric and a climate change Science and Services, Ocean Science, Technology and services, Polar and geoscientific research. Adequate attention has been paid in the formulation of these proposals, particularly for inclusion of ongoing schemes from XI plan to XII plan which were considered after having an independent evaluation. This exercise has been conducted taking into account of the Zero Based Budgeting, suggested by the Planning Commission. Some of the projects which have accomplished the desired targets during XI plan, have been closed. Further, during 11th plan, about 34 schemes were approved for implementation and some of them have certain common elements which needed to be factored in formulation of 12th Plan proposals. The proposals were discussed in great length in a series of sessions of ESSO council (vision committee meetings) and Working Group meetings. To implement 12th plan proposals more efficiently, in a focused way, the schemes have been broadly recast into 10 major schemes as detailed below:

3.1 ATMOSPHERIC & CLIMATE SCIENCE AND SERVICES

The meteorological services have significant impact on society in general and agricultural community in particular. Public/private/government demand for accurate prediction of weather and climate at various temporal and spatial scales is increasing due to possible impacts of global climate change. Improved and reliable forecast of weather and climate requires high-resolution dynamical models (e.g. coupled ocean-atmosphere-biosphere-cryosphere models). Thus, a combined approach involving land, ocean and atmospheric processes hold the key to improve the forecasts of various temporal and spatial ranges. On the other hand, intensive monitoring of various weather systems through different platform based observing systems including satellites provide not only the necessary information about current weather systems, their effective assimilation in numerical models provide important guidance for accurate forecasts. ESSO has taken positive steps to implement comprehensive developmental programs in these lines involving all its related units.

Climatic information in form of seasonal prediction of summer monsoon rainfall is available over India since 1886. India specific climate related activities like Climate Monitoring and Analysis, Climate Data Management, Climate Research and Climate Prediction (Seasonal Forecasts) are important aspects for the Climate services. It forms a strong basis to understand the natural climate variability and is an important tool for assessment of the magnitude of perturbations that arise due to climate change.

India is committed to establish its role as a partner for the Global Framework for Climate Services (GFCS) through optimizing its resources to support key priorities for the safety and well being of people throughout the world. This will be achieved through capacity building along with Integrated global observing system , disaster risk reduction and strengthening and development of new services.

3.1.1 Atmospheric Observation Systems

Atmospheric observation system forms the backbone of any meteorological service. Reliable and accurate measurement of upper air and surface Meteorological data is a basic requirement for defining current weather, weather forecasting, NWP and disaster management. Radiosonde provides the vertical profile of temperature and humidity at a place and this data is used for calibrating the satellite observations as well. High resolution data from improved radiosonde, wind profilers, wind Lidars as well as measurements from aircraft through dropsondes lead to improved initial conditions of vertical profiles which in turn improve the forecast. The high quality upper air data and its sustenance is thus essential for improved performance not only at National level but at the International level as well since it provides input for global model. The long series of archived observational data also forms an integral part of the climate studies. The radiation measurements are undertaken to get the atmospheric radiation profile. This data along with ozone measurement data collected from all the stations are used for environmental monitoring and in the air pollution studies. Radars have an essential role in detection of storms and for detection and tracking of cyclones. Radar observations and lightning detection systems are used for Aviation services and also used for Now-casting (up to 6 hours in advance) of severe weather systems. Radar data is also used for undertaking research on the understanding of the dynamics and micro physics of convective weather phenomena which are crucial for tropical region like India. Similarly the data from automatic weather systems as well as Automatic rain gauges distributed over the country provide information over various regions capturing the variability of surface parameters over different locations including remote areas.

Atmospheric observation network (Continuing):

The measurement of various atmospheric parameters through surface, upper air, aircraft and satellite-based platforms is a prime requirement for weather forecasting. The current observations need to be continued The augmentation of observation system through Doppler Weather Radars (DWRs), AWSs, ARGs is also proposed. In addition, in order to understand specific atmospheric processes, there is a need to continuously undertake observations pertaining to cloud microphysics, radiation budget, aerosol physics etc that are required to be established, sustained and augmented. Observations/field campaigns related to air-sea interaction would support the objectives of monsoon mission.

(a) Objectives:

i. Sustenance of observational networks covering DWRs, ARGs & AWSs, Upper air, surface and environmental observatories etc on 24x7 basis.
ii. Provision of adequate communication system for data and product transmission.
iii. Maintenance of operational forecast system, delivery system for forecast and other services.

iv. Conduct of special campaigns for improving Cyclone, Thunderstorm and Fog forecasting, etc.
v. Planning of new observations and augmentation of existing observation system.
vi. Planning and sustenance of specific process related observing systems over India

(b) Participating Institutions:

India Meteorological Department, New Delhi
Indian Institute of Tropical Meteorology, Pune

(c) Implementation Plan:

Some of the new observing systems planned include Wind Profilers (5 stations); Microwave Radiometers (at 5 stations) to provide vertical profiles of boundary-layer wind, temperature & atmospheric humidity, column-integrated total amount of water vapour, liquid water, vertical profiles of cloud liquid water, and atmospheric stability (now-casting of convection, thunderstorms) and measurement of fog; Wind Lidar to provide wind velocity measurements with higher resolutions both in space and time; Pilot Balloon observatories with GPS based wind measurements up to 20-25 km in all weather conditions; Polarimetric S-Band Doppler Weather Radars in coastal regions; Disdrometers for installation around Doppler Weather Radars for surface Rainfall Intensity and other hydrological products; Augmentation of Radiation Network. ; and procurement of Digital Station Barometers (100 Nos.).

Since large number of various instruments is being deployed, the upgradation of Test and Calibration Facility of surface meteorological instruments is necessary.

Environmental Monitoring is one of the major requirements to provide inputs on air quality. This would include black carbon, trace gases such as Ozone, SO_2, NO_2, CO_2, and physical and radiative characteristics of aerosols.

The study of Antarctic Meteorology is focused to understand meteorological and atmospheric processes and develop forecasting models/tools for operational use during expeditions, and to find out tele-connections of Antarctic weather and Indian Summer Monsoon. The climatology of Schirmacher Oasis, Maitri is to be developed.

Hydrometeorology studies would include rainfall summary, Probable Maximum Precipitation (PMP) Atlas, development of QPF using rainfall predictions with very high resolution models

In respect of Positional Astronomy, Observational Studies and Web-based services are to be continued.

Under Communication and Information Systems, efforts would include replacement and commissioning of AMSS to enhance data availability atenhanced speed at the national and international level. Enhancement of the communication facilities at Central and field stations facilitates speedy exchange of Numerical Weather Prediction (NWP) data and products for the day-to-day forecasting work. The maintenance of website and upgradation activities are to be continued.

(d) Deliverables:

i) Establishment of sustained observational network for process studies specific to India viz. cloud microphysics and aerosols.
(ii) Efficient upkeep of commissioned observing systems
(iii) Ensuring fast and efficient acquisition of national and global observational data in a fail-safe environment

(e) Budget requirement including foreign exchange component: ` 700 crores

(Rs. In crores)

Name of Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Atmospheric |Observation Network	110.0	120.0	180.0	150.0	140.0	**700.00**

Satellite meteorology (including aircraft-based) (Continuing):

Weather forecast is an initial value problem indicating the need for accurate initial condition that is achieved through data assimilation. As conventional data coverage is spatially and temporally limited, satellite data provides much better coverage in both space and time. About 90% of the data that goes into the assimilation of any analysis-forecast system comprise of data from satellite and rest from *in situ* platforms.Satellite Meteorological services involve receiving satellite data from Indian and International satellites, its processing for generation of images in all channels, derivation of operational products their archival and their real time utilization for weather forecasting. The various products include cloud top temperature, vertical profiles of temperature, humidity, fog, sea surface temperature, atmospheric motion vectors, outgoing long-wave radiation, total precipitable water etc.

(a) Objectives:

i. To acquire, process satellite data and generate products for operational needs as per the needs from time to time
ii. To establish a dedicated dissemination system of satellite data and products using INSAT transponders
iii. To set up a countrywide network of GPS Stations for measurement of integrated precipitable water vapour for use in nowcasting and NWP models
iv. To augment and enhance Satellite Data Centre

(b) Participating Institution:

India Meteorological Department, New Delhi

(c) Implementation Plan:

INSAT 3D Prime ground segment with data processing capabilities would be installed. 200 GPS station level measurement of net precipitable water would be created. A state-of-the art Data Centre would be established with high bandwidth connectivity with user friendly features. A system by the name of IMETCast would be installed for dissemination of data products in broadcast mode for the benefit of

remote and ship based users. Several R&D and training programs would be initiated to fully utilize an ever increasing supply of satellite data.

(d) Deliverables:

- Real Time generation systems of satellite derived products with redundancy for continuous monitoring of weather systems over India and neighbouring seas
- Building a dedicated satellite data broadcast infrastructure for the Indian geostationary meteorological satellites

(e) Budget requirement including foreign exchange component: ` 70 crores

(Rs. In crores)

Name of Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Satellite Meteorology	10	10	20	15	15	**70.00**

Modernization Phase II of IMD (New):

The Cabinet Committee on Economic Affairs had approved the program on `Modernization of Observation & Forecast of India Meteorological Department (IMD) to be implemented in a phased manner. The Phase-I of the program got implemented during the XI plan. This resulted in commissioning of state of art observing systems throughout the country with their networking and integration, utilizing them in high resolution numerical models in high performance computing facility, their visualization, archival and dissemination to the user community in a skilful manner. The second phase of the modernization is aimed towards augmentation and enhancement of various observation systems as per requirement over different parts of the country. The first phase has established a fully integrated system and the second phase will enhance the existing system with optimal augmentation of observing systems.

(a) Objectives:

Augmentation of Observing Systems and Forecast Facilities of the India Meteorological Department (IMD)

The modernization phase II shall enhance the coverage and density of observations for the entire country with a centrally connected digital observational data acquisition, processing and visualization systems. It will render the full benefit of the modernization in terms of automation and improved quality of service. In order to achieve the envisaged objectives, the following facilities/observing systems are required to be commissioned. The framework of the observing systems is originally recommended by the Sikka Committee constituted by the MoES. The observing systems proposed for modernization phase-II are on the basis of Sikka Committee recommendations.

Table 3.1: Proposed Atmospheric Observation System

S.N.	Item	Number Ph-II

1	Synoptic AWS	400
2	ARG	2000
3	Upper Air	14
4	Wind Profiler	52
5	Doppler Weather Radar	34
6	Public weather systems	5
7	Forecasting System	100
8	Information Processing System (Mirror for DRC at Pune)	1

(b) Participating Institution:

India Meteorological Department, New Delhi

(c) Implementation Plan:

Phase I of the modernization of IMD was implemented since 2007-08 upon the approval of the Union Cabinet, at a cost of Rs. 920.0 crores. All lesson learning experiences along with unforeseen predicaments of phase-I of the modernization shall help in efficiently completing the critical components of procurement and commissioning cycle of state-of-the-art observing system viz., design, planning, bidding, procurement, preparedness for civil works and site identification/preparaton, commissioning etc., In fact, site identification and acquisition activities for the identified DWR stations has already been initiated during the XI plan itself. Similarly, all long lead actions related to other observing systems have been initiated to reduce the preparatory period for launching the implementation of the phase-II of the modernization soon after its approval from the competent authorities.

(d) Deliverables:

(i) Commissioning and sustained operation of modern observing systems would provide improved quality of weather, climate and early warning services for the hydro-meteorological hazards and high impact weather phenomena
(ii) Implementation of improved global, regional, meso-scale and now-cast data assimilation and forecast models to cover all spatial and temporal ranges

(e) Budget requirement including foreign exchange component: ` 1000 crores

(Rs. In crores)

Name of Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Modernization Phase-II of IMD	200	250	300	100	150	1000

Integrated Himalayan Meteorology (New):

In the Indian subcontinent context, Himalayas govern the climate and weather of the region and drive the major weather systems viz. Western Disturbances (WDs) during winter time and monsoon phenomenon during summer time. Heavy snowfall events over the Western Himalayan region and the subsequent avalanches over the region affect life and property of the habitats. It also has a strategic importance for army operations. Impact of the weather events are enhanced by topography which

makes the area more prone to cloud bursts, flash floods and landslides**.** In order to meet the region specific user requirements, it is important to have an optimal network of surface and upper air observing systems. Existing surface observations from the Meteorological Centres at Srinagar, Shimla, Dehradun, Gangtok and Itanagar along with upper-air stations at Jammu, Manali and Sasoma are only available to meet weather forecasting requirements of the specific region which is very sparse. An enhanced network of surface and upper-air observations over the region will lead to improved weather forecasting services. Agriculture is highly sensitive to weather and management practices in mountain regions. IMD in collaboration with different organisations/institutes issues Agromet Advisories for state and district level for in the entire Himalayan region from Jammu and Kashmir up to Tripura. In order to improve the services in the entire region, skilful forecasts are essential that can be achieved through enhanced observation systems along with high resolution numerical weather models.

(a) Objectives:

i. To improve and upgrade mountain weather and climate monitoring and forecast services over the Himalayan region by establishing additional and critical state-of-the-art surface and upper air observatories for generating real time observations.
ii. Interfacing the Indian side observational network for integration with those of neighboring countries in the Himalayan region for a comprehensive analysis of mountain weather phenomena.
iii. To establish a robust mechanism to exchange scientific analysis based meteorological information towards the holistic Himalayan development through customized weather, climate, hydrological, ecological and environmental services.
iv. To build enhanced understanding of weather and climate processes over complex Himalayan terrain and render quality forecasting services.
v. To build improved understanding of physical processes along with rapid intensification of valley scale high impact weather phenomena leading to heavy rainfall, heavy snowfall leading to cloud burst, flash floods, avalanches etc. towards the development of early warning systems.
vi. To develop exclusive Himalayan climatology database for the region to capture the significant climate variability indices to meet the requirements of all users.

(b) Participating Institution:

India Meteorological Department in association with the efforts of Snow and Avalanche Study Establishment of the DRDO

(c) Implementation Plan:

The implementation of this project will help to accurately identify, capture and monitor various weather systems affecting the region and provide better weather forecasts and warnings. Improved data collection and archival will help in preparation of improved climatology for the region for the future. With the availability of additional ground truth, verification of forecasts of numerical models can be carried out more realistically which will in turn, help in improving the mountain meteorological services. Improved data collection, forecasts and warnings in respect of heavy precipitation/cloud bursts will help many sectors like army operations,

agriculture, tourism, border roads and communications, power generation, water management, environmental studies and general public. All of these would also help in hydrometeorological hazard preparedness and risk reduction planning.

(d) Deliverables:

- Commissioning and operation of full scale observing systems over the Indian Himalayas
- Building appropriate local/valley scale numerical weather analysis-assimilation and prediction models
- To operate exclusive mountain meteorological services for the Himalayan states of India
- The meteorological parameters will form an integral part of the mass balance studies of selected Himalayan glaciers proposed to be taken up under the Cryosphere studies by NCAOR.

(e) Budget requirement including foreign exchange component: ` 300 crores

(Rs. In crores)

Name of Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Himalayan Meteorology	30	60	100	60	50	300

Centre for Atmospheric Technology (New):

There is no dedicated institution existing in the country exclusively for addressing technology related issues by fully considering the emerging observing needs of the country by leveraging the global advancements of the observational and communication technologies related to weather and climate. In order to consolidate, expand and sustain the state-of-the-art observing systems for India, it is necessary to identify and put in place an overarching agency who can pool-in the national technical resources/facilities from different government departments, autonomous organizations, universities and even private industrial enterprises towards design and development of prototype technologies through appropriate R & D efforts; and transfer the technology to industries for the ultimate mass production through complete indigenization efforts. Such a dedicated and orgnaised effort can only ensure the cost effecitve and state-of-the-art observing systems for India to provide quality forecasting and early warning services for all times to come.

(a) Objectives:

Establishment of an exclusive Centre for Atmospheric Technology with a mandate to develop indigenous capabilities in India through innovative efforts towards development of contemporary instrumentation sensors/communication assembly components for atmospheric measurements.

(b) Participating Institutions:

(i) India Meteorological Department, New Delhi
(ii) Indian Institute of Tropical Meteorology, Pune
(iii) National Institute of Ocean Technology, Chennai

(c) Implementation Plan:

National Centre for Atmospheric Technology should be located preferably in the vicinity of a viable institution having proven expertise in respect of instrumentation, Indigenization of sensor development, integration of sensor, power and communication sub-systems such as AWS, ARG, PDWR, MPAR, RS/RW, Wind Profilers, Space technology components. Such an effort is strategically important from the point of view of reducing dependency and at the same time enhancing self-sufficiency for weather and climate sensitive sectors of the Indian economy and reduce commissioning costs of global technology imports. Secondly, lot of interfacing with information technology development effort would be needed to manage, visualize, process and generate customized products for multiple areas of application of forecast products which are not available off–the-shelf.

The National Centre for Atmospheric Technology (NCAT) could be set up as an incubation unit of a well established institution like NIOT with focus on development of microwave, IT, opto-electronic and space science and technology related to sensors, digital measurement, communication and networking, processing, visualization, storage and retrieval and dissemination of atmospheric variable. It will also transfer technology to PSUs and private industrial organizations for mass manufacture of atmospheric observational equipment indigenously. The centre will have Atmospheric Technology Advisory Council with members drawn from IMD, NCMRWF, IITM, NIOT, Centre for Climate Change Research (CCCR), etc., along with other allied institutions, thus to have linkages with premier institutions. The establishment of the NCAT will have strong linkages to the requirements of atmospheric science and services by meeting all observation technology development needs of the country.

(d) Deliverables:

It is envisioned to build advanced atmospheric technology development system for the country through indigenous and self-sustaining efforts in coming ten years.

(e) Budget requirement including foreign exchange component: ` 85 crores

(Rs. In crores)

Name of the scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Centre for Atmospheric Technology	17.0	17.0	17.0	17.0	17.0	85

3.2 ATMOSPHERIC PROCESSES, MODELLING AND SERVICES

The country receives more than 80% of the annual rainfall during a short span of four months (June to September) of southwest monsoon season. Variability in the onset, withdrawal and quantum of rainfall during the monsoon season has profound impacts on water resources, power generation, agriculture, economics and ecosystems in the country. An improved capability to predict Indian monsoon seasonal rainfall variability would be of profound significance to many sectors. The accuracy of the forecasts still remains a challenge in the medium range (upto two week time scale) that entails running of an end to end analysis forecast system.

Since this is an initial value problem, it is pertinent that the initial condition is most realistic. This involves a robust global assimilation scheme that utilizes various platform (land ocean and space) based observations in most optimal manner. Continued research and developmental work for most realistic representation of physical processes along with their complex non linear interactions need to be included through improved parameterization schemes to achieve skillful prediction. This includes cloud resolving processes, inclusion of dust and aerosols, realistic representation of land surface processes etc . In addition, for the week two forecasts, studies have shown the importance of atmosphere ocean coupling resulting in enhanced skill of predictions. It is also important to quantify the estimation of the uncertainty that is associated with the analyses and the forecasts. This is achievable through utilization of an ensemble prediction system which use perturbed initial conditions or have a stochastic physics in the model for short and medium range weather prediction. Currently, in India ensemble prediction system is not being used operationally. Hence it is essential to start work on implementing ensemble prediction system.

3.2.1 Numerical modeling of weather & climate:

a) Objectives:

The objective of this programme is to improve the accuracy, reliability and range of weather forecasts. through (i) better understanding of atmospheric processes and their representation in numerical model, (ii) assimilation of data from all available platforms including satellites/radars and (iii) use of ensemble and multi-model ensemble techniques.

b) Participating Institutions:

National Centre for Medium Range Weather Forecasting, Noida

c) Implementation Plan:

(i) To increase temporal range and spatial resolution of the Global Forecast System. This will be achieved by developing and improving data assimilation techniques (especially 4D VAR and Ensemble Data Assimilation) to make use of data from Indian Observation Systems (both land and space based), particularly high resolution data from the DWR and AWS, and improving physical parameterization schemes with particular reference to cloud resolving schemes and radiation processes with respect to aerosols.

(ii) Observation System Experiments (OSE) / Observation Simulation System Experiments. The experiments will be carried out for evaluation of an existing observing system, and to design new observing systems which would have an impact on model forecast. These activities are required to optimize the deployment of observation systems (land based and space based) and maximize the information extracted from the observations.

(iii) Implementation of a dynamical Global Ensemble Forecasting system.

The short and medium range weather forecasts are very sensitive to the initial state of atmosphere from which the models begin their computations. Hence, many of the leading international centres use an ensemble prediction system which either use perturbed initial conditions and/or have

a stochastic physics in the model for short and medium range weather prediction. Currently, in India ensemble prediction system is not being used operationally. Hence it is essential to start work on implementing ensemble prediction system. A state-of-the art global ensemble prediction system that is most suited for short and medium range weather prediction over Indian region.

This will involve:

- Implementation of global ensemble prediction system of NCEP with 20 ensemble members at T190L28 during 2012-2013.
- Implementation of global ensemble prediction system of NCEP with 20 ensemble members at T254L42 (~50 km) during 2013-2014.
- Implementation of global ensemble prediction system of UKMO with 24 ensemble members at N216L70 during 2012-2013.
- Implementation of global ensemble prediction system of UKMO with 50 ensemble members at N320L70 (~60 km) during 2013-2015.

(iv) Produce a regional reanalysis dataset for understanding the climate variability and climate change over South Asia. . This will generate refined description of the regional hydroclimate state (from 1979 till date) through assimilation of conventional observations as well as radiance and precipitation observations in numerical weather prediction model finally at 15km horizontal resolution.

(v) To implement a Coupled Ocean Atmosphere system and test its utility for week-2 forecasts. Implement an ocean data assimilation system to provide input to the ocean model component.

(vi) Real-time seasonal prediction for monsoon. Development of calibrated probabilistic high-resolution seasonal prediction system.

(vii) Real-time medium range MME prediction for monsoon.

(viii) Development and improvement of methods for location specific forecasts including dynamical and statiscal approaches.

(ix) Development and testing of new and novel applications like dust forecasting system, global transport of radioactive materials in the atmosphere etc.

Dust forecast system: Short-range (up to 72 hrs) forecast of dust aerosol parameters such as mass concentration, size distribution, Optical depth etc. at different levels in the horizontal resolution of 12 km or below, to be developed.

Transport model: (i) Trajectory forecast based on the requirement (ii) Global forecast of the different gases and aerosol.

UKMO-based dust forecast system will be implemented in 2012-13. Product development based on the dust model will be taken up in the year 2013-14. Simultaneously from 2012-13, work towards developing an aerosol forecasting system, which can be initially incorporated into the NCEP GFS system and subsequently in any other Indian model. It is expected to complete the first phase of this work in NCMRWF GFS by 2013-14. Development of aerosol assimilation system expected to be developed as an aerosol assimilation system by 2015-16.

A Lidar system to measure the vertical aerosol distribution (upto 10 km) for validation of the model, (2012-13) is required. Measurements will be carried out during the entire plan period.

This work will be initiated with a latest chemistry-transport model. The transport model will be linked to NCMRWF model. Installation of the model, linked with NCMRWF forecast and experimental forecast: 2012-13. Product development 2013-14.

(x) Utilization of New Satellite Data sets: Utilisation of new satellite data sets with a special emphasis on using Indian Satellite data, viz. INSAT 3D and Meghatropiques (MT)in the NCMRWF Data Assimilation Forecasting (DAF) system will be taken up.

Direct satellite radiance assimilation schemes are based on Fast Radiative Transfer Models (FRTM's) which are based on pre-computed coefficients specific to a particular sensor. These coefficients are computed from the Sensor Response Functions and thus depends on their make. Due to un-availability of these information most of Indian sensors are not supported by these FRTMs. Thus at the first instance it required to carry out development work with FRTM groups to include Indian satellite information. In the case of INSAT-AMV assimilation, the methodology for AMV calculations are to be fixed. Data, for a sufficient long period, from that fixed method will enable calculation of observational error and other statistics. Once these statistics are computed then the data can be assimilated. Most of major Global operational NWP centers are connected to the NOAA- NESIDS data distribution server and EUMETSAT. These two centers provide about 90% of global operational meteorological satellite data sets on near real time basis. NCMRWF has an access to EUMETSAT data sets through EUMETCAST broadcast. This broadcast is being received through Space Application center, Ahmedabad. But it has limited access to NESDIS data distribution server through internet. It is required to establish direct optical fiber link with NESDIS so that the data can be received in faster and reliable mode. By making this arrangement more satellite data will be available resulting in two to three hours time gain in the GFS model runs at NCMRWF and IMD .

The work will start after getting access to simulated MT data and completed after experimenting with one year real time data. With this experience, NCMRWF will be able to include INSAT-3D radiance data independently in the next one year. Monitoring of INSAT AMV wind quality and representativeness will be carried and will be included in assimilation after achieving satisfactory quality mark.

(xi) **Daily Rainfall Analysis for Merged Satellite Gauge Gridded Product:** To prepare daily gridded merged gauge-satellite rainfall data for Indian region

Reliable daily rainfall data at various resolution are required for model validation, model development and process studies. Rainfall estimates from satellite, observations from rain-gauges, AWS and ARGs are available for India and neighboring region. These data have to be suitably combined to produce gridded rainfall datasets at various resolution for various

applications. Quality control of regular gauge, AWS and ARGs have to be developed. Then satellite rainfall data from microwave, IR and other channels have to be integrated to make a single best satellite product. Several rainfall analysis algorithms are being proposed. Out of these a suitable one for monsoon has to be finalized. A near-real time rainfall analysis algorithm will be available for operational use. Historical and current daily data will be available. A quality control procedure of gauge, AWS, ARG will be available. Several new products based on this data can be developed for water management and water resources applications.

NCMRWF will work with IMD and IITM for a inter-comparison of the rainfall analysis algorithms. Joint work with groups working on rainfall analysis at NOAA, UK universities and BMRC Australia will be helpful.

(xii) **Improved prediction of severe weather systems:** Assimilation of DWR data for improved forecasting of local storms and rainfall. Advanced Hurricane WRF (AHW) for track and intensity prediction of tropical cyclones.
Improved prediction in polar regions

High resolution DWR data available for assimilation in the models. The quality of the data and the impact of the assimilation in the models will be understood only after extensive experimentation.
With the present modelling framework the tropical cyclone forecast tracks feature large errors. A complete modelling framework for improved prediction of tropical cyclone track and intensity should include suitable tropical cyclone relocation (to correct the initial position of the cyclone in the first guess) and a coupled ocean model(simple slab ocean to represent the air-sea interaction). High resolution modelling and assimilation system -
for improved forecasting of local storms and rainfall.
for improved prediction of track and intensity of tropical cyclones.
Improved predictions over polar regions

This project will be implemented in two phases.

Setting up of the model configuration and realtime and hindcast model integrations and verification. Development of DWR data quality control procedures.Realtime model integration and verification. Development background error statistics for inclusion in the assimilation system. Development of DWR data quality control procedures.Realtime model integration and verification. Revised estimate of background error statistics for inclusion in the assimilation system. Assessment and review of strategy.Realtime model integration and verification. Revised estimate of background error statistics for inclusion in the assimilation system. Assessment and review of strategy.Realtime model integration and verification. Final review and report.

(xiii) **Observing System Simulation Experiments (OSSE):** Achieve the cost-effective deployment of observing systems and design a suitable observation network, relative impact of various observing systems on predictions of different weather systems affecting India .

Scenario of observing network is changing continuously worldwide, at the same time data assimilation and forecast models are also getting sophisticated day by day. Leading NWP centres of the world carry out OSEs regularly to see the changes of the relative importance of observing systems in this changing scenario. OSSEs are planned well before deployment of new observing systems. In India though few OSEs have been carried out but those are not very systematic and also not repeated in regular intervals.

Quantification of relative importance/impact of various observing systems on prediction of Indian weather systems (useful tool for future planning). OSEs will be carried out using the operational data assimilation and model by data denial method for various in situ and satellite observations (both Indian and Global) with special emphasis on the impact of various observations on predictions over Indian region. OSE will be repeated for different seasons which will indicate the relative impact of observations on different types of weather systems affecting India.

Depending of relative importance of observations on different weather systems, observation targeting (e.g. dropsonde observations for tropical cyclone over Indian seas) and associated OSE by 'data inclusion' method will be carried out.

(xiv) **Regional Forecast System:** To implement and test UM regional forecast system for improving the short range weather forecasts over Indian and neighboring region.

The regional/mesoscale forecast systems may be useful for obtaining the mesoscale details of the synoptic systems predicted by the global models. By the assimilation of high resolution/additional observations better initial conditions and better forecast performances are expected. The regional/mesoscale forecast systems have evolved over the last couple of decades with many options for physics parameterisarions and with the capability to assimilate many high resolution and non-conventional data sets. UK Metoffice Unified model is having both 3-D and 4-D variational assimilation options in both global and regional configurations. Currently the performance of the regional/mesoscale models are far from satisfactory due to the initial condition errors and physics inadequacy for the tropics. There is more need for development/tuning of physics parameterisations for tropics and for improvement in the quality and quantity of existing and new types of observations. A state-of-the art regional forecasting system that is most suited for short range weather prediction over Indian and neighboring region

Testing and evaluating regional/mesoscale model forecast and assimilation system based on Unified Model, and implementation of the regional configurations will be carried out during 2012-2014 and 2014-2015 respectively.

(xv) **Infrastructure Development**

To establish a Data Centre which shall streamline the Data archival, retrieval and monitoring system at NCMRWF. This will also serve as an online repository of all past, present and future NWP data and products.

Provide necessary physical infrastructure (new building for HPC/library) in NCMRWF to facilitate quality research and services at par with global standards and practices..

d) Deliverables:

State-of-the-art global numerical weather prediction (both deterministic and ensemble) systems for forecasts over short, medium range and week-2 time scales.

A coupled ocean atmosphere modelling system for generating week-2/monthly forecasts

Assimilation of new satellite data sets especially from Indian Satellites (viz. , INSAT 3D and Meghatropiques for improved weather prediction.

Quantification of relative importance/impact of various observing systems on prediction of weather systems over India.

Sophisticated land surface models to provide better assessment of soil moisture and surface weather conditions for usage in various application fields like agriculture and water resources sector.

High resolution regional modelling and assimilation system for improved forecasting of local storms, tropical cyclones and polar weather.

A regional reanalysis dataset for understanding the climate variability and climate change over South Asia.

.A near-real time rainfall analysis will be available for applications in water management and water resources.

An ocean data assimilation system to provide input to the ocean model.

Short-range forecasts of dust aerosol parameters (viz., mass concentration, size distribution, optical depth).

On-demand Trajectory forecasts using transport model and global forecast of the different gases and aerosol.

Improved methods for location specific forecasts including dynamical and statistical approaches.

Providing Forecasts in the neighbouring countries through appropriate mechanisms

e) Budget requirement: ` 100 crores

(Rs. In crores)

Name of the scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Numerical Modelling of Weather and	14.00	26.00	22.00	23.00	15.00	100.00

Climate						

3.2.2 Agrometeorology (Continuing):

Agrometeorological services programme of the Ministry has a direct impact on agricultural production. The services are available in 550 districts. Farmers receive advisories before various stages of farming. Currently, about 25 lakh farmers are using this information through mobiles. This programme would be continued to have larger coverage with improved advisories, and having closer coordination with State government authorities.

a) Objectives:

(i) To improvise the existing district level Agromet Advisory Services (AAS) to deliver crop and location specific AAS to farmers at block level advisories.
(ii) To design optimum observatory network for issuance of villagelevel advisories for implementation of crop weather insurance.
(iii) To establish District Agromet Units as nodal centre for catering to needs of agriculture services
(iv) To provide customized advisory bulletins through last mile connectivity to farmers with personalized agromet advisory services.
(v) To extend the weather based advisory service to the allied areas like livestock, grazing of farm feed etc.
(vi) To establish appropriate dissemination and support system for weather-based crop insurance in the country.

b) **Participating Institutions**:

(i) India Meteorological Department, New Delhi
(ii) Agricultural Universities

c) Implementation Plan:

District Agromet Units (DAUs) would be set up to address the objectives at block level. It will strengthen the existing centres of (SAU's), ICAR and Krishi Vignan Kendrass. Preparation of high resolution weather forecast at block/taluka level is required. It is proposed to start issuing the forecast, particularly for the agromet service at relatively smaller areas at sub-districtt level. Efforts are to be increased to disseminate the advisories and cover 50 percent of farming community. Need-based agromet advisory services are to be rendered for the farmers engaged in cultivation of commercial field crops and horticultural crops involving Crop Growers Associations for important cash crops like tea, coffee, apple, mango, sugarcane, cotton, grapes, etc. Application of Remote Sensing in AAS (crop, productivity and soil moisture status of a region under water stress, other biotic or abiotic conditions along with the possibility of forewarning pest and disease outbreak for smaller areas) is to be expanded. Training to extension workers as well as farmers along with climate awareness programmes is also important, and should be planned. The studies will be undertaken to observe whether weather based advisories have a positive impact on the overall yield and also how best can help in decreasing the cost of cultivation. These exercises will be carried out at all the field units and DAMU stations.

d) Deliverables:

- Improved district scale agromet advisory services and experimental generation of sub-district scale agromet advisories
- Development of customized advisories for livestock and grazing of farm feed (in drought prone areas)

e) **Budget requirement** including foreign exchange component: ` 265.00 Crore

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Agrometeorology	58.00	52.00	49.00	52.00	54.00	**265.00**

3.2.3 Aviation Services:

Weather forecast (nowcast) continues to be a challenge in providing accurate forecast for aviation sector. In order to contribute towards the safety, economy, regularity and efficiency of **global air navigation**, National Meteorological Services throughout the world make meteorological observations and forecasts through establishment of sustained monitoring and warning systems in their respective countries, as per the standards and guidelines provided by World Meteorological Organisation (WMO) and International Civil Aviation Organisation (ICAO). India Meteorological Department (IMD) is the national agency in India, which is responsible in all the matters related to Aviation Meteorological services. Aviation services are provided for National and International flights for safe and efficient operations in terms of take off, landing and en-route forecasts. These services are provided through a network of Meteorological Watch Offices (MWOs) in four international airports at Chennai, Kolkata, Mumbai and New Delhi and 68 other aviation meteorological offices. The aviation meteorological offices provide airport specific current weather reports, forecasts and warnings for safety, economy and efficiency of aircraft operations. In view of this there is a continuous need to upgrade and augment instrumentation through state of art observing systems, establishment of decision support systems in tune with the pace of the modernization of various airports throughout the country in a phased manner.

a) Objectives:

(i) Up gradation of Airport Meteorological Instruments (AMIs) at runway locations for the major airports.
(ii) Aviation Weather Decision Support System (AWDSS) for four metro airports.
(iii) Implementation of Aircraft Meteorological Data Relay (AMDAR).

b) **Participating Institutions**:

India Meteorological Department, New Delhi

c) Implementation Plan:

(i) Upgradation of 42 airports to be carried over from 2011-12 to be accomplished.

(ii) 50 new airports are likely to be commissioned/operationalized during the period of 12th FYP. These 50 airports will require 50 additional Aerodrome Meteorological Offices. A multi-observational facility will be set up at each airport monitoring meteorological parameters relevant to aviation safety which shall be processed automatically for assessment of hazardous conditions.

d) Deliverables:

Improved Aviation support services in major airports of India by the end of XII FYP.

e) **Budget requirement** including foreign exchange component: ` 200.00 Crore

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Aviation Services	73.00	61.00	36.00	15.00	15.00	200.00

3.2.4 Metropolitan Air Quality and Weather Service (New)

Recently, IITM had taken a lead to successfully develop and implement the SYSTEM of AIR POLLUTION monitoring and FORECASTING (SAFAR) to understand the current level of air pollution and to forecasting their level 24-48h in advance during the Commonwealth Games 2010 held in Delhi. Other than the operational service during the Commonwealth games, the SAFAR system revealed many scientific results which points towards the deteriorating air quality in the Metropolitan cities like Delhi, which could have adverse effect on the health as well as agriculture yield and closely linked to climate change on long run. One of the most important conclusions of these scientific finding is that regular SAFAR system is essential not only as public information tool but also useful in enhancing our scientific understanding on spatio-temporal variation of several pollutants. This work is proposed to extend the SAFAR in other metropolitan cities including some big cities in India. This will be accomplished using both dense observational network and high resolution air chemistry-transport forecasting model. To forecast the accurate status of air quality development of high resolution emissions inventories of important gaseous and particulate pollutants arealso proposed.

a) Objectives:

(i) To develop a System of Air Quality Forecasting and Research (SAFAR) in major metropolitan cities of India (including Delhi, Pune, Chennai, Kolkata, Mumbai, Bangalore, Hyderabad, etc.) under the studies of Atmospheric Chemistry and Climate.
(ii) To provide near real time and 1-2 day advance forecast for weather and air quality information for several Metropolitan cities.
(iii) To forecast weather in now-cast and short range scales over different sections of the Metropolitan cities including severe weather warnings.
(iv) To provide detailed customized meteorological products on-demand basis
(v) To study the impact of air pollution on Health and Agriculture.

b) **Participating Institutions:**

(i) Indian Institute of Tropical Meteorology, Pune
(ii) NCMRWF, New Delhi
(iii) India Meteorological Department, Delhi

c) Implementation Plan:

(i) Installation of Meso-urban observation networks in major Metropolitan cities.
(ii) Development of high resolution dynamic emission inventories of air pollutants for proposed Metropolitan cities.
(iii) Wind profilers, Radiometers and Wind Lidar for continuous upper air observations.
(iv) Configuration and operationalization of meso-scale and nowcast models.
(v) Configuration and operationalization of high resolution atmospheric chemistry transport forecasting models nested to different proposed city domains.
Operation of Air Quality forecast services through dynamic web based portals and public display systems.

The Indian Institute of Tropical Meteorology (IITM) will coordinate and lead the effort for the development of SAFAR system and continue its effort in improving the skill of forecasts. NCMRWF will help in providing the boundary conditions for coupled weather model using GFS and also help in assimilation of air quality and weather data. Once SAFAR system is fully developed and tested for operations, it will be transferred to India Meteorological Department (IMD) for operational services. Provisions for funding the National as well as the international partners will be year marked for improving the parameterization of chemical transport models and implementing the global MACC boundary conditions to initialize the online CTM for air quality forevasting. These partners will be allowed to use the HPC facility at IITM.

d) Deliverables:

(i) Develop and dedicate the System of Air Quality Forecasting & Research (SAFAR) to nation as an operational service in at least 6 Metropolitan cities.

(ii) Delivering the comprehensive seasonal air pollution scenario and relative contribution of different emission sources for various metropolitan cities under study.

(iii) Identification of pathways of pollutants from neighbouring states and relative contribution between local versus distant sources along with its interpretation for different cities.

(iv) Role of meteorology in the distribution of air pollutants and visa-versa by revealing the spatio-temporal behaviour of pollutants and their variability specific to the location.

(v) A mechanism to spread public awareness and preparing the basis for mitigation strategies to protect our health by displaying the level of air quality well in advance as operational services.

e) Budget requirement including foreign exchange component: ` 90.00 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Metropolitan Air Quality and Weather Service	25.00	30.00	20.00	10.00	5.00	**90.00**

3.2.5 Monsoon Mission (New):

Monsoon has always been critical for India's economy. The current prediction capabilities are not adequate. In recent times, several new approaches (high resolution, super parameterizations, data assimilation etc.) have shown that the variability in tropics can be reasonably resolved, thereby creating a great scope for improving the monsoon prediction. The mission will support focused research by national and international research groups with definitive objectives and deliverables to improve models in the short, medium, extended and seasonal range scales through setting up of a framework for generating dynamical forecasts and improving skill of forecasts. The mission will also support observational programs that will result in better understanding of the processes.

a) Objectives:

(i) To improve Seasonal and Intra-seasonal Monsoon Forecast
(ii) To improve Medium Range Forecast.

b) **Participating Institutions**:

(i) Indian Institute of Tropical Meteorology, Pune
(ii) National Centre for Medium Range Weather Forecast, Noida
(iii) India Meteorological Department, New Delhi

c) Implementation Plan:

The Indian Institute of Tropical Meteorology (IITM) will coordinate and lead the effort for improving the forecasts on seasonal and intra seasonal scale. National Centre for Medium Range Weather Forecasting (NCMRWF) will lead and coordinate the efforts for improving the forecasts in the medium range scale up to week two forecasts. These will be made operational by the India Meteorological Department (IMD). In a bid to improve the skill of the forecasts in various temporal and spatial ranges, proposals will be invited from National as well as international Institutes on very specific projects and deliverables. Provisions for funding the National partners as well as the international partners will be year marked. These partners will be allowed to use the HPC facility at IITM and NCMRWF which will be suitably enhanced for the

purpose. A National Steering group is being put in place to steer the program and review the progress of the mission.

d) Deliverables:

(i) Establishment of a reliable forecasting system in the seasonal and intra seasonal scale
(ii) in the medium range scale up to week two

e) Budget Estimate: ` 290 crores*

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Monsoon Mission	10.00	66.00	77.00	64.00	73.00	290.00

* Fund for HPC has been kept in HPC facilities (please see 3.13)

3.2.6 Physics and Dynamics of Tropical Clouds (New)

Monsoon prediction on all time scales using numerical models has been an important requirement of the country. The parameterization of convection, incorporation of land-surface processes and coupling to ocean have been the most outstanding challenges to the numerical weather predictions on the short to medium range scales in India. The inaccuracy in formulation of clouds in the weather and climate prediction model is the most significant source of systematic errors in these models. The parameterization of convection in weather and climate models depends on our understanding of how small scale clouds interact with the large scale environments and how aerosols interact with the clouds. Significant role of aerosols has been proved on the short to long range weather predictions, and therefore demanding to be studied in the intensive way. Aerosol effects on monsoon water cycle dynamics are extremely complex and strongly dependent on aerosol distribution and characteristics, as well as on spatial and temporal scales. This substantiates the need for cloud aerosol studies in India.

The efficiency with which clouds produce rain at the surface varies greatly. The understanding of these processes is very essential for rain enhancement programmes. The potential for rain enhancement by cloud seeding is strongly dependent on the natural microphysics (size and concentration of water droplets and ice particles inside clouds) and dynamics (forces affecting air motions in and around clouds) of the clouds that are being seeded. The microphysics in turn dependent on background aerosol levels, because it is the aerosol particles that attract water vapour to form cloud droplets, and in cold clouds, ice particles. Furthermore, the types and concentrations of aerosol particles can be influenced by trace gases (i.e., air pollution). It is, therefore, essential to understand atmospheric aerosols and pollution levels, and their effects on the microphysics and dynamics of naturally forming clouds. This will help effectively design the seeding experiment subsequently. As a first step to partially overcome the lack of aerial measurements, limited number of samples, strong natural variability in the large scale atmospheric conditions etc. the CAIPEEX has been undertaken as one of its 11th Five Year Plan Schemes.

For studying the cloud aerosol interaction, there is a need for simultaneous measurements of aerosols and cloud microphysics. This will be fulfilled through the airborne platform.

The scope and the extent of the subject will increase in future. With the experience of CAIPEEX Phase I & II, it was realized that in order to meet the challenges of the expanding subject and to be at par with other atmospheric science community in the world, India should have its own airborne platform as a national facility for aerosol-cloud research.

a) Objectives:

(i) To take cloud microphysics and aerosol observations during different seasons using the instrumented airborne platform and to study the cloud aerosol interactions over different parts of country. Also, to undertake randomized cloud seeding program for rain-enhancement.
(ii) To understand the interactions between clouds and large-scale environment by analysing the simultaneous measurements of cloud microphysical parameters and large scale meteorological parameters at high temporal resolution and by using the cloud resolving models.
(iii) To study the cloud classification, rainfall and rain rate estimates in the tropical environment and to study precipitation modification using randomized cloud seeding method.
(iv) To study the microphysical and dynamical characteristics of tropical clouds and interaction with aerosols.
(v) To develop a parameterization scheme for tropical clouds for weather and climate models.
(vi) To investigate precipitation processes in the monsoon region and undertake cloud classification and rain rate estimates in the tropical environment.
(vii) To develop the High Altitude Cloud Physics Laboratory at Mahabaleshwar.

b) Participating Institutions:

Indian Institute of Tropical Meteorology, Pune
National Centre for Medium Range Weather Forecasting, Noida

c) Implementation Plan:

Special cloud, aerosol observations over different parts of the country will be arranged. A wealth of atmospheric, aerosol and cloud microphysics data will be generated which will be useful to validate the convection and cloud schemes, and for improving the model physics. Also, it will be useful in the research for years to come. A guide lines can be prepared for the state governments and agencies interested in carrying out the precipitation enhancement experiments.

In addition to the direct radiative effects of aerosols on climate, aerosols also influence, indirectly, through modifying cloud types and their distribution. The ‘indirect effect’ of aerosols on climate has so far been poorly understood and quantified due to lack of appropriate data. The program on large scale will provide valuable data for advancing our understanding and quantification of ‘indirect effect’ of aerosols on climate.

The proposed program will be useful in air pollution assessment and associated impacts over India (health, visibility, climate), hydrological and water resources Studies, and enhancement of research infrastructure (human resources and technology).

The storage capacity of the existing High Performance Computer system of IITM with necessary infrastructure will be upgraded for archival of the observational data.

d) Deliverables:

(i) Establishment of National facility of airborne platform for cloud and aerosol microphysics observations and cloud seeding for rain enhancements.
(ii) Parameterization of microphysics schemes of monsoon clouds for improvement of numerical forecasts of monsoon on short to climate scales.
(iii) Algorithm for categorization of stratiform, convective and mixed stratiform-convective clouds over India.
(iv) Guidelines for operational cloud seeding programs.
(v) Continuous data sets of aerosol, CCN and cloud microphysical parameters for studying the cloud-aerosol interactions during different synoptic conditions over mountainous region

e) **Budget Requirement:** ` 350 crores*

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Physics and Dynamics of Tropical Clouds	28.00	268.00	18.00	18.00	18.00	350.00

* Fund requirement for additional storage capacity has been made in HPC component

3.2.7 High Impact Severe Weather Warning System (New)

The Indian region is frequently affected by a variety of hydro-meteorological disasters such as heavy rains, tropical cyclones, storm surges, severe local storms like thunderstorms, hailstorms, cloudburst, tornadoes, floods, heat and cold waves, etc. almost every year. These disasters cause huge loss of lives and properties worth several thousand crores of rupees every year. While the natural disasters cannot be prevented or controlled, the loss of lives and damage to property can be substantially minimized by issuing accurate forecast/advisories of the impending impact of these disasters. Accurate and advanced advisories will greatly help the disaster managers getting sufficient lead time to initiate all necessary preparedness and mitigation actions which would help reducing risk due to these disasters.

The hydro-meteorological disasters such as severe local storms, heat and cold waves continue to take its toll on the human lives and economy of the country despite the fact that there has been considerable advancement in the prediction models which have demonstrated significant increase in the accuracy of short and medium range predictions in recent years. There is enough scope for further substantial improvement in skill of prediction of localized severe weather systems

over India. There is a need to develop suitable assimilation and modeling system for Indian conditions for improved prediction of localized high impact extreme weather systems. It may consist of utilization of observations of different types in data assimilation, model dynamics and physics, proper post processing ,bias removal, ensemble and super-ensemble approaches, etc. The products may be linked to required GIS system for better utilization in developing warning system for risk/vulnerability assessment, mitigation and management strategies by various central and state agencies.

a) Objectives:

(i) To carry out field research through observations and modeling to improve the basic understanding of severe weather processes
(ii) Development and testing of cloud resolving model to improve forecast & warning of severe weather systems
(iii) Development of Observation Test Beds for severe weather systems

b) **Participating Institutions**:

(i) National Centre for Medium Range Weather Forecast, Noida
(ii) India Meteorological Department, New Delhi

c) Implementation Plan:

The programme may be taken up in an intense collaborative manner including operational, research and academic communities along with disaster management authorities for R&D as well as operational implementation in time bound manner.

d) Deliverables:

Establishment of National facility for conducting field research on atmospheric processes.

e) **Budget requirement** including foreign exchange component: ` 89.00 crores.

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
High Impact Severe Weather Warning System	10.00	20.00	25.00	20.00	14.00	89.00

3.3 CLIMATE CHANGE RESEARCH:

During the plan, it is intended to carryout extensive research in a comprehensive manner through observational, theoretical studies and modeling studies involving state-of-the-art coupled climate system models to study the sensitivity and stability of the earth system to a variety of forcings, including changes of greenhouse gases, aerosols, GHGs, solar irradiance, volcanic forcing, land characteristics, land use change etc. The various programmes will integrate the operational research and the

university/academic/R & D research communities to serve as a resource to the science of climate change in the country.

3.3.1 Short Term Climate Prediction and Variability

The seasonal prediction of the Indian summer monsoon rainfall (ISMR) is very important for our country, especially for planning strategies towards management of agricultural production and water resources. The seasonal prediction of the monsoon by dynamical models is based on the fact that the slowly varying boundary conditions like sea surface temperature (SST), soil moisture, snow cover, etc. exert significant influence on atmospheric development on seasonal time-scales in the tropics. Although the seasonal mean monsoon seems to be potentially predictable, atmospheric GCM simulations have not shown enough skill in capturing the inter-annual variations in the monsoon rainfall. Considerable research on predictability of the monsoon has established that the Indian Summer Monsoon has a limited potential predictability. It has also been recognized that ocean-atmosphere coupling is crucial in determining the potential predictability of the monsoon. Therefore, a coupled ocean-atmosphere climate model will be required for predicting the monsoon.

Indian summer monsoon season has periods of active (above normal rainfall) and break (below normal rainfall) epochs. Frequent or prolonged breaks lead to drought conditions. The long breaks in critical growth periods of agricultural crops lead to substantially reduced yield. Poor rice production in India during 1972, 1979 and 1987 appear to be due to such long breaks. Prediction of monsoon active and break spells, two to three weeks in advance, therefore assumes great importance for agricultural planning (sowing, harvesting etc) and water management. So there is a need for development of techniques based on statistical and dynamical methods for the forecasting of active break periods in ensuing monsoon season in the extended range time scale. Prediction of monsoon intra-seasonal oscillation is a major research program at the international and national domain.

a) Objectives:

(i) To develop and improve a System for Seasonal Prediction of Monsoon.
(ii) To develop and improve a System for Extended Range Prediction of Active/Break Spells.
(iii) To carry out basic research on variability and predictability of the tropical climate system required for improving forecast.

b) Participating Institutions:

Indian Institute of Tropical Meteorology, Pune

c) Implementation Plan:

This is a continuing scheme. Following major activities would be continued to meet the objectives:

(i) To develop an Indian model based on CFS coupled model and improve the skill of the seasonal forecast by the model to useful range.
(ii) To improve prediction skill for both summer (SW) and winter (NE) monsoon over Indian region by improving the parameterization schemes of

the model and replacing different modules in the system, wherever required. Once the model is suitably established at IITM, it can be gradually transferred to IMD (for operational forecast of Indian monsoon) after training some IMD scientists for its use.

(iii) To develop Multi-Model Ensemble (MME) system for improving the skill of monsoon prediction.

(iv) To develop new empirical techniques in addition to improvement in the existing empirical models for improving the prediction skills of active and break phases of monsoon. To evaluate, validate and improve the forecast skills of Coupled Climate Forecast System (CFS) for extended range forecast, etc. and to disseminate forecast in real time using both empirical and dynamical models. Thus, continuance of the programme is well justified.

(v) To set up the pollution monitoring stations and forecasting system within the regional model domain to provide accurate validation of the regional chemical model.

(vi) Physical mechanism responsible for Indian monsoon variability on each time scale will be will be built up.

(vii) The existing tree-ring data network will be enhanced by developing tree-ring chronologies from different parts of the country as well as from other South and Southeast Asian countries.

(viii) A mobile laboratory facility equipped with all the observational equipments to observe development of clouds and aerosols under different background meterological conditions will be developed.

(ix) The existing free-fall tube is proposed to be renovated and some new facilities to be added to produce and suspend sub-millimeter drops for the study of the interaction between microphysical and electrical properties of thunderstorm**.**

(x) The importance of global electrical changes will be assessed in providing a physical mechanism for amplifying the small changes associated with atmospheric and climate effects.

(xi) A 3D lightning mapping array will be designed and fabricated to reconstruct the lightning channel and study the charge distribution of thunderstorm.

(xii) Role of land surface processes on boundary layer evolution will be studied.

(xiii) A regional chemical transport model zoomed in for the Indian region will be used for interpretation.

(xiv) Monitoring tropospheric vertical distribution and seasonal variability in Black carbon and air pollutants over India with special reference to Indo-Gangetic plane.

(xv) Study the long-term changes (anthropogenic and natural variabilities) in ozone and other climate forcing parameters in the middle atmosphere using 3-D general circulation model. Also to study the impact of GHG forcing on the middle atmospheric climate and navigation system.

(xvi) To upgrade the existing High Performance Computer system of the IITM with storage and necessary infrastructure.

d) Deliverables:

i. Improved prediction skill of seasonal mean monsoon at 3 months lead time

ii. Improved prediction skill of active/break cycles of summer monsoon at 20 days lead time

iii. An Indian dynamical model based on NCEP coupled model, namely the CFS model.

iv. Unravel the physical processes responsible for ‘internal’ IAV of monsoon.

v. Build a reliable high-resolution proxy climatic data base in India, particularly for the past few centuries.

vi. Understand the coupling processes that exist between physicochemical, radiative, dynamical and biological phenomena in the Earth's environment and provide valuable input information for modeling, sensitivity and simulation studies of weather/climate, hydrological cycle and environmental pollution. These studies have special significance over the tropics, where the convective and dynamical processes associated with high-altitude thunderstorms greatly affect the vertical distributions of aerosols and gases.

vii. Prediction of thunderstorm formation and its severity by establishing an Automatic Weather Station network around Pune. Design and fabricate a 3D lightning mapping array to reconstruct lightning channel and to study charge distribution of thunderstorm.

viii. Monitoring tropospheric vertical distribution and seasonal variability in Black carbon and air pollutants over India with special reference to Indo-Gangetic plane and mountain regions to understand the radiative forcing from the chemical constituents using aircraft with high response time technology development for aircraft. This will also help in validation of chemical climate radiative forcing model (CCRM) and facilitate the calculation of radiative forcing over Indian region.

e) Budget Requirement: ` 200 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Short Term Climate Prediction	55.00	45.00	35.00	34.00	31.00	200.00

3.3.2 Centre for Climate Change Research (CCCR)

The increased trend of global temperature in the recent decades has focused attention of the scientific community on the specific aspect of global climate and regional monsoon variability in a changing climate

Addressing this issue involves research and development of an Earth System Model (ESM), together with comprehensive assessment of various interactions among the different Earth System components viz., the atmosphere, ocean, biosphere, hydrosphere, cryosphere, It is necessary to strengthen and continue the basic research required for improving the Earth System Model components.

a) Objectives:

(i) To develop the high resolution climate models or Earth System Models (ESM) to address scientific questions on attribution and projection of regional climate change.

(ii) To use regional climate models to produce projections of Indian monsoon under different scenarios and assess the uncertainty in these projections.

(iii) To study Monsoon Variability and Predictability by identifying regional and global climate drivers for monsoon interannual variability and to identify useful predictors and to understand the dynamics of dry and wet epochs of

the Indian summer monsoon rainfall (ISMR) and their relation to the ENSO and other global coupled phenomenon.

(iv) To document chief features of regional monsoon climate change based on climate reconstructions derived from high resolution proxies and to understand the long-term monsoon climate variability over the Asian region.

(v) To build in-house capacity in global and regional climate modeling to address all issues concerning the science of regional climate change with particular emphasis on the South Asian monsoon system.

(vi) To generate reliable climate inputs for impact assessments.

(vii) To develop hydrological model for large-scale estimation of run-off and soil moisture using satellite derived data.

(viii) To understand the role of aerosol loading over the Indian region in monsoon interannual variability and its possible implications on the Indian Monsoon.

(ix) To study and understand the role of aerosol chemistry (both organic and inorganic ionic species) in radiative forcing and regional climate change.

b) Participating Institutions:

Indian Institute of Tropical Meteorology, Pune

c) Implementation Plan:

This is a continuing scheme. Following major activities would be continued to meet the objectives:

(i) To unravel the physical processes responsible for 'internal variation of the monsoon system

(ii) To improve the understanding of monsoon system by studying various climate model systems and data-model comparison over the Asian monsoon region.

(iii) To generate high resolution (35 km grid size) simulations of the South Asian monsoon during the 20th century (1890-2005) and future climate (2005 – 2100) based on the AR5 scenario projections. The model outputs will be used for impact assessment studies (eg., impacts on climate, water resources, agriculture, health, etc)..

(iv) To understand the coupling processesand feedbacks among physical, chemical, radiative, dynamical and biological processes in the Earth's environment and to carry out the comprehensive studies using climate modelling and observational techniques i.e. instruments and in-situ facilities acquired and put in function during the recent years.

(v) The Earth System Model (ESM) will be fully developed, tested and implemented. Several long model runs will be performed using the ESM and CCCR will formally participate in the next Coupled Model Inter-comparison Project (CMIP6) and contribute to IPCC AR6 assessment

(vi) To understand the radiative forcing from the chemical constituents by monitoring tropospheric vertical distribution and seasonal variability in black carbon and air pollutants over India with special reference to Indo-Gangetic plain and mountain regions.

(vii) To monitor and understand interactions among aerosols, cloud processes and large scale dynamics in organizing large scale cloud systems in the monsoon environment.

(viii) To upgrade the existing High Performance Computer system of the IITM with storage and necessary infrastructure.

(ix) Physical mechanism responsible for Indian monsoon variability on each time scale will be will be built up.

(x) The existing tree-ring data network will be enhanced by developing tree-ring chronologies from different parts of the country as well as from other South and Southeast Asian countries.

(xi) Monitoring of atmospheric GHG concentration over Indian stations to understand long-term variations in the GHG and understand the anthropogenic and natural processes affecting the GHG variation. Establish a network of GHG flux towers for long-term monitoring of GHG fluxes in different environments.

d) Deliverables:

i. An Earth System Model (ESM) which includes a realistic and comprehensive representation of all interactive processes occurring among the different components of the Earth System. The ESM would be rigorously tested and validated with regard to simulation of the global climate, the Indian and Asian monsoons, coupled climate phenomena like ENSO , IOD, Pacific and Atlantic decadal variability, etc.

ii. High resolution projections of future monsoon climate until 2100 for different climate scenarios. . This will be used for various impact assessment studies (eg., climate, water resources, agriculture, health, etc).

iii. Generate knowledge base for detecting, understanding and attribution of observed climate changes to natural and human induced effects.

iv. Generate human capacity in the country in the field of Earth System and Climate Modeling required for addressing all scientific issues concerning climate change.

v. Generate observations about GHG concentration variations over Indian region by in situ measurements

vi. Generate observations of GHG fluxes over network of Indian stations and identify the sources and sinks of GHG

vii. Generate observations about cloud and aerosol interactions over Indian monsoon region through in situ measurements.

viii. Generate proxies of past monsoon climatic variations through stable isotope analysis of climate proxies (e.g., tree rings, corals, speleotherms, etc).

e) **Budget Requirement:** ` 100 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Centre for Climate	25.00	22.00	20.00	18.00	15.00	100.00

Change Research						

3.3.3 Climate services (New)

The climate related problems of South Asian countries are influenced by similar large scale atmospheric circulations. With the advent of ocean-atmosphere coupled global climate models and with a large volume of observed data available for this region for over two centuries, a range of climate services are now being demanded by Government planners and the hazard mitigation community across the entire south Asian region.

Two recently concluded training workshops cum joint monsoon seasonal prediction exercises in 2010 and 2011, named as SASCOF, evoked encouraging response from neighbouring countries. The RCC shall be built around such interactions.
Assimilation of diverse kinds of observational information covering meteorological variables, atmospheric composition of trace gases and aerosols, sea level, cryospheric and biospheric information etc is essential to the assessment of climate and climate impacts in months to years and to decadal scales of time. A centralized approach to data management, GIS processing and applied analyses are absolutely necessary.

a) Objectives:

(i) To create facilities for providing Climate Services through the establishment of a Regional Climate Centre (RCC)-South Asia of the WMO, within IMD.
(ii) To cater to the need of a comprehensive set of specialized climate services for the country and for South Asia as a region identified with the South West Monsoon climate.

b) **Participating Institutions:**

(i) India Meteorological Department, New Delhi
(ii) Indian Institute of Tropical Meteorology, Pune.

c) Implementation Plan:

(i) Continued development of statistical and hybrid Prediction models for the region.
(ii) The centre in co-ordination with the neighboring countries shall develop high quality regional climate data bases that will be helpful in studying the regional climate change issues and their impacts.
(iii) Support regional modeling studies using the regional data base to achieve higher resolution and accuracies of predictions.
(iv) To issue information pertaining to drought monitoring.
(v) To generate value added products like comfort indices, heat stress indices, air quality.
(vi) To set up joint studies with ICMR on understanding climate – disease relationships to develop advisory services.
(vii) To rescue and retro-convert old data and charts and create Web based archives with user friendly front end

d) Deliverables:

- Build and operate national and regional scale climate services

e) **Budget requirement** including foreign exchange component: ` 60.00 crore

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Climate Services	10.00	20.00	15.00	10.00	5.00	60.00

3.3.4 Modelling of Changing Water Cycle and Climate

India's water resources are under stress due to population growth and economic development. Water being a prime natural resource, a basic human need and a precious asset, its use needs appropriate planning, development and management. With rapid growing population and improving living standards, the pressure on our water resources is increasing and per capita availability of water resources is reducing day by day. Due to spatial and temporal variability in precipitation, the country faces the problem of flood and drought syndrome. Over-exploitation of groundwater is leading to reduction of low flows in the rivers, declining of groundwater resources and salt water intrusion in aquifers of the coastal regions. The quality of surface and groundwater resources is also deteriorating because of increasing pollutant loads from point and non-point sources. The eleventh Five Year Plan recognized the special challenges of water resources management facing India and the likelihood that these would only intensify over time due to rising population, expected growth in agricultural and industrial demand, the danger of pollution of water bodies and, over the longer term, the effect of climate stress on water availability in many parts of the country.

The present observation network (especially for hydro-meteorological variable such as precipitation, evaporation, snow melt, stream flow, runoff, infiltration) is not adequate for getting a quantified estimate of water balance in most of the river basin of the country. Therefore, existing observation network needs to be augmented with additional observing stations. Though the NCMRWF provides real-time weather and climate information in variety of spatial and temporal scales, these are not customized for user needs. Recently, there have been requests from few reservoirs management boards (such as Bhakra Beas Management Board) for customized predictions which can be input to hydrological models for efficient management of water in the reservoir. Therefore, the existing hydrological, weather and climate models have to be integrated, evaluated and calibrated for each catchment area and river basin. The calibrated models are required to run with different future climate scenarios to predict the likely impact on hydrological response at basin scale.

a) Objectives

(i) To augment the present hydro-meteorological observing systems especially in the Himalayan glacier region (interfaced with Himalayan Meteorology phase-I Program).
(ii) To develop high-resolution modeling systems to enhance predictions of hydro-meteorological variables at basin scale.

(iii) To develop integrated basin-scale hydrological modeling system by incorporation of conventional and satellite data..
(iv) To investigate the impact of climate change scenarios on hydrological response at basin level.
(v) To assess the impact of sea level changes on saline ingress in coastal zones.
(vi) Monitoring and quantification of fresh river water discharge into Bay of Bengal and Arabian Sea (to study salinity and density stratification of sea water).
(vii) To undertake coordinated research to study the changing water cycle under the following themes (under MOU with NERC,UK):

- Land, Ocean and Atmosphere interaction
- Regional scale precipitation characterization
- Detection and Attribution of Water Cycle Changes
- Consequences of Changing Water Cycle
- Research inputs for Adaptation Strategy

b) **Participating Institutions:**

(i) National Centre for Medium Range Weather Forecast, Noida
(ii) India Meteorological Department, New Delhi
(iii) Indian Institute of Tropical Meteorology, Pune
(iv) Academic and other research groups in the country

c) Implementation Plan:

i. Review and strengthening of hydro-meteorological observational network for the chosen river basins shall be carried out.
ii. Development of modeling systems for water cycle and for prediction of hydro-meteorological variables shall be done.
iii. Appropriate hydrological models to simulate hydrological systems at basin scale shall be customized for the chosen river basin.
iv. Appropriate statistical and dynamic downscaling methods shall be developed for predicting the future climate scenarios at river basin scale.
v. Impact of climate change scenarios on hydrological response at basin level shall be investigated.
vi. Impact of sea level changes on saline ingress in coastal zones shall be assessed.
vii. Fresh river water discharge into Bay of Bengal and Arabian Sea shall be monitored and quantified to study salinity and density stratification of sea water.

Program shall be implemented jointly involving NCMRWF, IMD, IITM, CCCR-IITM, academic and other research groups in the country along with MoWR agencies to meet the requirements of National Water Mission under NAPCC.

A review panel of experts from MoES and NERC will be constituted which will guide the project implementation on yearly basis.

d) Deliverables:

Development of hydrological resource assessment and management tools to quantify possible response to climate change and variability.

e) Budget: ` 120 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Modelling of Changing Water Cycle and Climate	19.0	24. 0	29.0	29.0	19.0	120.0

3.3.5 Geoengineering - CO_2 Sequestration (New)

Increasing rate of carbon dioxide (CO_2) release to atmosphere after industrial revolution had triggered the studies on green house gases effect and its impact on global warming. Sustained worldwide growth in population and economic activity has increased anthropogenic CO_2 emissions and are beginning to stress the natural carbon cycle. Earth's climate is expected to warm even more rapidly during this century, as global CO_2 emissions increase from present rates near 7 GtCy–1, to 15 GtCy–1 or more by 2050. Estimates of warming expected through the 21st century vary among models, but all are responsive to levels of carbon dioxide in the atmosphere. The concentration of CO_2 in the atmosphere is increasing at a rate of about 1-2 parts per million (ppm) per year and it is currently around 390 ppm from the pre-industrial level of 280 ppm. Increasing concentration of atmospheric CO_2 will exert greenhouse effect that traps solar energy and intern may warm our planet and changes in regional climates.

Major forums like UN convention of climate change, Kyoto Protocol and Global Climate change program had addressed the mitigation plans in controlling the green house gases to control the human impact in triggering the climate cycle. Our society needs to understand the options available for controlling levels of atmospheric carbon dioxide, and the threat of CO_2-induced climate change prove real. If we wait until there is definitive proof of harmful climate change, it will be too late to develop large-scale solutions to the problem. Hence, while addressing the mitigation efforts, carbon dioxide sequestration studies in the ocean is an important field of activity which is in progress in many international laboratories.

a) Objectives

To understand the mechanism of ocean CO_2 sequestration techniques in the ocean by capacity building; study and establish the feasible CO_2 capture technology from industrial sources, arriving feasible field executable transportation technology; and development of ocean instrumentation for EIA observation and monitoring.

b) Participating Institutions:

National Institute of Ocean Technology, Chennai

c) Implementation Plan

To start working on this domain of research to understand the ocean CO_2 sequestration techniques for controlling the global warming phenomena by CO_2 emission to atmosphere.

Wherever required, it is proposed to work in collaboration with academic institutes, research and development organizations, industries and international organizations.

d) Deliverables:

CO_2 capture, transportation and ocean sequestration technology

e) Budget: ` 50 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Geo-engineering - CO_2 Sequestration	5	5	10	10	20	50

3.3.6 Carbon-cycle Research

The link between anthropogenic greenhouse gas emissions, especially CO_2, and global warming has been unambiguously established by the IPCC's 4th Assessment Report but still a considerable gap exists in our knowledge of the global carbon cycle, especially in the estimates of land and ocean sources and sinks of CO_2. The need to reduce this uncertainty, especially in regional and country-wise emissions and uptake is paramount for reliably estimating impacts of future emission trends as well as retain knowledge based initiatives in negotiating international treaties for limiting CO_2 emissions.

Terrestrial and oceanic carbon cycles are quite difficult to quantify because of the complexity of the processes involved – photosynthesis, respiration, plant growth and decay, ecosystem dynamics, chemical kinetics and transport, considerable headway can be made through a judicious mix of observations and modelling. It would therefore be prudent for India to plan for rapid progress in this field during the next plan.

The estimation of robust GHG fluxes from India and surrounding seas involves a synthesis of high quality atmospheric GHG measurements and inverse modelling to infer fluxes. The accuracy demand of the measurement as established by WMO/GAW is of the order of 0.01 ppm for CO2 and 1 ppb for CH4 as we try to extract very small interannually-varying signals in the background measurements which are representative of reasonably large areas. WMO/GAW has established procedures for participating labs to ensure that these standards are maintained and India must participate in this activity to establish credibility of its measurement programme.

We estimate that a network of ~20 GHG measurement stations, both flask and in-situ, would be necessary to obtain robust regional estimates of GHG fluxes from India and its adjacent seas. As these stations are expensive to set-up and maintain, an analytically designed network strategy is required to gain maximum trade-of in the minimization of aposteriori errors. A final refinement will be based on a synthesis of back trajectory analysis and network design.

The complexity of inversion will keep pace with the density of measurements. From a coarse (spatial and temporal) resolution methodology based on synthesis inversion, we should progress to full scale 4D-variational assimilation which will have the ability to track the complete fate of CO_2 emitted from anywhere on the globe.

The refinement of biogeochemical models (carbon, nitrogen, silica, phosphorous, iron cycles) in the various earth-system components (atmosphere, land and ocean) should be a major focus of activity in the XII Plan. This will involve a close synergy between different observation programmes (biological and chemical oceanographic cruises, remote sensing of marine and terrestrial productivity) and development of terrestrial and marine ecosystem models. These will finally be integrated into Earth System Models (ESM) which will have the ability to predict future climate impacts which may include ocean acidification, loss of biodiversity and productivity. The ESMs will also assist us in evaluating strategies for climate-change mitigation such as ocean fertilisation and other futuristic schemes.

a) Objectives:

(i) Knowledge/Knowledge Products: A comprehensive knowledge of the carbon cycle – sources, sinks, and biogeochemical interactions.

- Very robust estimates of regional estimates of GHG fluxes.
- A state-of-the-art earth system model which will be part of the 5th IPCC assessment.

(ii) A detailed assessment of the terrestrial ecosystem and its carbon-carrying capacity.

(iii) Instrument Systems and Technology

- A state-of-the-art GHG measurement network capable of an accuracy of 0.01 ppm CO_2 and 1 ppb CH4.
- An analysis centre with state of the art GC and Mass specs which can deliver above accuracy. The centre will ensure adherence to WMO standards.

b) Participating Institutions:

(i) Indian Institute of Tropical Meteorology, Pune
(ii) Academic and R & D Institutions

c) Implementation Plan

- A National Level Steering and Project Advisory Committee will guide the scientific studies implementation

d) Deliverables:

- Analysis of identified carbon sources, sinks, and associated terrestrial biogeochemical interactions.
- Assessment of terrestrial carbon carrying capacity
- Build all necessary instrumentation systems and technologies for the research support in India

e) Budget requirement: ` 170 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Carbon-cycle Research	20	30	40	40	40	**170**

3.3.7 IITM – Operation & Maintenance

A major HPC facility has been established at IITM with peak performance of 70.2 TF. This is not only allowing us to make state of the art seasonal prediction of the monsoon using a coupled model, it has also placed us in league with major players in seasonal prediction in the World. Under 12th Plan, it is planned to upgrade this facility to 600 TF in the next year or so to cater to the additional need of National Monsoon Mission, Climate Change Research etc and maintain it as a National Facility. The funding requirement of power, HVAC etc for 24x7 operations without down time of such a facility is significant. Operational maintenance of computer & associated infrastructure is one of the major activities that need to be attended in order to achieve the goals and objectives of the IITM. In addition to this all the laboratories need proper and timely maintenance for observational programmes required in various research projects. The other infrastructural facilities such office buildings, Seminar/ Conference/ Training Halls, residential quarters, guest house, hostel, community hall, canteen, etc. also need repairs and maintenance from time to time. IITM has expanded its infrastructural facilities by adding new office buildings and residential complex. IITM has a branch office housing a laboratory in New Delhi for the observations related to the Study of Aerosols and Atmospheric Chemistry in the area of New Delhi and North India. A High Altitude Cloud physics Laboratory at Mahabaleshwar would be set up very soon.

In addition IITM is maintaining some state of the art observational facilities such as (i) A mobile Doppler dual polarized X-Band Radar, (ii) a mobile Doppler dual polarized Ka-Band radar, (iii) a Microwave radiometer, (iv) a LIDAR wind profiler etc. These are national resources and participate in National experiments like CTCZ and special field experiments designed by IITM. In order for these equipments to provide reliable data on demand, considerable investment on maintenance and spare parts is required. Since the funds for research programmes are not sufficient to meet the expenses for maintenance of the above mentioned infrastructure a separate proposal entitled **"**IITM Operations and Maintenance**"** is proposed**.**

a) Objectives

(i) Maintenance of infrastructure for High Performance Computer System, Office buildings, laboratories, seminar/conference halls, Training hall, laboratories, residential quarters, hostel, guest house, canteen, community hall etc.

(ii) Expenses on maintenance of air-conditioning, electricity, water, phone, fax, security, house keeping, etc..

(iii) Expenses on maintenance of New Delhi Branch of IITM and High Altitude Cloud Physics Laboratory at Mahabaleshwar.

b) Participating Institutions:

Indian Institute of Tropical Meteorology, Pune.

c) Implementation Plan:

IITM will implement the maintenance of its infrastructural facilities.

d) Deliverables:

(i) State of the art computing facility for MoES scientists to meet the emerging demands of reliable weather and climate forecasts.
(ii) Data Assimilation of Ocean and atmospheric data in dynamical models.
(iii) State of art laboratory and field observational facilities at IITM in Pune, New Delhi and high altitude laboratory at Mahabaleshwar.
(iv) Maintenance office buildings and other supporting infrastructure including Institute's campus.

e) Budget requirement: ` 110 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
IITM -Operations and Maintenance	15..00	20.00	25..00	25.00	25.00	**110.00**

3.3.8 Impact of Sea Level Rise

For centuries, the coastline has been a focus for a variety of activities including industry, agriculture, recreation and fisheries. The coastline is a national heritage and in order to sustain it for future generations, proper management of coastal resources and defense is essential. The short and long term variations in sea level impact the coastal ocean in many different ways. Long term sea level rise is expected to have a significant impact on the straight coast as well as islands, barrier reefs, entrance processes of river estuaries, inlets, bays, coastal lagoons, etc, which will subsequently have a cascading effect on environmental processes of these coastal environments.

Mean sea level, on a global scale, has been increasing over the past century, approximately 1.8mm/yr due to the thermal expansion of the oceans and glacial melting. IPCC (2007) project an increase in mean sea level of between 0.18 and 0.59m by the end of the 21st century, with the possibility of an additional 0.1 to 0.2m due to ice sheet flow. This would lead geomorphic evolutionary processes on the coast, including the landward transgression of coastal barriers.

a) Objectives:

Study the impacts of sea level rise on coastal geomorphology and geometry. Some of the local scale shoreline changes especially causing erosion/accretion in the selected islands of Lakshadweep will be studied so as to explore feasible structural/non-structural protective/adaptive options

b) Participating Institutions:

(i) Integrated Coastal and Marine Area Management – Project Directorate, Chennai
(ii) Indian National Centre for Ocean Information Services, Hyderabad
(iii) Indian Institute of Tropical Meteorology, Pune
(iv) Academic and R & D Institutions

c) Implementation Plan:

(i) Assess the factors attributable to the sea level changes through a comprehensive studies
   - associated with the change in volume of the Indian Ocean basin in terms of sea water density (steric), salinity (halosteric), temperature (thermosteric) and change in mass due to glacier/ice melting (Eustatic)
   - associated with the changes to the shape of the Indian Ocean geometry due to vertical displacement of land (tectonic) and deltaic subsidence

(ii) Classify coastal environments based on tidal oscillations and using relative wave/tide energy, fluvial discharge in a temporal framework including transgression and progradation.

(iii) Studying changes in sea level and its impact on shoreline migration. Carbon dating and age determination based on bore hole samples and identifying sediment depositional trends – deriving brief overview of the Indian coastal zone based on sediment supply and geologic heritage (antecedent geology) such as Quaternary sea level history.

(iv) Beach profile measurements to study the changes in beach volume in the event of erosion caused by rise in sea level and predict the extent of loss of beaches - Sediment transport and associated models to assess the fate of lost sediments

The proposed programme is an integrated approach based on utilization of expertise from physical, chemical, biological and geological scientists together with scientists working in remote sensing and will be implemented by ICMAM-PD

d) Deliverables

(i) Development of zone-specific coastal zone circulation models and impact assessment tools
(ii) Quantification/Assessment of the factors contributing to the manifested sea level rise over the Indian Ocean and assess the associated impacts over the Indian coastline

e) Budget requirement:* ` 7 crores

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Impacts of Sea Level Rise	1.00	2.00	2.00	1.00	1.00	**7.00**

* Amount projected is part of Rs.185 cr of 3.6.5. Coastal Research

3.3.9 Studies on carbon and nitrogen biogeochemistry in coral ecosystem with reference to climate change

Eutrophication is the enrichment of nutrients in aquatic environment (organic matter increase in water), is an ongoing problem in coastal marine and freshwaters worldwide. The large loading of N and P stimulates the growth of phytoplankton, microalgae and microbial populations and processes which says the undesirable disturbance to the balance of organisms, ultimately photosynthesis exceeds

respiration. On the other hand, decomposition of the greater supply of organic matter microbial populations often result in depletion of dissolved oxygen (anoxia and hypoxia: oxygen concentration > 2 ppm) therefore, lead to an increase in marine N_2O emission in stratified bottom water to levels, which is very low to sustain fishes and invertebrates.

The coral reef ecosystem, besides facing the above situations, also to experience rise in seawater temperature due to climate change. The increases in temperature besides causing bleaching also alter the metabolic processes, which may affect the health of the corals.

a) Objectives:

To develop an ecosystem model for coral reef areas in Lakshadweep to predict likely changes of health of coral reefs in the event of climate variability especially the rise in seawater temperature and increase in anthropogenic activities

b) Participating Institutions:

(i) Integrated Coastal & Marine Area Management-Project Directorate, Chennai
(ii) Centre for Marine Living Resources & Ecology, Kochi.
(iii) Indian National Centre for Ocean Information Services, Hyderabad
(iv) Centre for Climate Change Research, IITM, Pune
(v) Academic and R & D Institutions

c) Implementation Plan:

(i) Determination of coastal circulation patterns through hydrodynamic modelling
(ii) Understanding the nutrient cycles through isotope studies
(iii) Integrating with the activities of the island and coastal ecosystem scale monitoring through environmental and GHG Flux measurements
(iv) Assess the performance evaluation of the coral health monitoring bulletins of the INCOIS
(v) Integrating with the activities of SIBER in respect of ocean biogeochemistry studies in around around island ecosystems of India
(vi) Prediction of water quality including temperature under changing environmental conditions
(vii) Inter-relationship between other fauna and flora and coral organisms.
(viii) An ecosystem model to predict health of corals under changing environmental conditions.

d) Deliverables:

Ecosystem scale Assessment of manifested climate change impacts in respect of island ecosystems

e) Budget requirement: Amount projected is part of Rs.185 cr of 3.6.5.Coastal Research

3.3.10 Reconstruction of the palaeoclimatic conditions (New)

In the present context of global warming due to climate change and climate variability a firm understanding of what has happened in the past is of paramount importance to asses futuristic trend of climate in a better way helping modelers, policy planners and economist for advance preparedness for any climate linked calamity ahead. As a sequel to the SIBER and GEOTRACES programme a number of proxies are expected to be utilized for the purpose of palaeoclimatic reconstruction from different geographic regions and at varying time scale ranging from last 10,000 years BP to Quaternary period and beyond. It is therefore proposed to induct new science component namely Paleoclimatic reconstructions using various proxies. In order to bring out a comprehensive and inclusive science component with regard to palaeoclimatic reconstructions a number of approaches / data / proxies shall be applied.

In view of the above, it is proposed to initiate new science component namely palaeoclimatic reconstructions studies using various proxies at an estimated total cost of ` 95.00 crores involving institutions across the country having expertise in palaeoclimatic reconstructions through various research projects. The year-wise phasing of projected estimates is given below.

(a) Objectives

Several Institutions and Scientists in India have actively pursued studies on the past monsoon (palaeomonsoon) variability during the Quaternary. However most of these efforts are on a sub critical level with limitations of data density, data quality, proxy validation and chronology. However, a recent synthesis clearly indicates that a direct comparison of different dataset is non-trivial on account of difficulties with chronologies and proper understanding of proxy responses. Furthermore, so far, in general landforms have so far been correlated to climate without a proper elucidation of the sediment production, transport and preservation aspects. These imply lags in their response times that are dependent on sites and parameters controlling the sedimentation. Thus, the need to create a securely dated and properly calibrated database cannot be over emphasized as only this can provide an estimate of the natural variability of the Indian climate system that is needed both for policy formulation and regional developmental scenarios. The brief objectives are provided below

(i) Identification of millennial scale changes in the southwest monsoon with emphasis on rainfall variability using high-resolution multi-proxy data from sedimentary archives.
(ii) Understanding the behavior of rainfall events i.e. the beginning and end of the wet phase.
(iii) Evaluation of flood chronologies (extreme events) of large rivers through time and their relation to climate.
(iv) Interdependence of lake and river responses of large rivers.
(v) Estimation of human impact on lake and fluvial systems, and its consequence on agriculture and mining through their influence on landscape dynamics.
(vi) Expansion and contraction of desert and desert margins and climatic implication of archeological remains within the region.
(vii) Development of new palaeoenviromental tools such as calcareous tufa, molecular proxies, .

(viii) Understanding of processes and time scales of soil formation in relation to climate.

(b) Participating Institutions

(i) Indian Institute of Tropical Meteorology
(ii) National Centre for Antarctic & Ocean Research
(iii) Various academic / R & D institutions of the country

(c) Implementation Plan:

(i) Geophysical survey with GPR and selection of core sites. Collection of undisturbed cores.
(ii) Generation of multi-proxy climate data using sedimentology, micropalaeontology, palynology, clay minerals and isotope geochemistry. Developmentof new proxies from varves, phytoliths, ostracods, pollens, dinoflagellates, diatoms, mineral magnetics, clay minerals, grain sizes, isotopes.
(iii) Study of various trace elements in the shells of various micro-fossils to derive paleotemperature equation for region specific.
(iv) Study of marine sediments, lake sediments riverine sediments and cryospheric samples of past ice from Himalayan and polar regions.
(v) Dendrochronology
(vi) Study of cosmogenic nuclids (such as 10Be and other feasible nuclids)as palaeoclimatic tool
(vii) Chronology using accelerator mss spectrometric radiocarbon dating, ^{210}Pb, ^{137}Cs and luminescence dating techniques.
(viii) Logging and river profiling for palaeoflood analysis; Geomorphic mapping and DEM generation using satellite images and image processing.
(ix) Drilling and coring of lakes (to a depth of ~ 20m).
(x) Sedimentology, mineralogy and stable isotope composition of carbonate and organic fractions.
(xi) Mineral magnetic studies.
(xii) Sediment provenance studies using Sm/Nd, Rb/Sr systematics.

(d) Deliverables:

High-resolution subsurface stratigraphy, core raising and preparation of palaeoclimatic database on sediment characteristics, microfauna and flora, geochemistry, stable isotope, chronology, effect of shoreline shifts on human occupation in this part of the land.

(e) Budget: ` 95.00 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Reconstruction of the palaeoclimatic conditions	25.00	20. 00	20.0	15.00	15.00	95.00

3.3.11 Cryosphere Processes and Climate Change (CryoPACC)

Objectives

(i) To study the fundamental processes involved in the biogeochemical cycling (measurements of processes and factors influencing the same) within the snow packs as well as during the subsequent transformation to firn and ice in the polar and other region and elsewhere.
(ii) To study the biotic components in the cryosphere responsible for meditating the exchange processes.
(iii) To study the glaciological processes, accumulation patterns and snow layering characteristics for understanding the fundamental processes influencing the temporal records of ice.
(iv) To reconstruct the environment variables like temperature, precipitation, aerosols, and sea ice conditions during the past 200-2000 years with annual to sub-annual resolution to better understand the recent climate change in polar/tropical region and their global teleconnections.
(v) To decipher the role of various internal and external forcing mechanisms on polar and global climate on a decadal centennial and millennial time scales.

Justification for the proposal:

The global warming and the associated loss of global ice cover are leading to large environmental changes. However, our knowledge of the functioning of the cryosphere within the global climate system and its spatial and temporal complexity is relatively less known. To identify the role and response of cryospher system in global climate change, it is vital to carry out long-term climate data. Such studies are best conducted using proxy records obtained from ice sheets. In fact, ice core studies have become a keystone of research into climate and biogeochemistry during the last several hundreds to thousands of years. In order to obtain more accurate and better climate information from proxy based studies, it is essential to have a sufficiently detailed and fundamental understanding on the biogeochemical processes involved in the air to snow transfers. Additionally geophysical and glaciological studies would help in understanding the quantitative interpretation (inversion) of ice core records.

Ice core records are best known for the unprecedented information they have provided of climate and climate forcing on long timescales-millennial and longer. However, one of the major requirements climate change research is the production of high resolution (at least annual) data of sufficient quality to be used in quantitative studies of climate variability and in determination of changes in climate forcing. Some of the most valuable ice core records are obtained from Antarctica. In order to obtain more comprehensive understanding of climate change, it is also required to have climate records from Arctic region and Himalayas in addition to the Antarctica.

Budget: ` 23 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Cryosphere Processes and Climate Change (CryoPACC)	8	7	3	3	2	23

3.3.12 Cryosphere Studies in Himalaya

The Cryosphere is the second largest component of the climate system, after the ocean, that stores about 75% of the world's freshwater. In terms of the ice mass and its heat capacity, therefore, it plays a significant role in the global climate. The Himalaya forms the most important concentration of snow covered region outside the polar region. The Himalayan glaciers are highly sensitive to the on-going warming. The detailed glacier inventory of Indian Himalayas (GSI, SAC) indicates presence of 9579 glaciers in the Himalaya, some of which form the perennial source of major rivers. Changes in glaciers are one of the clearest indicators of alterations in regional climate, since they are governed by changes in accumulation (from snowfall) and ablation (by melting of ice). The difference between accumulation and ablation or the mass balance is crucial to the health of a glacier.

a) Objectives

(i) To study the dynamics and the rate of change in glaciers to understand its impact on hydrology, ecology and climate;
(ii) To assess the climate change using ice as an archive of information on past climate and its future implications.
(iii) To study the biogeochemical aspects of Himalayan ice and compare it with the polar environment.

b) Participating Institutions

(i) National Centre for Antarctica and Ocean Research, Goa
(ii) India Meteorology Department. Delhi

c) c) Implementation plan

(i) Identification of a few type glaciers such as Chota Sigri, Hamta and others for which some previous glaciological data are available, for detailed glacial assessment and mass balance studies.
(ii) Establishing AWS (in association with IMD) and Observational huts at the areas close to the snout of the glaciers for monitoring purposes, conduct geomorphological mapping of glacial landforms.
(iii) Undertake airborne and ground GPR surveys over the above and below the ELA and conduct drilling for retrieving ice cores at selected sites, conduct sampling for TL/OSL,AMS dating to establish chronology of retreat of glaciers
(iv) Monitor the seasonal snow cover with the help of satellite remote sensing data, collect winter and summer snow samples to study variation in pattern, size, and chemistry of the aerosol and particulate matter on the snow surface

d) Deliverables

The glaciological studies comprising mass balance, GPR profiles and snow cover assessment, conducted over a sufficient length of time will reflect the health of the glaciers. Glacial melt streams and run off thereof would give important feedback to the hydrological system.

e) Budget requirement: ` 70 crores

Name of Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Himalayan Cryosphere Studies	20.00	15.00	15.00	10.00	10.00	**70.00**

3.3.13 Long-term monitoring of the Konfsfjorden system in the Arctic for climate change studies

Kongsfjorden, an icy archipelago having a length of about 40 km and width ranging from 5 to 10 km, is a glacial fjord in the Arctic (Svalbard). It lies in the northwest coast of Spitsbergen, the main island of Svalbard, and is a site where warmer waters of the Atlantic meet the colder waters of the Arctic. Being an open fjord without sill it is largely influenced by the processes on the adjacent shelf. The Transformed Atlantic Water (TWA) from the west Spitsbergen current and the glacier-melt freshwater at the inner fjord creates strong temperature and salinity gradients along the length of the fjord. Southerly winds will produce down-welling at the coast and cause hindrance on exchange processes between the shelf and the fjord, while the northerly winds will move the TWA water below the upper layer towards the coast. The melt water during summer not only stratifies the upper water column but significantly alters the turbidity. This would have profound influence on the seasonality in the phytoplankton biomass and primary production. Thus, an altered interaction between the Atlantic water with the (turbid) melt waters from tidal glaciers on a seasonal to inter-annual time-scale is likely to affect the pelagic ecosystem in the fjord. Alternately, the benthic ecosystem is more likely to be affected by long-term changes in the fjord hydrography and sedimentation.

Ever since India commenced her scientific activities in the Arctic realm, one of the major locales of study has been the Kongsfjorden system. Considering the scope of scientific research the locale afforded and the fact that an integrated study of the fjord has been has been identified as a flagship program of the Svalbard Research Program (SSF), NCAOR in consultation with the Norwegian Polar Institute (NPI) began exploring the feasibility of initiating a major long-term program on the fjord during 2009-10. The basic background data collection on the hydrodynamic, hydrochemical and biological characteristics of the fjord were initiated by NCAOR during the summer of 2010. The encouraging results of the initial data collected and the positive response by the NPI to India's proposal has culminated in the plans to implement the studies as a long-term national programme.

a) Objectives:

The overall objective of the studies planned is to establish a long-term comprehensive physical, chemical, biological and atmospheric measurement programme aimed at understanding:

(i) The variability in the Arctic/Atlantic climate signal by understanding the interaction between the freshwater from the glacial run-off and Atlantic water from the west Spitsbergen current.

(ii) The effect of interaction between the warm Atlantic water and the cold glacial-melt fresh water on the biological productivity and phytoplankton species composition and diversity within the fjord.
(iii) The winter convection and its role in the biogeochemical cycling.
(iv) The trigger mechanism of spring bloom and its temporal variability and biomass production.
(v) The production and export of organic carbon in the fjord with a view to quantify the CO_2 flux.

b) Participating Institutions:

National Centre for Antarctic & Ocean Research, Goa

c) Implementation Plans:

It is proposed to implement the programme under the aegis of NCAOR and NIO from the Indian side and the NPI from the Norwegian side. The deployment of the mooring and its maintenance shall be done in concert with and by NIOT/INCOIS. One ocean-atmosphere mooring will be deployed in the central region of the Kongsfjorden fjord for long-term measurement. The mooring is proposed for an initial 5-year period which will be extended for another 5-year after assessing the performance. This will help addressing the climate change issues.

d) Deliverables:

The scientific studies proposed will contribute significantly to the global community's ongoing efforts in understanding the climate change phenomena in the Arctic as well as the ecosystem responses if any, to short-term climatic variabilities..

b) Budget requirement: ` 57 crores

Name of Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Long-term monitoring of the Konfsfjorden system in the Arctic for climate change studies	11.00	11.00	16.00	7.00	12.00	**57.00**

3.4 AIRBORNE PLATFORMS:

It may be mentioned that except Indian Ocean basins, the aircraft reconnaissance flights have been successfully operated in major cyclone basins of Atlantic, Pacific and Australian region. An actual flight by an aircraft into and around the cyclonic storm during various stages of its development and movement provides invaluable data for studying and understanding the structure and movement of a storm, thus improving the accuracy of track prediction to a great extent. Studies taken up in USA, Japan and Australia have shown that inputs generated by aircraft improve track prediction errors by as much as 30%. A number of experiments in recent years have established that weather predictions can significantly be improved by adoptive sounding – choosing the best time and place based on the atmospheric state to

generate most accurate and direct observations from the cyclone environment using efficient aircraft probing technologies.

The positive results in Indian Institute of Tropical Meteorology (IITM)'s past cloud seeding experiments have been taken as the basis for carrying out the operational programmes. There are many factors which limit the use of these results in the present scenario. During the past 30 years, after the IITM's experiments, there are large changes in the atmospheric constituents due to anthropogenic activities and increase in pollution (aerosols) levels.

In this situation there is a strong and urgent need for a definitive and authoritative conclusion to be drawn primarily for the scientific reasons to understand different pathways and secondarily to provide science based guidance to state governments and other social organizations who consider seeding as a solution to mitigate the drought conditions. IITM undertook a national multi year experiment "CAIPEEX" to address above referred issues by hiring an aircraft for such studies.

A need for long term measurements in respect of Aerosol sampling, measurement of cloud properties, cloud physics, CTCZ, atmospheric chemistry etc. is strongly felt by the research community in this country to address all relevant scientific issues for improving the treatment of rain making processes in the monsoon environment in particular and other cloud-aerosol-radiative feedback mechanisms associated with the climate variability and change over India in times to come.

a) Objectives:

(i) Establishment of APC facilities of the cyclone core environment to address critical data gap for cyclone predictions

(ii) Planning observational campaign for the advancement of R&D efforts in cyclone forewarning (up to 200-250 days per year, including such cyclonic disturbances formed during the monsoon season, pre-monsoon thunderstorm events in eastern India – Kalbaisakhi in addition to Cyclone Seasons (May; Oct-Nov) – and the collect dropsonde observations for studying of other high impact weather phenomena over land)

(iii) Airborne Doppler Weather Radar for identification of heavy rainfall and strong wind zones (cyclone/flood/heavy rainfall impact assessment)

(iv) The APC Facility can also be used for the study of monsoon systems in South Asian countries, the Effects of Climate Change Research and for Defence Applications as well.

(v) To provide crucial data on Atmospheric Chemistry, aerosol and Cloud microphysics required for understanding aerosol-cloud interaction and parameterization of tropical clouds.

b) Participating Institutions:

(i) Indian Institute of Tropical Meteorology, Pune;
(ii) India Meteorological Department, New Delhi

c) Implementation Plan:

National Committees are constituted for the finalization of the DPRs for the establishment of the Airborne Research Facilities for India

d) Deliverables:

(i) Establishment of National Research Airborne Platform for Aerosol sampling, measurement of cloud properties, cloud physics, CTCZ, atmospheric chemistry etc.
(ii) Establishment of Aircraft Probing of Cyclone Facility to generate critical observations from the cyclone core environment

e) Budget requirement: ` 700 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Airborne Platforms	70	200	250	80	100	700

3.5 OCEAN OBSERVATION NETWORKS:

Ocean observing system has a central role to deliver the ocean services to the society. The data from observing systems is also necessary for assimilation in ocean general circulation models. Ocean observations also facilitate fundamental research on

(i) determining the role of ocean on climate and climate change'
(ii) quantifying the exchange of heat, water, momentum and gases between the ocean and atmosphere;
(iii) determining the cycling of carbon in the oceans and the role of the oceans in moderating the increase in atmospheric carbon dioxide;
(iv) in improving the ocean general circulation and mixed layer models;
(v) understanding the patterns and controls on biological diversity in the oceans;
(vi) determining the origin, development and impact of episodic coastal events such as harmful algal blooms;
(vii) assessing the health of the coastal ocean; and
(viii) determining the nature and extent of microbial life in the deep crustal biosphere.

3.5.1 Moored buoys, drifting buoys, current meters, etc. (Continuing)

The observation platforms are required for ocean state forecast and weather prediction. The newly proposed ocean observation systems shall provide richer and more accurate time series data sets which are difficult to build with moving/oscillating platforms. NIOT has an experience in developing Sea Bottom or Ocean Bottom Pressure Recorder and time series observations using moored buoy network. Expertise developed and the knowledge gained would be useful to develop such new instruments. These technologies developed will have spinoff in other activities like surveillance in the ocean and these would be unmanned, unattended and self powered automated ocean observation system. The systems proposed have the following advantages

- Long Term, Unattended, Multi Parameter observations
- User Specified Sensors fit

- Integration with any Cabled Underwater Observatory
- Deployment as Completely Autonomous, Standalone System
- Coastal, Continental Shelf, and Deep Ocean Configurations

a) Objectives:

(i) To collect marine meteorological and oceanographic data using moored Met-Ocean buoy systems and to disseminate data to INCOIS.
(ii) To collect water level data in deep sea using Bottom Pressure Recorder(BPR) and disseminate data to INCOIS for Tsunami Early Warning System
(iii) To calibrate and validate sensors and buoy (Met Ocean & Tsunami) systems
(iv) To maintain HF Radar sites installed along Indian coast.
(v) Develop and Demonstrate proto type underwater observation systems, platforms and devices
(vi) To establish INSAT communication dedicated specifically for real time communication of ocean observation systems

b) Participating Institutions:

(i) National Institute of Ocean Technology, Chennai
(ii) Indian National Centre for Ocean Information Services, Hyderabad.

c) Implementation Plan:

The trend to develop fully automatic observing systems, using new observing and information technologies will continue; Access to real-time and raw data will be improved; Observing system test-beds will be used for inter comparison and evaluation of new systems and development of guidelines for integration of observing platforms and their implementation; and Observational data will be collected and transmitted in digital forms.

Presently the ship to shore communication is done using Inmarsat-C terminals. There is a need for more bandwidth from Indian satellites covering the sea which can support two way communications for ship to shore. This will reduce dependence on foreign satellites for strategic communication and also for commercial shipping. Thus a satellite communication independently for ocean observation systems is very much required.

Continuation of observational program on long term basis such as next two decades (20 years period) to obtain continuous data and to serve the nation technologically as well as to represent India among the international technical bodies by deploying and maintaining the moored buoys, augmented with sensors, in the Indian seas.

Maintaining tsunami buoys and Bottom pressure recorder as a part tsunami early warning system and establishment of an Optimal Tsunami Buoy Network in Indian Seas.

Maintaining HF radars and disseminate online data from HF radars on surface currents and waves along Indian coast.

The following activities to be taken up:

- Calibration of sensors and buoys to obtain the quality data
- Technology Demonstration of Moored Sea Bed Observatory (MSO)
- Proto type development of Fixed Offshore Reference Platforms (FORP)
- INSAT Communication for Ocean Observation Systems
- Development and testing of materials for ocean observation systems

The buoy, sensors and mooring system will be procured from the Indian and foreign vendors appropriately. The tsunami buoy systems consist of two units – a surface buoy and the Bottom Pressure Recorder (BPR). Communication between BPR and the surface buoy is established through acoustic modems and surface buoys uses satellite to communicate the recorded values to shore station. The inspection of individual component, testing, Integration of the buoy will be executed at NIOT. Periodic cruises will be taken up on-board vessels to deploy and to conduct service and maintenance of these buoys systems.

The basic design and site selection will be done in-house. The sensor and critical components required will be imported. The system integration will be performed in-house. After the component level testing, new sensor testing and integration, initial trials will be conducted in shallow waters. Subsequently, on the basis of the inputs and data collected, system will be tested for short duration in deep waters. Newer materials for moored buoy systems would be tested and developed through Inter-Institutional projects. In house calibration facility for met-ocean sensors would be established. This also involves larger capacity building exercise as this work requires special expertise and dedicated manpower. Newer R&D projects in design and development of ocean observation systems would be undertaken through collaboration with other Institutions in India and abroad under the Inter institutional projects.. NIOT is in the process of establishing Sea Front facility and it is proposed to establish OOS laboratory for testing and calibration. This facility will help to execute other new programmes envisaged earlier such as Reference Platform, Moored Sea bed observatory, Fixed Offshore Reference Platforms (FORP) etc., This Coastal Ocean Observing system Laboratory will be useful for the assembly, data reception, service, and storage and maintenance facility and also for field testing of indigenously developed equipment.
Dedicated INSAT communication will be established in collaboration with ISRO

d) Deliverables:

(i) Real time data on meteorological and oceanographic parameters from moored buoys and tsunami systems.
(ii) Underwater observation systems, platforms and devices.

e) Budget requirement: `.386 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Moored buoys, Drifting buoys, etc.	60	70	90	80	86	386

3.5.2 Bio-geochemistry (Continuing)

Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER) and Geotraces programme, for a period of 5 years, were launched in FY 2010-11. Due to limited fund availability under concerned budget head, all science components of this National programme could not be initiated at the same time and only prioritized science component were provided financial support.

The scientific component of the National Programme "*Sustained Indian Ocean Biogeochemical and Ecological Research* (SIBER)" and GEOTRACES are linked with time series experiments. These scientific activities are likely to be continued in the second half of the 12 Plan period as well and this programme may also include some new science component, such as palaeoclimatic reconstructions using various proxies.

a) Objectives:

(i) To set up time-series stations for bio-geochemical and ecological research.

(ii) To identify the processes, quantify the fluxes that control the distribution of key trace elements and isotopes in the Indian Ocean, Arabian Sea and part of Southern Ocean and to establish the sensitivity of these distributions to changing environmental conditions.

SIBER (India)

The objective of the proposed *sustained* Indian Ocean Biogeochemical and Ecological Research (SIBER) national programme will be to put on place time-series stations of the same quality as the BATS (Bermuda Atlantic time Series) in the Atlantic Ocean and HOT (Hawaii Ocean Time Series), in the Pacific Ocean.

GEOTRACES (India)

The objectives of GEOTRACES (India) programme are to identify the processes, quantify the fluxes that control the distribution of key trace elements and isotopes in the Indian Ocean, Arabian Sea and part of Southern Ocean and to establish the sensitivity of these distributions to changing environmental conditions.

Dedicated sensor for Biogeochemical observations to be deployed through various mooring

SIBER and GEOTRACES programme requires continuous oceanographic data for better understanding the bio-geochemical processes occurring in Northern Indian Ocean (BOB, AB and Indian Ocean). NIOT/INCOIS are already in the process of installing few moorings in these regions at different specific locations which can by additionally provided specific sensors catering to the requirement of data collection useful for SIBER and GEOTRACES programme's objectives on a long term basis. In order to cover the entire area we may require about 10-15 such sensors at different locations. The financial implications of these sensors is included in the financial projection in Table given at the end of the document

Studies on Nitrogen

Increasing Nitrogen pollution in coastal & marine ecosystems, in ground water and in the atmosphere is the outcome of the leakages of N compounds from farm and fuel

consumption processes humans engage in order to meet the growing demands of food and industrial development. This cascading of Nitrogen into coastal and marine waters is bound to rise and is unstoppable because of the pressure to increase fertilizer application to grow more food and to consume more fuel to meet the spiraling demands of the growing population.

Available data on reactive N in the Indian environment is scarce and therefore simulation of N cycle is not possible adequately. A coordinated program of measurement, research and modeling to enable backward integration of N flow rates through the land-air-ground water-stream-river-coasts-estuaries-ocean continuum in the Indian sub-continent is very essential. The above integration coupled with the knowledge of the regional estimates of current levels of reactive nitrogen, quantification of assimilation capacity and thresholds of various ecosystems to the rising N values and loading rates based on various development/policy scenarios will enable us to set up the necessary decision support system to learn how quickly the carrying capacity of the marine and coastal environment may be breached. An integrated research component to understand the dynamics and processes of Nitrogen cycle in different environment shall be initiated during XII Plan period under over all SIBER/GEOTRACES programme which has already been initiated.

b) Participating Institutions:

(i) National Centre for Antarctic & Ocean Research, Goa
(ii) National Institute of Oceanography, Goa
(iii) Physical Research Laboratory, Ahmedabad
(iv) Indian National Centre for Ocean Information Services, Hyderabad

c) Implementation Plan:

The time series experiments would be undertaken by NIO and PRL, while the paleo-reconstruction studies utilizing proxy indicators would be taken up by NCAOR and PRL. A clean chemistry lab is proposed to be established at NCAOR for the GEOTRACES component of the program. NCAOR would be the archival agency for all the data emerging out of the program.

The participating institutes shall be shouldering responsibilities to generate data of their specific science component from open ocean region. The companion projects will provide complimentary information from coastal areas. The SIBER/GEOTRACES programme is envisaged as the National multi-institutional and multi-disciplinary research programme of the MoES where various institutions / Universities would participate in this Programme from time to time. All participating organizations / Universities shall submit their regular inputs to the lead agency. A review and monitoring committee shall be constituted by MoES for regular review and Mid Term Correction (it any) during the period of implementation of these programmes.. INCOIS Hyderabad will host all data generated by Participating institutes through this Programme. The scientific description of the programme is given below.

(1) Two open ocean time series locations have already been identified: At the Arabian Sea location a sediment trap/current meter mooring is already deployed; the Bay of Bengal site is the same as that chosen by INCOIS for the Bay of Bengal Observatory. It is planned to deploy another sediment trap mooring at this site. These sites will be visited at frequent intervals using research ships. Underway measurements (especially of pCO2) will be carried out on all cruises. These will

provide data needed for refinement of estimates of air-sea fluxes. It may be pointed out that current estimates of CO2 emissions from the region vary widely: from 7 to 94 Tg C yr1 for the Arabian Sea; the available data are even more sparse from the Bay of Bengal, and it is still not quite certain whether the Bay serves as a net source or sink of CO2. Time series sampling at each site for process studies will initially last for 4-6 days, but longer sampling period may be necessary if and when more investigations are added to the programme.

The core measurements will include temperature, salinity, dissolved gases (oxygen, nitrous oxide and dimethy1 sulphide), nutrients (nitrate, nitrite, ammonia, phosphate, silicate, total nitrogen, total phosphorus), dissolved inorganic carbon, dissolved and particulate organic carbon, alkalinity, biogenic silica, choroghy11 and other phytoplankton pigments, phytoplankton composition (size fractionation and biomass), primary production (including new production), bio-optics, zooplankton biomass (meso and micro) and composition including grazing experiments, bacterial and viral abundance and production rates. Studies on effects of hydrodrological factors on viral population will also carried under this programme.

The moorings will include current meters and some specialized equipment (e.g. smart samplers and, if possible, nutrient analyzers) to get higher resolution data during the intervening periods.

(2) Data collection and Management: The programme will generate volumes of data. There would be provisions for quality control of the data and a proper policy in place for data submission, storage and access. The core data will be accessible to all PIs within a reasonable time (as decided by MoES) after collection.

(3) Samples: There will be a well thought out and agreed upon sampling strategy. Many samples may have to be shared among various PIs, and provision must be made to collect adequate amount of samples for such multi-disciplinary studies

d) Deliverables:

Significant deliverables expected from the studies include (i) an understanding of the processes that govern the spatial and temporal distribution of key trace elements and isotopes in the seas and ocean surrounding the Indian landmass as well as in the Indian Ocean sector of the Southern Ocean, and (ii) the responses of these key traces to changing environmental conditions.

e) Budget requirement: ` 100 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Bio-geochemistry	20.00	20.00	120.00	20.00	20.00	100.00

3.6 OCEAN SCIENCE AND SERVICES (CONTINUING)

The Ocean Science and Services mission aimed at providing a wide range of ocean information services to various sectors like fisheries, shipping, ports, offshore industry, academia, coastal states and island development authorities. The generation of ocean information services involves archival and integration of real-time data acquired from a network of both *insitu* and remote sensing platforms, and

through running of a suite of global and regional ocean models using the state-of-the art computational facilities.

3.6.1 Integrated Ocean Information Services

The achievements of PFZ and Ocean State Forecast programmes are highlighted in the recent study of National Centre for Economics and Applied Research revealed that ~ 90% fishermen in Tamil Nadu and 64% fishermen in the eastern states, Andhra Pradesh and Orissa, are aware of and are utilizing these advisories together with the ocean state information. The study further stated that the total annual net economic benefit due to the scientific identification of PFZs based on satellite information is estimated to lie in the range of Rs. 34,000 to 50, 000 crores. INCOIS operationalised advisories on Tuna species based on satellite derived SST, Chlorophyll, water clarity and model based mixed layer depth.

Currently, the wave forecasts are provided on a spatial resolution of 25x25 km grids and the other parameters (SST, MLD, etc.) on 1/8°x1/8° grid (ie. ~ 13 km resolution). In addition to providing the forecasts on aforementioned parameters, INCOIS also set up operational tidal predictions (tidal elevation) at 137 major and minor ports along the Indian region. Another useful service, named ‘high wave alert’ is found to be highly useful for the coastal community.

Considering thermal stress as an indicator, coral health bulletins are issued bi-weekly indicating the hot spot composites (early signs of bleaching), degree of heating weeks (DHWs) (intensity of bleaching) and time series satellite observations. Currently, this service covers the coral environs of the Gulf of Kachchh, Gulf of Mannar, Lakshadweep and Andaman and Nicobar Islands.

Currently, INCOIS data bank holds ~ 17,00,000 records of in situ data. Other notable achievements are in the improvements in the generation and archival of satellite data downloaded them daily using the ground station at INCOIS as well as the data downloaded from elsewhere (current holdings of satellite data is ~ 5 TB) and the preparation of special data products (Argo data CD that has ~ 1,40,000 temperature and salinity profiles obtained during 2001 – 2010).

An important achievement in the dissemination is the development and deployment of new generation electronic display board (EDB) that communicates with the server in INCOIS and automatically obtains the necessary information (PFZ advisories and ocean state forecast) relevant to the location where it is installed. During the XI plan, INCOIS installed ~ 100 new EDBs at various locations along the Indian coast.

Several projects involving coastal geospatial applications were carried out during XI plan to identify the changes in shorelines of Lakshadweep Islands, mapping of coral reefs and for the preparation of coastal vulnerability index (CVI) maps. The CVI maps at 1:100000 scale for the entire coastline of India including Andaman & Nicobar and Lakshadweep Islands and the maps of coral reef in the Andaman & Nicobar Islands are near completion

a) Objectives:

(i) To generate, archive and provide data and value added data products to user communities.

(ii) Sustain and improve the Potential Fishing Zone (PFZ) advisories and Tuna Fishing Zone advisories, Ocean state forecasts, coral reef health bulletins, data products, etc.
(iii) Operationalise the improved WWIII, ROMS and other models for more accurate forecasts of ocean waves, currents, SST, etc.
(iv) Set up a state-of-the-art 'Ocean Data Processing Lab' and the development of 'Digital Ocean' that will allow the users to examine, view and experience the ocean on 4D.
(v) Develop, maintain and improve INCOIS website and Ocean portal.
(vi) Data search and rescue - Digitization and archival of available old records to update Indian Ocean Hydro Base (IOHB) and development of distributed *in situ* data network.
(vii) Setting up of special data centre for OBIS and development of tools for data processing, quality checking and dissemination.
(viii) Install 100 new Electronic Display Boards (EDB) and integrate them with INSAT communication system to enhance dissemination of PFZ, ocean state forecast and disaster information.
(ix) Conduct user interaction and awareness campaigns – reach out to new user groups and users.
(x) Prepare upgraded CVI maps at 1:50,000 scale (Version2).

b) Participating Institutions:

Indian National Centre for Ocean Information Services, Hyderabad.

c) Implementation Plan:

Data and modeling being the kernel for information and forecasting services, concentrated efforts will be made to improve the quality of data sets and accuracies of existing models. In addition, new models will be developed to location specific, parameter specific forecasts.

The cloud contamination of satellite data limits its usage for the generation of PFZ advisories. To address this issue, high resolution modeling utilizing the available high resolution data will be taken up.

Forecast of ocean parameters, (waves, currents, SST, etc) near the coast and the seas around India, has become a necessity for safe navigation and other marine activities. This requirement will be met through the improvements to the existing ocean models and improved dissemination systems.

Data management and information generation and their dissemination will be improved through new technology and enhancement in observing systems.

d) Deliverables:

Regular advisories to fishermen on the potential fishing grounds, tuna fishing grounds, ocean state forecasts for the benefit of fishing, navigation, marine industries, etc.

Data archival, data products and dissemination

CVI maps of the Indian coast at 1:50000 scale

Regular advisories on the health of coral reef, harmful algal blooms, etc.

Training to users and policy makers on how to use the advisories, data and data products

e) Budget requirement:` 73 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Integrated Ocean Information Services	15.00	16.00	15.00	14.00	13.00	73.00

3.6.2 Early warning system for tsunami and storm surges

The tsunami on December 26, 2004 has been one of the strongest in the world and the deadliest of all time by an order of magnitude. The Indian tsunami early warning centre was operational from 15 October 2007. It has now become Regional Tsunami Service Provider (RTSP), and will provide advisories to the Indian Ocean Rim countries.

a) Objectives:

(i) Detect, locate, and determine the magnitude of potentially tsunamigenic earthquakes occurring in the Indian Ocean and provide timely advisories on 24x7 basis.
(ii) Maintain the core observing systems (2-4 BPRs & 21 tide gauges and communication systems for data transmission)
(iii) Real time tsunami modeling and inundation mapping
(iv) Enhancement of DSS application & other associated elements for RTSP, etc.
(v) R & D on probabilistic tsunami hazard assessment.
(vi) Development and implementation of multi hazard (storm surge) forecasting service.

b) Participating Institutions:

(i) Indian National Centre for Ocean Information Services, Hyderabad
(ii) National Institute of Ocean Technology, Chennai
(iii) Integrated Coastal & Marine Area Management-Project Directorate, Chennai.

c) Implementation Plan:

INCOIS will be responsible in automatic detection of earthquakes and for issuing the tsunami warnings and also for the deployment and maintenance of tide gauges along the Indian coast. NIOT will contribute by way of deploying and maintaining the bottom pressure recorders and ICMAM will provide the support in modeling.

d) Deliverables:

INCOIS will issue early warning, etc as and when required

e) Budget requirement: ` 100 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Early warning system for tsunami and storm surges	15.00	20.00	25.00	20.00	20.00	100.00

3.6.3 Ocean Research and Modelling (Continuing)

SATCORE programme aims long-term measurements of bio-optical properties in the Indian coastal waters at 9 locations covering both the Arabian Sea and the Bay of Bengal. While continuing the research and data collection programme on ocean colour, during the XII plan it is also planned to expand the scope of SATCORE to satellite derived sea level measurements and their usage. The satellite altimeter that measures the sea level slopes and hence the geostophic currents in the sea are proved to be useful to study the ocean currents. Together with the Argo data and models it is possible to generate the maps of absolute ocean currents in the coastal as well as open ocean regions with a reliable degree of accuracy. Such a product of ocean currents with sufficient accuracy has potential applications in optimal ship routing, tracking the oil spills, estimation of oceanic heat transport that affects the climate change due to its influence on ocean and atmospheric circulation, etc.

The INDOMOD programme was designed to encourage the researchers in the universities and other academic institutions in the country to take up the research projects for the development of ocean models were extremely successful in developing the much needed capacity in the development and handling of ocean models. Some of them succeed in process studies and identifying the dynamics of the phenomenon observed in the Indian Ocean.

a) Objectives:

(i) Continue the bio-optical measurements at existing time-series stations and set up new stations in the Indian coastal waters.
(ii) Validation and development of new algorithms for the retrieval of geophysical parameters from ocean colour sensor on board satellites Oceansat, MODIS, validation of altimeter derived sea levels in the coastal waters using bottom pressure records and tide gauges
(iii) Analyze the effect of atmospheric turbidity and aerosol size distribution on radiative transfer to improve the atmospheric corrections of satellite data.
(iv) Modeling of primary productivity using *in situ* and satellite data.
(v) Development of operational ocean current products for their assimilation in high resolution coastal ocean models and development of algorithms to obtain the river discharges using altimeter, especially SARAL/Altika data.

(vi) Generation of near real time fields of Cyclone Heat Potential for the North Indian Ocean using altimeter, Argo and Hycom model.

(vii) To support the research groups/researchers in constructing/developing ocean models for the operational forecast of ocean parameters in improving the understanding of dynamics and thermodynamics of Indian Ocean, and understand and model the tsunamigenic earthquakes and tsunami propagation models.

b) Participating Institutions:

Indian National Centre for Ocean Information Services**,** Hyderabad.

c) Implementation Plan:

Programme will be implemented by INCOIS and in partnership with universities and other institutes. Other institutes and universities will be engaged in the routine measurements.

d) Deliverables:

New algorithms for the accurate/improved retrievals of ocean parameters using satellite data

Ocean models to understand and predict the process in the Indian Ocean

Enhancement of our knowledge on the working of Indian Ocean and understanding the role of ocean in sustaining the monsoonal activity over

e) Budget requirement: ` 75 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Ocean Research and Modelling	15.00	15.00	15.00	15.00	15.00	75.00

3.6.4 INCOIS –Operations and Maintenance (Continuing)

Operations & maintenance of computing infrastructure, communication facilities, electrical installations and web based services including its human resource is major activity that continued since its inception in 1999

Operational maintenance of computer & associated infrastructure including its human resource is major activity that continued since its inception in 1999.

During the XI plan, INCOIS recruited 14 scientists, 17 scientific assistants and 07 administrative assistants and 01 Accounts Officer. At present, the strength of permanent manpower is 53. Of this 24 are scientists and 10 of them hold Ph.D. degrees. In addition INCOIS also employees 44 project scientists and project assistants on temporary basis under various projects. In addition, MoES has sanctioned 10 new permanent positions of scientists for INCOIS. The call for applications and the recruitment process is in progress. Similarly, over the past

years, INCOIS has also developed fine estate to house the human resource, computer infrastructure and communication systems.

a) Objectives

(iv) Management of human resources (salary and travel, LTC, medical, etc.)
(v) Administration of the institute (expenses on postage, stationary, consumables, payment to consultants/resource persons hired for specific purposes, honorarium for committee members, etc.)
(vi) Operational and maintenance of real estate and buildings (expenses on maintenance of air-conditioning, electricity, water, phone, fax bills, security, housing keeping, etc.)
(vii) GOOS secretariat & contribution towards membership to various agencies.

b) Participating Institutions:

Indian National Centre for Ocean Information Services, Hyderabad.

c) Implementation Plan:

INCOIS will implement the management of human resources, upkeep and maintenance of estate and buildings, etc.

d) Deliverables:

Operations, maintenance and augmentation of computing, communication, electrical and web based services that are necessary for the operational and research activities of INCOIS.

Cohesive management of INCOIS activities, maintenance of buildings and infrastructure

Facilitation of the implementation of operational and scientific projects

e) Budget requirement: ` 195 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
INCOIS – Operations and Maintenance	26.00	74.00	28.00	31.00	36.00	195.00

3.6.5 Marine Living Resources Programme (MLRP)

Marine Living Resources Programme (MLRP) is proposed to be implemented as continuing multi-institutional scheme with CMLRE-Kochi as the lead agency. During the XII plan period, the focus will be on the development of output products in the form of models, information system and advisories. Major topics to be addressed include:

(i) Monitoring and Modeling of the Marine Ecosystems (MMME)
(ii) Harmful Algal Blooms (HAB)

(iii) Study on Marine Benthos (Benthos)
(iv) Assessment of Deep-Sea and distant water fishery resources (DSDWFR)
(v) Southern Ocean MLR (SO-MLR)
(vi) Integrated Taxonomic Information System for Indian Ocean (ITIS-IndO)
(vii) MLR Technology development (MLR-TD)
(viii) Operation & Maintenance
(ix) MLR – Drugs from the Sea

3.6.5.1 Monitoring and Modeling of Marine Ecosystems (MMME)

Besides continuing with the ongoing projects on monitoring the environment and productivity patterns of Indian EEZ and time series studies on biogeochemical aspects in the estuarine and coastal waters off Kochi, two modelling projects viz; Coastal upwelling systems-SEAS and Warm pool ecosystem of Lakshadweep are proposed to be taken up during the XIIth Plan as a collaborative work of CMLRE and ICMAM.

a) Objectives

(i) Collection of physical, chemical and biological data covering the 6 marine ecosystems within the Indian EEZ
(ii) Synthesis of available data and generation of data products
(iii) Quantify primary production, grazing and export flux for each season
(iv) Elucidate the role of microzooplankton in the food web of these marine ecosystems
(v) Explain seasonal/interannual variations in environment and productivity and its influence on Marine living Resources and
(vi) Time-series biogeochemical measurements & studies [SIBER}
(vii) Develop models on SEAS upwelling system and LIE warmpool.
(viii) Hydrobiology of Andaman sea & tip of peninsular India.
(ix) Qualitative and quantitative estimates of gelatinous zooplankton off the east and west coasts.
(x) Studies on fish eggs and larvae of SEAS and Acetes centered food web of NEAS.

b) Participating Institutions:

Centre for Marine Living Resources & Ecology, Kochi.; NIO –Goa/Mumbai; CUSAT-Kochi; CAS-Annamali; KUFOS- Kochi; ICMAM-Chenni.

c) Implementation Plan:

Programme will be implemented as a multi-institutional scheme coordinated by CMLRE. Routine measurements of the 6 major ecosystems covering the Indian EEZ will be carried out onboard FORV. Sagar Sampada. Time-series measurements along the Kochi transect is being undertaken as part of SIBER programme. NIO-Goa and CMLRE together will focus on the hydobiological studies of Andamans and the eddies of BoB. The warm pool of Lakshdweep (LIE) will be studied and modeled by CMLRE. Ecotone at the tip of peninsular India will be studied by CMLRE and CUSAT. Gelatinous zooplankton of BoB and AS will be studied by CAS & KUFOS respectively. Ocean models developed by CMLRE will be integrated with the coastal sea models of ICMAM.

d) Deliverables:

Ecosystem models for SEAS & LIE.
Trophodynamic model for SEAS & LIE.
Models on Tertiary production.
Predictive model for pelagic fishery and selected tunas

3.6.5.2 Studies on Harmful Algal Blooms in the Indian EEZ (Multi-Institutional)

The frequency and extent of HAB in the world oceans is believed to be on the rise. Realizing the possible consequences of these blooms on the marine ecosystems and the marine biota the Intergovernmental Panel on HAB [IP-HAB] of the IOC have taken up HAB studies as a thrust area of research. India is implementing the HAB monitoring of the Indian EEZ since 1998 and proposes to continue this during the XII plan period also. Continuation of this scheme is important as the HABs are expected to influence the spread of OMZ.

a) Objectives

(i) Monitoring and surveillance of HABs in the coastal and open oceans of Indian EEZ
(ii) Development of a data base on HAB species of Indian Ocean as per IP-HAB format
(iii) Studies on HAB cysts and potentially harmful benthic micro algae
(iv) Studies on HAB toxins and its impacts on shellfishes and finfishes
(v) HAB toxins in desalination plants
(vi) Development of *Trichodesmium* bloom retrieval algorithm
(vii) Studies for early detection, monitoring, forecasting of algal blooms using field and satellite measurements - Development of HAB models
(viii) Organizing Regional workshops on HABs.

b) Participating Institutions:

CMLRE-Kochi; INCOIS; CAS-Annamalai; IISER-Culcutta; Kerala Univ; Cochin Univ; CIFT-Kochi; Goa Univ; SAC-Ahmadabad; Selvam Arts & Science college, Namakkal.

c) Implementation Plan:

Open ocean HAB will be monitored by CMLRE and coastal ocean HABs by the coastal universities. Studies on HAB cysts will be undertaken by the Kerala University. CIFT will undertake HAB toxicological studies. Satellite based retrieval algorithms will be attempted by SAC. HAB modeling will be undertaken by CMLRE & INCOIS.

d) Deliverables:

Species specific HAB models.
Model to evaluate system response to HABs.
Identification and preservation of HAB cysts.

3.6.5.3 Marine Benthos of the Indian EEZ

The sea floor harbours a variety of organisms, which contributes substantially to tertiary production. Besides being important from the biodiversity angle, these organisms also form food to several demersal fish species. Bottom trawling operations continiouslly disturb the ocean floor and is a constant threat to the benthos and the fishery it supports. A data base on the marine benthos of the shelf and slope areas of Indian EEZ has been generated under the MLR scheme which needs periodic revaluation.

a) Objectives

(i) Role of micro-benthos in the process of re-mineralization (SEAS, shelf)
(ii) Detailed study of benthos of continental margin upto 2500m depths (Arabian Sea)
(iii) Life stages of macro-benthos and their contribution to pelagic food webs (SEAS)
(iv) Studies on benthos of continental shelf and slope of East coast, Andaman & Nicobar Islands and Lakshadweep Islands
(v) Studies on epifauna (Echinoderms, sponges, crustaceans etc.) of the Indian EEZ
(vi) Decadal changes in macrofaunal composition of the shelf area.

b) Participating Institutions:

(i) Centre for Marine Living Resources & Ecology, Kochi
(ii) Cochin University of Science and Technology, Kochi
(iii) CAS-MB, Annamalai University
(iv) Pondicherry University, Port Blair Campus.

c) Implementation Plan:

Studies on benthos up to 2500m depth zones will be carried out by CMLRE. A&N will be covered by Pondicheery Univ and Lakshadweep by CMLRE. Studies on microbenthos and the process of mineralization will be done by the CUSAT.

d) Deliverables:

Digitized Information system on Marine Benthos.
Advisory on Closed Fishing Season
Atlas on Marine Benthos of Indian EEZ.

3.6.5.4 Assessment of deep sea and distant water fishery resources (Multi-Institutional)

Currently our fishery is restricted upto the 100 to 150m depth zones; despite the fact that approximately one million tons of fish can be harvested from the areas beyond this. Studies undertaken by MLRP so far has shown promising results for commercial scale harvesting of these resources. Neverthless, it is mandatory to quantify these resources on a temporal and spatiall scales and understand their growth dynamics before deep sea fishery advisories are disseminated.. FURTHER, DISTANT WATER FISHER WHICH IS VAUGE IN India need to be focused through survey and assessment of potential resources such as the Krill resources of SO, the

myctophid resources of the Arabian sea, Tuna resources of the Central Indian Ocean, etc. The goal is to provide advisory on commercial exploitation.

a) Objectives

(i) Assessment of demersal fishery resources in the 200-1000m depth zone of Indian EEZ
(ii) Assessment of myctophid Benthosema sp. in the Arabian Sea
(iii) Assessment of fishery resources in the Central and Southern Indian Ocean
(iv) Tuna Fishery Forecast system (TUFFS)
(v) Southern Ocean MLR Survey & Assessments

b) Participating Institutions:

Centre for Marine Living Resources & Ecology, Kochi; INCOIS; CIFT; CMFRI; KUFOS; CUSAT

c) Implementation Plan:

.
All surveys will be conducted onboard FORV Sagar Sampada. For deep-sea demersal operations standard gears such as expo model trawl and the HSDT (CV) will be utilized. Myctophid and krill surveys will be undertaken using an imported krill net. The MWT of CIFT will also be attempted on an experimental basis. Biomass estimations will be attempted through a combination of acoustic and krill surveys.

d) Deliverables:

Deep sea fisher Advisories
Advisories for harvesting Myctophid resources.
Post harvest technologies on Myctophid
Advisory on Krill harvesting and utilization
Models correlating fishery to environment.

3.6.5.5 Southern Ocean MLR

Southern Ocean (South of 55°S up to Antarctic Continent) is an ocean with unique characteristics. The living resources of which are exploited in a sustainable way by Member countries of the Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) which is an International body of 27 countries. India represented by CMLRE is a member of CCAMLR since 1984. Southern Ocean ecosystems are dominated by the Antarctic Krill *Euphausia superba* which form the key species in the food web. Commercially important fishes include the tooth fish (Patagonian tooth fish), Ice-fish (*Champsocephalus gunnari*), Mackeral fish etc. which are all being exploited. Further, the unique features of the southern Ocean and the adaptations of the living resources to these environments make it an important area for biological research with focus on identification of novel microbes and other bioactive materials and molecules. Though the southern Ocean is covered for most part of the ear by thick snow, exploitations of the resources are possible during the summer season. Identification of the front and zones of southern Ocean is one important requirement for exploitation of these resources. Through proper planning and management, India will be in a position to divert source of its fishing fleets to the

southern Ocean as for distant water fishing (Central Indian Ocean, western Arabian sea etc) which can reduce the fishing pressure on the fisher within the Indian EEZ.

a) Objectives

i) Identify the fronts and zones along the western Indian Ocean sector (CCAMLR sub area 58.6, 58.7, 58.4.49 and 58.4.46) and south Atlantic Sector (Sub area 48.6).
ii) Make assessment of the krill resources in these areas and develop advisories thereof.
iii) Undertake census of marine life at these areas.
iv) Identify microbes and other organisms for extraction of bioactive molecules
v) Represent India in CCAMLR meetings.

b) Participating Institutions

CMLRE-Kochi, NIO-Goa, CMFRI-Kochi, CIFT-Kochi, IISER-Kolkatta, CAS-Annamalai Univ. NBFGR-Lucknow etc.

c) Implementation plan

Cruises to western Indian sectors and south-east Atlantic sector of southern Ocean will be conducted during summer monsoon every year. National level participation in these cruises will be ensured. FORV Sagar Sampada and or hired vessel will be utilized for these studies, till the time the new fishery Oceanographic Vessel is commissioned. Once exploitable resources are identified and the economic returns evaluated private fishing industries will be encouraged to undertake distant water fishing as a major activity. Concurrently R & D efforts will be made for the extraction of bioactive molecules on materials found in these organisms and for the commercialization of such value added products.

d) Deliverables

(i) Advisories on Antarctic fronts and zones where exploitation of resources are possible.
(ii) Report on assessment of resources and economic viability of harvesting.
(iii) Value added products from krill and other Antarctic living resources.
(iv) Identification of novel microbes and technology for their utilization.
Develop national expertise on southern Ocean Living Resources.

3.6.5.6 Integrated Taxonomic Information System for Indian Ocean (ITIS-IndO) (Multi-Institutional)

The program components of IT IS-IndO includes (i) Ocean Biogeographic Information System (OBIS), Census of Marine Life-Indian Ocean (IO-CoML), FORV Data and Referral Centre (CMLRE) and National Marine Museum and Taxonomic Centre (NMM-TC). The CMLRE is the IOC recognized nodal agency for the implementation of IndOBIS and CoML.

a) Objectives:

(i) Develop Information System on the marine biota of Indian Ocean.

(ii) Identify and catalogue all species of organisms in Indian Ocean through DNA Bar-Coding.

(iii) Maintenance of voucher samples and specimens from Indian Ocean and act as a Regional Repository.

b) Participating Institutions:

CMLRE, Kochi; NIO, Mumbai, MS University, INCOIS; NBFGRI; ZSI; IISER; CMFRI; KUFOS; CAS Annamali; IISC-Bangalore; CUSAT; Adikavi Univ; Goa Univ; NIO-Mumbai; Andhra University, Indian Institute of Science, CARI, Port Blair; Pondicherry University, Port Blair.

c) Implementation Plan:

OBIS and CoML are activities initiated during 2010-11 and proposed to be continued during the XIIth plan period also. OBIS aims to develop an information system on species records from the Indian Ocean on a fine scale. OBIS port at CMLRE will be linked to the OBIS international website and will form a component of the world ocean bio-geographic Information system. Through the CoML programs, DNA finger prints for all marine eukaryots from Indian Ocean will be generated and deposited in the GenBank. FORV Data and Referral Centre is an ongoing activity of CMLRE wherein data and samples collected through the various cruises of FORV Sagar Sampada are collated, quality checked and stored/preserved for future references. With the vast taxonomic activities undertaken/proposed under MLR, it is proposed to establish an NMM-TC for India at the new CMLRE premise, which will form the hub of marine taxonomic and biodiversity studies in India. The NMM-TC shall also complement the marine Oceanarium to be set up by the Government of Kerala in the adjoining site.

d) Deliverables:

Biogeographical Information System on Indian Ocean.
Catalouges for major groups from Indian Ocean.
Indian Ocean Marine Museum.

3.6.5.7 MLR technology Development (MLR-TD) (Multi-Institutional)

Under the MLR-TD; various technology development projects such as technology for; Black-lip pearl production; Breeding and rearing of ornamentals; various endangered marine gastropods etc are taken up with a view to benefit Islanders. Also in line with the Drugs from the sea Programme; extraction of bioactive materials ans molecules from deep sea organisms will be attempted. Another area of focus will be to establish expertise in the field of Bioacoustics

a) Objectives

(i) Commercialization of ornamental fish and live-bait fish culture techniques
(ii) Marine biogeographic Information System for Lakshdweep
(iii) Materials and molecules from marine Organisms
(iv) Technology for sonic characterization of Marine species
(v) Indigenous development of pop-up archival tags.

b) Participating Institutions:

Centre for Marine Living Resources & Ecology, Kochi; CAS-MB; CMFRI; CUSAT; Amrita Institute; NIO, Kochi; Institute of Science-Mumbai; VIT-Vellore; CIFT-Kochi, IIT, Delhi; NPOL, Kochi.

c) Implementation Plan:

Black-lip pearl production and its commercialization will be undertaken jointly by CMFRI & CMLRE. Hatchery technology for marine ornamentals will be strengthend at the CMLRE field station Agatti. CMLRE & CAS Annamali will be the collaborating agencies. Bioactive molecules and materials will be attempted from deep sea organism collected onboard FORV Sagar Sampada. Bioacoustics will be implemented jointly by CMLRE, NPOL, IIT-Delhi and CUSAT-DoE**.**

d) Deliverables:

Technology for production of Black pearls
Technology on breeding & rearing of marine ornamentals
One or more bioactive molecule and material from marine biota

e) Budget requirement: ` 150 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Marine Living Resources & Building	38.00	44.00	28.00	22.00	18.00	150.00

3.6.5.8 CMLRE – Operation & Maintenance

CMLRE is an attached office of the Ministry at Kochi, mandated with the implementation of Marine Living Resources Programme including the effective utilization of the Fishery Oceanography Research Vessel FORV Sagar Sampada. At present CMLE have a staff strength of 27 which include 9 scientists (including 3 vacant post of scientist – C), 1 US, 1 Sr. AO, 3 TA, 3 Administrative staff, 1 RTO, 6 Fishing Hand and 3 multi utility staff. During the XIIth plan, it is proposed to add 6 more Scientists and 7 Technical Assistants to meet the operational requirements of the Centre. A sum of Rs. 3.15 crore shown on contributions under the operational expenses of CMLRE is towards payment of Membership fee of India to the Commission of Conservation of Antarctic Marine Living Resources (CCAMLR) of which India is a Member since 1984. The membership for 2010-11 was Rs. 58 lakhs.

The CMLRE research station is under construction at Kochi at an approved estimate of Rs. 31 crore of which Rs. 12 crore is expected to be utilized during the XIth plan period and the balance of Rs. 19 crore is projected for the XIIth plan. Similarly construction of the Referral Centre which is already approved under XIth plan is planned to be taken-up. A sum of Rs. 9.00 crore will be required in addition towards landscaping and setting up of laboratories and office. Another critical requirement is the replacement of FORV Sagar Sampada during the XIIth plan period. FORV Sagar

Sampada which was commissioned in 1984 is the main platform for collection of data and samples to meet the requirements of MLR programme. The vessel will be 28 years old by the end of XIth plan period and taking into consideration the lead time (appx. 5 years) needed to commission a new vessel, various committees constituted by the Ministry have recommended taking up this on priority basis during the XIIth plan period itself. The estimated cost towards this is Rs. 500 crore which is reflected separately in the approach document of this Ministry for the XIIth plan period.

a) Objectives

(i) Establish and maintain adequate manpower to run and maintain the activities of Marine Living Resources Programme.
(ii) Establish and maintain research laboratories and facilities to undertake research in the field of Marine Living Resources & Ecology.
(iii) Complete the construction of CMLRE Research station including the Referral Centre.
(iv) Commission the new fishery oceanographic Research Vessel.

b) Participating Agencies

National Institute of Oceanography; Central Marine Fisheries Research Institute; Central Institute of Fisheries Technology; Fishery Survey of India; National Bureau of Fish Genetic Resources; IISER-Kolkatta; IISc Bangalore; IIT- Delhi; and Universities like Cochin University, Annamalai University, Mangalore University, Kerala University and Manonmanium Sundaranar University. etc.

c) Implementation plan

The operational maintenance needs of MLR programme are proposed to be met by the establishment of various laboratories and manpower by the CMLRE/MoES. Construction of the Research station and Referral centre is entrusted to the CPWD and the progress is the implementation of these programme will be monitored by an independent committee to be constituted by the Ministry. Commissioning of FORV Sagar Sampada will be through global EOI. All the above said activities are proposed to be completed during the XIIth plan period in a phased manner.

d) Deliverables

(i) Correlate living resources with the physical environment and develops short term/medium term forecast capabilities.
(ii) Prediction needles on Living Resources including response strategies to a possible climate change scenario.
(iii) Evolve national coordinated efforts on MLR and generate various type of advisories.
(iv) Technologies for harvesting and investigation of resources from distant water and non-conventional resources.
(v) State-of-the-art Referral Centre for living resources of Indian Ocean.
(vi) Commissioning of new fishery Oceanographic Research Vessel
(vii) Human Resource Development and Research publications on MLR.

e) Budget requirement: ` 32 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
CMLRE – Operation & Maintenance	6.00	6.00	6.00	7.00	7.00	32.00

3.6.5.9 Drugs from the Sea

The Drugs from the Sea is an on-going programme of the Ministry for the last few plan periods. The focus so far was concentrated on extraction of bioactive molecules from organisms found in the coastal waters. Since FORV Sagar Sampada is involved in the collection of such samples from deep waters (from depths upto 1500 m) there is a scope to extent our activities to the deep sea microbes and organisms, which definitely have a greater scope in sticking novel molecules and drugs. Initially, the CMLRE will focus on the collection and routine sampling of these organisms and if extracts with promising potentials are obtained these will be sent to the core group of the drugs from the sea programme for further screening, isolation and purification of these extracts. Further, the CMLRE have expertise in the genetic manipulation of microbes and for undertaking extensive culturing of these organisms. Commercial scale culturing and harvesting of these organisms, will be an important contribution of CMLRE to these programme. The CMLRE will also act as the repository of all voucher samples collected under the drugs from the Sea programme. It is also proposed to establish a Centre of Excellence on drug research at CMLRE.

a) Objectives

i) Collection and preservation of samples from deep sea
ii) Extraction of bioactive compounds and initial screening.
iii) Transfer of potential candidates to the core group of Drugs from the Sea programme for further screening and testing.
iv) Maintain voucher samples of all samples.
v) Undertake commercial scale culturing on microbes and marine algae.
vi) Establish a Centre of Excellence in drug research at CMLRE.

b) Participating Institutes:

CMLRE-Kochi, Amirta Institute of Medical Sciences-Kochi, Dept. of Biotechnology, CUSAT, Vellore Institute of Technology, and Institute of Science-Mumbai in association with the group engaged in drugs from the sea research.

c) Implementation plan:

Deep sea microbes and microalgae will be collected following standard procedures utilizing FORV Sagar Sampada from depths up to 1500 m. Preliminary extraction and testing of bioactivity will be carried-out following the protocols established by the Drugs from the Sea Research groups**.** Mass culture of microalgae and microbes will be attempted to ensure commercial scale availability of potential organisms. Genetic manipulation will be attempted in standardizing culture techniques. All voucher samples will be maintained at a specialized repository with accession numbers.

Centre for Excellence on Drug Research will be established in a phased manner, starting with the XIIth plan.

d) Deliverables

(i) Supply of deep sea organism showing good bioactivity including those from Southern |Ocean.
(ii) Commercial scale culture techniques for potential species.
(iii) Genetic manipulation techniques for extraction of enzymes and mass production of microbes.
(iv) Fermentation activities.
(v) Establishment of central repository of organisms from Indian Ocean and Southern Ocean with potential bioactive properties.

e) Budget requirement: Provided in para 3.6.7

3.6.6 Coastal Research

Integrated Coastal and Marine Area Management (ICMAM) aims to apply scientific tools and techniques in addressing problems like erosion and ecosystem changes and Coastal Ocean Monitoring and Prediction System (COMAPS) programme aiming to monitor the levels of marine pollutants in the seas around India.

The ICMAM programme has been operating on a project mode since 1998. The projects being implemented include preparation of Model ICMAM plans, GIS-based information for critical habitats, determination of waste assimilation capacity, development of EIA guidelines, determination of 'no impact zone', determination of use classification for coastal waters, shoreline management plans for selected locations, ecosystem modelling for coastal habitats, marine ecotoxicology and storm surge inundation modelling. These programmes of national importance and social relevance are being continued in project mode. In order to provide a long-term organisational framework to continue this programme, the Project Directorate is being renamed as Coastal Research Centre. The centre requires adequate building space to operate the programmes. This would also attract more interaction by research communities at the national and inter-national level with the centre, to enhance the countries capabilities in addressing the challenging the problems prevailing in the coastal zone.

It has been proposed to give a major fillip to the socially relevant scientific programmes such as seawater quality monitoring, prediction of levels of pollutants, ecosystem modelling, and marine ecotoxicology.

The major projects are as follows:

(i) Monitoring and prediction of health of estuarine and coastal waters.
(ii) Habitat specific water quality criteria
(iii) Ecosystem modelling

3.6.6.1 Monitoring and Prediction of Health of Estuarine and Coastal Waters

Estuarine and coastal areas of India in the recent years are under immense stress due to rapid growth of population density and economic activities. The estuaries, coastal waters and wetlands provide highly diverse and productive ecosystems and are therefore important food sources for human beings. Pollution through both domestic and industrial wastes, either as point or non-point sources, affects the water quality in the productive estuarine, coastal and marine environment. Long-term monitoring of health of estuarine and coastal seas is highly essential to assess the status of pollution in relation to remedial measures taken periodically. In view of this, a programme on Coastal Ocean Monitoring and Prediction System (COMAPS) addressing the above issues is being operated along Indian coastal areas since 1991.

a) Objectives

To assess the health of estuarine and coastal waters through an observations network and provide current status of pollution, trends of variation and their predicted levels for the future.

b) Implementation Plan

(i) To establish a baseline pollutant inventory for all known pollutant sources (domestic sewage, industrial effluents surface run-off, etc) in the respective regions.
(ii) Monitoring water quality, sediment, biological and microbiological parameters
(iii) Inter-laboratory comparison exercise to ensure compatibility between the data acquired by various monitoring agencies
(iv) To identify and preserve marine microbes and to serve as a reference facility
(v) To develop the database for the data collected under COMAPS monitoring programme for ready dissemination of various data sets to end users
(vi) Monitoring of organic compounds like Polyaromated Hydrocarbons in selected organisms collected at selected locations along the coasts of India
(vii) Prediction of selected marine pollutants through modelling studies at critical locations

The proposed activities on Water quality monitoring and prediction of pollutants through modelling will be implemented by the proposed Coastal Research Centre with the support of leading R & D institutions and Universities.

c) Deliverables

(i) Prediction of levels of DO, BOD, Nutrients and Bacteria, for selected estuarine and coastal locations along Indian coast and generation of periodical health bulletins

(ii) WEB based modeling information system on Estuarine and Coastal Environment Assessment and their Health

3.6.6.2 Habitat-specific Water Quality Criteria

The management of pollution is a major task as the marine environment is constantly seen as a convenient zone for dumping of wastes. In order to ensure prevalence of seawater quality to perpetuate the reproduction of marine organisms leading to continuous availability of fishery resources to the dependant population, the most accepted method in control of marine pollution is limiting the quantity and characteristics of the wastes up to the extent to which coastal waters can assimilate. This is being achieved only by determining Waste Assimilation Capacity of coastal areas, as at several locations, the seawater quality have shown signs of degradation and likely to worsen further in future. The waste assimilation capacity needs safe water quality criteria as its target water quality to be achieved after estimating quantity of waste to be dumped and hence, the Marine Ecotoxicology project which prescribes safe seawater quality criteria which is extremely essential and need to be continued.

a) Objectives:

To develop specific habitat quality criteria for ecological sensitive areas like coral reefs and coastal waters of Ennore.

b) Implementation Plan:

(i) Acute toxicity tests to derive LC_{50}/EC_{50} values and chronic tests (for sub-lethal stress) under continuous flow through method, biomarker enzyme assay and histopathology studies would be carried out:

(ii) Seawater Quality Criteria in the form of numerical values for the proposed target chemicals supported with the activities of stress stabilizing enzymes and the extent of tissue injury and cellular changes.

The proposed activities will be implemented by ICMAM with the support of R&D laboratories.

c) Deliverables

Seawater Quality criteria for selected metals and organic compounds as aids in Pollution control activities

3.6.6.3 Ecosystem Modeling of South West coastal Waters of India

Tropical seas sustaining rich bio-resources are the most valuable ecosystem related to human activity. The human interventions such as engineering modifications, hydraulic controls, industrial establishments etc. lead to progressive transformation in the coastal ecology. Excessive nutrient loadings have become a serious environmental issue in coastal waters causing eutrophication and unusual phytoplankton blooms. The nutrient distributions in coastal waters are controlled by a complex physical-chemical–biological interaction process associated with input, advection/dispersion, and export. Since these are complicated and non-linearly coupled, studies on eutrophication usually rely on water quality models involving transformation and utilization of inorganic and organic matter. Frequent occurrences of hypoxia have caused significant reduction of fishery harvests, toxic algal blooms, and loss of bio diversity. The quantification of all sources and biogeochemical

processes like biochemical processes and tropic level relationships using mathematical models greatly help prediction of primary and secondary productivity. The study is expected to explore and formulate an environmental management plan to rejuvenate these coastal area based on the present status and projected demands. The present proposal is an attempt to predict the primary and secondary production through an ecosystem model to the south west (SW) coastal water of India.

Besides, climate change related impacts like SST may affect metabolic processes of organisms which would be reflected in annual rate of production and biodiversity.

Understanding the health of the ecosystem in terms of productivity, it's likely trend in the future are extremely essential to plan measures required for preventing decline of resources. One of the most reliable tools available today to fulfill this need is an ecosystem model to understand the dynamics of components of ecosystem, their inter-relationships and to quantify the transfer of energy from one trophic level to the other. Use of such tools would certainly facilitate to delineate the causes of decline of productivity of the coastal waters of southwest coast of India

a) Objectives

(i) To understand the varied biogeochemical processes in the south west coastal waters.
(ii) Development of a coupled hydro-ecosystem model for predicting primary and secondary level production with quantification energy transfer up to tertiary level.
(iii) Simulation of hydrodynamic characteristics, water quality and phytoplankton biomass in terms of chlorophyll through models.
(iv) To prepare a sustainable management plan to help the local community.

b) Implementation Plan:

To fulfill the above objectives, the following studies has been proposed

(i) Time-series data for physical, chemical and biological parameters to understand the circulation and dynamics of the ecosystem up to 50m depth.
(ii) Biogeochemistry of carbon and nitrogen
- Tasks to determine coefficients through field and laboratory experiments.
- Estimation of primary production using the water quality model and secondary production using ecological model.

(iii) An optimized ecosystem model to be formulated specially for SW coast of India

The proposed activity will be implemented by ICMAM.

c) Deliverables:

An Ecosystem model for Southwest coast of India providing scenarios of changes in productivity under the changing environmental conditions useful to plan take measures to ensure optimum productivity

3.6.6.4. Coastal circulation and Sediment Transport modelling along Indian Coast

The coastline is subjected to several geo-morphological changes due to natural processes and manmade activities. Shoreline changes are one of the serious problems in several pockets along the Indian coast. Understanding the coastal circulation shoreline changes is essential in order to sustain it for future generations. The shoreline retreat leads to the loss of the beach and consequently to a setback of the coastline that threatens the coastal communities. The major information that is required to understand the shoreline changes is coastal circulation and sediment transport pattern. Therefore, during the 12th plan a comprehensive programme in this regard will be taken up.

a) Objective

To understand the Coastal circulation and sediment transport processes in Coastal Waters to provide the seasonal pattern of sediment transport at priority areas to facilitate assessment of shoreline changes
Tasks involved

- Assessment of Shoreline Changes using satellite data & Field verifications of maps to generate shoreline changes maps
- Setting of Regional Coastal Circulation model for 3-4 regions along Indian coast using data collected from other programmes of MoES and limited observation programmes
- Sediment transport modeling using Secondary data & Littoral Environment Observations and estimation of sediment transport rate cell wise /region wise

Mode of implementation

The component on Shoreline Changes which is mainly focus on the Modelling and GIS application with statistical analysis will be implemented by ICMAM-PD at national level. The component on data collection, numerical modeling and sediment budget computations for regional scale will be implemented jointly by ICMAM PD, and NIOT. A common Project Document shall be prepared indicating the division of work among the above institutions. and these details also reflected in section 3.8.6.
Deliverables

(i) A GIS based database shoreline change maps at 1:25000 for entire country and 1:5000 scale for selected locations and mapping Annual/periodical Shoreline changes
(ii) Understanding coastal circulation and process influencing the sediment transport
(iii) Location wise information on direction of sediment movement and estimation of sediment budget seasonally

3.6.6.5. Operation and Maintenance of ICMAM-PD (Continuing)

The Ministry of Earth Sciences have been operating the ICMAM programme on a project mode since 1998. The projects being implemented since 9th plan period and a variety of research on Area Management Plan, shoreline management, Seawater quality criteria, Ecosystem modelling, tsunami modelling modelling and mapping etc.

are being conducted. These programmes of national importance and social relevance are being continued in project mode. In order to provide a long term organisational framework to continue this programme, the Project Directorate is being renamed as Coastal Research Centre. The centre requires adequate building space to operate the programmes. In order to operate and maintain the ICMAM PD and to purchase land and construct new buildings (about 40000 sq ft), substantial funding is required.

Budget requirement: ` 185 crores.

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Coastal Research	23	50	44	37	31	185

3.6.7 Drugs from the Sea (Continuing)

The programme is being implemented since 1990 under the leadership of Central Drugs Research Institute (CDRI), Lucknow. There are 14 different National/State R&D labs including Universities are actively participating.

a) Objectives

(i) Bio-prospecting of marine organisms occurring in Indian waters
(ii) Drugs discovery
(iii) Drug development with state-of-the-art facilities proposed during the XII Plan Period.

b) Participating Institutions

(i) Central Drug Research Institute (CDRI), Lucknow
(ii) National Institute of Oceanography, (NIO), Goa
(iii) Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar
(iv) Indian Institute of Chemical Technology (IICT), Hyderabad
(v) Institute for Minerals and Materials Technology (IIMT), Bhubaneswar
(vi) National Institute of Ocean Technology, (NIOT), Chennai
(vii) Advanced Centre for Treatment, Education and Research (ACTREC), Mumbai
(viii) Central Institute of Fisheries Education (CIFE), Mumbai.
(ix) Department of Fisheries, Government of West Bengal, Kolkata
(x) Toppiwala National Medical College, Mumbai.
(xi) Andhra University, Visakhapatnam
(xii) Calcutta University, Kolkata
(xiii) Annamalai University, Parangipettai
(xiv) University of Madras, Chennai.
(xv) Central Marine Living Resources & Ecology, Kochi

c) Implementation Plan

In the light of the foregoing, the programme is proposed for continuation into the next five years during XII Five Year Plan period i.e., 2012-17, undertaking the exploration, identification, extraction, bio-evaluation, re-combinatorial chemical analysis, synthesis of active compounds up to product development with the participation of pharmaceutical industries concerned and work in mission-mode. It is proposed to establish a "**Centre of Excellence on Drugs from Sea**" at CMLRE, Kochi during the XII Plan period and strengthen the infrastructure facilities at NIOT, Chennai including manned submersibles and deep sea samplers, etc., so as to engage a team of experienced and dedicated scientists including taxonomists on full time in all relevant fields starting from collection of marine samples till the product development with industrial partners. In addition to the existing participating Centres, it is also proposed to induct/involve more number of institutions along with pharmaceutical industries.

Exploration Work

(i) Collection of new organisms from coastal and offshore (manned submersible);
(ii) Repeat collection of active samples for confirmation of activity, etc;
(iii) Large scale collection of active materials for follow-up studies;
(iv) Characterization and structural determination, synthesis of active materials base on patentability and commercial value/merits;
(v) Expansion and upgradation of "*in-vitro*" and "*in-vivo*" test models for biological screening will continue;
(vi) Strengthening of information technology using data base and other facilities will continue; and
(vii) HRD training in bioassay, chemical analysis, IPR and Benefit sharing will continue.

Conducting Clinical Trial

CDR-134-D-123 - Anti-hyperglycemic product
CU1-002 - Anti-hyperlipidemic product
CDR-134-F-194 -Anti-hyperglycemic-cum-anti-hyperlipidemic product
CDR-134-D125 - Anti-diarrheal

In order to expedite the screening; patentability of active compounds, structural analysis, re-combinatorial chemistry and manipulation of molecules to improve its efficacies including synthesis the following activities are proposed:

Introduction of new *in vitro* and *in vivo* test systems, enzymes and cell based bio-assays and receptor binding studies which will facilitate rapid biological screening and determination of possible mechanism of action of active compounds;

Development of new models for evaluation of samples for anti-cancer, anti-bacterial, antifungal and anti-inflammatory properties and expression/lack of expression of new proteins during healing process, molecular target based High throughput screening for various activities & learning improvement & test system to evaluate reverse transcriptase inhibition;

Establishing Centre of Excellence at CMLRE, Kochi;

Procuring a manned submersible / chartering two manned submersibles for deep sea sampling so as to initiate study the deep sea organisms occurring in 2.02 million sq.km of Indian EEZ;

The microbial strains collected under "Coastal Ocean Monitoring and Prediction System (COMAPS)" to be screened for wide spectrum bioactivities, etc; and

Involving Pharmaceutical Industries for training project staff in screening, bioassay development, lead optimization, chemical synthesis, product development.

d) Deliverables:

Encouraging tests are indicative of the yield of potential drug/s at the end of the project.

e) Budget: `.200 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Drugs from Sea	20	30	50	50	50	200

3.6.8 Multi-hazard Vulnerability Mapping (Continuing)

The coastal areas of India especially along the east coast and Gujarat are most prone to coastal disasters like cyclones, floods and tsunamis. The sea level rise which is expected to occur may inundate coastal areas to various degrees. The super cyclone of Orissa in the year 1999 devastated the coastal area of Paradip with storm surges penetrating up to 100 along the river Mahanadhi causing extensive damage to human life and property. Similarly, tsunami of 2004 caused loss of human life and damage to property to the coast of Tamilnadu. Impact of natural disasters can be minimized significantly if proper and timely information is available. Multi-hazard mapping process supports the requirement of availability of relevant information which helps in preparing disaster mitigation strategies to reduce loss of life and properties.

Multi hazard maps provides details of extent risk involved due to hazards along with details of extent of geographical impact, level of risk and geographical details like extent of human settlement, resources and infrastructure that will be affected. These details are essential to assess the vulnerability of the area to various hazards and take preventive measures. Without such details it would be extremely difficult to deal with disasters.

a) Objectives:

(i) To assess the vulnerability of the Indian coastline by developing methodology, identifying suitable modelling tools and data assimilation techniques for multi hazard modelling and mapping of the Indian coast

(ii) A develop a webGIS based coastal vulnerability information system with information on vulnerability of the entire Indian coast due to multihazards and the areas most vulnerable to climatic variants such as sea level rise demarcated using the hazard line.

(iii) Development of CVI and Multi-hazard Vulnerability Mapping (MHVM) for the entire coastline of India.
(iv) Real-time inundation forecast modeling by focusing on development of Stand-by Inundation Models (SIM) and Reference Inundation Models (RIM).
(v) 3-D GIS mapping and survey for selected priority coastal regions, based on population density, economic importance and vulnerability identified from the CVI and MHVM analysis.
(vi) Risk maps of vulnerable regions
(vii) Enhanced modeling and forecast capability of NTEWS.
(viii) 3D Geo-coded Object models

b) Participating Institutions:

(i) Integrated Coastal & Marine Area Management-Project Directorate, Chennai
(ii) Indian National Centre for Ocean Information Services, Hyderabad.

c) Implementation Plan:

The coastal vulnerability maps will be prepared in 1:10000 scale after assessing the coastal vulnerability for each hazard i.e. tsunami, sea level rise, storm surge, extreme waves, coastal erosion, coastal geomorphology, coastal slope and others. The generic available resources/ information about these hazards will be used to analyse to the study the changes in coastal zone due to each hazard, using GIS and analytical modelling tools through a rational scaling of the weightage induced risks for each hazard be delineating risks areas/contours zones. The maps generated will be disseminated to the users through WebGIS.

d) Deliverables

A webGIS based Coastal vulnerability information system will be generated to disseminate information about the vulnerability of the coastal line due to multi hazards. The anticipated hazard line will also be generated to enable scientific and future planning of the coastal zone activities. These maps will be overlaid with information on the critical infrastructure, roads, waterways and environmental resources of the area. In some of priority area, 1:5000 scale maps will also be prepared with greater details of resources and other infrastructure details.

INCOIS developed a comprehensive coastal vulnerability index (CVI) for the Indian coast using different physical and geological parameters on a regional scale.

Case studies depicting MHVM for Nellore District and the Cuddalore Region were found to provide intuitive and critical information useful to coastal managers.

Availability of High resolution topographic data from ALTM (5m) and Carto-DTM (10m) data along Indian coast allows the preparation of map at larger scales.

e) Budget requirement: ` 80 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total

Multi-hazard Vulnerability Mapping	10	20	20	15	15	80.00

3.6.9 Microbial Oceanography (New)

Evidence from scientific research over the last one decade; have brought to light the complex and crucial role played by marine microbes in the marine food web, nutrient cycling, formation of Oxygen Minimum Zone (OMZ), etc. Marine microbes such as picoplanktons, archea, bacteria, actinomycetes, fungi and virus occupy all realms in the ocean including bottom sediments, hydrothermal vents, polar ice caps, etc. Their numerical abundance is much higher than all known marine species put together. These microbes may be free living or associated with other marine biota as commensals, symbionts, parasites and phages influencing the host physiology and metabolism in ways unknown to us. Microbial mediated bioluminescence and toxin secretions are reported from many marine organisms. Many microbes, especially the actinomycetes secrete specialized enzymes and antibiotics having therapeutic and pharmaceutical applications. Whereas, microbes such as cynaobacteria, clostridium, help in nitrogen fixation, the anaerobic bacteria associated with POM of the OMZ area causes denitrification and release of nitrogen oxide – a green house gas- as the end product. The roles of bacteria in the anammox reactions have also been recently reported. Viruses, besides being known pathogens also cause senescence of microalgae, lysis of bacterial cells and production of dimethyl sulphide (DMS) by enzymatic hydrolysis of dimethyl sulphoniopropionate (DMSP). The realization that the functional role of microbes in the marine environment are diverse and perhaps more significant than thought earlier, have lead to the emergence of microbial oceanography as a specialized field of marine sciences.

a) Objectives

(i) Conduct field experiments in open oceans, complemented by remote sensing, metagenomics, bioinformatics and laboratory studies to gain insights into working of a few important ecosystems along the coast of India. Development of algorithms for use with remote sensing for identification of microbial activity.
(ii) Improve our ability to simulate the physical system. Microbial diversity including those of as yet uncultivable forms, Keystone microbes, Bioinformatics – functional metagenomics.
(iii) Develop tools for predicting evolution of the microbial oceanography influenced ocean services and products (like microbial CDOM linked primary productivity estimates) using empirical, stochastic, and dynamical models. Biogeochemical cycles with N (and others) as a proxy element, energetic, Microbial physiology (addresses issues by experimentation), and Coupling of Microbial process between atmospheric, pelagic and benthic, including OMZ, sub-surface *in situ* observations (telemetry, including arrays and ROVs)
(iv) Elucidation of role of microbial communities in nutrient flux in marine environments and in modulating climate change. Biotechnological investigations.
(v) Modelling including transformation to GIS applications.

b) Participating Institutions:

Centre for Marine Living Resources & Ecology, Kochi; NIOT; NCAOR; NIO-Goa; NIO-Kochi; Goa University; Pune University; Mangalore University; CASMB, Annamalai University.

c) Implementation Plan

(i) Microbial Taxonomy and Biodiversity: Goa Univ & NIO
(ii) Microbial Biogeochemistry; CMLRE, NIO, NCAOR
(iii) *In vitro* bioprocessing of polymetallic nodules using deep sea microorganisms-NIOT
(iv) Centre for Microbial Oceanographic Studies (C-MOS) and augmentation of vessel facilities

The scheme is proposed as a multi-institutional activity addressing major areas of microbial oceanography research. In order to evaluate the activities under the various disciplines it is proposed to have a Project Monitoring Committee constituted that will oversee the progress of projects and suggest mid-term corrections, if any. Besides this a Steering Committee for the programme is also to be put in place for guiding the policies and strategies that have relevance and importance for the nation in the field of microbial oceanography.

d) Deliverables:

(i) Information system on marine microbes of NEAS & SO

e) **Budget:** ` 100 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Microbial Oceanography	5	20	25	25	25	100.00

3.6.10 High Resolution Operational Ocean Forecast and Reanalysis system (New)

Ocean General Circulation Models are routinely used for operational ocean forecasting and reanalysis on global or regional scale throughout the world. Various programs like Bluelink FOAM, Mercator, TOPAZ are using various models viz., MOM, NEMO, HYCOM for operational forecast of the ocean. In the lines of international efforts of the operational ocean forecasting, INCOIS also has been carrying out f

ocused research towards developing an operational forecast system for the Indian Ocean. Regional Ocean Modeling System (ROMS) was setup and customized for the Indian Ocean domain after conducting extensive inter-comparison experiments. Initially, ocean forecasts (sea surface temperature and currents, mixed layer depth and depth of thermocline) were provided at spatial resolution of 25 km x 25 km. Due to the limitation of model, these forecasts were valid and only for the open ocean where the water depths are more than 150 m. These forecasts, however, were well received by the user community, particularly by the Indian Navy. Recently, the model

was modified using improved parameterization and higher resolution (1/8 deg x 1/8 deg resolution). These improvements allowed valid forecasts for the open ocean waters beyond 75 m. Moreover, no assimilation of observed data is enabled in this model.

Several operational agencies around the world provide seasonal forecasting, which requires near-real-time knowledge of the ocean state. Seasonal forecasting systems are based on coupled ocean atmosphere general circulation models that predict SST and their impact on atmospheric circulation. Many studies highlighted the importance of better oceanic initial condition, particularly the information on the ocean upper thermal structure, on the skill of climate model forecasts at the seasonal scale. The error in upper ocean thermal structure, particularly the SST, strongly influences atmospheric circulation in the coupled model.

a) Objectives

(i) To set up data assimilation in $1/8^{th}$ degree resolution Indian Ocean model and set up the Regional Ocean Modeling System (ROMS) for the coastal waters around the Indian subcontinent at a horizontal resolution of $1/36^{o}$ including tides and boundary conditions from basin wide Indian Ocean model, set up of high resolution WRF model forced with atmospheric boundary conditions to force the high resolution ROMS and SWAN, set up of WAVEWATCH III for the Global Oceans (at 1^{o} resolution), Indian Ocean (at 0.5^{o} resolution), Arabian Sea and Bay of Bengal (at 0.25^{o} resolution), set up of SWAN the coastal waters along the Indian subcontinent at $1/20^{o}$ resolution forced by the atmospheric forecast from the high resolution WRF model, Couple the SWAN with WAVEWATCH III model.

(ii) Forecast surface chlorophyll concentration in the Indian Ocean on short time scales using ROMS-NPZD model set up.

(iii) Provide ocean reanalysis (1979 to present) products for the global ocean with unique historical data from Indian Ocean region at 10 km resolution using a MOM P4 global model with capabilities of data assimilation.

(iv) Establish an oil spill modeling and trajectory forecast system in operational mode.

b) Participating Institutions:

Indian National Centre for Ocean Information Services, Hyderabad.

c) Implementation Plan

The high resolution forecasts of ocean parameters (waves, currents, SST, etc) near the coast and the seas around India has become necessary for safe navigation and other marine activities. To meet this requirement, ocean models with capabilities in data assimilation will be developed and set up covering smaller domains at finer resolutions.

Expertise on ocean data assimilation, which is minimal in the country, will be developed through the induction of young researchers and training them through collaborations with institutes/universities in other countries.

The forecasts of the ocean on daily basis will be done interpreting the information emerging from the high resolution models.

d) Deliverables:

Daily forecasts of ocean parameters (surface and sub-surface) using high resolution ocean models with data assimilation capabilities.

High resolution SST data for the generation of PFZ advisories on cloudy days.

e) Budget: ` 57 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
High Resolution Operational Ocean Forecast and Reanalysis system	2.00	1.00	51.00	1.00	2.00	57.00

3.7 OCEAN SURVEY AND MINERAL RESOURCES

With over 2 million sq. km Exclusive Economic Zone (EEZ) supplemented with the continental shelf extending beyond the EEZ, the survey and exploration remains an important activity being proposed to be extended in the XII Plan. The continental shelf programme would also need to be continued till our claims in the United Nations are accepted. The quest for resources continues to interest mankind and ocean minerals are no longer exception. Gas hydrates with their occurrence being ascertained with the help of Bottom Simulating Reflectors (BSR) need to be investigated in more details considering their potential. The programme on polymetallic nodules has matured from survey and exploration to technology development, while new minerals and associated marine ecosystems surrounding the hydrothermal vents and cobalt crusted seamounts have caught the attention of scientists.

3.7.1 Geoscientific studies of the Indian Exclusive Economic Zone

India, a traditionally maritime country with rich maritime heritage, has an Exclusive Economic Zone (EEZ) of about 2.37 million km^2 wherein India enjoy the exclusive legal right to utilize all living and non-living resources. The project mainly focuses on mapping the entire EEZ of India using the state-of-the art technologies of Multibeam apart from systematic sediment sampling and its analysis. The entire EEZ have been divided into two areas viz. deep water areas (> 500 m water depth) and shallow water areas (< 500 m water depth).

This is a continuing programme of the Ministry spill over from the 10^{th} plan and will be continued during the 12^{th} Five Year Plan. By implementing the programme, a clear picture of our exclusive economic zone will emerge. The comprehensive detailed bathymetric map of the EEZ will be helpful to mariners, navigators, planners, fisheries and mineral resource, researchers and many more. This benefit would be

enormous as the information on EEZ is essential for all round development of the coastal regions.

Systematic mapping of the Indian EEZ utilising state-of-the-art muitibeam bathymetric instruments was initiated during the XI Plan period, and to date,nearly 30% of the deep-water regions of the EEZ beyond 500 M water depth has been mapped. Some of the significant observations include the presence of channel-levée systems between Ninety east Ridge to its west and Andaman Trench in east. Two Seamounts off Lakshadweep, and pockmarks on the seabed off-Goa. In addition to bathymetric observations, sampling of the seabed-subseabed at select locations has also been carried out and the analytical studies are in progress. Considering the large area of the Indian EEZ in excess of 2 million km^2 and the need to extend the studies to the continental shelf areas beyond 200 M in view of India's submission for an extended continental shelf to the United Nations Commission on the Limits of the Continental Shelf (CLCS), it is proposed to continue the bathymetric mapping and systematic sampling on a mission mode using a dedicated chartered oceanographic vessel during the XII Plan.

a) Objectives:

(i) Preparation of a comprehensive seabed topographic map for the entire EEZ of the country using the state-of-the-art technologies of multibeam swath bathymetry..
(ii) To carryout systematic sediment sampling and analyze to assess potential of seabed resources within the EEZ.
(iii) To improve our understanding of the seabed morphology and enhance our knowledge of the existing scientific issues such as paleoclimatic regime of Indian peninsula.
(iv) Creation of a state-of-the-art marine geoscientific database facilitating its archival and retrieval for dissemination to the scientific community against approved projects of the MoES.

b) Participating Institutions

(i) National Centre for Antarctic & Ocean Research, Goa
(ii) National Institute of Ocean Technology, Chennai
(iii) National Institute of Oceanography, Goa

c) Implementation Plans:

The studies of the EEZ area falling within water depths of <500 m would be carried out by NIO and NIOT, while NCAOR would be responsible for the studies in water depths of >500m. NCAOR would also be the nodal agency responsible for the implementation of this program in its entirety including development of a web-based marine geoscientific database.

The existing project shall be continued in the forthcoming plan period too, with the same objectives and goals. The project would be implementation in two parallel streams as different multibeam specifications would be required for shallow water (20-500 m depth) and deep water surveys (beyond 500 m depth).

d) Deliverables:

The studies planned would provide (a) a comprehensive seabed map of the country's EEZ, and (b) a wealth of information on the seabed-subseabed sediment characteristics, which would be of particular significance for offshore mineral exploration as well as paleoclimatology

(i) Comprehensive deep seafloor bathymetric map of the entire EEZ of India

(ii) Analysis, interpretation and identification of various geomorphological features in the EEZ of India.

(iii) Archival of Sediment core samples collected from EEZ of India for the purpose of any future analysis.

(iv) Geochemical and sedimentological analysis to assess the potential seabed resources as well as to enhance knowledge about paleo-climatic regime.

e) Budget requirement: ` 122 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
EEZ Surveys	25.00	24.00	24.00	25.00	24.00	122.00

Delineation of the outer limits of the Indian continental shelf

The Indian Continental Shelf Project which commenced during November 1999, is a multi-institutional and multi-crore national mission that seeks to gather, analyse and document the requisite scientific and technical information that would help define the country's extended shelf boundaries beyond 200 M as per the provisions of the United Nations Convention on the Law of the Sea (UNCLOS). Underpinning our efforts has been a comprehensive multi-institutional marine geophysical survey and data analysis programme comprising state-of-the-art multi-channel seismic reflection, refraction, gravity and magnetic data profiling. The data acquisition work was initiated through a contractual agreement on the 17th July 2002 and was completed on the 7th of February 2004. Spread over 385 days of fair-weather period, around 31,000 km of seismic reflection, gravity and magnetic data were collected in and off the EEZ of India. In addition, for the first time in the country, 90 state-of-the-art Ocean Bottom Seismometers (OBS) were successfully deployed along several seismic transects to constrain the velocities from the reflection data as well as to develop a crustal model of the area. On the 11th May 2009, India submitted to the UN Commission on the Limits of the Continental Shelf (CLCS), the country's first partial submission for an extended continental shelf beyond 200 M under the provisions of article 76; technical documentation for a second partial submission under the provisions of the Statement of Understanding has also been provided to the Ministry of External Affairs for submission to the CLCS.

a) Objectives:

To gather the requisite scientific and technical data in and off the Indian EEZ that will help define, delineate and substantiate India's claims for an extended continental shelf beyond 200 M under the provisions of UNCLOS.

b) Participating Institutions

(i) National Centre for Antarctic & Ocean Research, Goa
(ii) National Geophysical Research Institute, Hyderabad
(iii) National Institute of Oceanography, Goa

c) Implementation Plans:

As in the previous years, all the aspects related the planning, co-ordination and implementation of the scientific and logistics aspects related to the programme shall be undertaken by NCAOR on behalf of the Ministry.

d) Deliverables:

The most significant deliverable from this project is the sovereign rights for the country to explore and exploit the natural resources (mineral and other non-living resources as well as the living sedentary organisms) of the seabed and sub-soil of the continental shelf beyond 200 M.

e) Budget requirement: ` 11.00 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
CLCS Project	2.00	2.00	3.00	2.00	2,00	11.00

3.7.2 Mineral Resources

Oceans have always influenced the life and history of man. The greatest unexploited mineral resources on earth are on the deep-sea floor, including manganese nodules; cobalt-rich manganese crusts that contain nickel, copper, cobalt, and manganese; and hydrothermal deposits that contain copper, lead, zinc, gold and silver.

3.7.2.1 Polymetallic Nodules programme (PMN):

The Polymetallic Nodules programme is oriented towards exploration and development of technologies for eventual extraction of nodules from the Central Indian Ocean Basin (CIOB) allocated to India. India is presently having an area of 75,000 square km, located about 1600 km away from her southern tip. India is one among the top 8-countries/contractors and is implementing a long-term programme on exploration and utilization of Polymetallic Nodules. The Polymetallic Nodules Programme consisting of four components viz. Survey and Exploration, Environmental Impact Assessment (EIA) Study, Technology Development (Mining) and Technology Development (Extractive Metallurgy).

Survey & Exploration:

a) Objectives

(i) To identify the most potential area in the Retained Area which would form the nucleus of the 1st generation mine site for nodules in the Central Indian Basin.
(ii) Select ideal blocks in the First Generation Mine Site and carry out detailed observations at highest possible resolution in order to provide precursor and essential data for pilot mining.
(iii) Integrate the grade and abundance data with the existing data in the retained area and generate a final picture of the best blocks as far as grade and abundance are concerned.
(iv) Comprehensive resource evaluation of nodules in the retained area.

b) Participating Institutions:

(i) National Centre for Antarctic & Ocean Research, Goa
(ii) National Institute of Oceanography, Goa

c) Implementation Plans:

(i) Generation of contour maps, slope angle map, 3-D map of the Minesite-M-3 (42 blocks) and select ideal blocks for high resolution studies from the existing data.
(ii) ROV investigation of pre-selected blocks using sub-bottom penetration, single beam and multibeam mapping for microtopography etc.
(iii) Data processing from ROV .

d) Deliverables:

The deliverables expected out of the work program would comprise detailed site-specific thematic maps of relevance for poly metallic mineral exploration, and a comprehensive geoscientific database of the area.

Preparation of a high resolution map (3-d and 2-d) of the explored area delineating microtopographic features and related analyses using GIS.

Understanding and estimation of possible seamount hydrothermal deposits in the CIOB nodule-rich area (first generation mine site)

e) Budget requirement: ` 75 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Survey & Exploration	15.00	15.00	15.00	15.00	15.00	75.00

Environmental Impact Assessment (EIA):

The environmental impact assessment has been aimed at evaluating the inter-seasonal as well inter-annual variability of environmental parameters in and around the proposed FGM site in the CIOB. The studies on sedimentological, geotechnical, geochemical, microbial and biochemical parameters have shown that environmental conditions vary over different time scales (seasonal and annual) on a wide range and

that these variations could probably well encompass the changes in conditions created by other activities such as deep seabed mining.

a) Objectives

(i) To evaluate environmental conditions associated with deep-sea minerals
(ii) To evaluate the sediment ecosystems and biogeography in abyssal areas
(iii) To understand the interplay between geo-bio-chemical processes in these areas
(iv) To develop environmental data to mine deep-sea mineral resources
(v) To prepare EMP for first generation mine (FGM) site

b) Participating Institutions:

National Institute of Oceanography, Goa

c) Implementation Plan:

During XII plan, it is proposed to improve our understanding on these through concerted efforts at sample / data collection through state of the art techniques.

d) Deliverables:

(i) Generation of multi-disciplinary data of deep-sea ecosystems in geologically unique settings
(ii) Establishing linkages between pelagic and benthic environments, provide estimates of export fluxes and chemical budget contributing to deep-sea ecosystem functioning
(iii) Providing environmental inputs for development of technology for harnessing deep-sea resources
(iv) EMP for FGM

e) Budget requirement: ` 82 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
EIA Studies	31.00	20.00	13.00	12.00	6.00	82.00

Extractive Metallurgy:

Various research endeavours were carried out at the National Metallurgical Laboratory (NML), Jamshedpur and the Institute of Minerals and Materials Technology, (IMMT) Bhubaneswar for optimizing the existing process routes for extraction of Cu, Ni, Co and Mn from the polymetallic nodules as well as initiate activities on new processing routes.

a) Objectives

(i) To develop alternative process routes for improving the techno-economics of processing nodules for recovery of Cu, Ni, Co, and Mn

(ii) Recovery of additional metals and value added products such as Mn, Mo, rare earth metals, etc.
(iii) Studies on environmental issues such as effluent and solid waste management, rheological studies for transportation of nodules / residues
(iv) Processing of new raw material (Co crust and polymetallic hydrothermal sulphides)
(v) CSIR-MoES Centre for Extracting Metallurgy for creating facilities and expertise for development of domain knowledge on processing of seabed minerals.
(vi) Preparation of manganese metal & high performance Electrolytic Manganese Dioxide (EMD).
(vii) Consultancy work on process appraisal, upscaling and implementation.

b) Participating Institutions:

Institute of Minerals and Materials Technology, (IMMT) Bhubaneswar and National Metallurgical Laboratory (NML), Jamshedpur

c) Implementation Plans:

This is a continuing programme of the Ministry of Earth Sciences to be taken up during 12th plan period.

d) Deliverables:

(i) Development of a process Flow sheets, scale up studies through pilot scale testing for recovery of metal values.
(ii) High performance EMD for battery industry
(iii) Development of flow sheet for processing ferro-manganese crusts.
(iv) Establishment of the probable mechanism for extraction of manganese, copper, nickel & cobalt from manganese nodule.

e) Budget requirement: ` 36 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Extractive Metallurgy	7.00	7.00	7.00	7.00	8.00	36.00

Mining Technology Development:

Please see section 3.8.2

3.7.2.2 Studies on Hydrothermal Sulphides

Mid-oceanic ridges are the primary sites of generation of new crust, host mineral resources, and support unique ecosystems. The program envisages the discovery of active hydrothermal vent fields in the northern Indian Ocean.

a) Objectives:

Characterization of slow spreading the Carlsberg and Central Indian ridge in terms of tectonic, volcanic and hydrothermal processes and to delineate the zones of hydrothermal mineralization, and their relation with seafloor and sub seafloor ecosystems.

b) Participating Institutions

National Institute of Oceanography, Goa
National Centre for Antarctic & Ocean Research, Goa

c) Implementation Plans

(i) Multi-beam mapping, acquisition of geophysical data (grav & Mag), seabed sampling and CTD and Miniature Autonomous Plume Recorder (MAPRs) observations along the Carlsberg Ridge & Central Indian Ridge to discover new vent fields as well as delineate the zones of hydrothermal mineralization.

(ii) Develop methodologies to locate vents more efficiently – conduct deep-tow, AUV-ROV combination nested survey.

(iii) Vent specific surveys and experiments. ROV surveys around the active vents to identify the locations of inactive vents and ti locate the zones of hydrothermal mineralization suitable for future mining.

(iv) Andaman Sea: Imaging the subducting Indian Plate. Influence of arc volcanism and back arc spreading on the geodynamics of Andaman Sea

d) Deliverables:

(i) Delineation of Tectonic, structural and magmatic zones
(ii) High resolution swath bathymetric maps and seafloor images
(iii) Deep-crustal structure along selected transects
(iv) Hydrothermal mineralization zones
(v) Maps showing active hydrothermal vent field in the Indian Ocean
(vi) Anomalous hydrographic zones in relation to Hydrothermal systems
(vii) Zones of hydrothermal mineralization

e) Budget requirement: ` 105.00 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Studies on Hydrothermal Sulphides	45.00	15.00	15.00	15.00	15.00	105.00

3.7.2.3 Studies on Cobalt Crust

Seamount ferromanganese crusts are known to enrich several high-value metals such as cobalt, platinum, cerium, tellurium, etc. The project is to identify areas of occurrence of cobalt-enriched ferromanganese crusts, assessment of resource potential of co-rich deposits on Afanasiy-Nikitin seamount in the Afanasiy-Nikitin Seamount region.:

a) Objectives

(i) Multibeam mapping of the entire ANS region
(ii) Sampling the entire ANS in grid-pattern to estimate Co-Pt resources – spot sampling
(iii) Continuation of collecting baseline environmental data from the ANS region

b) Participating Institutions

National Institute of Oceanography, Goa
National Centre for Antarctic & Ocean Research, Goa

c) Implementation Plans

(i) Extensive survey would be carried out in all the known seamounts in the Eastern Arabian Sea for mapping the occurrence of multi-metal ferromanganese crust deposits, and sampling.
(ii) Conducting necessary analytical/laboratory investigation to assess the metal enrichment in the deposits.
(iii) Preparation of maps of seamount ferromanganese deposits in the Eastern Arabian Sea and estimating tentative resource values. Processing of the scientific data generated for preparing scientific manuscripts and technical reports.
(iv) Create data bank for cobalt crust programme.

d) Deliverables:

(i) First information on the multimetal ferromanganese crust occurrence in the marine regime located in the vicinity of India and their quality.
(ii) Scientific papers and technical reports based on the data generated.

e) Budget requirement: `75 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Cobalt Crust	15	15	15	15	15	75

3.7.3 Gas Hydrates (Continuing)

Gas hydrates are crystalline form of methane and water, and exist in shallow sediments of outer continental margins. They are envisaged as a viable major energy resource for future. Thus, delineation of gas-hydrates by geophysical methods is very important for evaluating the resource potential along the Indian continental margin with a view to meet the overwhelming demand of energy for India

Gas hydrates with their abundant resource potential is emerging as a potential fuel resource. The preliminary assessment of geological condition and limited available seismic data suggests high possibility of occurrence of large quantity of gas hydrates within the EEZ of India. The multi-channel seismic data collected by various organisations during the last Plan period has been evaluated and based on the data, two promising sites of 100 km x 100 km in the Krishna-Godavari (KG) and the Mahanadi basins have been identified and surveyed.. During the XII Plan period, it is proposed to focus the studies on ground-truthing and the quantification of the resources at these two sites as well as to explore for similar occurrences in other potential areas of the Indian EEZ

With an estimated amount of trillions of cubic metres of methane gas available in the Gas Hydrate deposits in the Indian waters, Gas Hydrates can be the future source of energy for India. Development of technology to harvest Gas Hydrates can ensure energy security of the nation. Gas Hydrate exploration, development of tools for the environmentally safe recovery of gas from these gas hydrates is the need of the hour.

Basic infrastructure to take up studies on Gas Hydrates in India has been set in three collaborating National laboratories in India and expertise was gained during the 10^{th} and 11^{th} plan activity. In the present day energy demand with the increase in crude oil price, gas hydrates is one of the promising alternate viable resources and is a long term prospect. Exploitation of gas hydrates from continental margins of ocean basins is a technological challenge. In the international scenario, a proven field executable methodology for the exploitation is yet to be established, but lots of laboratory scale experimental works are in progress for safe exploitation. Krishna-Godhavari basin has evidence of occurrence of huge thickness of gas hydrates demonstrated by shale fracturing mechanism and world's deep seated occurrence of gas hydrates have been sampled in Andaman basin. To prove the developed concepts and technology from the capacity building which happened during 10^{th} and 11^{th} plan period, taking up this program is beneficial.

a) Objectives

(i) Quantification of gas hydrates reserves using Multi Channel Seismic (MCS) & Ocean Bottom Seismometer (OBS) data from Krishna Godavari and Mahanadi basins
(ii) Collection of geophysical and geological data at new potential locations
(iii) Demonstrate existence of methane hydrate by ground truth sampling/drilling at the identified potential sites
(iv) Establish laboratory scale experimental and numerical studies to establish the feasibility of methane recovery from gas hydrates
(v) Conduct field trials at potential gas hydrate site for environmentally safe recovery of gas from gas hydrates
(vi) Understand the impact of gas hydrates dissociation on geological environment and climate and establish mechanism for monitoring and management of environmental perturbation during harvesting of gas hydrate

b) Participating Institutions:

(i) National Institute of Ocean Technology, Chennai
(ii) National Centre for Antarctic & Ocean Research, Goa
(iii) National Geophysical Research Institute, Hyderabad.

c) Implementation Plans:

During the 12th plan stress will be on the numerical studies, laboratory and field experiments towards the extraction gas from the gas hydrates

Using the technologies developed earlier ground truthing & validation of occurrence and abundance of gas hydrates will be carried out.

New sites will be identified and explored for the gas hydrates.

Technology development for the exploration and methane generation experiments from gas hydrate will be carried out by NIOT. Science component will be carried out by National Geophysical Research Institute (NGRI), Hyderabad and National Institute of Oceanography (NIO), Goa. Science component will be coordinated by National Centre for Antarctic Ocean Research (NCAOR), Goa. Scientific data collected by NGRI and NIO will be deposited at NCAOR, Goa. NGRI and NIO would be continuing its concentration on the scientific aspects of the gas hydrates while the technological tool development would be implemented by NIOT based on the input and requirement of NIO and NGRI and vice versa.

Infrastructure facilities / lab requirements

It is proposed to have a Test beds for carrying out the testing of the systems developed for Gas Hydrates program. The Autonomous Coring System is of dimensions 8 X 3 X 6 m and weight is 10 tons in air. Infrastructure would enable testing of such systems.

d) Deliverables:

The most significant output from this program would be a comprehensive understanding of the gas hydrate occurrences in the Indian EEZ. In addition, the program also envisages development of suitable technology for methane generation experiments from the proved locations of gas hydrate occurrences,

(i) Study of attenuation, reflection strength, blanking and instantaneous frequency for qualifying whether the BSR is related to gas-hydrates or identifying gas-hydrates without BSR
(ii) Pre-stack depth migration of MCS data to produce improved structural image sediments including the BSR, base of free-gas layer and migration paths for fluid flow
(iii) Traveltime tomography of MCS and OBS data for delineating the extension of gas-hydrates/'free-gas' bearing sediments
(iv) Fine-scale and accurate velocity structure using full-waveform inversion of MCS data across the BSR
(v) Detection of fracturing and potentially delineating the reservoir type (fractured vs. pore space) from the analysis of 4-C OBS data

- Field trials at potential gas hydrate sites for environmentally safe recovery of gas from gas hydrates.
- Quantification of gas hydrates reserves using Multi Channel Seismic (MCS), and Ocean Bottom Seismometer(OBS).
- Experimental and numerical studies to establish the recovery of Methane from gas hydrates.

e) Budget requirement: ` 143 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Gas Hydrates	14	32	32	35	30	143

3.8 OCEAN TECHNOLOGY

Ocean resources are abundant and it is imperative for the mankind to depend on these resources in the near Future. However these resources are to be used in sustainable way and the need of the hour is to develop dependable and cost effective technologies for this. To be self-reliant, such technologies would have to be largely developed, tested and operated indigenously. In the areas of ocean surrounding India, the present extent of Exclusive Economic Zone (EEZ) is 2.02 million sq. km. With India's claim for an additional area of EEZ, under the UN Convention of Law of the Sea, India is likely to get approximately 1 million sq. km added to its original EEZ area of 2.02 million sq. km. This large area of EEZ has a vast potential of variety of resources, both living and non-living, which can substantially contribute to the augmentation of societal benefits as well as help the economic development of the country.

National Institute of Ocean Technology is implementing various programs in the Ocean sector which are strategically important and beneficial to the society under the aegis of Ministry of Earth Sciences (MoES).

3.8.1 Ocean Energy and Fresh Water (Continuing)

The main forms of ocean energy are wave, thermal energy and ocean currents. India being a tropical country a constant difference in temperature is available between surface water and the deep ocean. This gradient can be used to generate power and fresh water simultaneously. Using this method desalination has been very successfully implemented in the Kavaratti Island at Lakshadweep as also demonstrated on a barge moored in 1000m water depth and in a power plant using the condenser reject water. Now a floating offshore plant of larger capacity has to be attempted to serve coastal mainland water requirements. To this end industry participation has already been sought and the steps towards implementing the first phase, that of design, have been commenced. Parallel work is in progress towards harnessing power from ocean currents, increasing efficiency of power modules for harnessing wave energy and developing turbines for power from thermal gradients.

The acute shortage of power and water faced by the country, demands extensive studies in these areas.

Research on solar desalination has reached a stage where demonstration plants are established in selective localities.

a) Objectives:

(i) Implementation of large scale floating desalination plant

(ii) Generating fresh water using the Low temperature thermal desalination technology by utilizing the waste heat at North Chennai Thermal power plant
(iii) Development of turbines toward OTEC / Wave energy to run LTTD plants or run small loads or increase efficiency of wave energy plants
(iv) Theoretical and experimental studies on components like heat exchangers for desalination and energy conversion
(v) To install a floating wave powered device to power loads or to meet the lighting requirements of small islands
(vi) Generation of theoretical, experimental and field data for optimization of components and suitable adoption towards commercialization of extraction of renewable energies and fresh water including solar desalination.
(vii) Selection of working fluids, turbines, power plant components and experimental studies related with thermal gradients.
(viii) Develop hydro-kinetic ocean current turbines and wave turbines to suit for power generation along Indian coasts
(ix) Design and performance study of heat exchangers, turbines including Analytical modeling, numerical modeling, experimental comparison etc.
(x) Design, Development and installation and commissioning of an improved power plant desalination technology in a coastal power plant for meeting the industrial and drinking water requirements.
(xi) Develop techno-economical solar desalination units for commercial implementation in coastal and rural areas of the country.

b) Participating Institutions:

National Institute of Ocean Technology, Chennai

c) Implementation Plans:

(i) Selection of working fluids, turbines, power plant components and experimental studies related with it.
(ii) Develop hydro-kinetic ocean current turbines to suit for power generation along Indian coasts
(iii) Design and performance study of heat exchangers, turbines including Analytical modeling, numerical modeling, experimental comparison etc.
(iv) Design, Development and installation and commissioning of an improved power plant desalination technology in a coastal power plant for meeting the industrial and drinking water requirements.
(v) Develop techno-economical solar desalination units for commercial implementation in coastal and rural areas of the country.
(vi) Material Studies for cold water pipe for desalination
(vii) The implementation, commissioning and operation and maintenance of the large scale floating desalination plant will be taken up in the XII Plan.

The prototypes of power modules for harnessing wave energy and developing turbines for power from thermal gradients will be designed and implemented in the field in the upcoming plan period.

After testing of scaled models, it would be a significant achievement to power the desalination plants using the power generated by these renewable ocean energies.

The programs will be implemented by NIOT availing scientific and technical manpower in regular as well as project mode. Wherever required, it is proposed to

work in collaboration with academic institutes, research and development organizations.

The large scale floating desalination plant will be realized through partnership with industries and international organizations. Programs like solar desalination plants etc will be implemented with help of the local communities and authorities. Projects will be monitored as per the NIOT procedures.

Infrastructure facilities / Lab requirements

NIOT has gained a lot of experience in desalination due to several successes. However, for large scale production and commercialization, more optimization is required in the components related to the thermal cycle and vacuum systems. While the present campus does have a small laboratory, continuous data collection is not possible, since continuous flow of sea water is not possible. Locating the laboratory right at the sea shore will have the advantage of continuous flow of water. Thus the facility could house a desalination research laboratory drawing sea water continuously for long duration experiments on heat transfer, fouling, coatings for marine applications, development and performance of newer materials for heat exchangers, etc.
Research will be carried out on hybrid systems of wind / wave / solar energy. A wind turbine in a platform in the water can be installed, which could supply power to the seafront facility itself.

d) Deliverables:

(i) Large scale Floating desalination plant
(ii) Floating wave powered device to power small loads or to meet the lighting requirements of small islands.
(iii) Current Turbines and wave turbines for power generation.

e) Budget requirement: ` 365 crores.

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Energy and Fresh Water	43	69	76	80	96	365

3.8.2 Development of Deep Sea Mining Machine (Continuing)

The Polymetallic nodules containing copper, cobalt, nickel and manganese are viewed as potential resources to meet the increasing demand for these strategic metals worldwide. India has a status of Pioneer Investor and has been allotted a site in the Central Indian Ocean Basin (CIOB) by the International Sea Bed Authority (ISA) for exploration and technology development for polymetallic nodule mining. Development of reliable Deep-sea mining system for harnessing resources from ocean will help to meet the country's growing mineral requirements and increase the country's self sufficiency, in the near future.

a) Objectives:

(i) Design and development of a new crawler based mining machine capable of collecting and pumping nodules from water depth up to 6000m.

(ii) To develop a flexible riser system for transporting nodules from the ocean floor to the mother ship/barge.
(iii) To qualify the underwater mining system from ship/floating platform equipped with Dynamic Positioning (DP) system using winches, cable and handling systems at water depth up to 6000 m.
(iv) Development of upgraded version of soil tester
(v) Testing for qualification of system at Central Indian Ocean Basin.

b) Participating Institutions:

National Institute of Ocean Technology, Chennai

c) Implementation Plans:

The development of flexible mining systems requires conveyance of nodules of 30 mm diameter (max.) through a flexible hose with an internal diameter of 90 mm at a maximum concentration of 30% by weight considering various factors pertaining to the system. However if a buffer storage is used, a centrifugal pump/ suitable pump capable of handling solids up to 75 mm will be required. The same requirement will also be there for pumping other deep-sea minerals from lower depths (about 3000 m). Such pumps have to be developed for subsea operations and the performance requirements studied. The power requirement is also higher and requires utilization of a higher voltage system.

It is proposed to carry out studies for materials and welded joints in various areas where underwater pressure, corrosion and fatigue come into play. Also , development of sub-sea control systems, and acoustic positioning and imaging systems, study of corrosion, fatigue, wear, corrosion, hydraulic fluids, underwater flow and density meters for large solid media, , underwater electrical and electronic systems – indigenization would be carried out wherever feasible..

Development of Control Systems that can facilitate long term uninterrupted operations and configuration design of systems for large scale mining operations like Floating Platform are also envisaged in this proposal

Analysis of behavior of multiple mining machines connected to a single floating station and associated design will be carried out .

Wherever required, it is proposed to work in collaboration with academic institutes, research and development organizations, industries and international organizations.

Infrastructure facilities / lab requirements

An underwater mining vehicle test facility having a bentonite bed to simulate the deep ocean floor, with large handling facilities are required for conducting developmental studies on the underwater mining vehicle. The vehicle test basin should have a depth of more than 5 m and should also have an assembly and integration bay adjacent to it. A common EOT crane should be used to facilitate assembly operations of sub-sea mining machine as well as deploy the mining machine on the bentonite bed. In view of the above, a full fledged proto type Test Basin with an operable depth of 10 m and associated testing facilities is essential for testing of underwater systems.

d) Deliverables:

(i) Mining System with flexible riser system for 6000m operation.
(ii) Upgraded soil tester

e) Budget requirement: ` 247 crores.

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Development of Deep Sea Mining System	93	88	36	14	16	247

3.8.3 Manned and Unmanned Underwater Vehicles (Continuing)

Suitable underwater vehicles are required for the exploration and harvesting ocean resources. Underwater vehicles have applications in the areas of exploration of oil & gas and minerals, defense, surveillance, pipe line survey, drilling support, exploration of oil & gas etc. With recent development of ROV with 6000 m depth capability India has joined select band of nations with such technology. It has always been left to indirect techniques for exploring the oceans, their resources and assessing the performance of the underwater systems. A manned submersible with scientists onboard with suitable observation, sampling and intervention devices can be a tool for the direct observation and intervention and sampling in deep oceans. Different stages of ocean technology development projects need direct observation by manned submersibles and it would be impractical to hire manned submersibles to meet this requirement

a) Objectives:

- To design and develop a 6000 m depth rated manned submersible with a capacity to carry three crew members and scientific equipment in association with a joint partner
- Development of work class remotely operated vehicle (up to 500m depth rated) for shallow water and polar application.

b) Participating Institutions:

National Institute of Ocean Technology, Chennai

c) Implementation Plans:

Developing a manned submersible with capacity to carry one pilot and two scientists to a water depth of 6000 m will be taken up with the help of joint partner.

Based on the experience gained in building Remotely Operable Vehicle for 6000 m depth a new state of the art work class deep water ROV will be developed with enhanced specifications A shallow water ROV will be developed to suit the needs of the off-shore industry will be developed. This ROV will also be suitable for research activities in polar regions too.

Joint partner for developing the manned submersible will be identified through global tender. The submersible will be classed by international certifying agencies like ABS, DNV etc. Complete technology transfer will be ensured by the active participation of Indian scientists & engineers at every stage of design, development, assembly and testing.

Development of deepwater work class ROV and shallow water polar ROV will be carried in-house based on the experience gained so far. Field testing and exploration studies will be carried out in association with the industry users and other research organizations.

Infrastructure facilities / lab requirements

It is proposed to have Test jetty for Tow vehicles. The group developed a Remotely Operable Vehicle with dimensions of 1.5 m X 1.5 m X 3 m height and the Tether Management System with a height of 3 m. The combined weight of the system is 8 ton in air. The manned submersible with a weight of 20 tons is also on the anvil. The proposed bay will have the facilities to assemble, integrate and test these types of underwater vehicles.

d) Deliverables:

(i) Manned submersible.
(ii) Shallow water Remotely Operable Vehicles.

e) Budget requirement: ` 206.00 crores.

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Manned & unmanned underwater vehicles	27.00	48.00	56.00	55.00	20	206.00

3.8.4 Marine sensors, Electronics & Ocean Acoustics

Sensors form the heart of any oceanographic instruments and Sonar. Most of these sensors are imported with huge costs and many a time not supplied for the strategic reasons. Development of sensors such as underwater acoustic transducers, biosensors, buried-object detection systems will help India in bridging the technological gap with the developed countries. Different platforms employ a large variety of sensors, which operate in a wide range of hostile environments and use different measurement protocols. Suitable underwater electronic systems that are cost effective and that could withstand long term operations in the sea need to be developed. Since acoustics is the only efficient mode of communication in underwater, research, development and implementation in key areas of underwater acoustics such as ambient noise measurement, analysis, characterization and modeling, acoustic vector sensor, sea bed classification/characterization, underwater signal processing algorithms for shallow water applications etc, are taken up where in only a very few initiatives have been taken up in our country in the last one decade.

a) Objectives:

(i) To establish underwater Electronics Support Facility
(ii) To develop underwater components
(iii) To develop marine sensors, underwater acoustic transducers and systems for Oceanographic applications like shallow water sub bottom profilers, sensor technologies and systems to detect and classify buried objects under sea bed and various custom based sensors.
(iv) To develop deep ocean pressure recorders for tsunami detection and data acquisition & processing unit in the surface buoy.
(v) Sea bed classification/characterization using underwater acoustics.
(vi) Development of acoustic vector sensor and underwater signal processing algorithms for shallow water applications
(vii) To establish a network of ambient noise measurement stations in shallow waters along the coast of India.
(viii) Development of a shallow water model for prediction of high frequency ambient noise.
(ix) To develop Time Reversal Mirror based underwater communication system for long range applications.

b) Participating Institutions:

National Institute of Ocean Technology, Chennai

c) Implementation Plan:

(i) Adapt suitable Fuel Cells technology for various underwater applications
(ii) Coordination and interaction with ISRO organizations will be madeto have reliable data communication over Indian seas using dedicated Indian satellites to cater all the Oceanographic data, voice and broadcasting applications
(iii) Region specific model for ambient noise prediction in other regions will be studied . Already available long period data for our sites will be used for modeling high frequency noise in our regions.

(iv) Time reversal mirror based singal processing algorithms that are currently being developed will be tested in the field and TRM based Underwater acoustic communication system for long range applications, will be developed

Wherever required, it is proposed to work in collaboration with academic institutes, universities, research and development organizations, industries and international organizations. A few projects would be executed through inter- institutional programs with IITs, IISc, NIO, NPL , etc .

Infrastructure facilities / lab requirements

It is proposed to establish SONAR Testing facility, Underwater Precision Engineering Laboratory and Biosensor Labs, Analytical / Microscopy Laboratory.

It is proposed to have a towing tank and a float calibration facility to enable calibration of sensors and floats. A wind tunnel is proposed for calibration of meteorological sensors, storage yard for mechanical components / electronic instruments / accessories.

An open sea acoustic laboratory would act as a fully instrumented measurement station and facility for testing and calibration of underwater acoustic devices. The laboratory would be a floating platform which could be operated up to 100 m depth. The frequency range is 20 kHz to 200 kHz. It would have facility for testing of underwater systems and measurements in the open sea. The facility would also enable experiments for single transmission and reception for carrying out sound propagation studies.

d) Deliverables:

(i) Marine sensor systems for Ocean Applications
(ii) Deep Ocean pressure recorder for Tsunami detection
(iii) Acoustic sensors and systems for shallow water applications
(iv) Shallow water model for prediction of high frequency ambient noise.
(v) Time reversal mirror based underwater communication system for long range applications.

e) Budget requirement: ` 78 crores.

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Marine sensors, Electronics & Ocean Acoustics	16	17	17	16	12	78

3.8.5 Technical Criteria Atlas (Continuing)

The program of Technical Criteria Atlas was formulated with the aim of characterizing the shoreline using observations at selected locations and modeling with numerical simulation. Study of the components (Tide, wave and currents) to produce a database/atlas of engineering parameters like extreme statistics with different return periods have been initiated in the 11th plan and it is proposed to continue in 12th plan period for completion of the atlas for our regions.

a) Objectives:

To develop a reference for engineering design of coastal infrastructure and coastal protection along the coast of India, providing seasonal extreme value estimates of hydrodynamic loads in the form of waves, currents and water levels at 10 locations for different return periods such as 5,10, 25, 50 and 100 years.

b) Participating Institutions:

National Institute of Ocean Technology, Chennai

c) Implementation Plans:

Eight stations are to covered with long term shallow water wave and met-ocean observation

Existing coastal installations like ports, power plants and industries will be used for carrying out continuous observation. Arrangements would be made to collaborate with such agencies to improve observational coverage with local involvement for mutual benefit.

Efforts would be initiated to integrate data through various observation schemes currently operating in the country like tide gauge network, HF Radar, Port monitoring systems, LEO observations, etc into a suitably formatted database for use of coastal engineering community and to feed the data into TCA for future refinements.

The program will be implemented by NIOT. Local academic Institutions, Universities and NITs shall be involved in conducting numerical modelling and measurements at the site. Research scholars / students shall be involved in the project. Secondary information available with IMD, INCOIS, SAC, etc. shall be obtained. The major steps involved in implementation are:

Hydrodynamic modelling and validation with field data (tide, wave and currents)
Computation of various parameters for the Atlas.

Software development for web based Atlas.

Arrange local agencies (ports, coastal power plants, etc) to install shore based observatories and feed data for periodical improvement of TCA.

Among the project modules, assessment of sea level rise for studies related to beach stability in islands will be carried out in coordination with ICMAM. It is proposed to form a common work plan and a strategy to achieve the end product with combined efforts of both ICMAM and NIOT. It is also proposed to form a task group to coordinate the site selection, common quality procedure for data collection and formats along with work flow.

Infrastructure facilities / lab requirements

The Coastal Engineering facilities available in India are limited at few centers such as IIT and CWPRS and these facilities do not contain shallow water test facilities. The current research needs more investigations in near shore/wave breaking area. The research areas include estimating of wave loads on structures, wave transformation in near shore, sediment transport studies. For the above research the facilities required are as follows:

An open coast pier, in up to water depth of 8 m from the land, that can be used for coastal engineering research facility as well as instrumentation.

A Large Scale Laboratory for sediment transport

A building with all test equipment and facilities

d) Deliverables:

- An atlas for waves, currents and tides for Indian seas.

e) Budget requirement: ` 36 crores.

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Technical Criteria Atlas	13	8	6	5	4	36

3.8.6 Coastal circulation, sediment transport, and Shoreline changes (Continuing)

The coastline is subjected to several geo-morphological changes due to natural processes and manmade activities. Shoreline changes are one of the serious problems in several pockets along the Indian coast. The shoreline retreat leads to the loss of the beach and consequently to a setback of the coastline that threatens the coastal communities. The information of shoreline changes and understanding the trends of sediment pattern in coastal zone are very important in the case of the Indian coast which is thickly populated and where a lot of developmental activities are undertaken along the coast. Therefore, there is an increased demand for accurate information regarding past and present trend in shoreline changes and near shore circulation pattern. Such information along with seasonal movement of sediment along the coast will be useful to understand cause of erosion, designing navigational channels, breakwaters, jetties etc and deciding disposal grounds for dredged material etc.

This program was formulated with the aim of characterizing the shoreline using observations at select locations and stabilizing the shoreline at selected sites for demonstration purposes.

a) Objectives

(i) To assess shoreline changes annually and to understand the Coastal circulation and sediment transport processes in Coastal Waters to provide the seasonal pattern of sediment transport at priority areas using modelling
(ii) Characterization of littoral transport along the Indian coast and detailed measurements at select sites
(iii) Develop a database in the form of atlas for coastal sediment dynamics covering the entire country.
(iv) Assessment of impact of alteration of sediment transport on coastal geomorphology

b) Participating Institutions

(i) National Institute of Ocean Technology, Chennai
(ii) Integrated Coastal & Marine Area Management – Project Directorate, Chennai

c) Implementation Plan:

(i) Assessment of shoreline changes using satellite data and field verifications to generate shoreline-change maps (ICMAM)
(ii) Setting of regional coastal circulation model for 3-4 regions along the Indian coast. (ICMAM & NIOT)

(iii) Sediment transport modeling using secondary data and littoral environment observations and estimation of sediment transport rate cell wise /region wise (ICMAM & NIOT)
(iv) Development of data base on sediment transport in the form of Atlas (NIOT)
(v) Water quality related inlet stabilization measures at prioritized tidal creeks and estuaries (NIOT)
(vi) Location specific studies on impact of alteration of sediment transport on sand dunes

The project will be implemented jointly by NIOT and ICMAM PD. A common project document shall be prepared indicating division of work avoiding overlap among the participating institutions. Further, an inter-institutional work group will be formed involving NIOT, ICMAM and other institutions like NIO, CESS, NIT, Universities etc to collaborate in sediment transport studies. Being a field extensive project it would be desirable to involve organizations at different locations of the country to ease the observation efforts and better management.

Efforts would be initiated to integrate data various observation schemes currently operating in the country like tide gauge network, HF Radar, Port monitoring systems, LEO observations, etc into a suitably formatted database for use of coastal engineering community in managing shoreline management issues.

d) Deliverables:

(i) A GIS based database shoreline change maps at 1:25000 for entire country and 1:5000 scale for selected locations and mapping Annual/periodical Shoreline changes.
(ii) Location-wise information on direction of sediment movement and estimation of sediment budget seasonally. and an Atlas for sediment transport along the Indian coast
(iii) Recommendations on tidal inlet management to achieve best dilution as a part of water quality control programmes.
(iv) Changes in sand dunes due to alteration of sediment transport processes

e) Budget: ` 65 crores (projected in 3.6.6)

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Shoreline Management	15	18	13	10	9	65

3.8.7 Offshore structures & Numerical Offshore tank

Rising oil prices, increased environmental awareness and energy security issues are driving the rapid development of renewable energy technologies and dependence on offshore resources. There is increasing need of floating plants, design of the plat form the riser pipe and its attachment have to be studied from the point of dynamic interaction among them due to the action of waves, currents and wind. Symmetrical platforms, spar type platforms, semi submersible platform with suitable connections to riser are some of the technological options. The development of an integrated platform, riser and its mooring are major technological constraints for the design of a

floating plant and it has to be studied on priority basis in the coming years, through studies of various design options, simulations and model studies.

Studies need to be continued for getting a proper understanding of the materials.

Study of breaking wave forces for optimizing the structural design with innovative construction techniques will help to reduce the cost of structures. Another way of reducing costs is to have facilities with multiple purposes rather than a single purpose. The breakwaters would also serve as shore protection devices from cyclones and tsunamis for the fishing community.

Land based wind mill technology is well developed and popular. They do not need the costly coastal land area for erecting the wind mills. Secondly the offshore wind mills experience larger wind speeds since there is no obstruction as on land. However, the design & construction of foundation for these wind mills in shallow waters is a challenge. In keeping with the newer advances, floating wind turbine platforms need to be studied.

Numerical Offshore Tank is a dynamic Simulator, capable of analyzing the complete hydrodynamics of production units as well as structural loads of mooring lines and risers.

The main goal of the facility is to complement model basin tests, simulating the whole production system behavior under a wide range of different environmental conditions (wave, wind and current), enhancing the accuracy of the whole analysis in a fast and in economical way. The facility of virtual environment with stereoscopic capabilities can simulate various elements like floating/fixed structure, risers, mooring lines/anchors, sea state, and sea bed topography in 3 D environments.

a) Objectives:

(i) Interface design to riser connections to floating bodies
(ii) Analysis, Design, model studies of Fixed and Floating Platforms Moorings, Suction pile anchors
(iii) Fixed and Floating Platforms for offshore wind turbine
(iv) Studies on submarine pipeline for high energy environment
(v) To develop Numerical Offshore Tank Facility for offshore production systems for exploration or exploitation of resources

b) Participating Institutions:

National Institute of Ocean Technology, Chennai

c) Implementation Plans:

The design of sumps for drawing warm water and cold deep sea water for small islands will be optimized to minimize its weight and volume to facilitate its construction on land and towing and seating at offshore location in water depths of around 5 m.

Optimization of structural design for Wave forces (breaking & non breaking. Assessing the wave forces accurately and develop a cost effective structure to with stand high wave loads for which there is no code. The outcome of above research

can be applied to other structures which are built in shallow coastal waters. The steps involved are:

- Study of materials and deployment procedures for the cold water pipe.
- Development of High Performance computing system with relevant hardware/software for computation and visualization.
- Numerical modeling software for hydrodynamics and structural analysis.
- 3 D Visualization/animation tools for simulating end product.
- Networking with other MoES and other research institutes in the country.

The research institutes like IIT, NIT and universities will be involved in undertaking physical/ numerical models studies. For the research areas like wave structure interaction and design of substructure for wind turbine, the expertise available with research institutes outside the India will be utilized.

The expertise available with other countries in like TPN, Brazil will be utilized in developing numerical offshore facility. Also, the state of art research institutes like IIT will be involved in development of numerical tools and its validation. Offshore consulting companies like EIL/ONGC will be consulted it development stage to indentify the industrial requirement.

Infrastructure facilities / lab requirements

Deep water applications like Desalination, Ocean Energy and Mining require several configurations of offshore platforms to be studied. While small model testing can be carried out in the IIT wave basin, slightly scaled up models need to be tested at sea. Models of various types of platforms with instrumented moorings can be tested in the open sea in a seafront located laboratory. Long term experiments can be carried out for motion response to include different waves and currents for the entire year. A large coastal wave basin with facilities to create 2 D and 3 D waves provides a unique capability within the country to conduct 2D and quasi-3 dimensional studies on structures and shorelines at medium to large scales.

d) Deliverables:

- A virtual reality facility for development of offshore structures .
- Fixed and Floating platforms for offshore wind turbine.

e) Budget requirement: ` 68 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Offshore structures & Numerical Offshore Tank	2	16	21	17	12	68

3.8.8 Marine Bio-technology (Continuing)

During 11th five year period this group is in the process of developing 350 bar pressure rated high pressure retainable water sampler, high pressure low temperature serial dilution and fermentor system. Using this experience it is proposed to design 600 bar pressure rated instruments to explore deep sea microbes.

Metagenomic technology tries to overcome this bottleneck by the development and utilization of culture independent approaches. In metagenomics the power of genomic analysis (the entire DNA in an organism) is applied to entire communities of microbes, bypassing the need to isolate and culture individual microbial species and thus provides a relatively unbiased sampling of a vast untapped genetic diversity that is present in various microenvironments. An additional advantage is that the genes that encode biosynthesis of product of interest can be isolated and analyzed using bioinformatics tools.

The proposed research will provide descriptive information about the diversity of organisms in an extreme environmental condition (deep sea) with great through put to utilize even uncultivable microbes for various novel and useful products discovery. Isolation of barotolerant gene from deep sea samples will give a background idea for presence of such microbes in particular environmental niches and thus the same can be used as supporting information for isolating microbes (cultivable if any) from same environmental niches.

A few major challenges confronting the algal nutraceutical industry are the mass production of marine microalgae including the search for an ideal microalgal species, determining less energy intensive methods for the extraction of products from microalgae and reducing the high unit cost of biomass production from microalgae. Hence this project will aim to rectify these problems for the production of omega three fatty acids and astaxanthin from marine algae. Similarly, availability of resources for biocrude and bioplastics in marine environment, especially from macroalgae is not explored fully.

Meeting Ballast water performance of IMO standards will require development of suitable technologies to evaluate it according to the criteria prescribed by the IMO. Such verification facilities are very much in demand in India.

a) Objectives

(i) Development of technology for collection, isolation and characterization of deep sea barotolerant and barophilic bacteria and their mass culture.
(ii) Identification of novel biomolecules and genes through metagenomics approach.
(iii) Collection and isolation of lutein accumulating microalgal strains from marine environment.
(iv) Mass culture of the prospective candidate species for the production of lutein.
(v) Development of newer materials and nanoparticles with antifouling property.
(vi) Testing ballast water, validation and certification of ballast water treatment systems
(vii) Anti-biofouling measures through plasma pulse field generation for inactivation of biofilm forming bacteria.

(viii) Development of a complete package of breeding, larval rearing, seed production and demonstration of fin fish culture at open sea cages
(ix) Development of technology for collection, isolation and characterization of barotolerant and barophilic bacteria and their mass culture. Identification of novel biomolecules and genes through metagenomics approach.
(x) Isolation, purification and characterization of bioplastics and nutraceuticals (EPA, DHA, etc.) from marine microalgae, macro algae and blue green algae.
(xi) Establishment of a land based testing facility for the ballast water management systems.
(xii) Training of manpower in basic scuba diving skills at various levels for biological and engineering applications.

b) Participating Institutions

National Institute of Ocean Technology, Chennai

c) Implementation Plans

Though considerable progress is achieved in fulfilling the objectives of the 11th plan some of the objectives are yet to be achieved. It is proposed to continue the project in the 12th Plan to complete the following tasks.

- Isolation and identification of barotolerant and barophilic bacteria and their mass culture.
- Identification of novel biomolecules and their genes through metagenomics approach.
- Production of lutein from marine microalgae.
- Interaction with adhesive proteins to tackle biofouling in marine environment.
- Development of sea cages of various size and shapes to suit Indian coastal waters.
- Provision of hands on training to the traditional fishermen in offshore mariculture
- Metagenomic approach to overcome non cultivability of the microbes present in many environment
- Development of suitable technologies to evaluate Ballast water performance according to the criteria prescribed by the IMO
- Development of diving expertise and infrastructure

This program will be implemented by NIOT through the scientific and technical staff in collaboration with other institutes such as CMLRE, NCAOR, IIT, etc.

Infrastructure facilities / lab requirements

This group would require the following facilities:

- Sea water intake and supply system including pump house
- Hatchery
- Nursery
- Freshwater intake and supply system
- Experimental earthen ponds
- Raceway culture system for micro algae
- Wet Lab
- Instrumentation Lab

- Storing facility
- Jetty
- Training cum administrative Facilities
- Feed Plant
- Accommodation facility for trainees and hatchery workers
- Commercial Grow-out Ponds
- Sea water pool for testing

d) Deliverables:

- Isolation and identification of barotolerant and barophilic bacteria and their mass culture.
- Production of lutein from marine microalgae.
- Land based ballast water management facility

e) Budget requirement: ` 105 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Marine Bio-technology	31	28	23	13	10	105

3.8.9 Seafront Facility (Continuing)

The seafront facility is taken up in order to enable the activities in development of proto type systems, testing and calibration of indigenous developed marine systems in the ocean. The present campus was established in stages from 1998 at Pallikaranai. There is a need to have additional facility as activities have expanded phenomenally.

a) Objectives:

To establish state-of-the-art seafront facility for testing, calibration, trials and demonstration of Ocean Technological activities at the sea including laboratory facility on Shore.

b) Participating Institutions

National Institute of Ocean Technology, Chennai

c) Implementation Plans

It is proposed to complete the land acquisition along the sea coast and to establish common amenities such as the estate, guest house, roads etc. Minimum equipment required for any field testing will be kept and operational maintenance of the facility will be performed.

This seafront facility would be taken up in three phases viz. acquiring land from Government of India, construction of testing labs and premises and establishing seafront facility with fully equipped laboratories.

d) Deliverables:

- State- of-the- art seafront facility for testing, calibration, trials and demonstration of Ocean Technological activities at sea including laboratory facility on shore.

e) Budget requirement: `175 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Seafront facility	57	44	31	24	19	175

3.8.10 Technologies for Development of Island community (New)

The problems associated with the islands are reduction in forest cover, population increase, generation of domestic waste, reduction in fishery production, tourism development, etc. In this regard, the islands should be improved at least in three major issues like food, energy and water. This implies self-sufficiency in these issues in an eco friendly manner. All technologies developed / developing in NIOT can be put together in an Indian Island to enhance our knowledge in these fields and create a model community.

a) Objectives:

- To develop an island community with the following activities.
  - Desalination plants for water supply to the island community
  - Renewable energy units
  - Development of sea cages of various sizes and shapes to suit islands.
  - Formulation of quality feed to support the offshore fin fish farming.
  - Increase of demersal fisheries through emplacement of artificial reefs.
  - Production of bio crude and bio fuel marine microalgae and macro algae.
  - To increasing species diversity or in conserving a unique habitat intact for future generations.

b) Participating institution:

National Institute Of Ocean Technology, Chennai

c) Implementation Plan:

An island suitable for establishing these facilities will be identified. As this is a programme of societal importance, local population and authorities will be involved in planning, and establishing, running and maintaining the facilities.
Wherever required, it is proposed to work in collaboration with academic institutes, research and development organizations, industries and international organizations.

d) Deliverables:

A model island community

e) **Budget :** ` 70 crores

(Rs in crores)

Name of the program	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Technologies for development of Island community	11	16	17	16	10	70

3.8.11 NIOT manpower and operational expenses (Continuing)

NIOT has basic focus on field demonstration of new technologies. It has rapidly expanded in the last decade and has created a lot of infrastructure to meet the growing ongoing research activities. It has established laboratories and procured equipment that need continued maintenance for prolonged productive use in the research activities.

Infrastructure and manpower form the core facility for implementing various programs. Numerous programs are envisaged under XII-plan period in various fields like Ocean Energy, Deep Sea Mining, and Development of technology for gas hydrates exploration, Marine sensors and systems, Ocean acoustics and Ocean electronics, Marine bio-technology besides maintaining operational programs like Vessel Management.

In order to carry out the continuing programs, the facilities and manpower are in place for the proposed work quantum, where as augmentation of new manpower is planned for many new programs and also for expanded scope of old programs. To meet the project schedule, however, services of contract staff have been utilized wherever possible. Major portions of non-technical works (like Campus House-Keeping, Gardening, Security, etc.) are being outsourced and self-help groups are being encouraged to get involved.

a) Objectives:

(i) To provide effective and efficient administration for executing the above programs with changing needs ie. receive funds and incur expenditure on designated functions, to provide a system for procurement processes and its management thereof.
(ii) To enhance infrastructural facilities such as computer center, laboratories, library, campus etc. and to maintain it for effective utilization. As the activities have grown, the corresponding manpower requirement has substantially increased. So it is needed to enhance office infrastructure, computers, accessories, servers, networks and add new journals, and books.

b) Participating Institution:

National Institute of Ocean Technology, Chennai

c) Implementation Plan:

Ocean Technology is an interdisciplinary subject. As NIOT is engaged in new frontiers of Ocean Technology, it is imperative to retain / keep in reserve such trained manpower. The capacity building process has to seen as a long term commitment of the organization to the nation.

At present, long term technology programs, like deep sea mining technologies, Gas Hydrate technologies etc were provided only with limited regular staff and augmented largely by temporary staff. In future, such core technology development programs should be manned by regular staff so that the expertise generated is retained on a long term basis. Therefore, a quantum jump is needed in the category of permanent staff in the technical cadres and also in the administrative cadres to service all the technology programs.

During this plan period, it is proposed to maintain and augment the NIOT core strength of manpower and enhance the facilities required for research activities. The staff strength will be distributed as per requirement and the common facilities are to be maintained with an emphasis on maximizing the user accessibility.

Infrastructure facilities / lab requirements

In addition, administrative block is required for office space for Scientists / other staff members and also for Data Management Centre.

A separate block for computer centre is required to install high end servers, workstations, high performance computers, desktop computers and other peripherals such as printers, plotters, scanner etc. This centre will also have a data reception management cell and would be the central point for receiving all the data in real time from the systems deployed in the sea/coast etc.

d) Deliverables:

- Effective and efficient administration for executing all the programs of NIOT with changing needs.
- Enhancement of infrastructural facilities such as computer center, laboratories, library and campus.

e) Budget requirement: ` 199 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
NIOT manpower and operational expenses	31	35	40	44	49	199

3.9 OCEAN RESEARCH VESSELS

The research-vessel fleet consists of six research vessels viz ORV Sagar Kanya, FORV Sagar Sampata, TDV Sagar Nidhi, BTV Sagar Manjusha, CVR's Sagar Purvi & Sagar Paschmi currently, and a seventh being the Polar Research Vessel (PRV) which is being considered for construction. Of the total seven vessels, four of them

fall under the ageing research vessel catergory and the remaining three research vessels have been acquired/being acquired, recently. The four research vessels that have been proposed for their replacement, two are ocean going class and two are coastal research vessel class. During the current (XI Plan) the replacement of two Coastal Research Vessels (CRVs), viz., Sagar Purvi and Sagar Paschimi have already been proposed. The EFC proposal for acquisition of two CRVs at a cost of Rs.127.75 crores is under consideration during 2011-12 and the spill over component to the XII plan.

The details of the ocean going class research vessels proposed for replacement during the XII Plan period are provided as below:

It is pertinent to note that the two Ocean going Research Vessels, viz., ORV Sagar Kanya and FORV Sagar Sampada were built under an exchange programmes of German and Danish Governments way back in 1983-84 and they catered to the requirements of all the major programmes of the MoES as well as the national institutions under CSIR, ISRO, DRDO, ONGC and Universities during the last three decades. Their replacement is imperative due to the fact that the annual investments for their repairs, running and maintenance is increasing due to their ageing and the endurance of the vessels is also considerably reduced. The ship time availability for various programmes also reduced vis-à-vis the increasing demand of ship time for the scientific programmes has been many fold.

It is therefore proposed that ORV Sagar Kanya replacement is projected to cost Rs.600 crores and FORV Sagar Sampada replacement costs are of the order of Rs.500 crores.

a) Objectives:

(i) Replacement of ORV Sagar Kanya, FORV Sagar Sampada, two Coastal Research Vessels (CRVs), viz., Sagar Purvi and Sagar Paschimi.
(ii) To provide National facility for undertaking cruises to cater to the requirements of all the major programmes of the MoES as well as the national institutions under CSIR, ISRO, DRDO, ONGC, Universities etc.
(iii) Construction and commissioning of an ocean research vessel with state-of-the-art instrumentation for atmospheric sciences and physical, chemical, biological and geological oceanographic studies.

b) Participating Institutions:

(i) National Centre for Antarctic & Ocean Research, Goa
(ii) Centre for Marine Living Resources & Ecology, Kochi
(iii) National Institute of Ocean Technology, Chennai

c) Implementation Plan:

All tasks related to the planning, drawing up the design specifications including onboard scientific instrumentation, floating of a Global Tender, identification of a suitable shipyard, monitoring the work vis-à-vis the timelines, sea-trails and commissioning would be co-ordinated by NCAOR with guidance from a National Committee to be constituted for the purpose.

1. Replacement of two CRVs, Design, Ships Construction Costs by 2014-15

2. Replacement of ORV Sagar Kanya, Concept, Design, Ship Construction by 2016-17.
3. Replacement of FORV Sagar Sampada, Concept, Design, Ship Construction by 2016-17.
4. Operation, Running and Maintenance of all replaced vessels as above & existing vessels.

d) Deliverables:

A state-of-the-art oceanographic research vessel for studies pertaining to atmospheric sciences and physical, chemical, biological and geological oceanography.

i. Four new Research Vessels in place of Two CRVs, ORV Sagar Kanya and FORV Sagar Sampada
ii. about 200 cruises for implementing scientific programs of the MoES as well as the national institutions under CSIR, ISRO, DRDO, ONGC and Universities.

e) Budget requirement: ` 1483 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Replacement of Two CRVs, Design, Ships Construction Costs	60.00	55.00	15.00	---	---	130.00
Operation, Maintenance and Running Costs of Two CRVs after their acquisition	---	---	5.00	6.00	6.00	16.00
Operation, Running and Maintenance of Two CRVs until the acquisition of Two & Sagar Nidhi & Sagar Manjusha	54.00	45.00	39.00	53.00	46.00	237.00
Replacement of ORV Sagar Kanya, Concept, Design, Ship Construction Costs	5.00	220.00	260.00	90.00	25.00	600.00
Replacement of FORV Sagar Sampada, Concept, Design, Ship	5.00	180.00	240.00	50.00	25.00	500.00

Construction Costs						
TOTAL	129.00	490.00	614.00	198.00	102.00	1483.00

3.10 POLAR SCIENCE & CRYOSPHERE

The world's polar regions and their contiguous oceans are attracting more interest than ever before. Once regarded as barren, inhospitable places where only explorers go, the north and south polar regions have been transformed into high profile sites of scientific research. Be it in understanding the role of the polar realm in modulating the global climate or for studying the ecosystem adaptability and survival under extreme conditions, there has been an increasing interest in the science of the polar realm, over the past two-odd decades. . Realizing the importance of Antarctica as a pedestal for scientific research, India launched the first of her Annual Scientific Expeditions to the Antarctica way back in 1981. This was followed by the country's successful entry to the realms of Southern Ocean research in 2004 and the Arctic, three years later. To cater to the requirements of the Indian scientists in both the polar regions, two stations "Maitri" and "Himadri" have been established to serve as living-cum-research bases in the Antarctic and Arctic respectively. Another permanent research base in Antarctica is scheduled to be commissioned during the austral summer of 2012.

The focus areas of scientific studies in the Arctic and the Antarctic have been largely confined to earth, atmospheric and biological sciences. As regards the studies of the cryosphere, the research initiatives by Indian scientists in the Antarctic comprise monitoring of the glaciers in Dronning Maudland, studies of ice dynamics and energy balance and climatic reconstructions from ice core analyses. Systematic studies if the cryospheric domain of the Arctic is as yet to be initiated. Considering the significance of the polar ice cap and the sea ice in the polar regions in modulating, if not driving the global climate, it is proposed to initiate during the XII Plan period, a major national mission of cryospheric studies of both the polar regions as well as of the Himalaya.

3.10.1 (a) Polar Expeditions - Antarctica

The importance of Antarctica as a pedestal for front-ranking scientific research was recognized by Indian way back in 1981 itself, when the first Indian Scientific Expedition to Antarctica was launched. Since then, India has made great strides in initiating scientific projects of both national and global relevance as well as in catering to the entire gamut of complex logistics operations called for, in the Annual Expeditions to Antarctica. Experiments mounted by Indian scientists in such disciplines as atmospheric sciences & meteorology, earth sciences and glaciology, biology and environmental sciences have also contributed directly to global experiments mounted under the aegis of the Scientific Committee on Antarctic Research (SCAR). The Indian research station Maitri has also served as a platform for collaborative studies with some Antarctic Treaty nations i.e. Germany, Italy, France, Poland and the United States of America. It has also facilitated scientists from Malaysia, Columbia, Peru and Mauritius to work in Antarctica.

Some of the noteworthy accomplishments of Indian scientific community in Antarctica are:

- Identification of a number of new species of bacteria from the cold habitats of Antarctica- 30 out of 240 new species discovered so far have been by Indian scientists.
- Identification of new genes from the bacteria as genes required for the survival of bacteria at low temperature.
- Identification of a number of lipases and proteases active at low temperatures and useful for the biotechnology industry.
- Preparation of comprehensive geological and geomorphological maps of the Schirmacher Oasis.
- Studies of cold adaptability of human beings in the harsh environment of Antarctica which have provided significant baseline data for use in similar studies on India's armed forces serving in the Himalaya.

a) Objectives:

(i) Continuation of the scientific programs in the Antarctica in the fields of atmospheric sciences, climate change, geoscience and glaciology, human physiology and medicine, polar biology and environmental science.

(ii) Initiating novel programmes in the frontier realms of polar science, viz. *Assessment of microbial diversity in Arctic and Antarctic: Past and Present; Environmental monitoring and health of the Indian Antarctic Stations in pursuit of Antarctica-Treaty-System and its governance; Long-term monitoring and modeling of precipitation over Antarctica; and Satellite-based monitoring Antarctic sea ice and land ice topography, with special focus on glaciers.*

(iii) Ensuring a prominent and sustained presence of India in the Antarctica through initiation of scientific research in some of the frontier realms of polar science including paleo-climate reconstruction from the Antarctic coastal water.

(iv) Continue to play a lead role amongst the nations with a sustained presence in Antarctica.

b) Participating Institutions:

National Centre for Antarctic & Ocean Research, Goa

c) Implementation Plan:

As in the previous years, all the aspects related the planning, co-ordnation and implementation of the scientific and logistics aspects related to the Indian Scientific Expeditions to Antarctica shall be undertaken by NCAOR on behalf of the Ministry. The science component of the work programme would a multi-institutional national endeavor with the involvement of scientists from all major national institutions, laboratories and Universities with a sustained interest in the polar realm.

d) Deliverables:

The scientific studies proposed and being carried out by Indian scientists in Antarctica will be contributing significantly to the global community's ongoing efforts in understanding the climate change phenomena. In addition, the studies would be providing a wealth of data in such diverse but inter-related fields as earth sciences, biology, atmospheric sciences and climatology.

e) Budget requirement: ` 733.00 crores.

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Polar Expedition - Antarctica	153.00	155.00	140.00	142.00	143.00	733.00

3.10.1 (b) Indian scientific endeavors in the Arctic

India began its scientific endeavours in the Arctic in 2007 when a team of five scientists visited the International Arctic Research Facilities at Ny-Ålesund to initiate studies in the fields of Arctic microbiology, atmospheric sciences and geology. Following the success of this initial step, the Ministry embarked on a long-term program of regular scientific activities in the Arctic in the frontier realms of polar biology, glaciology and earth and atmospheric sciences. To date, 57 scientists from 18 national institutions, organisations and universities have participated in the Indian Arctic Programme, which is being co-ordinated and implemented by NCAOR on behalf of the Ministry. The focus areas of research by the Indian scientists at Ny-Ålesund are confined to some of the frontier areas of polar sciences of special relevance to the Arctic realm, such as glaciology, atmospheric science, biology and climate change. A comprehensive long-term Science Plan of research activities by Indian scientists in the Arctic realm has also been developed. To facilitate the Indian activities, a station building has been taken on lease at Ny-Ålesund to serve as India's Research Base in the Arctic. India is a member of the Ny-Alesund Science Managers Committee (NySMAC)- the apex body responsible for coordinating and advising all the Member Nations on scientific projects at Ny-Alesund. India has also an observer status in the International Arctic Science Committee (IASC) since 2011.

a) Objectives:

(i) Continuation of the scientific programs in the Arctic in the fields of atmospheric sciences, climate change, geoscience and glaciology, and polar biology.
(ii) Ensuring a prominent and sustained presence of India in the Arctic through initiation of scientific research in some of the frontier realms of polar science.

b) Participating Institutions:

National Centre for Antarctic & Ocean Research, Goa

c) Implementation Plans:

All the aspects related the planning, co-ordnation and implementation of the scientific and logistics aspects related to the Indian Scientific endeavors in the Arctic shall be pursued on behalf of the Ministry.

The science component of the work programme would however, be a multi-institutional national endeavor with the involvement of scientists from all major national institutions, laboratories and Universities with a sustained interest in the polar realm.

The expeditions would be launced in phased manner from March to September depending upon the requirement of the science objectives.

d) Deliverables:

The scientific studies proposed and being carried out by Indian scientists in the Arctic will be contributing significantly to the global community's ongoing efforts in understanding the climate change phenomena. In addition, the studies would be providing a wealth of data in such diverse but inter-related fields as earth sciences, biology, atmospheric sciences and climatology.
The success of the scientific program, apart from contributing to the international efforts to understand global issues will also help India in getting entry in the IASC.

e) Budget requirement: ` 50 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Arctic Expedition	4.00	20.00	19.00	3.00	4.00	50.00

3.10.1 (c) Southern Ocean

The Program for India's research activities in the Southern Ocean realm primarily underlines the sensitivity of the Southern Ocean region to climatic variability and its importance in our understanding the global environment. In pursuance of this, NCAOR, on behalf of MoES took a lead role in organizing a multi-disciplinary and multi-institutional pilot expedition to the Indian Ocean sector of the Southern Ocean during January-March 2004. In continuation of the studies initiated during this Pilot Expedition, another multi-disciplinary endeavor in the Southern Ocean was taken up as a part during a Special Expedition to the new Indian base in the Larsemann Hills during January-March 2006 onboard a Russian chartered research vessel "Akademik Boris Petrov".

The success of these two initial endeavours prompted the Ministry to embark on a major national initiative of planning, co-ordinating and implementing multi-disciplinary and multi-institutional scientific programmes in the Indian Ocean sector of the Southern Ocean. To date, five such expeditions have been successfully undertaken (including the two initial endavors). Several national research institutions such as IMD, IITM, SPL, IISc, NIO-Kochi, FSI, CMFRI, SAC, PRL, NHO, KBCAOS, CMLRE, NIOT, and NCAOR and universities such as JNU, Annamalai, Goa, CUSAT, Karnataka and Gujarat have been active participants in these expeditions

a) Objectives:

(i) To understand the dynamics of the southern ocean, such as, current structure and variability; intra-annual and inter-annual variability of Antarctic Circum Polar Current and surface currents; geostrophic currents; thermohaline circulation; water masses structure; mixing process; mesoscale perturbations.
(ii) Biogeochemical fluxes of carbon, nitrogen, silica and iron in the Southern Ocean and their influence on the trophic structure.
(iii) To document factors and processes which regulate the variability of primary productivity as well as fate of the biogenic material.

(iv) Past climate and oceanic variability.
(v) Reassessment of 'Iron limitation hypothesis' and a comprehensive study on the role of iron in mediating biogenic processes with respect to CO_2 fluxes.
(vi) Southern Ocean carbon process.
(vii) To carry out detailed isotopic, chemical and micropaleontological studies on the sediments from the Southern Ocean to decipher their response and feedback to past climate changes.
(viii) Hydrodynamics of the coastal Antarctica.

b) Participating Institutions:

National Centre for Antarctic & Ocean Research, Goa

c) Implementation Plans:

All the aspects related the planning, co-ordnation and implementation of the scientific and logistics aspects related to the multi-institutional Indian Scientific endeavors in the Southern Ocean realm shall be undertaken by NCAOR on behalf of the Ministry. The proposals will be invited from universities, Survey Organizations and Other institutes involved in the Oceanographic studies, examined by a Group of Expert, and then shortlisted as per the theme of the Expedition.

d) Deliverables:

The multi-institutional national mission of scientific studies in the Southern Ocean realm would be providing an exhaustive database which could throw light on several as yet-unanswered questions related to the dynamics of the southern ocean, the biogeochemical fluxes of carbon, nitrogen, silica and iron and their influence on the trophic structure, the role of the Southern Ocean in modulating the global climate etc

e) Budget requirement: ` 87 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Southern Ocean	16.00	22.00	15.00	20.00	14.00	87.00

3.10.1 (d) Construction of the third research base in Antarctica:

The action for the pre-construction work at the Larsemann Hills environs has been completed. All the heavy earthmoving/construction material and cargo were transported from ship to shore either by the two helicopters or by vehicles over the fast ice. About 250 m long road from landing site up to the helipad was also carved out. The construction activities related to Phase II are scheduled to commence during the austral summer of 2011.

a) Objectives:

(i) Commissioning of the research base
(ii) Establishing the laboratories
(iii) Establishment of the requisite communication facilities
(iv) Initiation of scientific studies from the new Indian base.

b) Participating Institutions:

National Centre for Antarctic & Ocean Research, Goa

c) Implementation Plan:

The construction and commissioning of the new station is being undertaken in two phases. The first phase of construction which was undertaken through a Service provider identified on the basis of a Global Tender was initiated and completed during the austral summer of 2010. Concurrently, activities for the Phase-II were initiated at NCAOR. Adopting the same procedure as that for Phase-I, a Service Provider was identified through Global Bidding. The construction activities related to Phase II are scheduled to begin during the austral summer of 2011.The station will be occupied in 2012 but facilities such as R.O. System for water supply, construction of jetty, and equipping the station with modern scientific equipments will be taken up subsequently in a phased manner. Construction of Communication and data receiving antennas , establishing a modern medical set up, wind and solar power generating systems and a Met lab will be taken up .

d) Deliverables:

A state-of-the-art year-round research base, *Bharati*, at Larsemann Hills with living space and laboratory facilities, when dedicated to the nation, will enhance India's presence and visibility of its Polar Program. The data collected from this sub-aroral region will supplement the *Maitri* data and together will add scientific endeavors to establish tele-connection of Polar climate to Monsoon. Since the site of the *Bharati* station in Antarctica, represents an area linked to the Eastern Ghat Mobile Belt of India during Pre- rift period, station will offer excellent opportunity to conduct comparative crustal evolution studies. The station being next to the open sea, will also facilitate studies in marine scientific fields, a field that could not be covered from *Maitri*. The Station being very close to international hubs of Australia, China, Russia and Romania will enable scientific cooperation with these SCAR nations.

e) Budget requirement: ` 149 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Construction of the third station	31.00	25.00	28.00	31.00	34.00	149.00

3.10.2 Construction of Polar Research Vessel

Ever since the first Indian Scientific Expedition to Antarctica way back in 1981, India has been managing the transportation of the expedition personnel and cargo to and back from Antarctica through chartered vessels. However, the very fact that these vessels were basically ice-class cargo vessels rendered them unsuitable for oceanographic research work. Taking into consideration (i) the growing need of the scientific community to initiate studies in the frontier realms of ocean sciences, (ii) the uncertainty in the charter-hire of polar vessels and the ever-escalating chartering costs, and (iii) the expansion of our scientific activities into the Arctic and Southern

Ocean, the Ministry, during the early part of the XI Plan period, decided to explore the feasibility of constructing and commissioning a polar research vessel which can cater to both the scientific and logistics aspects of the polar and Southern Ocean programmes. As the nodal agency responsible for the implementation of the country's polar and Southern Ocean programmes, NCAOR was entrusted with the task of planning, co-ordinating and accomplishing the various facets of the work programme. Pursuant to the approvals of the EFC and related competent bodies/authorities, NCAOR initiated the preliminary work towards the implementation of the programme during 2008-09.

a) Objectives:

(i) To construct and commission a research-cum-supply vessel for the Antarctic, Arctic, Southern Ocean and Indian Ocean operations.
(ii) To equip the vessel with the state-of-the art scientific equipment/instrumentation to undertake front ranking oceanographic research.

b) Participating Institutions:

National Centre for Antarctic & Ocean Research, Goa

c) Implementation Plan:

(i) Finalization of the design specifications including the onboard laboratory instrumentation and infrastructure.
(ii) Floating of a Global Tender for the construction and identification of the Shipyard.
(iii) Finalization of the Agreement with the identified Yard
(iv) Initiation of construction of the polar research vessel. (2012-13)
(v) Construction and sea trials (2013-15)
(vi) Commissioning of the vessel (2015-16)

d) Deliverables

When delivered the polar research vessel will cater to the scientific and logistics needs of the Indian scientific endeavors in Antarctica, Southern Ocean and Arctic seas.
So far the expeditions have been launched using cargo vessels with the result that no significant marine scientific experiments could be launched.
Owning our own ice breaker vessel will reduce India's dependence on foreign vessels and give us freedom of planning diverse scientific programs.
The ship will also cater to two different Indian stations- Maitri and Bharati- so far as replenishing the life saving commodities such as fuel, food and medicines as also other equipment such as snow vehicles, scientific equipment are concerned, thereby saving huge foreign exchange.

e) Budget requirement: ` 797 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total

Construction of Polar Research Vessel	316.00	321.00	137.00	22.00	1.00	797.00

3.10.3 Replacement of Maitri station:

It is proposed to rebuild the Maitri station during the XII Plan period, incorporating the modern energy conservation systems i.e. CHP units and integrated power generation through wind energy and solar power, a waste conservation and waste disposal strategy through appropriate redesign of wastewater treatment and disposal system capable to recycle treated water to meet Environmental Protocol, integration of summer camp modules with necessary facilities to act as separate residential units and updating the laboratories facilities along with keeping provision for additional rooms and facilities for unforeseen activities in immediate future.

a) Objectives:

Maitri station, built in 1988-89 was assigned a life of about ten years considering the harsh Antarctic weather. The station has outlived its projected life more than two times. A two member expert team drawn from SERC-CSIR and EIL deputed to study the health of the station had pointed out the weakness of the structural columns on which the station stood.

Since Maitri is gateway to the interior mountains of Antarctica, and has important observatories that need to continue to collect vital met, geophysical and geological data, its continuation is essential for achieving the scientific goals of India in Antarctica.

It is therefore proposed to rebuild the station at a more favorable and environmentally friendly location satisfying the Antarctic Protocols.

b) Participating Institutions:

National Centre for Antarctic & Ocean Research, Goa

c) Implementation Plan:

(i) Site survey, levelling, approach roads. (2012-13)
(ii) Selection of consultant architect, finalisation of conceptual design, preparation of CEE (2013-14)
(iii) Tendering and identification of construction agency; procurement of machinery and equipment; pre-construction activities (2014-15)
(iv) Movement of machinery and construction equipment and initiation of construction (2015-16)
(v) Construction and commissioning (2016-17)

d) Deliverables:

When completed , the station would house 25 wintering over and an equal number of summer scientists enabling them to conduct research in a eco-friendly environment. The modern, green station will conserve energy and use additional alternative sources of Wind and solar means to reduce Carbon footprints and save fuel consumption.

The modern sewage disposal system will overcome the problems being faced in the current unfriendly procedure, where the sewage water finds way to the drinking

water source. The CHP techniques will make living and ambiance much better and in tune with other stations in Antarctica .

e) Budget requirement: ` 520 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Replacement of Maitri station	30.00	100.00	160.00	130.00	30.00	450.00

3.10.4 NCAOR – Operation & Maintenance:

It is proposed to complete the construction of Phase III civil works of NCAOR during the XII Plan period. The work which is being entrusted to the CPWD comprises an auditorium (677.55 sq. m) capable of seating 250 persons, a Fellows Lab/Guest House (1524.63 sq.m) and a Database building (841.86 sq. m) with linkage between the buildings.

In addition it is proposed to extend the existing laboratory building to cater to the new activities initiated by the Centre.

a) Objectives:

(i) Establishment of a state-of-the-art polar research centre in the country with leadership capabilities in planning, co-ordinating and implementing the entire gamut of operations related to the country's polar programs as well as its activities in the Southern Ocean realm
(ii) To establish and maintain such research and laboratory facilities which are unique and not available elsewhere in the country
(iii) To develop and nurture human resources in the realm of polar sciences
(iv) To manage the research vessel ORV Sagar Kanya and other chartered vessels
(v) To co-ordinate and implement the Ministry's programmes of national importance as the Indian Continental Shelf Program and mapping of India's EEZ.
(vi) To continue R&D activities in the scientific disciplines and themes of polar/oceanographic research such as Ice-core studies; chemical/geological/biological oceanography of the Southern Ocean; satellite application and remote sensing in polar regions; polar biological studies; Antarctic environment studies; paleoclimatic studies using proxy indicators from Antarctic lakes and Antarctic continental shelf; marine geophysical studies of the East Antarctica; development of National Antarctic Data Centre and its networking.

b) Participating Institutions:

National Centre for Antarctic & Ocean Research, Goa.

c) Implementation Plan:

All activities related to the day-to-day running of the Centre, including planning, co-ordination and implementation of the mandated scientific, technical and managerial

activities would be carried out by NCAOR under the direct guidance of the Research Advisory Committee, Finance Committee and the Governing Council constituted by the Ministry.

d) Deliverables:

(i) Planning, co-ordination and implementation of all scientific, logistics and technical aspects related to the various national programs entrusted by the Ministry for implementation, on its behalf.
(ii) Technical management of ORV Sagar Kanya and other chartered vessels
(iii) Completion and commissioning of Phase III Civil works at the NCAOR Complex
(iv) Management and upkeep of the National Laboratory facilities established at NCAOR. Implementation of scientific projects in the frontier realms of polar and Southern Ocean sciences as well as Geosciences
(v) Planning, co-ordination and implementation of all scientific, logistics and technical aspects related to the various national programs entrusted by the Ministry for implementation, on its behalf.
(vi) Technical management of ORV Sagar Kanya and other chartered vessels
(vii) Completion and commissioning of Phase III Civil works at the NCAOR Complex
(viii) Management and upkeep of the National Laboratory facilities established at NCAOR. Implementation of scientific projects in the frontier realms of polar and Southern Ocean sciences as well as Geosciences

e) Budget requirement: `105 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
NCAOR: Operation & Maintenance	24.00	22.00	18.00	20.00	21.00	105.00

3.11 SEISMOLOGICAL RESEARCH (CONTINUING)

The Indian landmass is affected by various natural disasters and earthquake is one of them, which take heavy toll of life and property besides having an adverse impact on the economic and social development of the country. During the last two decades, the country has seen many moderate to large earthquakes from various sources in the peninsular India and as well as in the Himalayas causing widespread damage and loss of life. Presently, there is no scientific technique available till date, which can forecast earthquakes in terms of size, location and time; however, with better understanding of earthquake source processes and its mechanism, efforts can be made to mitigate the earthquake hazard. In this regard, it is necessary to adequately address the R&D related aspects on different facets of earthquake and earthquake engineering for better understanding of earthquake source processes and its mechanism with ultimate goal of earthquake hazard mitigation. Following seven major thrust areas are identified towards addressing the earthquake hazard related aspects / research in the country during XII FYP period:

- Observational networks and data centre – Ongoing.

- Seismicity & Earthquake Precursors – Ongoing.
- Earthquake hazard assessment - Ongoing.
- National Centre of Seismology (NCS) – Ongoing.
- Deep borehole investigations in Koyna – New.
- Deep crustal studies – New.
- Development of Geotechnology – New.

3.11.1 Earthquake Hazard Assessment (Ongoing)

As per seismic zoning of the country, over 59% of India's land mass is under threat of moderate to severe seismic hazard, i.e. prone to shaking of MSK Intensity VII & above. Several important cities lying in seismic zone III, IV and V are vulnerable to earthquakes. EREC is mandated to provide scientific inputs for mitigating the disastrous impacts of earthquakes, and it's prime responsibility is to extend activities in a phased manner and take up studies for other cities and coordinate future activity as a national endeavor for providing inputs for construction of earthquake resistant structures and disaster management in the event of occurrence of damaging earthquakes. The main objectives of the program are given below:

a) Objectives:

(i) To undertake earthquake hazard assessment related studies in seismically vulnerable areas in the country in a phased manner.
(ii) To provide scientific inputs for mitigating the disastrous impacts of earthquakes towards reduction of earthquake risk.

b) Participating Institutions:

National Centre for Seismology, Noida

c) Implementation Plan:

It is proposed to take up Seismic Microzonation studies of about 30 cities lying in high seismic zones - III, IV & V:

(i) Collation of data pertaining to seismotectonics, geomorphology, geology and geotechnical frame work for identified cities.
(ii) Generation of data for the gap areas for preparation of multi-thematic maps on available base map.
(iii) Development of an earthquake scenario document for each city so as to know the consequences of an earthquake hazard.
(iv) Integration of these maps and generation of useable product for earthquake hazard mitigation planning through interaction with local state governments and disaster management agencies to provide technical support for earthquake risk appraisal and creating awareness.
(v) Future planning for the exploration of microzonation on larger scale maps.

d) Deliverables:

(i) Generation of large scale hazard maps.
(ii) Estimates of ground motion at specific sites to help in planning the future construction/structures.

e) Budget requirement: ` 105 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Earthquake Hazard Assessment	2.0	10.0	25.0	35.0	33.0	105.0

3.11.2 Observational Networks and Data Centre (Ongoing)

India Meteorological Department (IMD), is maintaining the National Seismological Network (NSN) consisting of 55 observatories spread over the entire country. India Meteorological Department is also maintaining a 16-station V-SAT based digital seismic telemetry system around National Capital Territory (NCR) of Delhi and a 20-station V-SAT based real time seismic monitoring network in Northeast India for close monitoring of seismic activity in the regions. The operational task of the department is to quickly analyze the data and estimate the source parameters of earthquakes occurring on Indian land mass and those of tsunamic-potential (in India) under the sea and immediately disseminate the information, in shortest possible time, to all the user agencies including the concerned State and Central Government agencies responsible for carrying out relief and rehabilitation measures.

The data collected from all these network stations is compiled, processed, analyzed and archived systematically at the National Seismological Database Centre (NSDC) at IMD Headquarters, Lodi Road, New Delhi. The earthquake data/ information and seismicity reports are supplied to various user agencies such as, insurance companies, industrial units, river valley projects and various scientific, academic and R&D institutions in India and abroad for research purposes. Seismological data and earthquake related information is also supplied to various agencies dealing with relief and rehabilitation measures, earthquake disaster mitigation and management related matters, seismic zoning, etc. Analog charts' are being digitized for long term preservation of seismic analog chart data in electronic form for use by research community.

a) Objectives:

(i) Monitoring of seismic activity in the country on a 24X7 basis and provide earthquake information to various user agencies in the least possible time.
(ii) Generation of higher resolution seismic and geophysical data sets for better understanding of physical processes associated with earthquakes, deployment of GPS systems & borehole sensors in critical locations, field investigations relating to monitoring of aftershocks, swarms, microtremors, site response studies, etc.
(iii) Systematic archival of seismic and other geophysical data sets generated by various observational networks.
(iv) Raster scanning of remaining significant historical seismograms, their vector digitization and archival in electronic media.
(v) Create a modern test and maintenance facility for testing and upkeep/rectification of sophisticated equipments.

b) Participating Institutions:

(i) India Meteorological Department, Delhi
(ii) National Centre for Seismology, Noida

c) Implementation Plan:

- The existing seismic observational systems and data centre facilities shall continue to be operated, maintained and suitably upgraded /augmented for round-the-clock monitoring of seismic activity in the country.
- Additional seismic stations shall be set up in seismically critical areas not only for improving the detection and location capabilities but also for studying seismically active areas more in detail. This activity includes continuation of ongoing schemes initiated in the XI plan.
- The existing observational networks shall be augmented with GPS and other geophysical systems, wherever required.
- Field studies shall be taken up, as per requirements, for monitoring of aftershocks, swarms, microtremors and site response studies, etc.
- Raster scanning and vector digitization of remaining seismic analog charts shall be continued.
- A modern test and maintenance laboratory shall be set up for proper upkeep and maintenance of various seismic equipments. The existing Data Centre facilities shall be suitably upgraded / augmented for systematic archival of various data sets generated.

d) Deliverables:

- Uninterrupted round-the-clock monitoring of seismic activity in the country, so as to provide earthquake information to various user agencies in the least possible time.
- Generation and systematic archival of high resolution seismological and other geophysical data for seismically critically areas in the country to facilitate R&D in seismology.

e) Budget requirement: ` 70 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Observational Networks and Data Centre	20.0	10.0	15.0	15.0	10.0	70.0

3.11.3 New facility for High Resolution Secondary Ionisation Mass Spectrometry (HR-SIMS)

Precise multi element- isotopic analysis at micrometer scale is paramount to understand basic geochemical processes that are generally controlled by ionic diffusion at submicron scale. Compared to the conventional isotopic analysis, the advancements in the SIMS instrumentation combine efficient ion transmission and high mass resolution capable of precise in-situ isotope ratio measurements with high-spatial resolution of the order of ~ 1 micro meter on selective analysis directly in solid samples. This technique now provides for *unprecedented precision and rapidity in in-situ isotope analysis of virtually the entire isotopic Periodic Table*. These

developments have significantly broadened the scope and application of isotope geochemistry in encompassing themes, virtually from “stars to life”.

In this context, it is proposed to set up a National Facility for High-resolution Secondary Ionization Mass Spectrometry to take up contemporary cutting-edge research in isotope geochemistry and geochronology pertaining to earth, atmospheric, oceanic and planetary sciences. The facility is expected to support several new lines of research in the areas of multi-element Isotope geochemistry and geochronology which are currently at the fore front of basic and applied research across the world. Some of the scientific questions that could be addressed using the facility are:

- U-Pb dating of zircon and several other accessory minerals at a high spatial resolution to decipher complex growth histories related to magmatic, metamorphic, sedimentary and diagenetic processes.
- Resolving basic issues of metallogeny and finger printing a variety of ore deposits.
- In situ stable isotope geochemistry such as C, O, S, N relevant to themes in palaeoclimate research through rapid analysis of growth layers in corals, speleothems, etc.
- Chronostratigraphy of sedimentary basins.
- In situ study of sulphur and oxygen isotope compositions of Indian ore deposits.
- Deep earth processes from the isotopic analysis of inclusions in diamonds.
- Volatile contents and halogen isotope chemistry of basaltic glasses from the Indian ocean ridge systems.
- Stable isotope studies related to cosmochemistry.

Indian Earth and Planetary Scientists depend largely on foreign laboratories to undertake advanced research in Isotope Geochemistry especially using instrumentation such as ASI-Sensitive High Resolution Ion Micro Probe (SHRIMP) or the Cameca-IMS 1280-HR SIMS. Though over 40 such facilities were established around the world including China in the last decade, India, this new technology is yet to reach India.

It is pertinent to note that Indian research institutions are capable of establishing such a facility. Conventional SIMS and nano-SIMS laboratories are operational at the Physical Research Laboratory, Ahmedabad. A new insitu isotope analytical facility (LAM-MC-ICPMS) has been established recently at the National Geophysical Research Institute (CSIR-NGRI), Hyderabad with partial support from the Department of Science and Technology, Government of India. The new National Facility shall serve as a centre for excellence in isotope geochemistry and geochronology with a great scope for not only advanced research but also for turning out excellent human resources in the fields of Earth, Atmospheric, Oceanic and Planetary Sciences.

a) Objectives:

(i) *Insitu* U-Pb dating of zircons and precise geochronology of important rock formations of the Indian shied; implications to crust evolution, and economic geology.

(ii) Hf isotopic compositions in zircons and ultramafic – mafic rocks with implications to crust-mantle dynamics and evolution of the Indian shield through its >3.5 billion year geologic history and the regional metallogeny.

(iii) Sr, Nd, Pb and Hf - Isotopic characterization of mafic - ultramafic rocks from the Carlsberg and Central Indian Ridge systems and the Andaman back arc basin, understanding magmatism and geodynamic processes at the Indian plate margins.

(iv) Isotopic studies on Ocean sediments, particulates and waters: implications to present and past climates and surface processes.

(v) Geochronology and Isotopic systematics of mantle xenoliths in Indian diamond bearing kimberlites: insights into the deep mantle and diamond exploration.

(vi) Isotopic compositions of elements such as Fe, Cr, Cu and Zn to understand the genetic controls of Indian base metal deposits.

(vii) To initiate Fe isotopic studies with implications to bio-geochemical processes and palaeoclimates.

b) Participating Institutions:

(i) National Centre for Antarctic & Ocean Research, Goa
(ii) National Centre for Seismology

c) Implementation Plans:

(i) Finalization of the specifications of the equipment and accessories
(ii) Floating of Global tenders, evaluation of the response.
(iii) Finalization of the vendor, placing of order
(iv) Identification of key personnel, Training of scientists
(v) Preparation of civil structure to house the equipment, obtaining clearances from BARC etc ,commissioning of the HR-SIMS,
(vi) Test run on standards.

d) Deliverables:

(i) Development of cutting edge science pertaining to characterization , origin and evolution of extra terrestrial objects (meteorites & inter-planetary dust, evolved Martian meteorites and relatively unevolved Lunar meteorites etc.

(ii) Window to the interior of earth will be provided by isotopic and trace element characterization of exhumed material such as ultramafic rocks and xenoliths in rocks (e.g. kimberlites).

(iii) Estimation of deep earth processes.

(iv) Isotopic and geochemical characterization including insitu micro characterization of the heterogeneities of ocean sediments and other geological archives (sediments, minerals and fossils) would be correlated with the cryosphere evolution , especially in Himalaya to yield data on uplift and tectonics vs sedimentation and palaeo-monsoons..

(v) Isotopic characterization of Sr, Nd, Pb ,Hf etc will yield conclusive data on understanding of magmatism and geodynamic processes at the Indian plate margins and fill information gap in the structure of Andaman-Nicobar subduction zone and other similar regions.

(vi) The facility will help in studies on genetic aspects of mineral deposits and thus open new directions for exploration strategies.

e) Budget requirement: ` 115 crores.

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
HR-SIMS	15.00	40.00	30.00	20.00	10.00	115.00

3.11.4 National Centre for Seismology (Ongoing)

The National Center for Seismology (NCS) has been set up by bringing together all Seismology related activities of IMD (including those of EREC) under one umbrella. On creation of the NCS, all the ongoing activities and projects of IMD related to Seismology (including those of EREC) shall continue to be operated / implemented through the NCS. In addition, specific R&D activities will also be undertaken by NCS, using the data sets generated by various seismic and GPS networks.

a) Objectives:

Set up a new centre of excellence in Seismology, the 'National Centre for Seismology', at NOIDA, as a subordinate office, under the Ministry of Earth Sciences, by separating and bringing together all Seismology and earthquake hazard related activities of India Meteorological Department (IMD), under its ambit, for deriving the desired scientific developments in the field of earthquake science.

b) Participating Institutions:

National Centre for Seismology, Noida

c) Implementation Plan:

- New laboratory buildings shall be established for the National Centre for Seismology (NCS) at Noida.
- All the Seismology related activities of IMD, including those of EREC shall be transferred from IMD to NCS and new posts shall be created and filled up.
- Specific R&D related activities shall be taken up by the Centre for better understanding of earthquake processes and associated phenomena, as detailed below:

  i. Crust and upper mantle structure of sections of Indian shield and Himalayan regions using receiver function techniques
  ii. Estimation of expected ground motions for critical areas from future scenario earthquakes using empirical Green's function technique
  iii. Detailed seismicity and seismotectonic studies of seismically active areas in the country
  iv. Earthquake source characterization in distinct tectonic environments
  v. Carryout earthquake precursor observations and comprehensive analyses of the data sets to establish possible relationship with the earthquake occurrences.
  vi. Standardization of earthquake catalogs, etc.

- As part of human resource development, state-of-art facilities shall be established for organizing periodical training programs in Seismology and earthquake awareness programs.

d) Deliverables:

i. Creation of a new centre of excellence, 'National Center for Seismology', with state-of-art infrastructure, laboratory buildings and human resource development, to address all earthquake science related matters in the country.
ii. Better understanding of earthquake processes under different tectonic environments in the country, through specific R&D related projects for better preparedness and mitigation of disastrous impacts of earthquakes.

e) Budget requirement: ` 105 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
NCS Activities	15	25	30	20	15	105

The cost towards setting up NCS includes the expenditure on the construction of the laboratory buildings for NCS at NOIDA, the recurring costs towards office expenses of NCS, R&D related activities, training and awareness related programs.

3.11.5 Deep Borehole investigations in Koyna-Warna Region (New)

The Koyna Dam located in Maharashtra, western India is the most outstanding example of Reservoir Triggered Seismicity (RTS), where triggered earthquakes have been occurring in a restricted area of 20x30 sq km since the impoundment of Shivajisagar Lake in 1962. These include the largest triggered earthquake of M~6.3 on Dec 10 1967, 22 earthquakes of M>5, about 200 earthquakes of M~4, and several thousand smaller earthquakes since 1962. The RTS was further enhanced by impoundment of the nearby located Warna reservoir in 1993. The seismicity is restricted in depth generally in the top ~10 km, but more commonly in the top 7 km of the Earth's crust. The site is active. The latest M5.1 earthquake occurred on 12 December 2009. There is no other source of seismic activity within 50 km of the Koyna Dam. This makes it an ideal and natural observatory for earthquake studies. The frequent occurrence of earthquakes including a few with M~5 in a region hosting two important dams, underlines the importance of monitoring and studying this region in detail.

The role of pore fluid pressure changes for RTS has been underlined through several studies and experiments however due to limited direct observations in the near-field of triggered earthquakes; our understanding of these issues is mainly dependent on theoretical computations and modeling. Also, limited data is available to examine the fluid pressure regime, its variations and its correspondence with the occurrence of earthquakes. There is also uncertainty about the relative importance of fluid-driven (hydraulic) fracturing compared to shear failure in different geologic environments, and the interplay of temperature and pore-fluid pressure in reducing the frictional stability.

Super-deep borehole investigations at KTB, Kola, SAFOD and several other locations worldwide have significantly increased our understanding of the processes of the deep continental crust and physics of the Earth's interior. Useful information has been obtained about fault characterization and fault behavior at depth, transition from brittle to ductile behavior in the crust, fluids in the deep crust, lithospheric dynamics and deformation, impact structures and mass extinctions, volcanism, and nature of thermal transport processes in the continental crust.

Considering the importance of deep borehole investigations, it is proposed to undertake a suite of observations in deep borehole(s) in the area of persistent and focused seismicity. The work will be carried out in collaboration with ICDP and the observations will include stress regime, pore fluid pressure and its variations, heat flow and its variation, orientation of faults, study of chemical properties of fluids, before, during and after earthquake. The proposed boreholes will also facilitate i) observation and analysis of data, generated through the operation of borehole for 4-5 year of time, when it is anticipated that a few earthquakes of magnitude ~3 would occur in the immediate vicinity of borehole, ii) continuous observation to study the data in the far and near field of the earthquake and temporal variation w.r.t. occurrence of earthquake and iii) development of a model of RTS mechanism.

Continuous observations directly within the fault zone at seismogenic depths will help in testing and extending current theories about phenomena that might precede an impending earthquake. Also, the roles of fluid pressure, intrinsic rock friction, chemical reactions and the physical state of active fault zones in controlling fault strength will be evaluated. These studies will also allow for improved models of static stress transfer and earthquake triggering at a regional scale and between specific faults, as needed for intermediate-term seismic hazard forecasting following large earthquakes.

Through long-term fault zone monitoring and in-situ observations of the earthquake source, models for earthquake rupture dynamics, including such effects as transient changes in fluid pressure, fault-normal opening modes and variations in slip pulse duration may be improved. These observations can be used directly in attempts to generate improved predictions of near-field strong ground motion (amplitude, frequency content and temporal characteristics) and more reliable models for dynamic stress transfer and rupture propagation. Latter processes are believed to control earthquake size (i.e., whether or not a small earthquake will grow into a large one) and, hence, are crucial to long-term probabilistic assessments of earthquake hazard.

The deep borehole investigations, which are expected to continue for a period not less than 15-20 years, will also provide insight into Deccan volcanism and Mass Extinction; Thermal structure and state of stress in the lithosphere; Geothermal potential of the West Coast Belt as well as Geothermal Record of Climate Change in the region. The estimated cost for this proposed initiative would be around Rs.400 crores during the XII FYP.

b) Participating Institutions:

(i) National Centre for Seismology, Noida
(ii) National Geophysical Research Institute, Hyderabad

c) Implementation Plan:

- It will be implemented under the Ministry's Umbrella in collaboration of NGRI and ICDP. Various concerned govt. agencies, research Institutions and universities will also participate in the programme.

- A preparatory study will be carried out for establishing the hydrological connectivity between the reservoir and host country rock and to constrain the fine structure of the seismic zone in the area including detailed mapping of the causative faults. Based on those studies, location for drilling the 7 km deep bore hole will be finalized.

- The deep borehole drilling in Koyna will be carried out in collaboration with ICDP which will extend their technical expertise in deep drilling and logging, training of manpower and support towards drilling.

- Various parameters will be measured and studied in situ as well as from the logs obtained during this drilling, by various identified govt. agencies, research Institutes and universities.

d) Deliverables:

- Deep borehole investigations in Koyna region would allow direct characterization of the underlying fault geometry, and measurements of rock physical properties, fluid composition, pore fluid chemistry, heat flow, and in-situ stress to name a few, which may ultimately lead to better understanding of stable continental region earthquakes in general, and Reservoir Triggered Seismicity in particular.
- The deep borehole investigations will also provide insight into Deccan volcanism and Mass Extinction; Thermal structure and state of stress in the lithosphere; Geothermal potential of the West Coast Belt as well as Geothermal Record of Climate Change in the region.

e) Budget requirement: ` 400 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Deep Bore-hole investigations in Koyna-Warna region	20.00	60.00	80.00	120.00	120.00	400.00

3.11.6 Deep Crustal studies (New)

Lithospheric rifting is a fundamental process in the growth and evolution of continents, and it is one that has substantial societal relevance by virtue of the global hydrocarbon reserves accumulated within basins formed through rifting. Rifting proceeds from the application of extensional stress to the accumulation and localization of strain until the lithosphere ruptures, whereupon seafloor spreading

and production of oceanic lithosphere accommodate most extension. Continental breakup thus constitutes a dramatic expression of two fundamental geological processes: deformation and magmatism. Yet first-order questions exist about every process in the rift-to-drift sequence. We lack a full understanding of both the magnitude and cause of the stresses that drive rifting, the deformational mechanisms by which continental lithosphere responds to those stresses, and the key parameters that control this deformation. Similarly, the role of the rift-related magmas in localizing strain and advecting heat from asthenosphere to lithosphere is poorly understood, as are the controls on mantle melting during extension (e.g., mantle temperature, volatile content, and small-scale convection). Understanding these processes is one of the fundamental goals of earth scientists today.

The project is aimed at detailed study of the SWIM with special emphasis on correlating onshore-offshore structures along this margin. The best observations of complete rifting at lithospheric scale come from seismic studies across rifted continental margins. Any thorough study of continental rupture requires high-quality images of the velocity and impedance structure of the crust and uppermost mantle. These images, furnished by detailed reflection/refraction seismic profiles, provide essential information on patterns of deformation and crustal thinning, crustal composition, subsidence history, magmatic additions, and the onset of seafloor spreading.

Volcanic rifted margins are characterized by voluminous syn-rift volcanism far in excess of that expected for passive decompression melting of normal asthenosphere. These are also commonly identified by wedges of seaward dipping reflectors (SDRs) in seismic records. The wedges, which may have thicknesses of more than 6 km, consist of numerous lava flows and thin inter-bedded sediments. The extrusive region is usually underlain by several km thick body of high seismic velocity (7+ km/s) interpreted to have been added to the base of the crust during the break-up events. SDRs are found on more than 70% of the world's rifted margins. Such margins are common (e.g. White and McKenzie, 1989; Eldholm et al., 2000), yet we lack a complete understanding of their development, particular in linking the thermal/dynamic models required to explain the effusive magmatism with the mechanical models that describe lithospheric deformation.

While decades of such observations along Indian continental margins have resulted in various hypotheses based on limited sub-surface data coverage, the seismic studies of Indian continental margins have till date not conclusively addressed the degree of complexity involved. This is largely because of the lack of high quality seismic transects across the margin. In recent years loads of seismic data have been acquired by various agencies for different purposes. Taking a cue from such information, a pilot project was initiated at NCAOR, Goa to analyses and interpret MCS data available through Directorate General of Hydrocarbons (DGH), Government of India. The outcome of this project was presented (Nair et al., 2010) before the scientific community which forms the basis of this long-term program. The project envisages high-resolution, deep-penetration seismic reflection/refraction data set along the SW Indian margin to examine the precise nature (such as magma poor or magma rich) of this rifted margin and to provide any insight into the demarcation of the continent–ocean transition (COT) of this area. Moreover, offshore interpretations would be tied up with the onshore studies carried out by extensive DSS studies.

b) Participating Institutions:

National Centre for Seismology, Noida
National Centre for Antarctic and Ocean Research, Goa

c) Implementation Plan:

As the first step in the implementation of this program, it is proposed to carry out the studies along an E-W corridor through the Udipi-Kavali seismic transect in the Southern Peninsular India and linking up with the Arabian Sea Basin off the Laccadive Islands. The high-quality multichannel seismic reflection, gravity, and magnetic data available from the Arabian Sea offshore as well as from the Udipi-Kavali deep-transect which cuts across the entire southern peninsula makes this an ideal corridor for study. In addition, the geological information from the two deep sea drilling sites (DSDP 219 and 221) would offer excellent constraints on the geophysical data. Based on the preliminary results, it is proposed to undertake additional high-resolution MCS and refraction data collection along critical stretches of the WCMI.

d) Deliverables:

The proposed work is expected to usher in new frontiers of geo-scientific research in the country. Using new data as well as new technologies, the Project is anticipated to fill the gap in knowledge about the relationship between onshore and offshore sub-surface structures. The program will provide an opportunity for the Indian Earth scientists to closely understand rifting architecture as well as its geodynamic implication.

e) Budget requirement: ` 13 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Deep Crustal studies	5.0	4.0	2.0	1.0	1.0	13.0

3.11.7 Development of Geotechnology (New)

Majority of geoscience related programmes are highly field intensive and require different kinds of observational and test units. Though our country has one of the largest pools of geo-scientists in the world, however, no mechanism is there to address instrumentation and engineering for this science and service function. For most of our applications, we are depending upon importing the required equipments. With so much economic interest in stakes, like mining, Coal gasification, exploration of resources like geothermal energy, including instrumentation for geo-sciences, cannot and should not remain dependent forever.

The development and implementation of indigenous cutting-edge technologies is possible with integration of continued advance research in instrumentation, design and fabrication of state-of-the-art sensors, data acquisition system including digital communication etc. In order to achieve excellence in all major areas of geotechnology in a reasonable time frame, it requires organized planning and

backup of institutions where indigenous development in instrumentation is one of the primary mandates.

a) Objectives:

To set up a Centre whose primary mandate would be geotechnology developments to cater national needs. The Centre shall promote advance research, design of geo-instrumentation and decide priority and time frame for geotechnology intervention.

b) Participating Institutions:

National Centre for Seismology, Noida.

c) Implementation Plan:

(i) Advance research and design of geo-instrumentation and priority fixation for geotechnology intervention.

(ii) Human Resource Development and Capacity Building in Inter-disciplinary specialization.

(iii) Inter-linkage with National Earth Science Institutions to identify up-coming technology needs with changing phase of earth sciences.

(iv) Networking with International Geotechnology Centres to remain front line partner in knowledge exchange and development.

(v) Private-Public linkage for the development and commercialisation of technologies in SE Asia.

(vi) Technical service provider to Earth Science Institutions in training, commissioning, and helping in maintenance of field monitoring networks and analytical laboratories.

(vii) Highest priority will be given to areas where mass production and deployment of equipments have immediate social benefits.

The design and fabrication of the main sensors proposed under this category include Broad Band Seismometer for earthquake monitoring, accelerographs for strong motion recording, seismic switches for earthquake early warning system, strainmeter/ tiltmeter for landslide monitoring and early warning, etc. Satellite communication methods will be used for real-time data transmission to terrestrial monitoring stations, enabling effective monitoring of large areas and from far inaccessible regions. Design and fabrication of wireless geophones and heat pumps are also proposed to make modest beginning in deep imaging and exploitation of natural geothermal resource.

d) Deliverables:

Development of geotechnology for instruments, which are required in large numbers and have visible societal impact for upgrading the national field monitoring systems.

e) Budget requirement: ` 101.00 crores

(Rs. In crores)

Name of the	2012-13	2013-14	2014-15	2015-16	2016-17	Total

Scheme						
Development of Geo-technology	1.00	10.00	20.00	40.00	30.00	101.00

3.11.8 Seismicity & Earthquake Precursors (Ongoing)

Seismicity and earthquake precursors programme is a research driven programme with a long prospective to provide impetus to the studies related to seismology.

It is, therefore, necessary to continue these efforts in 12th plan period to further help in understanding the possible relationship between various earthquake precursory phenomenon and the earthquake generation processes.

Efforts will be made towards generation of long-term, comprehensive multi-parametric geophysical observations in seismically active areas, analyse the data in near real time and, to attempt developing a model for establishing possible relationship between various earthquake precursory phenomenon and the earthquake generation processes.

Specific R&D projects are planned to be evolved and supported, covering the following broad themes viz: Geodynamics of Himalayan region and Earthquake Hazard Assessment; Deep crustal structure across the Indian continental margin; Studies of the Andaman subduction zone; Active faults; Seismological studies; Crustal Deformation studies using GPS/ GNNS; Collateral geophysical studies; Earthquake engineering related studies; Setting up of Multi-parametric Geophysical observatories. Efforts will also be made to disseminate the basic knowledge of earthquake among the common masses, with particular reference to seismic hazard. Possibility will also be explored for initiating collaborative endeavors, wherever necessary. However, the major emphasis, in the 12th Plan, would be on the following:

Paleo-seismology:

Paleo-seismology is a useful tool in reconstructing the history of fault zones and it is now being used in assessing the past seismic productivity in many active regions. A relatively young field in earthquake studies, techniques in paleoseismology, combined with advances in dating techniques is leading to better estimates on the timing and size of past earthquakes, and development of recurrence models. Thus, paleo-seismological investigations, in particular, along the Himalayas and the NE India assume importance as a priority area of earthquake studies. The focus of paleo-seismological investigations in the Himalaya should be to identify the previous slips and secondary featured and associate them with the faults/seismic source zones and compute the size of the earthquake taking into account the role of decollment and the wedge deformation. Use of balanced cross sections and possibly other geophysical techniques such as shallow reflection should enhance the capability to interpret the subsurface structures, in particularly the geometry of the decollement and ramp structures. The GPS slip models must eventually be integrated with these observations to develop models of slip and earthquake frequency in the Himalaya.

Andaman subduction zone:

Our understanding about the tectonics and earthquake occurrence process along the Andaman subduction zone is very poor. We need to understand:

- ✓ Crustal structure of the region,
- ✓ Earthquake occurrence processes.
- ✓ Detailed plate motion in the frontal and back arc.
- ✓ Tsunamis propagation models.
- ✓ Structure safety and public awareness about earthquakes and tsunami.

Some of the specific programs that need focus in the coming decade include:

- ✓ Crustal structure studies: delineation of deep structures by seismological (including ocean bottom seismometer), seismic, heat flow and gravity methods, and surface or shallow subsurface structures using GPR, shallow seismic, resistivity, geological methods, etc.
- ✓ Earthquake occurrence processes: seismological and geodetic methods, dating of corals and paleotsunami deposits.
- ✓ Geodynamic modeling: structure and thermal modeling using the above information, investigation on relation between earthquake occurrence in the frontal arc and volcanic eruption in the back arc (the Barren volcano), paleo-reconstruction for arc evolution.
- ✓ Structural safety and public awareness: Structural engineering research and improvement in practices, training and public awareness about earthquakes and tsunamis.

Active Faults:

The Seismotectonic Atlas of India shows existence of over 66 neotectonic/ active faults of regional extent. The Himalayan belt, extending for 2400 km, is dissected by 15 major active faults, disposed both parallel and transverse to the Himalayan trend. Most of these came into existence during the terminal phase of the Himalayan orogeny and still participate in the strain accumulation and release. The Indo-Gangetic and Brahmaputra Plains are marked by the presence of 16 tectonically active faults, the traces of which are found generally concealed under a thick mantle of alluvium. The Peninsular India is marked by the presence of about 30 neotectonic faults, confined mostly in the palaeo-rift systems. The Andaman and Nicobar Group of Islands, falling under Zone V of the Seismic Zoning Map of India, are characterized by the presence of three N-S trending faults of regional extent and two active faults in the NE Region. The above-mentioned faults, in addition to some of the hidden ones, govern the seismicity of India. It is, therefore, imperative that a systematic study of these tectonic discontinuities, including their classification and characterization, needs to be taken up under a Mission mode for identification of the seismic source zones and assessment of seismic hazard.

Continental Collision Tectonics:

The Indian sub-continent contains many geologically unique features, and among them the Himalayan collision orogen is the most important. The tectonic effects of this collision are manifest not only in the orogen itself, but these are transmitted in the hinterland (Tibet) and the Indian shield (foreland). Since the collision of India and Asia at ca. 55 Ma the Himalayan orogen is being built up due to thrust stacking and growth and collapse of critical taper whose exact implication on post-collision tectonics within the orogen is not clearly understood. Moreover, continued post-

collision underthrusting of the Indian lithosphere beneath Asia and foreland-ward propagation of the Himalayan orogenic wedge are transmitting the stress toward the Indian shield that show evidences of post-collision deformation in the formation of foreland basin (Ganga-Brahmaputra), forebulge (Narmada-Son), wrench faulting (Aravalli) and plateau uplift (Meghalaya) and recent seismicity.

The Indian lithosphere has many unique features such as the mantle depletion consequent upon the voluminous eruption of the Deccan traps, unusually thin continental crust and lithosphere, large tract of passive continental margin whose transition to oceanic crust is little known, and the Himalaya, the proto-type of collision orogen whose lithosphere dynamics is the topic of current international interest. Neotectonic deformation, especially related to post-collision crustal deformation, is tectonically important both in the northern part of the peninsula and in the Himalaya, particularly in the foothill belt where the critical taper is getting deformed. Tectonic, tectonic geomorphologic and crustal dynamics research has great relevance to studies on climate change and natural hazards. Following broad topical research topics on the theme of Continental Collision Tectonics need special attention in the Indian context are identified:

- ✓ Post-collision continental tectonics
- ✓ Interaction between tectonics, climate and earth surface processes
- ✓ Himalayan collision tectonics

a) Objectives:

(i) To promote R&D in the field of Seismology and Earthquake Engineering.
(ii) Create scientific infrastructure in the form of monitoring and test facilities for generating high quality data sets to facilitate advanced research.
(iii) To generate inputs for preparing knowledge-based products such as large scale zonation maps.
(iv) To intensify seismological, geological and geophysical studies in selected regions for generating a comprehensive database of scientific significance.
(v) To monitor the specific corridors, considered to be seismically active.
(vi) Establish possible relationship between various earthquake precursory phenomenon and the earthquake generation processes
(vii) To organize specialized training courses/ workshops and earthquake awareness.
(viii) To promote collaborative research programmes.

b) Participating Institutions:

National Centre for Seismology,
Indian National Centre for Ocean Information Services, Hyderabad
Academic Institutions and Universities

c) Implementation Plan:

(i) Short term Research and Development oriented projects of specific nature in Seismology and related fields shall be evolved and supported for implementation by various research academic institutions in the country where such expertise is available.
(ii) A peer review mechanism shall be adopted for evaluation and approval of the R&D projects, through various experts and Project Advisory and Project

Monitoring Committees. However, the responsibility of coordinating all the activities of the program will be with the Programme Office, MoES.

d) Deliverables:

- Better understanding of geophysical and geodynamic processes relevant to the Indian sub-continent.
- Creation of state-of-art infrastructure facilities at various premier institutions for carrying out R&D related studies in the field of Geosciences.
- Human resource development not only through implementation of R&D projects but also through organizing specialized training programs, workshops, etc.

e) Budget requirement: ` 200 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Seismicity & Earthquake Precursors	30.00	35.00	45.00	45.00	45.00	200.00

3.12 GEOSCIENCES

The geoscientific studies proposed to be undertaken by NCAOR during the XII Plan period primarily seek to address issues related to the Indian landmass and the oceans surrounding it, such as the geological evolution of the Indian landmass through time, the origin of the Arabian Sea basin, the growth of the Himalaya vis-a-vis the build-up of the Indus Fan, the ersosion response of Himalaya to a hypothesized strengthening of the monsoon at ~8my BP, the nature of the crust under the continental margin, the continent-ocean boundary off the Arabian Sea and the Bay of Bengal etc. The access to the deep sediment and ocean bottom rocks through deep drilling in oceans and studies in Andaman subduction zone to understand the geological complexities of the processes involved in tectonic movements.

3.12.1 Integrated Ocean Drilling Program (IODP)

The Integrated Ocean Drilling Program (IODP) is a research consortium of 24 member nations to drill & explore the ocean floor. India joined the IODP fraternity as an Associate Member during 2008-09. A formal MoU in this regard was also signed between MoES and NSF/MEXT- the two lead Agencies for IODP Operations.

a) Objectives:

(i) To develop a long-term science plan for initiating integrated marine geological studies through deep drilling in select locales in the Arabian Sea and the Bay of Bengal
(ii) Initiation of deep-sea drilling activities as an international endeavor through associate membership in the International Integrated Ocean Drilling Program (IODP)
(iii) Participation in the varied scientific activities of the IODP.

b) Participating Institutions:

National Centre for Antarctic & Ocean Research, Goa.

c) Implementation Plan:

The Programme would be implemented as a multi-institutional national endeavor. As the first phase of operations, a scientific proposal titled “Deep sea drilling in the Arabian Sea: Discovering the tectono-climatic unknowns” has been submitted to the IODP for its consideration. The proposal for implementation primarily aims at recovering deep sea cores from five different sites from the Arabian Sea to:

(i) Obtain high-resolution climate records from regions of high pelagic sedimentation in the Arabian Sea (vs. records of Himalayan erosion in the Indus Fan).
(ii) Reconstruct the erosion response of the western Himalaya to proposed monsoon strengthening at 8 Ma.
(iii) Recover Paleogene sediments from Arabian Sea to understand significant issues pertaining to the evolutionary history of this region such as offshore extension of Deccan Traps and the Mesozoic sediments beneath them and the nature of crust in the Laxmi basin area of the Arabian Sea.

d) Deliverables:

The wealth of scientific data sought to be collected through deep-sea drilling in the Arabian Sea basin is expected to provide answers to several of the key questions pertaining to the geological evolution of the basin, and the role of Himalaya in modulating the Indian climate on a millennial scale. Furthermore, the program once implemented, would help develop a core competence at a national level in various facets of deep sea drilling and related studies.
The participation in different cruises run by IODP for drilling of deep Ocean cores will enrich Indian scientists with rare experience and enhance the capacity building in this field.

e) Budget requirement: ` 120 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
IODP	7.00	62.00	31.00	12.00	8.00	120.00

3.12.2 Exploring the origin of the largest Geoid low on the Earth

a) Objective:

To study the nature and origin of the geoidal low in the Indian Ocean centered around south of Sri Lanka.

Justification:

Geoid is an equipotential surface of the Earth's gravity fields that best fits the global mean sea level in a least squares sense. Recent gravity models and satellite based observations show that geoid rises and falls over spheroid as much as-100 m to +100 m. The undulations in geoid are caused due to subsurface density heterogeneities and long wavelength geoid anomalies are often interpreted as present-day mantle density heterogeneities. These have a direct bearing on the physical and chemical properties of deep mantle and processes that are responsible for phenomena such as mantle convection, plate tectonics etc. Thus elucidating large wavelength Geoid anomalies is of significance in global geodynamical studies.

Despite the significance of the gravity low in the context of global geodynamics, no systematic study of this anomaly has been undertaken. The available seismic stations in the vicinity are few and far between and there are no ocean bottom observatories (OBOs) in the area. Ray paths are scanty, particularly over central low.

b) Implementation Plan:

It is proposed to deploy two kinds of seismic arrays over this low, along with global seismic network (like IRIS): one along a North-South line, over Chagos-Laccadive, Sri Lanka and southern India, and another array along a line orthogonal to it. Along this latter line of 2500 to 3000km, it is proposed to deploy OBOs at every 100-200 km. The OBOs in the eastern part can also provide additional information about Andaman-Sumatra subduction zone.

c) Budget requirement: ` 54 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Exploring the origin of the largest Geoid low on the Earth	20	20	7	4	3	54

3.13 HIGH PERFORMANCE COMPUTING (UPGRADATION AND MAINTENANCE OF HPCS)

The Earth behaves as a single interlinked and self regulating system. It's subsystems, viz. atmosphere, hydrosphere, cryosphere, geosphere and biosphere function together and their interactions are significant and complex. The energy and material transport within and across subsystems occur from local to global scale in varying space and time. Improved and reliable forecast of weather and climate requires integration of observations using very high resolution dynamical models with realistic representation of all physical processes and their complex non linear interactions. Since weather is an initial value problem, accuracy of the initial condition is as important as the accuracy of the model. Thus, data assimilation is a crucial component of weather predictions. As conventional data coverage is spatially and temporally limited, satellite data provides much better coverage in both space and time. About 90% of the data that goes into the assimilation of any analysis-forecast system comprise of data from satellite and rest from *in situ* platforms. In addition, it is important that adequate computing facility is available for carrying out

various numerical experiments pertaining to various programs of the Ministry. This involves augmenting the computational power for the training school where hand on training are to be conducted with high resolution state of the art weather and climate numerical models , conducting research and development work for improving forecasts in the short, medium and long range scales for monsoon mission programs that involve sensitivity experiments for various physical processes. , the impact studies of different physical parameterization schemes etc. , data impact studies, ensemble prediction models with more members, climate change scenario generation for hundreds of years etc. In addition, it is essential to carry out studies related to observation simulation experiments (OSE), observation system simulation experiments (OSSE) and targeted observation experiments that can guide the planners on the location and type of observations that are crucial for the numerical models. Accordingly observation network can be better formulated. This is highly compute intensive job. Large number of numerical experiments shall have to be carried out to identify these crucial locations where observation network need to be strengthened. Hence, it is seen that the entire range of research work involves simulation runs of multiple versions of the same high resolution analysis forecast model which means the utilization of HPC time as well as storage also becomes manifold (directly depending on the total number of experiments undertaken by each student). In order to study the effect/impact on a large temporal scale (from monthly to decadal to 100s of years) , these runs are to be undertaken accordingly. In addition, for understanding the microscale process studies one has to go for extremely high resolution models that can resolve scales of the cloud and related processes. Thus these entire range of studies require not only high level of computer storage, high computational power as well

(a) Objectives:

i. To establish a petaflops-scale HPC facility at MoES institutes to cater the needs of modeling activities of Monsoon Mission, Climate Change Research and National Training Centre and other programs of the Institute, and also to share the facility with other groups in the country.
ii. To establish, update and maintain an extensive database required for modeling and observational studies.
iii. To provide assistance in processing the data.
iv. To provide programming and software support for model improvement.
v. To maintain the facility by providing the necessary supporting infrastructure such as UPS, cooling system, Power and Generator backup. Significant investment has to be planned for maintaining the Community Facility.

(b) Participating Institution:

(i) Indian Institute of Tropical Meteorology, Pune
(ii) India Meteorological Department, Delhi
(iii) Indian National Centre for Ocean Information Services, Hyderabad
(iv) National Centre for Medium Range Weather Forecast, Noida

(c) Implementation Plan:

Ministry of Earth Sciences has prepared a strategic plan for up gradation of HPCS at various MoES institutes. MoES has already set up a high level committee for

upgradation of existing HPC at MoES institutes and the committee in principle agreed with the strategic plan. The committee's main objectives are to finalize the HPC up gradation requirements of various MoES institutes and prepare RFP document for tendering procedure. The following requirements are proposed for upgradation in next five year plan.

Table 1: Current and projected HPC requirement by the various mission mode projects taken up by MoES during next 5 years from 2011.

Program	Current Requirement (Peak in TF)	By 2013	By 2016
Centre for Climate Change Research (IITM)	~75	~125	~150
Monsoon Mission (IITM/NCMRWF) • Development of Seasonal Prediction System • Development of a system for extended range prediction of Active / break spell • Development of a System for Medium/Short Range Prediction	~125	~170	~230
National Training on Weather and Climate Science (IITM)	~10	~15	~20
High Resolution tropical Cyclone and weather prediction operational and R&D (IITM, IMD, NCMRWF)	~70	~100	~180
Medium Range weather forecast, Atmospheric Data Assimilation, Regional Reanalysis (NCMRWF, IITM)	~80	~100	~300
Ocean State Forecast/Coastal Ocean State Forecast and Ocean Data Assimilation, Observing System Simulation Experiments (INCOIS)	~25	~30	~50
Support for Academic Institutes (Universities, IISC, IITs, IISERs). Also to act as a backup HPC resource for operational weather forecast centers in India	~25	~50	~100
Existing Facility ~120TF	~410TF	~590TF	~1030TF

(d) Deliverables

(i) State of the art computing facility for MoES scientists to meet the emerging demands of reliable weather and climate forecasts.
(ii) Improved simulations of Indian Monsoon weather and climate at very high resolution
(iii) Data Assimilation of Ocean and atmospheric data in dynamical models

e) Budget requirement: ` 900 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
High Performance Computing	150	150	200	200	200	900

3.14 RESEARCH, EDUCATION, TRAINING AND OUTREACH

ESSO has a mandate to provide weather, climate and hazard related forecast and services and translate the same into practical usage for societal benefit. During the XI plan, ESSI had initiated several programs to improve the understanding of Earth Science and thereby improve forecast of weather, climate and hazards by holistically addressing various aspects related to ocean, atmosphere, cryosphere, geosphere and biosphere processes. To do this, it is important to understand various processes of earth system, particularly the interactions among different components viz., land, ocean, cryosphere and atmosphere. Therefore during the XII plan, multi-institutional and multi-disciplinary projects on focused areas of national importance will be undertaken.

Indian Climate Research Programme (ICRP) originally launched in 1996 is one such program to understand the variability of the monsoon and the oceans (particularly the Indian Seas and equatorial Indian Ocean) over a range of time-scales through observational campaigns and analyzing the results. After the successful campaigns of Bay of Bengal Monsoon Experiment (BOBMEX) in 1999 and Arabian Sea Monsoon Experiment (ARMEX) in 2002 and 2003 , the next program on the Continental Tropical Convergence Zone (CTCZ) Programme that has been initiated in the 11^{th} plan period will be continued in the 12^{th} plan period with focus on understanding the variability of convection/rainfall over the Indian monsoon region.

Program on changing emission scenario and atmospheric chemistry over mega-cities is another program of National importance. This is aimed towards understanding current changes brought about by anthropogenic activities, the distribution and chemical properties of aerosols and their direct/indirect effects on climate (cloud precipitation and regional hydrological cycles) . It is essential that chemical composition of aerosols are accurately represented in global climate models for distinguishing natural from anthropogenic influences. This can be achieved through continuous monitoring, field observations and modeling studies. Over India it is especially important to address the issues pertaining to quantum of export of fluxes of aerosols, their precursors from mega-cities, biomass burning and desert dust as well as to understand the mechanism of human activities that may transform the dynamical and chemical properties of the future atmosphere.

In order to cater to the huge demand for manpower in the Earth Sciences, several academic programmes through initiation of MTech/ PhD programmes, establishment of Chairs and opening of Centers of Excellence will be continued to be launched. To bring the Indian weather services at par with International organizations, several international collaborative programmes will be undertaken under the new as well as existing MoU's and through sponsorship of scientific personnel to international labs. Keeping in view the operational and service-delivery oriented responsibilities of the

various units of the Ministry, adequate training modules of international repute in Oceanography and Meteorology will be taken up to upgrade institutional knowledge through in-house training programmes of the scientific personnel. India Africa Centre for Medium Range Weather Prediction under the India-Africa forum is being proposed to be opened in Africa. In order to bring awareness among the people about the vagaries of weather and the huge oceanic resources, awareness campaigns through outreach activities in the form of exhibitions, posters, quiz competitions will continue to be undertaken. During the XII plan, it is proposed to open a National Oceanarium, Goa to bring awareness about the marine life and the ocean ecosystems which will also help in creating R & D facilities for focused research in the field.

3.14.1 Research and Capacity Building

There is a need to continuously upgrade knowledge through assimilation of new ideas and application of new knowledge in the field of earth Sciences for improvement of weather and climate forecast. This can be effectively done through adoption of multi-institutional and multi-disciplinary approach involving amalgamation of expertise existing in various R & D institutes of the country. Therefore ESSO proposes to support focused R & D through networked projects involving various institutes within India and abroad during the XII plan. To facilitate exchange of ideas and to keep abreast with latest scientific and technology developments in the field of earth Sciences, special orientation programme for scientists through visit to various national/ international labs are proposed to be organized in their respective field either through international fellowships or sponsorships. To address the issue of depleting scientific manpower in the field of Earth Sciences, the Ministry would continue funding of MTech, MSc and PhD programmes at premiere institutes of the country during the 12th plan, establishment of MoES Chairs at IIT's and IISER, opening of Centers of Excellence at various Universities with state-of the art research facilities.

a) Objectives:

(i) To support Human Resource Development programmes through establishment of Chair in IITs and IISERs;
(ii) Initiation of academic programmes at IITs and IISER;
(iii) Opening of Centers of excellence in universities;
(iv) International fellowships and sponsored fellowships to train our scientists in specialized Universities/Labs will be taken up;
(v) Network projects on focused research areas of National importance through integration of multi-institutional and multi-disciplinary scientific expertise ;

Studies on Changing Water Cycle will be taken up with special reference to response of forests and agro-ecosystems to extreme rainfall events in the Western Ghats, South Asian Precipitation, Hydro-meteorological feedback and changes in water storage and fluxes in northern Indian basins, mitigating climate change impacts on India agriculture through improved irrigation water management, structure and dynamics of groundwater systems in northwestern India under past, present and future climates, and understanding the role of different regional drivers on erosion and flood risk hazard in the Ganges – Brahmaputra Basin. Thrust on indigenous capability will be given through support of joint activities in areas of common interest. Scientific and technical cooperation with national and international scientific groups in earth system science will continue. In order to get constant

feedback of the impact of the services provided by the Ministry and the benefits accrued by the end-user in economic terms, the Ministry will continue to support third party evaluation of its services periodically.

b) Participating Institutions:

Earth System Science Organization, Delhi

c) Implementation Plan:

(i) Proposals related to the activities of the Ministry will be considered for funding
(ii) The research proposals will undergo a review mechanism established at the Ministry while proposal for Chairs and Center of excellence will be considered case-to case basis depending upon the scientific caliber existing in the implementing institute
(iii) The proposal once funded will undergo a review mechanism at the mid-term stage
(iv) Further funds will be released subject to submission of Annual reports and utilization of funds
(v) At the completion stage a Project Completion Report will be submitted.

d) Deliverables:

The deliverables of the network projects, if found good, will be translated into operational use for overall improvement of weather and marine services of the country
It is expected that the MSc and PhD programmes will help in capacity building in Earth Sciences and thereby cater to the depleting scientific manpower in the MoES institutes. The establishment of Center of Excellence and MoES Chair/Professorship will help in encouraging focused research activities in the field of Earth and climate science.

e) Budget requirement: ` 290 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Research and Capacity Building	38	53	54	67	78	290

3.14.2 Earth Science and Technology Cells (ESTC)

During the plan period, the Ocean and Atmospheric Science and Technology Cells (OASTCs) will continue to function in the specified areas with the following objectives. Henceforth, the OASTCs will be known as Earth Science and Technology Cells (ESTC)

(i) To create adequate expertise in various disciplines of ocean and atmospheric science & technology for the benefit of the society for enhanced awareness about the phenomenon and processes of earth systems.

(ii) Encourage universities, colleges & institutes to perform front ranking research in science.
(iii) Evolving technology for harnessing of resources including energy and capacity building to meet the present and future needs for scholastic pursuits and industry.
(iv) To maximize the benefits that our country could realize from her vast ocean regime.
(v) To promote scientific temper and awareness among the public and school children about ocean and its resources, usefulness, management and development.
(vi) Promotion of proven/viable technologies for harnessing of resources for the benefit of the local communities in the areas of aquaculture, seaweeds, fishing gear improvisation etc.

a) Objectives:

(i) Continuation of the activities of ESTCs/CoEs towards manpower development and capacity building in earth system sciences.
(ii) Funding of research projects on earth system sciences
(iii) Opening up of new ESTCs and up-gradation of existing ESTCs into MoES Centres of Excellence (CoE)
(iv) Funding for international travel support to the scientists.
(v) Establishment of Programme management cell in the ministry

b) Participating Institutions:

Earth System Science Organization, Delhi.

c) Implementation Plan:

Each ESTC functions under the overall guidance and monitoring of the Management Board (MB). MBs are chaired by the Vice-Chancellor of the university or the Director of the institute where the ESTC is located; Research Coordinator is the Member Secretary of the MB. Steering Committee under the chairmanship of the Secretary, MoES is the apex policy making body for the programme.

d) Deliverables:

1. Addressing national and international issues of scientific relevance and finding solutions thereof.
   1a. Publication of papers in peer reviewed national and international journals.
   1b. Filing of patents in national and international patent offices
   1c. Undertaking National and international collaborative projects.
   Improved interaction with national and international scientists to address relevant scientific issues.
2. Manpower Development & Capacity Building
   2.1 Degrees awarded (Ph.D/M.Phil/MS etc)
   2.2 Visiting professorship awarded (National/ international)
   2.3 Workshop/seminar/symposium of national importance organized

3. Establishment of new ESTCs and up-gradation of existing ones into Centers of Excellence (CoE)
   3a. Improved functioning of the ESTCs

e) Budget requirement: ` 75 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Centre of Excellence	15.00	15.00	15.00	15.00	15.00	75.00

3.14.3 Establishment of India Africa Centre for Medium Range Weather Prediction

East African highlands play an important role on the development of Somali Jet which is a crucial component for understanding the Indian summer monsoon. In addition, the observations over African regions are sparse and any additional information over these regions will be beneficial since the air mass from African region flows over India during most time of the year. In addition, there are several buoys that are deployed by India that generates observations over Arabian Sea. It is proposed that Indian scientists will work towards quantifying the role of these highlands and improve medium-range predictions not only over India but also over Africa. In view of the above, Government of India has committed to establish a joint Indo African centre for medium range weather prediction in eastern Africa to build capacity in the African country that will help them to understand and adapt an end-to-end medium range weather forecasting system. This will not only be beneficial to both the countries, it will result in enhancing African countries' capability to understand, generate and disseminate weather forecast and products 3 to 10 days in advance.

a) Objectives:

To enhance the African countries' capability to implement an end-to-end medium-range weather forecasting system in Africa to generate and disseminate weather forecast and products 3 to 10 days in advance; with an aim to enhance African countries' capability to understand, anticipate and manage the impacts of weather fluctuations to support sustainable development through exchange of information, experience and expertise and strengthen institutional mechanisms.

b) Participating Institutions:

National Centre for Medium Range Weather Forecast, Noida.

c) Implementation Plan:

The India Africa Forum shall decide the location and the mechanism of governance of the India-Africa Centre for Medium Range Weather Forecasting. It is envisaged that the country hosting the Centre shall provide the land and building for the Centre and cater to the budget for recurring costs. it is proposed that the Centre is preferably located near the eastern coast of Africa since the wind flow from this region comes directly over India through the Arabian Sea. In addition this will also

ensure proximity to the buoys that are deployed by India that generates observations over the Arabian Sea. East African highlands play an important role on the development of Somali Jet (a crucial component of the Indian summer monsoon). Indian scientists shall be able to work and quantify the role of these highlands and improve medium-range predictions not only over India but also over Africa. Nairobi (Kenya) and Addis Ababa (Ethiopia) in the eastern Africa may be considered to host such a facility. Countries in eastern Africa have few pan-African and International Centres such the Headquarters of African Union is located in Addis Ababa, Inter Governmental Authority on Development (IGAD)- Climate Prediction and Applications Centre (ICPAC)in Nairobi. Headquarters of UNEP is also located in Nairobi. Proximity of eastern Africa to India will be an added advantage if the proposed Centre is located in any country in eastern Africa.

d) Deliverables:

Establishment of a complete centre for medium Range Weather Forecasting in Africa along with capacity building.

e) Budget requirement: `180 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Africa Centre	10.00	20.00	80.00	40.00	30.00	180.00

3.14.4 Centre for Advanced Training in Earth System Sciences and Climate (CAT ESSC): Continuing Scheme

The Centre for Advanced Training in Earth System Sciences and Climate (CAT-ESSC) started functioning from IITM during 2011. The main objective of the Centre is to create a large pool of trained and dedicated earth system and climate system scientists with in-depth hands-on expertise on individual physical processes of the land, ocean, atmosphere, biosphere and cryosphere with special emphasis on modeling. The aim is to go beyond the conventional training in individual systems and to address weather and climate as processes arising from interactions between the above component systems. Meritorious Masters in Science and Bachelors/Masters in Engineering degree holders are recruited and provided this induction training extending to eighteen months. On satisfactory completion of the training they are to be placed as ESSO scientist-B/C in any institute of the ESSO. The trainees are also given the option to pursue M.Tech. or/and Ph.D. before or after induction. For the program a new campus with self contained facilities for training and research is being developed in Pune. Hence, it is necessary to develop a campus exclusively for the CAT. It needs to be self-contained to meet all the long term demands of the training, trainees, faculty, visiting faculty and the staff.

a) Objectives:

(i) To place the first batch of the trainees in institutes of ESSO who will complete the induction training in 2012-13. This will be continued in the subsequent years of the plan period.
(ii) To increase the intake of the trainees systematically to 60 nos as per requirements.

(iii) To complete the new campus for the Centre of Advanced Training with all the required facilities for the training and to locate all the training activities to be there.
(iv) To develop and implement an one-year training programme for the SAARC, BIMSTAC, and Indian Ocean Rim countries.
(v) To complete recruitment of all the staff proposed in the program document.
(vi) To include different modules of advanced training at the induction, M.Tech. and Ph.D. levels to cover all aspects of earth system sciences and technology.
(vii) To enter into collaboration with institutions in the area at the national and international level for providing advanced training to the newly recruited trainees and for awarding degrees.

b) Participating Institutions:

Indian Institute of Tropical Meteorology, Pune.

c) Implementation Plan:

(i) The intake of trainees will be increased from the current 20 as per requirements with an aim to achieve the target of 60.
(ii) The campus development will be initiated with training, research, hostels, living quarters, guest houses and other facilities. However, in the beginning the CAT will start functioning by utilizing the existing facilities of IITM.
(iii) The faculty of IITM and other institutions will supplement the faculty requirements of the CAT.
(iv) The R&D programs will continue to be implemented jointly with IITM, other institutions of MoES and other centers at the national and international level.

d) Deliverables:

(i) CAT will provide well trained scientific manpower for research in weather and climate to ESSO starting with 20 nos. and systematically increasing as per requirement.
(ii) World class training infrastructure for training at the induction level, MTech and PhD for the ESSO institutions and one year course for other countries will be developed with the necessary faculty and other facilities.
(iii) The faculty will take up R&D programmes independently, with IITM and other institutions.
(iv) CAT will establish linkages with leading national and international institutions for training and research.

e) Budget requirement: ` 300 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
CAT	54.00	54.00	91.00	51.00	50.00	300.00

3.14.5 Training in Operational Meteorology

IMD is the operational agency for meteorological services of the Government of India since 1875. Formal training needs were felt as early as in 1946 whence the training division of IMD commenced function, in the process training a large number of users from across the country as well as within IMD. In 1986 it was declared as a Regional Training Centre for Asia and Africa by the WMO and started training foreign personnel also.

Modernization of the IMD operational system has brought in a host of digitally managed and mutually integrated observational, processing and communication systems. The training culture befitting this scenario will need a paradigm shift, essentially involving constant refreshing of knowledge and skills, substantial amount of self and guided learning and excellent library, laboratory and hostel facilities. Proposals of this program are essentially in the nature of augmentation and integration of the existing facilities. The core faculty proposed is a nominal increase from the presently deployed personnel drawn from other offices of IMD.

India has already started to engage neighboring countries in developing climate services for the region. These and many other countries look up to India for leadership because of our new policies and impressive infrastructure. We stand to gain much by offering fellowships to fulfill the training aspirations of many of these countries.

a) Objectives:

(i) To set up a comprehensive and continuously evolving training programme for S&T operational personnel of IMD, other Government and overseas meteorological organizations.
(ii) To create infrastructure and content for enabling a system of 'continuous learning' at all stages and levels during the careers of personnel.
(iii) To conduct licentiate courses e.g Aviation Meteorology etc as per needs of ICAO and /or other bodies.
(iv) To broaden the teaching resource base by collaborating with other organizations and setting up e-learning facilities.
(v) To encourage, document and monitor applied research output.

b) Participating Institutions:

India Meteorological Department, Delhi.

c) Implementation Plan:

(i) Set up Training Centre with modern teaching aids and hostel facilities
(ii) Capacity building in Indian context and in the context of South Asia and Africa who are dependent on India for training (10 Foreign fellowships)
(iii) New Training program with linkages with IITM, Universities and WMO
(iv) Development of Training Faculty – creation of additional posts for Core Faculty
(v) Development of infrastructure AT Pune, Delhi and 2 regional centers at Kolkata and Chennai

The following infrastructure is proposed:

- Annex building at Training Center, Pune (8000 sqft) and a new International Hostel wing (30 seater).
- Renovation of existing Trainees' Hostel at Pune.
- New Hostel and Training building at Delhi
- Modernization and augmentation of teaching and hostel facilities of the National Meteorological Training Center, Pune and Regional Training Centers at Delhi, Chennai and Kolkata.
- E-learning training portal
- Budget requirement including foreign exchange component:

d) Deliverables:

(i) Trained manpower for catering to the requirement of operational need of the National Weather Services.
(ii) Establishment of world class infrastructure in terms of technology and content for training international personnel associated with Meteorological and Hydrological services.
(iii) Establishment of specialized courses for Aviation meteorology as per recent ICAO/WMO guidelines.

e) Budget requirement: ` 99 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Training in Operational Meteorology	15.00	41.00	25.00	8.00	10.00	99.00

3.14.6 Training Centre for Operational Oceanography

This proposal is to set up a permanent training facility for capacity building for 'operational oceanography' in continuation to the statement of the Indian delegation in the 43rd meeting of IOC executive council at UNESCO, Paris during 8-16 June 2010 (IOC/EC-XLI/3 Annex IX – page 20) and to train the required manpower to maintain the operational units in India. The training programme will aim at equipping the trainees in handing the specific issues in operational oceanography like oceanographic data collection (in situ and satellite), data transmission, processing, archiving, analysis, adoption of ocean models for different regions, dissemination of information to the users, etc.

a) Objectives:

(i) Set up a permanent training facility for capacity building and long term training of manpower specialized in operational oceanography at INCOIS.
(ii) Build the faculty block and an international standard guest house cum hostel to accommodate the trainees and foreign faculty
(iii) Recruit the necessary faculty to offer the training.
(iv) Sign MoU/s with universities to award degree/diploma to the students who complete the long term courses.
(v) Conduct the short and long term training programmes.

b) Participating Institutions:

Indian National Centre for Ocean Information Services, Hyderabad.

c) Implementation Plan:

INCOIS will set up an international training centre 'Training Centre for Operational Oceanography'. The Ministry of Earth Sciences, Government of India will bear the cost of setting up of infrastructure, including land and building, and the operational cost including the salary of Indian faculty. The other cost, mainly, the travel and per dim for international trainees and the salary for international faculty will be borne by IOC or the member states who depute their faculty or trainees.

d) Deliverables:

- A state of art training centre for operational oceanography
- Training and capacity building of existing manpower
- Creation of specialized manpower to man operational oceanographic centers and to develop new operational services and prediction models.

e) Budget requirement: `150 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Training Centre for Operational Oceanography	6.00	43.00	38.00	45.00	18.00	150.00

3.14.7 Outreach & Awareness

With a view to propagate and bring awareness about the Earth, Atmosphere and Ocean Sciences and to inculcate scientific temperament the out reach & awareness programme is implemented by Ministry of Earth Sciences. This offers a common platform for scientist, engineers, social scientist and user community to exchange information and knowledge by supporting Seminar, Conference & workshop

Exhibitions, Fairs, Seminars and Symposia

Various exhibitions & Seminars/Symposia/workshops are organized for scientists, engineers, technologists. Experts, social scientists and user communities in area of earth system science. Several academic institutions, research institute, CSIR labs, universities, non governmental organizations, government bodies, etc. are involved in this sphere of activities. Further outreach activities include popularization on Television & print media, Olympiads, quiz & other competitions etc. These endeavors are supported by Ministry of Earth Sciences.

a) Objectives:

To bring awareness about Earth, Atmosphere and Ocean Sciences among public, student and user communities.

b) Participating Institutions:

Earth System Science Organization, Delhi.

c) Implementation Plan:

The Ministry has been actively participating in various exhibitions in India abroad, highlighting the research and development programmes and achievements. 125 National and International exhibitions have been participated during the XI Plan period. The Ministry would continue to participate in various exhibitions in India abroad, highlighting the research and development programmes and achievements

Earth Day Celebration
In an effort to bring awareness among the public, schools and colleges, Earth Day is being celebrated on 22nd April across the country every year with the financial support of the Ministgry. 300 centres including educational and Science Centers in the country started celebrating Earth Day since 2008.

In an effort to bring awareness among the public, Earth Day will be celebrated on 22nd April across the country specially in Schools, College, Educational Institutions and Science Centers.

Popularization on Television and Print Media

The film “Science Safari” in regional television channels in local languages on various activities of Ocean and Atmospheric Science and Technology, produced by the National Geography channel was telecast many a times
The articles related to earth system services published in “Geography & You”, “Frontline”, “Namaskar” and “Shrishti” popular Magazines in English and “Bhugol aur Aap” in Hindi which is being distributed to various school.

The film “Science Safari” in regional television channels in local languages on various activities of Ocean and Atmospheric Science and Technology, produced by the National Geography channel was telecast many a times
The articles related to earth system services will be published in leading English and Hindi magazines.

Participation in International Earth Science Olympiad

Ministry supported participation of Indian students in the International Earth Science Olympiad. Since 2008 Indian team (4 students) bagged one Silver Medal and three Bronze medals at the Olympiad 2010.

Ministry will continue to support participation of Indian students in the International Earth Science Olympiad organmised by Geological Society of India.

About 550 events are supported in area of Earth system sciences to provide platform to Scientists, Engineers, and Technologists. Experts, Social Scientists and User Communities. The beneficiaries are Professional bodies like IGU, IGC, ISCA, ISRS, IITs, NITs, National laboratories, Universities, Colleges/Educational Institutions, other Government bodies, NGOs etc.

About 1000 events are proposed for support in area of Earth system sciences to provide platform to Scientists, Engineers, Technologists. Experts, Social Scientists and User Communities across the country

d) Deliverables:

The Ministry will participate in approximately 50 exhibitions in India and abroad, highlighting the research and development programmes and achievements. Earth Day will be celebrated on 22nd April across the country. Ministry will support participation of Indian students in the International Earth Science Olympiad. Films in regional television channels in local languages on various activities of Ocean and Atmospheric Science and Technology will be produced and telecast. The articles related to earth system services will be published in leading 50 Newspapers and magazines. About 1300 events will be supported in area of Earth system sciences to provide platform to Scientists, Engineers, and Technologists. Experts, Social Scientists and user communities.

e) Budget requirement: ` 75 crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
Outreach and Awareness Programme	11.00	12.50	14.50	17.00	20.00	75.00

3.14.8 National Oceanarium

An Oceanarium is a large -scale set-up for display of marine organisms in their natural habitat. Besides being a recreational facility, Oceanariums provide first hand information on (i) marine biodiversity, (ii) behavioural patterns, (iii) feeding mechanisms, (iv) locomotory patterns and provide excellent opportunity to undertake research on various aspects of marine biology. Oceans are rich in flora and fauna which are unknown to common man. Many of the oceanic ecosystems such as the coral reefs, mangroves, seagrass ecosystem, coastal ecosystem, etc are fragile and delicate and needs protection and conservation to maintain them in healthy condition. Community participation is the key in the conservation of these ecosystems.

a) Objectives:

To bring awareness among public, students and researchers on the marine life and the ocean ecosystems and create R&D facilities for specialized research on rare marine life/species for protecting and conserving these resources.

b) Participating Institutions:

(i) National Centre for Antarctic & Ocean Research, Goa
(ii) Centre for Marine Living Resources & Ecology, Kochi

c) Implementation Plan:

It is proposed to establish R&D facilities within the Kochi Oceanarium.
It is proposed to establish the National Oceanarium in a suitable site to be allocated by the Government of Goa.

d) Deliverables:

Establishing National Oceanarium & R&D facilities at Goa & Kochi respectively for display of marine organisms in their natural habitat and to undertake research on various aspects of marine biology.

e) Budget requirement: ` 580 Crores

(Rs. In crores)

Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
R&D facilities in Kochi Oceanarium	50.00	60.00	40.00	5.00	5.00	160.00
Setting up of National Oceanarium in Goa	50.00	250.00	90.00	15.00	15.00	420.00
Total	100.00	310.00	130.00	20.00	20.00	580.00

4 Year-wise Summary of Financial Requirement for 12th Five Year Plan (2012-17) of MoES

Tabel 4.1: Proposed outlays for XII Five Year Plan (2012-17)

No	Name of the Scheme	2012-13	2013-14	2014-15	2015-16	2016-17	Total
I	**Atmospheric observation system network**	**367**	**457**	**617**	**342**	**372**	**2155**
1	Atmospheric observation system network	110	120	180	150	140	700
2	Satellite meteorology (including aircraft-based	10	10	20	15	15	70
3	*Modernization phase II of IMD* (N)	*200*	*250*	*300*	*100*	*150*	*1000*
4	*Integrated Himalayan meteorology programme* (N)	*30*	*60*	*100*	*60*	*50*	*300*
5	Centre for Atmospheric Technology (N)	17	17	17	17	17	85
II	**Atmospheric processes and Modeling and Services**	**207**	**530**	**257**	**200**	**190**	**1384**
1	Numerical modeling of weather & climate	14	26	22	23	15	100
2	Agrometorology	50	60	55	50	50	265
3	Aviation Services	70	60	40	15	15	200
4	*Metropolitan advisories for cities for sports, tourism* (N)	*25*	*30*	*20*	*10*	*5*	*90*
5	*Monsoon mission programme* (N)	*10*	*66*	*77*	*64*	*73*	*290*
6	*Physics and Dynamics of Tropical Clouds* (N)	*28*	*268*	*18*	*18*	*18*	*350*
7	Development of High Impact Severe Weather Warning System for India	10	20	25	20	14	*89*
III	**Climate Change Research**	**212**	**217**	**230**	**201**	**195**	**1055**
1	Short Term Climate Prediction -and -Variability	55	45	35	34	31	200
2	CCCR	25	22	20	18	15	100
3	*Climate services* (N)	*10*	*20*	*15*	*10*	*5*	*60*
4	*Integrated Program on Climate, Water Cycle and Prediction* (N)	*19*	*24*	*29*	*29*	*19*	*120*
5	Geoengineering- CO_2 Sequestration (N)	5	5	10	10	20	50
6	Carbon - Cycle Research (N)	20	30	40	40	40	170

7	IITM – Operation & Maintenance	15	20	25	25	25	110
8	Impact of sea level rise* (N)	Funds projected under VI(6) below					
9	Studies on carbon and nitrogen biogeochemistry						
10	Reconstruction of paleo-climatic conditions (New)	25	20	20	15	15	95
11	Cryosphere Processes And Climate Change (CryoPACC)	7	5	5	3	3	23
12	Cryosphere studies in Himalaya (N)	20	15	15	10	10	70
13	Long-term monitoring of Konfsfjorden system in the Arctic for climate change studies (N)	11	11	16	7	12	57
IV	***Airborne Platforms***	***70***	***200***	***250***	***80***	***100***	***700***
V	**Ocean Observations**	**80**	**90**	**110**	**100**	**106**	**486**
1	Moored buoys, drifting buoys, current meters etc	60	70	90	80	86	386
2	Sustained Indian Ocean Biogeochemical and Ecological Research (SIBER) and Geotraces	20	20	20	20	20	100
VI	**Ocean Science and Services**	**193**	**307**	**307**	**232**	**226**	**1265**
1	Ocean information and services	15	16	15	14	13	73
2	Early warning system for tsunami and storm surges	15	20	25	20	20	100
3	Ocean Research and Modelling	15	15	15	15	15	75
4	INCOIS –Operations and Maintenance	26	74	28	31	36	195
5	Marine Living Resources + building + Operation & Maintenance	46	52	38	34	30	200
6	Coastal Research (ICMAM O&M other related projects, COMAPS)	23	50	44	37	31	185
7	Drugs from the Sea:	20	30	50	50	50	200
8	Multi-hazard Vulnerability Mapping	10	20	20	15	15	80
9	*Microbial Oceanography* (N)	*21*	*29*	*21*	*15*	*14*	*100*
10	*High Resolution Operational Ocean Forecast and Reanalysis System* (N)	*2*	*1*	*51*	*1*	*2*	*57*
VII	**Ocean Survey & Mineral Resources**	**254**	**380**	**374**	**376**	**365**	**1749**

1	Swath Bathymetric Survey of the Exclusive Economic Zone (EEZ) + CLCS	27	26	27	27	26	133
2	Ocean Survey and Resources(EIA, Metallurgy, Hydrothermal sulfides, Cobal Crust)	113	72	65	64	59	373
3	Hydrothermal sulfides, Cobal Crust in the Indian Ocean Ridge	100	250	250	250	250	1100
3	Gas Hydrates	14	32	32	35	30	143
VIII	**Ocean Technology**	**324**	**370**	**323**	**282**	**248**	**1547**
1	Ocean Energy and Fresh Water (Continuing programmes)	43	69	76	80	96	365
2	Development of Deep Sea Mining Machine (Continuing programme)	93	88	36	14	16	247
3	Manned and Unmanned Underwater Vehicles (Continuing Programme	27	48	56	55	20	206
4	Marine sensors, Electronics & Ocean Acoustics	16	17	17	16	12	78
5	Technical Criteria Atlas	13	8	6	5	4	36
6	Shoreline management	Funds projected under VI(6)					
7	Offshore structures	2	16	21	17	12	68
8	*Marine Bio-technology* (N)	*31*	*28*	*23*	*13*	*10*	*105*
9	Seafront Facility	57	45	31	24	19	175
10	Development of Island community (N)	11	16	17	16	10	*70*
11	NIOT manpower and operational expenses	31	35	40	44	49	199
IX	**Ocean Research Vessels**	**124**	**415**	**518**	**249**	**177**	**1483**
1	Replacement and Operation, Maintenance and Running Costs of Two CRVs after their acquisition (N)	60	55	19	6	6	146
2	*Operation, Running and Maintenance of Two CRVs until the acquisition of Two & Sagar Nidhi & Sagar Manjusha*	*54*	*45*	*39*	*53*	*46*	*237*
3	*Replacement of ORV Sagar Kanya, Concept, Design, Ship Construction Costs* (N)	*5*	*220*	*260*	*90*	*25*	*600*
4	Replacement of FORV Sagar Sampada, Concept, Design, Ship Construction Costs (N)	5	95	200	100	100	500
X	**Polar Sciences &**	**586**	**679**	**531**	**377**	**255**	**2428**

	Cryosphere						
1	Expeditions(Arctic, Antarctic, Southern Ocean, 3rd Station	204	222	202	196	195	1019
2	Ice Class Vessel	316	321	137	22	1	797
3	Replacement of Maitri station (N)	30	100	160	130	30	450
4	NCAOR – Operation & Maintenance:	25	22	18	19	21	105
5	*Long-term monitoring of the Kongsfjorden system in the Arctic for climate change studies* (N)	*11*	*14*	*14*	*10*	*8*	*57*
XI	**Seismological Research**	**108**	**194**	**247**	**296**	**264**	**1109**
1	Seismic Hazard & Risk Evaluation	2	10	25	35	33	105
2	Earthquake Observational Network and Data Centre	20	10	15	15	10	70
3	*New facility for High Resolution Secondary Ionisation Mass Spectrometry (HR-SIMS)* (N)	*15*	*40*	*30*	*20*	*10*	*115*
4	National Centre for Seismology:	15	25	30	20	15	105
5	*Deep Borehole investigations in Koyna-Warna Region:* (N)	*20*	*60*	*80*	*120*	*120*	*400*
6	*Deep crustal studies of the South West Indian margin and its interior: An onshore-offshore perspective* (N)	5	4	2	1	1	13
7	*Development of Geo-Technology* (N)	*1*	*10*	*20*	*40*	*30*	*101*
8	Earthquake Research (Seismicity, Precursors, EREC, Observation)	30	35	45	45	45	200
XII	**Geoscience**	**15**	**79**	**46**	**21**	**13**	**174**
1	Integrated Ocean Drilling Program (IODP):	7	62	31	12	8	120
2	*Exploring the origin of the largest Geoid low on the Earth* (N)	*8*	*17*	*15*	*9*	*5*	*54*
XIII	***High Performance Computing***	***150***	***150***	***200***	***200***	***200***	***900***
XIV	**Research, Education, Training and Outreach**	**282**	**565**	**469**	**292**	**241**	**1849**
1	Research and Capacity Building	38	53	54	67	78	290
2	Centers of Excellence	10	15	20	20	10	75

3	Establishment of India Africa Centre for Medium Range Weather Prediction	10	20	80	40	30	180
4	Centre for Advanced Training in Earth System Sciences and Climate (CAT ESSC)	54	54	91	51	50	300
5	Training in operational meteorology	25	30	20	14	10	99
6	Training Centre for Operational Oceanography	6	43	38	45	18	150
7	Outreach and Awareness Programme	14	15	16	15	15	75
8	*R&D facilities in Kochi Oceanarium,* and *Setting up of National Oceanarium in Goa*	*100*	*310*	*130*	*20*	*20*	*580*
9	*Earth Enterprise/IT/Infrastructure*	***20***	***20***	***20***	***20***	***20***	***100***
	GRAND TOTAL	**2847**	**4358**	**4209**	**2978**	**2692**	**18284**

ANNEXURE-I

No.12016/3/2011-S&T
Government of India
Planning Commission
Science & Technology Division
…..

Yojana Bhawan,
Sansad Marg,
New Delhi-110 001.

Dated 18.04.2011

OFFICE MEMORANDUM

Sub: WG-12: Constitution of Working Group of the Ministry of Earth Sciences.

The Steering Committee on Science and Technology for the formulation of Twelfth Five Year Plan, during its first meeting held on 5th April, 2011 under the Chairmanship of Dr. K. Kasturirangan, Member (Science). Planning Commission has decided to constitute a Working Group for the Ministry of Earth Sciences. The composition and Terms of Reference of the Working Group are as under :-

COMPOSITION

S.No.	Name & Designation	
1	**Dr. Shailesh Nayak, Secretary, MoES - Chairman**	**Chairman**
2	Dr. Satish R Shetye, Director, NIO, Goa	Member
3	Dr. Debasis Sengupta, Assistant Professor, Centre for Atmospheric and Oceanic Sciences, IISc, Bangalore	Member
4	Dr. S.W.A. Naqvi, Scientist 'H', Director, NIO, Goa	Member
5	Prof. V.K. Gaur, Honorary Emeritus Scientist, CSIR-C-MMACS, NAL, Bangalore	Member
6	Dr. Y.J. Bhaskar Rao, Acting Director, NGRI, Hyderabad	Member
7	Prof. Somanath Das Gupta, IISER, Kolkata	Member
8	Prof. J. Srinivasan, Centre for Atmospheric and Oceanic Sciences, IISc, Bangalore	Member
9	Dr. Sulochana Gadgil, Centre for Atmospheric and Oceanic Sciences, IISc, Bangalore.	Member
10	Major General S.S. Sharma, 703, Cordia, Nyata Establishment, Mohammad Wadi, Pune-411 060	Member
11	Prof. S.K. Dube, Indian Institute of Technology, Delhi	Member
12	Prof. U.C. Mohanty, Indian Institute of Technology, Delhi	Member
13	Dr. Upadyaya, 12-5-35/A/2, Street No.6, Behind Canara Bank, Secunderabad-500 007.	Member
14	Dr. Shyam Lal, PRL, Ahemedabad	Member

15.	Dr. T. Balasubramanian, Professor of Physiology, RMMC, Annamalai University, Annamalainagar-608 002.	Member
16	Dr. A.K. Gupta, Head, Centre for Ocean River, Atmosphere & Land Science IIT, Kharagpur-721 302.	Member
17	Dr. Sudarshan, Naval Physical and Oceanographic Laboratory, Thirikkakara P.O. Kochi-682 021.	Member
18	Dr. P.K. Pal, Space Application Centre, Jodhpur Tekra, Ambawadi Vistar, P.O. Ahmedabad-380 015	Member
19	Dr. P.C. Joshi, Space Application Centre, Jodhpur Tekra, Ambawadi Vistar, P.O. Ahmedabad – 380 015.	Member
20	Dr. Ashok Singhavi, Scientist –F, PRL, Ahmedabad-380 009.	Member
21	Prof. Roonwal, C-520, SFS Flats, Sheikh Sarai Phase-I, New Delhi – 110 017.	Member
22	Dr. D. Sen, Department of Ocean Engineering and Naval Architecture, IIT, Kharagpur.	Member
23	Dr. Akhilesh Gupta, Adviser, Department of Science and Technology, New Delhi.	Member
24	Shri A.K. Verma, Adviser (S&T), Planning Commission or his nominee.	Member
25	Representative of the Director General, CII	Member
26	Financial Advisor, MoES	Member
27	Dr. S.K. Das, Adviser, Ministry of Earth Sciences	**Member Secretary**

Terms of Reference

1. To review and assess the performance and role of the Department at the end of the Eleventh Five Year Plan. Identify priorities of the Department for the Twelfth Five Year Plan and suggest measures including policy initiatives for enabling India to emerge as a major global technological power by 2025.

2. To suggest plan programmes for the Department by adopting a ZBB approach and keeping in view the priorities and goals for the Twelfth Five Year Plan as well as the agenda for the Decade of Innovations during 2010-2025.

3. To define deliverables as well as goals for the Department for the Twelfth Five Year Plan period as well as Annual Plans, both in terms of tangible and non-tangible outputs and formulate guidelines for deployment of resources for relating inputs to the specified goals.
4. To suggest an optimum outlay for the Department, comprising of the on-going commitment and new programmes proposed to be undertaken.

5. The Chairman may co-opt any other member.

6. The expenditure towards TA/DA in connection with the meetings of this Working Group in respect of Official Members would be borne by their respective Ministries/Departments. In respect of Non-Official Members, the

expenditure would be met by the Ministry of Earth Sciences, as admissible to Class-I Officers of the Government of India.

7. The report of the Working Group would be submitted to the Steering Committee on the S&T for the formulation of Twelfth Five Year Plan by 15th July, 2011.

Sd/-
18.04.2011
(R.K. Gupta)
Joint Adviser (S&T)

Copy forwarded to :-

1. Secretary, Ministry of Earth Sciences.
2. Chairman, all members and Member-Secretary of the Working Group.
3. PS to Deputy Chairman, Planning Commission.
4. PS to Adviser to PM on PI^3.
5. PS to Minister of State (Planning).
6. PS to all Members, Planning Commission.
7. PS to Member-Secretary, Planning Commission.
8. All Principal Advisers/Sr.Advisers/Advisers/HODs, Planning Commission.
9. Director(PC), Planning Commission.
10. Information Officer, Planning Commission.
11. Library, Planning Commission.

Sd/-
(R.K. Gupta)
Joint Adviser (S&T)

Annexure-II

पृथ्वी विज्ञान मंत्रालय / **Ministry of Earth Sciences**
ब्लाक १२ , सी जी ओ काम्प्लेक्स / **Block-12, CGO Complex**
लोदी रोड नै दिल्ली, /**New Delhi**

MoES/36/RFD/2009 PC-IV May 2, 2011

Office Memorandum

Sub: Constitution of Sub-Groups for finalization of Working Group Document of 12th Five Year Plan of the Ministry

The Planning Commission vide their letter No12016/3/2011-S&T dated 18.4.2011 has constituted a Working Group(WG) under the chairmanship of Secretary, Ministry of Earth Sciences (MOES) for 12th Five Year Plan as per the direction of the Chairman, Steering Committee. As a follow up action, the Chairman, WG decided to set 3 Sub-Groups to address activities of the ministry separately. These sub-groups are (i) Atmospheric & Climate Science and Services (2) Ocean Science and Services (3) Cryosphere and Geosciences, whose composition are as follows:

1. Ocean Science and Services:

- Prof. V.K Gaur, Emeritus Scientist - Chairman
- Dr. Satish R Shetye,, Director NIO - Member
- Dr. Debasis Sengupta, Assistant Professor, IISC -Member
- Dr. S.W.A Naqvi, Sci-H, NIO -Member
- Prof. T. Balasubramanian, CAS Annamalai University -Member
- Dr. P.K. Pal, Scientist, SAC -Member
- Dr. D. Sen, Professor, IIT- Kharagpur -Member
- Dr. Sudharshan, NPOL, Kochi -Member
- Dr. K.Somasundar , MoES -
  Convener

2. Atmospheric & Climate Science and Services

- Professor J. Srinivasan, Professor, IISC - Chairman
- Dr. Sulochana, Gadgil, Professor, IISc -Member
- Prof. S.K. Dube, Professor, IIT, Delhi -Member
- Prof. U.C. Mohanty, Professor, IIT, Delhi -Member
- Dr. Shyam Lal, Professor, PRL -Member
- Dr. P.C. Joshi, Scientist, SAC -Member
- Dr. Akhilesh Gupta, ScientistG, DST -Member
- Dr. Swati Basu, MoES -Convener

3. Cryosphere and Geoscience

- Dr. Ashok Singhavi, Scientist, PRL - Chairman
- Dr. Y.J Bhaskar Rao, Director, NGRI -Member
- Prof. Somanath Das Gupta, - Member
- Dr. A.K.Gupta, Head CORAL, IIT, Kharagpur -Member
- Prof. Roonwal , Professor, -Member
- Major General S.S. Sarma, -Member
- Dr. S. Rajan, NCAOR -Convener

The terms of reference of the work group are as follows:

- To review and assess the ongoing programmes and identify priorities of the Ministry for 12th Five Year plan and suggest measures including policy initiatives
- To provide advise and facilitate development a working group document for formulation of 12th Five year Plan
- The Chairman may co-opt any other member.
- The expenditure towards TA/DA in connection with the meetings of the Sub-Groups would be met by the respective Autonomous centre of MoES viz.., INCOIS, IITM, NCAOR.

(Kishan Kumar)
Under Secretary

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