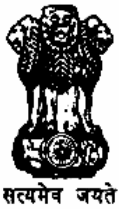
ELEVENTH PLAN
2007-2012

WORKING GROUP DOCUMENT
VOLUME 1



Government of India
Ministry of Earth Sciences

2006

VOLUME 1

VOLUME 2
(OCEAN DEVELOPMENT)

VOLUME 3
(ATMOSPHERIC SCIENCES)

PREFACE

The earth and ocean constitutes this globe. When coupled with atmosphere, it's this beautiful living planet. This very planet offers immense opportunities and challenges through its varying nature expressed strongly through weather and more evidently in the changing oceanic and atmospheric conditions. Floods, cyclones, hurricanes, storm surge, are such known vagaries of nature. Indeed, this has been the subject matter of inquisition and enquiry. While, common human perception distinguishes the tera firma, the oceans and the atmosphere from each other, we are slowly learning to look at these three systems as a part of a bigger entity earth-system. The formation of Ministry of Earth Sciences is an initiative in this direction. This is bound to unravel the interlinking forces playing within and influencing the weather, climate and the environment around us. India has a coastline of about 7500 kilometers, and the seas around India influence the life of about 370 million coastal population and the living of about 7 million strong coastal fishing community. Understanding our ocean and weather is therefore vital to their livelihood. Gathering adequate knowledge of the potential of ocean space especially within our Exclusive Economic Zone (EEZ) of about 2.02 million sq km (our landmass area being about 3.27 million sq km) forms a key area for multidisciplinary research which is again closely linked to weather and atmosphere. Further, the resource potential of our ocean would be enhanced with the delineation of continental shelf extending significantly beyond the existing EEZ.

I may recall the Department of Ocean Development was established in 1981, with a primary mandate of formulation and implementation of programmes in ocean science and technology for long term scientific, technical, economical and geopolitical benefits. Right from the inception of the Department, it has been implementing national programmes such as Polar Science and Polymetallic nodules. With the adoption of ocean policy statement and U.N conference on Environment Development in 1992 and with UN Convention on Law of the Sea coming into force in 1995 for India, the activities of the Department were expanded and oriented towards exploration and exploitation of living and non-living resources within our EEZ and beyond for the socio-economic benefit and sustainable development of marine sector.

For effectively implementing programmes, projects and missions in the forefront of Ocean Science, Technology and Services; two attached Offices were set up viz. the Centre for Marine Living resources and Ecology (CMLRE) at Kochi and the Project Directorate for Integrated Coastal and Marine Area Management (ICMAM) at Chennai; Three autonomous Institutions viz. the National Centre for Antarctic Research (NCAOR) at Goa, National Institute of Ocean Technology (NIOT) at Chennai and the Indian National Centre for Ocean Information Services (INCOIS) at Hyderabad, as well as nine Ocean Science and Technology Cells in universities/institutes and a chain of Marine Data Centres at National Institutions. The Department also maintained the permanent research station - Maitri in Antarctica apart from a fleet of oceanographic research vessels, which are well-equipped floating laboratories.

In a short span of over two decades, the Department/Ministry has done a creditable job by carrying out work of scientific and technological excellence and social relevance, addressing very important issues such as: (i) science in Antarctica and India's presence in Antarctic Treaty System, (ii) oceanographic surveys and analysis of data for claiming Legal Continental Shelf of 1.5 million sq.km, (iii) Setting up of a dedicated storm surge and tsunami Warning system,(iv) all aspects of deep sea Polymetallic Nodule programme including exploration, sea bed mining and extraction of strategic metals such as copper cobalt, nickel and manganese, (v) desalination plant demonstration (vi) Percolating the benefits of

development of technologies for Low temperature Thermal desalination for local population through setting up of 1 lakh litre plant in Lakshadweep islands (vii) improving understanding of Indian Ocean with a comprehensive network of observing systems (viii) marine instrumentation and technology development (ix) regular ocean information and advisory services including the Potential Fishing Zones (x) marine living resources and drugs from sea and (xi) integrated coastal area management.

The Ministry has developed a close interaction at both research and operational level between the scientific community and ensuring that there is a seamless flow of data, information and knowledge that percolates down to the end users, thereby getting integrated with the development process in the country. The setting up of a desalination plant with a capacity of generating 1 lakh litre freshwater per day based on technologies developed has brought direct benefits to the islander community and more than 1 crore litre of freshwater has been generated so far. The data on various met-ocean parameters collected from moored data buoys in the Arabian Sea and Bay of Bengal has been of immense value to the India Meteorology Department in forecast of weather and cyclones. The potential fishing zone advisories have brought direct economic benefits to the 7 million fishing community of the coastal states and island territories, by reducing search time and improving catch per unit effort up to 50 %.

The excellent work of the Ministry has enabled India to gain an important position globally in the oceanic realm. Scientists of the Department are occupying key positions in the apex bodies on ocean affairs e.g. (i) Vice Chairman of the Intergovernmental Oceanographic Commission of UNESCO, (ii) Chairman of the Regional alliance in Indian Ocean for Global Ocean Observing System, (iii) Regional Coordinator for International Argo Project in Indian Ocean, and (iv) Member of the Executive Council of International Seabed Authority. India is represented by the Department as one of the 28 Consultative Members of the Antarctic Treaty System.

However, it was increasingly felt that the technological advances can not be realised into the ocean development without understanding the atmosphere. Similarly, the role of ocean in influencing the climate was also getting more and more evident. This has led to consider land-ocean-climate coupled system as an integrated whole.

Any scientific policy that ought to reorient with the new dispensation of the Ministry of Earth Sciences must take into account the need to integrate the ocean and atmosphere related activities in the country, not so much as to treat them independently but more importantly to recognize and encourage the science of the interface that can leverage into an overall under framing. The activities in the core sectors of the two large subject areas must simultaneously receive due attention because of immense possibilities of extracting diverse services from them.

The India Meteorological Department is one of the oldest of organized meteorological services of the world. In course of time it was evident that the nature of meteorological phenomena was distinctly different not only in the tropics and mid-latitudes but also in different geographic regions characterized by large ocean basins like that of Pacific, Atlantic and the Indian Ocean. Thus topical research was the need of the day and the Institute of Tropical Meteorology came up in 1962 and the National Centre for Medium Range Forecasting came up in 1989. Today they complement each others role and add to the overall scientific capability in the country.

The progress in meteorological service has been a gradual process till date. The world has however taken a leap in recent decades towards atmospheric observations network and electronic integration and the IT. The upgradation of our national facility is therefore high on the agenda. The XI Five year plan being a path breaker in many ways is

the best forum to address such an objective. Improving short range, medium range and long range forecasts, Agromet Advisory Service, Civil Aviation support, earthquake monitoring, are some of the important areas of current focus. For this purpose, our observational network needs to be strengthened and automated with revamping. Numerical weather modeling, state of the art climate and atmospheric research are the necessary supplementing mechanisms to act as a dynamic feedback to improve weather forecast and services.

Regarding Ocean Development, it is proposed to continue several important continuing programmes with new elements viz. Polar Science and Antarctic Expedition, Marine Living Resources, Mastne Non-living Resources, Marine Environment and Coastal Zone Management, Ocean Observation and Information Services, Marine Research Capacity and Technology Building, etc, while taking up chosen new programmes viz. Arctic Expedition, desalination project, pilot project on shore protection measures, Integrated Ocean Drilling Programme to name a few.

Recognizing the larger of role of earth sciences in the forthcoming 5 year plan period, the Department convened a three workshops in October, 2005,June 2006 and September, 2006 to identify projects, programmes for taking up in XI plan upon review of continuing programmes in X plan. More than 50 participants including eminent scientists attended the workshop and reviewed the continuing programmes. The deliberations during the meeting have culminated into the formulation of the draft proposals for XI Plan period enumerated in this report. While the executive summary of all the proposals are contained in Volume 1, the details of proposals on ocean development and atmospheric sciences are contained in Volume 2 and Volume 3 respectively.

I sincerely thank all concerned for their contributions and guidance in shaping the course of the Ministry for the next five years and beyond. The effort of the officers and scientists of the Ministry of Earth Sciences in preparing this Report is commendable.

Dr. P.S. Goel
Chairman, Working Group
Ministry of Earth Sciences

Date: October 12, 2006
Place: New Delhi

1. EXECUTIVE SUMMARY

1.1 Ocean Development

Ever since the establishment of the Department of Ocean Development in 1981, the Ocean Science and Technology in the country has witnessed a significant progress primarily guided by the principles enunciated in the Ocean Policy Statement. The major responsibilities of the Department(now a Ministry) are formulation and implementation of programmes relating to long term economic and technological development. The Ministry acts as a nodal agency for the technology development, particularly in the areas relevant to economic and social development of coastal population and also as an agency to formulate and coordinate Marine Scientific and Technological projects for exploration of living, non-living and energy resources of the sea and protection and preservation of its environment. Currently the activities of the Ministry are directed towards the development of Technology with the active participation and support of national R&D laboratories, educational institutions and industries to harness the ocean resources. The Ministry of Ocean Development has played a pivotal role in harnessing potential living and non-living resources from the seas around India, including the research on Antarctica by implementing a wide range of schemes, which are highly multi-disciplinary in nature that required a multi-institutional approach. The activities under these schemes range from development of several cutting edge technologies, including deep sea mining technology, to providing ocean information services; and conducting marine geophysical surveys, development of potential drugs, setting up of metallurgical plant for extraction of metals from polymetallic nodules, conducting front-rank research in polar and southern ocean studies. Recognizing importance of translating scientific knowledge to the societal benefits, the Ministry had strengthened infrastructure facilities in its three autonomous bodies (National Institute of Ocean Technology(NIOT), Chennai, Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, National Centre for Antarctic and Ocean Research (NCAOR), Goa, and 2 attached offices (Centre for Marine Living Resources and Ecology (CMLRE), Kochi, Integrated Coastal Marine Area Management (ICMAM), Chennai) primarily to carry out most of its activities during the X Plan. These institutes, each having specific responsibility, now matured enough to execute any kind of activity pertaining to ocean sector.

Some of the significant accomplishments during the **X Five Year Plan** (reviewed in Ch. 2(Volume 2 of this document) are:

(i) Development and demonstration of desalination technology to cater to the needs of freshwater in coastal states and island territories of India,
(ii) Providing of Potential Fishing Advisories to fisherman, and Ocean State forecast for various stake holders,
(iii) Setting up an interim early tsunami & storm surge warning system,
(iv) Strengthening of ocean observing network by deployment of state-of-the-art technology data buoys and Argo floats, to operational weather forecast and climate variability studies,
(v) Indigenous development of buoys, tide gauges to meet the requirement of ocean observations,
(vi) Development and transfer of technology of lobster and crab fattening for the benefit of smaller fisherman community,
(vii) Networking of institutions for conducting polar research,

(viii) Completion of geophysical surveys for delineation of Continental Shelf
(ix) Close grid surveys in the allotted area in the Central Indian Ocean Basin under polymetallic nodule programme,
(x) Establishment of Extractive metallurgical pilot plant to obtain Copper, nickel and cobalt from the nodules found at the seabed,
(xi) Design development and demonstration of Remotely Operable Vehicle of 6000m depth
(xii) Development and testing of deep sea crawler at 500m depth
(xiii) Construction of Dyke at Haldia port leading to reduced cost of dredging, consultancy services to Sethusamudram & Kalpasar projects,
(xiv) Launch of clinical trials two potential drugs (antidiabetic and antihyperlipedemic) from the marine organisms,
(xv) Demonstration of leadership in the Indian Ocean region to address common issues of the countries in the region
(xvi) Conducting multi-disciplinary studies to assess the Marine Living Resources in the Indian seas, and to understand a large scale variation of fishery resources.
(xvii) Development of shoreline management plans in selected coastal sensitive areas and establishment of marine ecotoxicology
(xviii) Continued systematic monitoring of coastal pollution to assess the health of the coastal seas of India and
(xix) Strengthened basic research through setting up of a network of Ocean Science and Technology Cells.

Having established a leadership in the field of ocean science and technology of the country, the Ministry proposes embarking on specific application oriented projects, during XI Plan, besides continuing some of the schemes launched earlier to address the basic science. Considering the mandate and responsibility, the Ministry has formulated programmes, proposed to be taken up during XI plan, in consultation with experts/eminent scientists of India. Towards formulation of XI plan proposal, a 2-two day session with Group of Experts (GOE) was held at NAAS, New Delhi on 19-20th October 2005 for deliberations on plans. The primary objective of the session was to review the existing programmes and identify the areas/strategies for XI Plan. The participants were eminent scientists associated with the activities of the Ministry, and representatives of premier institutes relating to ocean activities including officers of the Ministry. The salient features of the XI Plan proposals of the Ministry pertaining to oceans (described in Chapter 3.1 to 3.16(Volume 2 of this document)) are summarized below: -

1. Front ranking research in Polar Science: The importance of Antarctica as a pedestal for front-ranking scientific research was recognized by India way back in 1981 itself, when the first Indian Antarctic Expedition was launched. Since then, India has made great strides both in Polar Sciences and related logistics, through a judicious and harmonious blend of multi-institutional expertise brought together under the umbrella of the Ministry of Ocean Development. This has paved the way for the country to sustain its scientific endeavor in the icy continent on a year-round basis, from the Indian Permanent stations “Dakshin Gangotri” (1983-89) and “Maitri” (1989 – till date). The major endeavors for XI Plan under this programme include (i*) Launch of research expeditions to Arctic preferably through international cooperation, (ii) construction of a new Antarctic Research Station to enhance research activities (iii) establishment of a dedicated satellite based communication and data transmission system between the Antarctic and India (iv) undertake southern Indian Oceanographic studies both in terms of assessment of living and non-living resources (v) Collaborative projects during International Polar Year (2007-08) (vi) Establishment of a dedicated facility at CCMB to undertake studies related to microbial prospecting and biotechnological applications.* In order to undertake the proposed activities, an ice-class research cum logistic vessel is an essential requirement and the same has been proposed for acquisition during the XI Plan. There is a

strong justification to acquire such vessel both for undertaking regular expeditions to Antarctica as well as conducting research in southern ocean, in the context of its importance from the point of view of Indian Climatic variability.

2. Consolidation of Desalination Technology: After a great deal of experimentation in the laboratory and field, NIOT has developed, and demonstrated commercial scale Low Temperature Thermal Desalination plant. A land based 0.1 million liter per day (MLD) LTTD desalination plant was commissioned at Kavaratti, in May 2005. In order to meet demand of major coastal cities of India, it is important to upgrade LTTD technology to *develop larger scale plants up to 500 MLD capacity,* which could be multiples of several basic modules of 25 – 50 MLD plants. Towards this end a 1 MLD barge mounted demonstration plant was taken up and commissioned in April 2006. After addressing some problems and fine tuning, it will be recommissioned in December 2006. The next step will be a 10 MLD barge mounted plant whose design has been taken up. During the XI plan, NIOT would take up a scheme to design, *develop, and demonstrate the large scale desalination plants (25-50 MLD). To realize such a large number of LTTD plants*, NIOT will *explore the industry partnership in a big way during XI Plan*. *The ultimate goal of the endeavour will be to establish such desalination plants along the coast and island territories of India to alleviate drinking water problem of coastal region*

3. Providing of reliable Coastal Ocean Services: INCOIS, Hyderabad being the responsible agency providing Ocean Information would provide all possible reliable services pertaining to ocean sector during XI Plan to meet the requirement of a wide range of user communities in India. The user-oriented data/data products would be generated and disseminated using existing and upcoming satellite and in-situ data, on operational basis, such as Potential Fishing zone advisories, Coastal Ocean State *Forecast, using a wide range of media for dissemination of information. These include setting up of electronic display boards, information kiosks in every coastal village covering the entire coast of India for providing information including storms, cyclones, weather, sea state, etc***.**, INCOIS would focus on *development & dissemination of effective early warnings of oceanogenic disasters such as Storm Surges and Tsunami. INCOIS should develop a core group in ocean-atmospheric modeling with a support of mix of ocean observations*. While INCOIS would make operational the ocean services, the other research agencies like NIO, Goa will work on science aspects particularly for development and improvement of these products.

4. World Class – Ocean Technology: Having demonstrated the ability to execute several coastal engineering projects, NIOT is intending to emerge as a full fledged entity to take up all the activities relating to development of marine technology during the XI Plan. NIOT is concentrating mainly on:

(i) D*esign, development and demonstrate underwater technologies for deep sea mining*

(ii) Development of underwater materials and sensors

(iii) Creation of sea front technology and other research infrastructure for testing of oceanographic equipment. (These include Deep sea technology, Deep sea mining system for 6000 m, In-situ soil testing in the Central Indian Ocean Basin, Marine vehicle Manned submersible, AUV (up to 3000 m), Hybrid ROV, Infrastructure Marine Sensors and Electronics to support Underwater electronic

support facility and component development, offshore structures, offshore operations, development of SGS, XCTD, XSV, ultrasonic current etc.)

(iv) Coastal engineering, demonstration of coastal protection measures, Sediment transport atlas, Rates and Constants Measurements for Mathematical modeling, Geomorphologic studies for Siltation control in Hughly, Monitoring and Modeling of Thermal and Oil Spill Modeling Resource Site, Deep water survey capability, Capacity Building for Marine Archaeology and Saltwater Intrusion, conduct marine corrosion and antifouling studies and other ocean and coastal engineering related projects.

5. Ocean Science and Technology for Islands (OSTI) : Having demonstrated the application of marine technology to the benefit of common man, OSTI would take up development of *Fish Aggregating Devices, Continuation of lobster and crab farming activity, Island resource information & GIS mapping Materials for marine application, Open Ocean Aquaculture of marine organisms under controlled conditions to meet the increasing demand and dwindling capture fishery resources.* Further, it is planned to take up development of technology for micro algal culture and value added products using deep ocean water along with the utilization of bioprocess engineering technology for commercial production of phycocolloids, chemicals and polysaccharides.

6. Integrated Coastal Marine Area Management (ICMAM) & Coastal Ocean Monitoring Area and Prediction Systems (COMAPS): India has a vast coast line of over 7,500 km having diverse marine environment enriched with living and non-living resources. Besides, the coastal developmental activities have been increased vastly in the past few decades causing a great threat to the flora and fauna of the region. In order to access the impact of these activities, it is necessary to develop inundation map for the entire coast of India and develop ICMAM plans for all the sensitive areas. During 11 Plan, ICMAM would concentrate on *Demonstration of Ideal Coastal Protection Measures, Coastal circulation, Ecosystem modeling, Marine Ecotoxicology, Carbon cycling in coastal waters and Preparation of Coastal Risk Atlas. Although, the Ministry has been monitoring the coastal waters by making systematic observations at regular interval in selected locations, it is important to collect the additional parameters at more locations*. COMAPS should bring out periodically bulletins indicating the *levels of these pollutants in various regions particularly in the hotspot region*s. More inter-calibration exercises campaign should be organized. The programme need to tie up the coastal states to suggest *measures to mitigate the effects in the sensitive areas. Under COMAPS the work for XI Plan will be continuation of existing monitoring, modeling and GIS data base programmes, undertaking of modelling of movement of oil spills along Western and Eastern EEZ of India, Microbial biodiversity* of coastal waters. Acquisition of a new vessel for COMAPS programme as a replacement of one or two Coastal Research Vessel(s).

7. Resource Mapping and Technology Development for Gas Hydrate: During X plan, Ministry has so far addressed some of the scientific aspects of Gas hydrates and proposed several concepts. These needs to be validated and the necessary technology also would need to be developed simultaneously during XI Plan. In order to explore the possibilities of harnessing the resources of Gas Hydrates, *NIOT would identify suitable technology devices for supporting offshore activities, Developing the submersibles and other tools suited for various*

applications, Developing skill base and infrastructure to support and maintain the deep ocean systems. It is important to conduct validation studies at selected locations particularly for demonstration of technology for exploration of these resources by enhancing the capability of coring system Storage, transportation and processing gas hydrates, Independent ship and up-gradation of support submersible. It is proposed to develop 6000m depth coring, Human Operated Vehicle (HOV), Autonomous Underwater Vehicle (AUV), and Hybrid Submersible (HYSUB). NIOT would also work on the associated Civil works required including Integration facility with handling and storing systems, Facility for Factory testing, Facility for component level qualifications, Infrastructure for working facilities, Laboratories for Electronics, etc

8. Limits of Continental Shelf: Under this programme, a considerable amount of work has been done during the X Plan period particularly in terms of collection, processing, analysis and interpretation of geophysical data beyond the Indian EEZ region. Currently, the work done so far and the report on delineation of India's continental shelf is under review. The Ministry is currently working with MEA to submit claims earlier than the deadline of submission of May 2009. It is important to identify the gaps and complete the remaining part of the work. NCAOR would initiate a comprehensive study of the geological and structural evolution of the Arabian Sea and the Bay of Bengal sectors. During the XI Plan, the major facets include, study of the Gulf of Mannar – its origin, whether it is a simple pull-apart basin or a nascent ocean developing as Sri Lanka is drifting away, *Delineation of the continental/ oceanic crust boundary on the Indian plate, both off the Western and Eastern offshore, Structural evaluation of the 85° Ridge, Offshore extension of the Deccan Volcanics, Formation of Chagos-Laccadive Ridge as a consequence of Reunion hotspot trail, Imprint and implications of hot spots on the Indian continental margin, Structural* highs and gravity lows in the Bay of Bengal – the reasons for their association, Fan sediment development vis-à-vis Himalayan orogeny.

9. Topographic survey: During X plan period, the Ministry conducted the geophysical survey (seismic reflection and refraction, Gravity, Magnetic, bathymetry) of the Indian EEZ which is important to assess the resources. The ministry should take up dedicated project on similar lines for undertaking topographic survey of the Indian EEZ during XI Plan period, considering the importance of the data generated from the survey in the context of exploitation of both living and non-living resources.

10. Drugs from the Sea. : During the XI Plan, *an Advanced Research Centre for Drugs from Ocean" should be created at CDRI, Lucknow and a Taxonomic Centre to preserve the marine organism in an appropriate location*, as considerable progress has been made under this programme which has been under implementation over a couple of decades. The MOD should continue clinical test of two compounds (antidiabetic, antidyslipidemic) derived from marine organisms are in the advanced stage of drug development. Besides, some lead compounds found to be having potential activities *such as antibiotic, antiviral, antileukemic should be taken up for toxicity and clinical trials during XI plan***.** For speedy progress of work, it is important to create infrastructural facilities, capacity building and develop skilled manpower. During XI Plan, the work includes continuation of clinical evaluation of existing compounds and take up on *new activities such as Bioevaluation for anticancer, anti-inflammatory, immunomodulatory, and if possible anti HIV compounds.*

11. Polymetallic Nodule: The potential of deep seabed mineral resources for strategic metals was realized early and exploration was initiated for deposits of polymetallic nodules which lie much beyond our EEZ. Multipronged progress was made simultaneously in exploration, extraction of metals, development of mining system and the assessment of potential environmental impact as well. Before the end of the Xth plan, the potential first generation mine site for nodules in the Indian Ocean would be identified (this has been arrived after extensive exploration of over 4 million square km of the Indian Ocean). For extractive metallurgy, routes have been narrowed down and the development of a metallurgical plant having the capacity of 500 kg/day has been set up. As a progressive step towards exploitation of these resources, an underwater mining system consisting of a crawler based mining machine has been developed and tested for operations at 410 m water depth on the Indian continental shelf with the final aim of designing and developing a system for mining manganese nodules from 6000 m depth. Further, as part of the environmental impact of nodule mining, the seafloor was disturbed at a test site and the progress in restoration and recolonisation has been monitored continuously.

12. Marine Living Resources (MLR) & CMLRE: The Marine Living Centre at Kochi should be upgraded into a full fledged centre equipped with state-of-the art laboratory facilities and research vessels to carry out sampling process and extraction of compounds. During XI Plan CMLRE should undertake projects such as (*i) Semi-Commercial Exploitation of Myctophid Resources of Arabian Sea which has an estimate potential of 100 tons(ii) Resource assessment of demersal stocks (200-1500m depths), Refine Harvest technology for deep sea fishing, Squid jigging (iii) Monitoring & surveillance of Harmful Algal Bloom (HAB), Setting up HAB centre and R&D on HAB (iv) Marine Benthos in the Indian EEZ (v) Fishery Oceanography (vi) Biodiversity & census of marine life & (vii) Survey, assessment and semi-commercial exploitation of krill and fishery resources from Southern oceans, and related studies.*

13. Sustained Ocean Observation Network: The Ministry demonstrated design, development, deployment, operation and maintenance of a wide range of ocean platforms, viz., Data Buoys, Tide gauges, Weather Stations, Argo Floats, it is important to establish and operation of an integrated ocean observations network. The in-situ observations from the oceans are the backbone for any kind of operational services viz., storm surges, cyclones, monsoon variability, tsunami etc. and research development including validation of data collected by remote sensing satellites. NIOT should strengthen the observation network considering the actual requirement, as the upkeep these networks are expensive. But the benefits derived from the data are enormous. During XI Plan, the major work should be *(i) integration of all the existing and planned observations network Data Buoys, Tide gauges, Drifters, HF Radar, XBT, Current meters, automatic Weather Stations, Argo Floats under one umbrella for wider utility,* **(ii)** *upkeep of existing 40-buoy network & possibility of augmentation of the network using low cost buoys to meet the requirement of operational weather services, (iii) setting up of 4 maintenance centers, 2 each on west coast and east coast of India for logistical operation and maintenance of observation network in addition to the routine work elements.*

14. Marine Research Technology Development (MRTD): During XI Plan, the programme mainly should focus on (i) *developing National Oceanarium (ii) increasing the number of OSTCs: 9 to 20 (iii) Upgrading another one/two cells into Centre of Excellence (CoE) (iv)*

augmentation of all the continuing programme including Coastal Ocean Monitoring and Pollution Control Non Marine Living Resources, Integrated Coastal and Marine Area Management.
Further, it is also important to work on other potential mineral deposits such as, sulfide deposits, cobalt crust, etc., in the mid oceanic ridge including the Andaman Areas. In addition, Deep-ocean drilling and core sampling would be taken up through the Integrated Ocean Drilling Programme. Further, it is also proposed to demonstrate the shore protection measures through pilot project to be implemented at selected locations. It is also proposed to take up soil testing in the central Indian ocean basin

15. Human Resource Development: There has been manifold increase in the activities of Ocean Development and it has become necessary to provide additional specialized scientific and technical manpower to the organizations executing these programmes on a continuing basis. Towards this end, it is proposed to induct and train the requisite manpower with the help of concerned university, Departments, R&D centres and the participant institutions. The additional requirement of scientific and Technical manpower during XI Plan is estimated as around 1100. The funds for manpower Development have been earmarked in the respective programmes/ institutes scheme. The provision of competent manpower is considered critical to the success of the XI Plan programmes.

The total allocation sought for the XI Plan is Rs 6271.84 Crores.

1.2 Atmospheric Sciences

Meteorological Forecasting is an age old practice which in recent decades has assumed vital importance in management of disastrous phenomena and a plethora of activities that factor-in meteorological information to raise productivity. The impact of meteorological services on society in general and on safety of life and property in particular is so profound in financial and social value terms that investment in a national meteorological infrastructure made in the right earnest should always be considered to fetch high returns.

Various premier organizations of the country are involved in this gigantic task. The overall focus and orientation of present and future activities are briefly provided below:

1.2.1 India Meteorological Department

A legacy of scientific achievements during the last 136 years and a demonstrated ability to reform and adapt puts the India Meteorological Department (IMD) on the leading front of scientific services in India. As a mature patriarch of the community it has created space for basic meteorological research in the form of the Indian Institute of Tropical Meteorology, established in 1962 and the National Centre for Medium Range Forecasting in 1989, to specialize on medium range forecasting in the country. In more than symbolic terms the migration of this community from the Ministry of Science & Technology to the newly constituted Ministry of Earth Sciences (MoES) in July 2006 has established an independent identity for meteorology and a new role for related services in the country.

The international commitments of India embodied in a charter of understanding with the World Meteorological Organization, rest mainly in the conduct of observations, data dissemination and issuance of neighborhood services in the capacity of a Regional Specialized Meteorological Centre for Tropical cyclones and a Regional Meteorological Training Center for the RA II region. In addition, it participates in global and regional research programmes of the WMO.

The Observational infrastructure of IMD is its backbone. It has surface, upper air, Radar and satellite components comprising of a mix of old and relatively recent systems. Coexistence of various technologies, though good for stand alone applications, hampers compatibility required for integration. In addition to conventional meteorological observations IMD is also the only agency in the country which regularly monitors environmentally significant atmospheric composition over the last 4 decades.

IMD presently issues short-range forecasts (up to 2-3 days) in spatial scales of meteorological Subdivisions (numbering 36 in the country). A demand has now set in to assist local governments at District levels to combat weather anomalies. This need for higher spatial resolution would put a severe demand on forecasting capabilities because of low atmospheric predictability at smaller scales. One must therefore resort to a much higher volume of data assimilation in numerical modeling suitably aided by manual value addition - something that cannot be dispensed with at the current state-of-art. A major revamp in materials and methods would be inevitable.

IMD has been practicing numerical modeling for the last 30 years even with its limited computing facilities. It has the requisite personnel and traditions that lead to success of numerical weather prediction. The use of satellite data to supplement conventional observations is also on a healthy rise. Moreover, experience has been earned in operation of sophisticated systems like the digital Doppler Radar. Initial R&D has demonstrated the prospects of indigenous improvement of upper air sounding equipment. Further, with a system of interaction with

Research and Specialized Centres also being put in place, the IMD stands out as an ideal candidate for a revamp that is now sought.

IMD has the responsibility to monitor earthquakes also. To detect the exact location and parameters of a seismic event, data is required to be brought at a central location from a large number of sensors. Recent advancements in telecommunication and computing technology have given opportunity to reduce detection time and errors by a significant amount. Such opportunities need to be availed and a rapid decision support system should be put in place targeting the need for overall preparedness against natural calamities.

IMD had an approved outlay Rs. 309.00 Crores in the X Plan and has consumed Rs. 350.70 Crores. **The major achievements of the X Plan** described in section 7.1 (Volume 3) are highlighted below:

1. cyclone warning and severe weather warning are now more specific and accurate with newly acquired ability to diagnose the storm structure using Doppler Weather Radars installed at Chennai, Kolkata, Machhilipatnam, Vishakhapatnam and Sriharikota,
2. dissemination of cyclone warnings directly to the concerned areas received a boost with installation of 100 Digital Cyclone Warning Dissemination systems along the Andhra coast,
3. upgradation of meteorological capability at 4 International airports was accomplished.
4. a Mountain Meteorology Centre was established at Delhi to provide meteorological inputs to prediction of landslides, avalanches and flash floods,
5. capabilities in numerical weather prediction were improved by the induction of high resolution models,
6. short range prediction lead time was extended from 2 days to 3 days with an additional 2 day outlook by adopting a new forecasting approach wherein several model outputs are taken into consideration,
7. a new Long Range Prediction model was introduced giving more lead time and also July rainfall as an additional forecast product for helping Kharif crop sowing,
8. detection and response times were considerably lowered by upgrading the seismic monitoring system, and
9. an Earthquake Risk Evaluation Centre was established at Delhi for seismic microzonation. Seismic hazard microzonations were carried out for the city of Delhi at a scale of 1: 50,000.

The common thread between these has been a conscious effort to introduce new services and strengthen ongoing ones within the existing framework.

The XI Plan proposals of IMD were first reviewed by an expert committee constituted by Department of Science & Technology (DST) under the Chairmanship of Dr. Harsh. K. Gupta, ex Secretary DOD and the new thrust areas defined. Subsequently, the Planning Commission constituted a Working Group within MoES in July 2006, Chaired by the Secretary MoES, for formulation of XI Five Year Plan. This Committee invited expert opinion and consulted the Regional heads of IMD to decide priorities and assess feasibility of the various schemes.

It is realized that the new demands are in the nature of a quantum jump. Agricultural production, water resources management, disaster preparedness etc are keenly seeking accurate meteorological information in their new system of operations. These services have been given a major lift in the XI th Plan proposals. Subjects like Environment and Climate have also been taken on board our new plans because of their undeniable impacts on society.

The new thrust areas are: 1) Observation and Met Telecom System, 2) Weather Forecasting System, 3) Specialized Meteorological services, 4) Seismology and Earthquake Risk Evaluation Centre, 5) Climate, Environment Monitoring and Research 6) Human Resource Development, 7) National & International Cooperation, 8) Infrastructure Development and 9) Capital Works.

Meteorology requires large inputs to advance forecasting capability even by a marginal amount. Countries deploy technology at different levels in conformity with their strategy of using weather as a resource. In India's case with a large population, vulnerability to weather hazards are an impediment to economic development and weather anomalies threaten to reduce productivity. It must however be mentioned that IMD has addressed both these needs commendably till date, especially for such a complex geographic region as this, but further improvement would require significant upgradation.

The salient features of the XI Plan proposals of the Ministry pertaining to meteorology (described in section 8.1 and 9.1 (Volume 3 of this document)) are summarized below:

1. Space Meteorology

Space meteorology has taken significant strides in India in the past 20 years. Cloud imageries and satellite derived winds are being used regularly for meteorological assessments. But the digital data that underlies these products have immense value if appropriately assimilated. On the other hand, satellite remote sensing though somewhat short on accuracy, overcomes the logistic limitation of establishing large number of *in situ* stations. It has been demonstrated that this data can positively impact forecasting through optimization and numerical assimilation. With the new INSAT 3D designed to carry several meteorological payloads the vast data that would be generated would greatly facilitate high resolution model predictions. The present proposals address the requirements of enhancing capabilities in data utilization. Capability will also be built to access data from High Resolution Picture Transmissions of foreign polar orbiting satellites to improve data quality by mixing. Space platforms shall also be utilized in a big way to disseminate early warnings and Met communications.

2. Met Telecom

Telecom as a spring board of IT will be the mainstay of physical integration of all data and information streams within IMD. Global connectivity will also have to be strengthened if IMD is to introduce global modeling as a backend exercise for nesting high resolution models. Upgradation of the Telecom Hub at Delhi is being envisioned to go beyond the present scope of message routing to perform new functions *viz*. data base management, multi-technological connectivity, web interfacing, application support and IT activities. It is also planned to run a real time backup of these services in the event of a calamitous failure at the main center.

3. Observational System

The existing surface observatory network probably needs a major transition from off line reporting to automatic satellite telemetry. This will throw open a large rainfall and surface parameter data base to real time assessment thereby helping better depiction of weather events in general and better estimation of water resources in particular. Rainfall being highly variable in space needs a 25km x 25km density for adequate representation; hence 3500 automatic raingauges are being planned. Similarly, 700 automatic Weather Stations proposed herein would ultimately be a part of 1000 strong network at 80 km x 80 km density.

All the locations where upper air wind measurements are presently done using Radars will be provided with theodolites for the specific purpose of tracking balloons thereby relieving the Radars to carry out storm detection. A large number of stations measuring upper air winds up to 10 -12 km using the method of optical balloon tracking will also be refurbished by replacing old

theodolites. Test equipment called wind tunnel is also proposed for replacement for extending the range and accuracy of wind instrument calibration.

4. Instrumentation Development

The most significant of weather observations for forecasting are in the upper air. The present number of stations is considered adequate. But the quality of sensors needs improvement and conversion to digital systems to simplify data handling. New balloon sounding equipment of indigenous design has been tried out and shall replace the ones used presently in the network. The data from the new system is expected to improve upper air data quality and therefore the predictions as well.

5. Cyclone Warning & Research

Doppler Weather Radars (DWR) have the capability to assess wind speeds and rainfall rates in all directions around the installation covering a distance of ~ 200 km, thereby giving the structure and severity of convection associated with storms and cyclones. Five of the existing 10 conventional Radars along the vulnerable east coast have already been replaced with DWRs and have demonstrated the usefulness of the additional information thus generated. About 55 Radars are required to cover the entire country and keep round the clock vigil. However, during this plan period it has been decided that an additional 25 number of Radars would be procured to cover the entire coastline and thunderstorm prone areas with priority. These Radars will come handy to nowcast several devastating phenomena like tornadoes, squalls, hail storms, cyclones etc. In addition, their digital outputs will be directly assimilated into Numerical Prediction Models for the purpose of forecasting and Research.

6. Forecasting Services

Forecast ranges currently in vogue are short range (1-3 days), medium range (4-10 days), extended range (11-30 days) and seasonal (greater than 30 days). The first and the last of these constitute the present forecasting services. Activities in the medium range – the current mandate of NCMRWF, has a large R&D component at the moment. An ultra short range of 1-12 hrs, known as “nowcasting” is practiced in some countries now a days to assist Aviation and Storm warning. It is heavily dependent on Radar inputs. With arrival of Doppler Radars nowcasting will be done in India as well.

Numerical models do not deliver the final product. Location specific value additions are required to supplement model simulations. In the new scheme of things the regional forecast offices will be empowered with data, products and tools to apply the fine scanner so to say and as for the numerical products themselves, confidence can be built by correcting model errors from past performances on an online basis and also by ensembling multiple model products to seek convergence. These methods will ensure better performance at higher spatial resolutions. Thus, the goal is reachable provided data and methods are appropriate.

A nested global and regional data assimilation system will be procured and installed by IMD to make it completely self reliant in numerical weather prediction for operational purposes. In the present system the model results of other global centers are used to initialize the regional models of IMD. This results in considerable delay in the issue of final forecasts. Running both global and nested regional models on the same computer platform would give tremendous tactical advantages and can pin point sources of error for the purpose of R&D. High end computers and supporting workstations clustered around in the network at various forecasting offices would make an effective and strategic operational system.

7. Specialized Meteorological Services

IMD needs to strengthen its specialized services in areas such as Aviation in view of increased safety concern in the rapidly growing industry. Airport Met facilities would be modernized to

facilitate easy transmission of complete data and information to Airport Authority, Airlines and Pilots.

IMD is providing Agromet Advisories for the last 30 years to all State Governments for interpreting weather information for agricultural management. This system needs to be based on a strong IT system so that a large number of clients can be handled by expert systems. In the new scheme of operations networking with Agricultural Colleges, ICAR institutes, NCMRWF, State Governments and local and National level TV, Radio etc will be accomplished so that a single window service can be issued from IMD to reach the farmers and managers both.

Hydrological services shall receive a major thrust with installation of Satellite telemetry rainguages so that large data would be available on real time basis for drought and flood monitoring. The extension of World Bank aided Hydrology Project into Phase II covering northern India shall strengthen the District rainfall monitoring programme in the region.

8. Environmental Studies

The Climate system is never static. Whether affected by anthropogenic emissions or not there are natural cycles that cause drastic changes in climatic regimes. The observation of climate change and the causative atmospheric environmental change are an integral part of observing the atmosphere. IMD has a long standing programme on Ozone monitoring which in the last five years has seen a comprehensive upgradation at its 4 centres chosen to represent the meridional section of the country, principally because ozone varies latitudinally across the globe. However, lower tropospheric ozone which is a bye product of pollution is gaining in climatic significance because of high chemical reactivity. The eastern parts of the country are particularly prone due to large scale biomass burning in the Northeast and in adjoining countries. In the new plan the ozone network will be extended to the Northeast to study this.

Atmospheric composition with respect to green house gases, aerosols, ozone and acidic precursors are planned to be monitored comprehensively and linked with global climate models in order to understand the nature of their impacts.

9. Seismology and Earthquake Risk Evaluation

The Seismic network needs to be increased in density to be able to capture earthquakes of lower magnitude, which are required for precursor studies, and more detailed zoning of vulnerability. In addition it must be connected by telemetry to reduce the time lag of occurrence and detection. Such a system will be especially required for Tsunami genic earthquake detection. Geo technical evaluation of vulnerability at map scales of 1:10,000 is required by town planners to redefine building byelaws. In this proposal some of the important cities with high risk shall be taken up for such studies.

10. Human Resource Development

Induction of new technology by itself cannot deliver the goods unless proper utilization is done and maintenance is up to the mark. Thus, with every new system such as Radars, Numerical Models, Satellite retrieval and Observational equipment appropriate Training has been planned and provided for in the outlay. In addition to the primary training there have been plans to strengthen the routine in-house training programs to sustain the programs by ensuring a steady availability of specialized manpower.

11. District Meteorological Information Centre and Early Warning System

Forecasts need to reach the end user at District, State and Institutional levels for application. The outreach component of IMD's activities needs to be strengthened so that graphically displayed and well structured advisories can be made available at the destination be it an official desk or a media room. IMD has a system of intimating official agencies but played a relatively less important role in dissemination of its products directly to the public. It is realized that new

communication and media trends have created opportunities to add depictive value to the products and make them package-able for media consumption. On the request of the newly formed Disaster Management Authority and the official electronic media agencies the XI th plan therefore includes a series of projects to improve outreach at District levels and to the public at large.

12. Climate Research and Monitoring

The subject of climate predictions in seasonal to inter decadal and century scales comes under the purview of a vigorously growing science called Climate Research. There is tremendous use of future climate information in bolstering climatic preparedness especially if it is available early because many of the corrective actions may require extreme persuasion to be accepted in society. The modeling efforts that are the basis for such a science need attention in the official meteorological agency of the country. The XI th plan proposal in this regard focuses on the computing and data requirements that are required to build a credible climate service facility in India.

The XI plan proposal is a complete proposal in itself containing the objectives, feasibility and benefits from each proposal and how they relate to the overall build up of capacity within the National Meteorological Services of India.

The total allocation sought for the XI Plan is Rs 5055.85 Crores.

1.2.2 National Centre for Medium Range Weather Forecasting

(NCMRWF) was created as a mission mode project of the Government in 1988 and continues to function in the same mode. The mandate of the Centre at the time of establishment was to provide medium range location specific forecasts to farmers through development of Agro-Advisory Service for the 127 Agro-climatic zones(ACZ) of the country.

Noting the complex nature of the problem, to provide forecasts beyond a couple of days, An end-to-end Numerical Weather Prediction (NWP) system based on a global Atmospheric General Circulation Model(AGCM) of horizontal resolution of 150 km and 18 levels in vertical was implemented and made operational in June 1994. This involved use of voluminous global meteorological and oceanographic data, their assimilation to provide initial conditions, numerical models, and high end computing resources. The NWP system generates forecasts up to seven days in advance. Over a period of time Agromet Advisory Service(AAS) Units were started and until March 2006, 107 units have been opened. Presently forecasts in respect of meteorological parameters relevant for planning agricultural operations are provided up to 4 days in advance twice a week to these units which formulate Agromet Advisories based on these forecasts. Only 20 units remain to be opened for which sites have already been identified and efforts are on to make them functional. Forecasts over the country up to a week in advance are also being provided to Crop Weather Watch Group in the Ministry of Agriculture. The project has fulfilled the given mandate. The other significant achievements during X Plan are summarised below(details provided in Chapter 7.2 in Volume 3):

- An end-to-end NWP system was developed. Uninterrupted medium range forecasts based Agromet advisory service is being rendered since 1994.
- Continuous effort to increase reliability and scope of the forecasts was made, increasing resolution, improving physical processes and data assimilation, optimizing use of satellite and other data, extensive verification and validation experiments.

- For improving the location specific Medium Range Forecasts(MRF) Dynamical/statistical downscaling techniques were implemented. The Meso-scale modelling systems were implemented on specific demands from Ministry of Defence, Department of Atomic Energy and ISRO.
- On demand from Agriculture Sector and planners, challenging task of dynamical extended/seasonal prediction of monsoon was undertaken. As part of this effort, work on ocean state forecast and development of coupled model was initiated.
- To reduce the uncertainty in prediction and providing MRF in probabilistic terms, an ensemble prediction system was developed.
- A project to assess economic impact of agro-advisories based on Centre's MRF was undertaken. Preliminary results indicate a positive impact of 10-20% by way of saving the inputs and enhancing the yield levels.
- Crop-weather models for varieties of cops were validated, calibrated and transferred to AAS units for implementing weather based decision support system for farming operations.
- Customized forecasts for various other important applications(e.g. power distribution, water resources, defence, emergency response, adventure sports, special events etc.) in different sectors of economy were delivered to user agencies.
- NCMRWF is hosting a regional Centre for weather and Climate to support technological support for Economic Advancement in BIMSTEC countries. Forecasts were also provided to some other countries on their request.
- The high-end computer infrastructure was upgraded. At present the combined resource provides 1.5 TFlop peak performance.
- The construction of one of the buildings of office complex and first phase of residential complex was completed. The NCMRWF started functioning from its new premise since March 2004.

Monsoon is a very complex, land-ocean atmosphere coupled system. Details of land surface and oceanic processes have to be included in modelling effort. Further, it is known that for capturing weather systems over Indian monsoon region and tropics, proper definition of initial conditions is required for which we need to use direct satellite radiances. To do this, advanced data assimilation techniques have to be used. So far, very high resolution models, crucial for increasing the accuracy ,reliability, and range of forecasts, could not be implemented .The quantity and quality of observations , over land, atmosphere, and surrounding oceans are required to be significantly enhanced to meet the requirements of high resolution NWP for MRF.

Computing resource, networking, and supporting infrastructure require to be significantly enhanced at increase frequency to achieve all the above. The fast developments in the field require more intense human resource development effort and closer international partnerships with major operational global NWP Centre.

The main goal during the XI plan is to further enhance the accuracy, reliability and range of medium range weather forecasts and its outreach. In the XI Five Year Plan, NCMRWF is recasting its mandate towards a Centre of Excellence in Numerical Weather Modeling and it is proposed to focus on the following thrust areas (details provided in Chapter 8.2 and 9.2 in Volume 3):

- To increase temporal range and spatial resolution of operational Medium Range Forecasts.
- To deliver district level medium range weather forecasts based agromet advisory services.
- To develop capability for providing site and event specific prediction system. The immediate demand for such a system is for upcoming Commonwealth Games in 2010.
- Further improving the accuracy, reliability, range, and scope of Medium Range Forecasts entails:

  - Development of higher resolution(40 km for operational and 25 km for research; 60 levels) global model with much improved physics, dynamics. Use of large member based(50-60 members) ensemble system as well as multi-model approach.
  - Development of advanced data assimilation system capable of utilizing direct satellite radiances, clouds and rain data.
  - Further improvement in meso-scale models and corresponding assimilation for dynamic downscaling focussing on high impact weather systems for agricultural risk management at district level.
- Weather Modeling support for early warning system for weather related disasters.
- Development of a coupled modelling and assimilation system for improving monsoon prediction over medium and extended scale.
- To significantly enhance manpower, computing, networking, data handling, library, and related infrastructure including additional building construction.

Presently, NCMRWF continues to function in project mode. For achieving the accelerated improvement in quality and range of Medium Range Forecasts, it needs to be given a permanent status as a Centre with full and independent administrative and financial authority.

At present there are 32 scientists, 2 technical support staff, and 7 administrative support personnel are in place as against the sanctioned strength of 241 a the time of creation of the centre. This number is one order less than the minimum required for NWP, a highly specialized and strategically important field. Accordingly, additional consolidated man power of 233 is projected to meet the requirements of plan projects.

The total financial requirement during the XI plan is Rs. 381.22 crores.

1.2.3 Indian Institute of Tropical Meteorology

Since its inception in 1962 as Institute of Tropical Meteorology (ITM) and its subsequent transformation in an autonomous institution as Indian Institute of Tropical Meteorology (IITM) in 1971 the Institute has been functioning as a national centre for basic and applied research in monsoon meteorology of the tropics in general with special reference to monsoon meteorology in India and neighbourhood. Its primary functions are to promote, guide and conduct research in the field of meteorology in all its aspects. The Institute has made significant contribution in the challenging areas of the Atmospheric Sciences like Weather Forecasting, Climatology, Hydrometeorology, Monsoon Variability, Climate Modelling, Cloud Physics, Weather Modification, Atmospheric Chemistry, Atmospheric Electricity, Instrumentation for the Observational Studies and Studies relating to Land Surface Processes. The Institute has built up importance and expertise for the study of atmospheric sciences in India and for application of the knowledge as a national resource in terms of weather, climate and related atmospheric processes. The IITM provides its input to the India Meteorological Department for the national forecast of seasonal monsoon rainfall of the country.

The IITM has, from time to time, widened its objectives and scope of research activities to meet the critical challenges and the national needs for providing information relating to various aspects of atmosphere and the increasing concern among the Government and general public about a variety of environmental issues. One important national need is to have reliable

extended range prediction of the monsoon and to establish India's stand on a variety of issues related to global warming and climate change. While recognizing this need, it is also recognized that basic research is crucial for improving any prediction capability. Keeping this national need in mind the XI Plan of the Institute while nurturing some of the existing projects on basic research, a new programme on **"Climate Dynamics and Extended Range Prediction of Monsoon"** is proposed. The science plan of the programme and infrastructure and manpower required for this purpose is as follows:

- A system for long range prediction of seasonal mean monsoon and extended range prediction of active/break spells is proposed to be developed. It would involve assessing component models, coupling strategy, assessment of bias of the coupled model, data assimilation, development of forecast strategy etc. A quantum jump in the computing resource and existing research staff in the area will be required.
- Estimation of monsoon climate under different climate change scenarios through downscaling using a regional climate model, quantification of uncertainty in estimation of monsoon climate under climate change scenarios and study of sensitivity of the estimate of monsoon climate under climate change due to downscaling of the output from a large number of global models and understanding of roles of internal variability and external forcing in predicting the future monsoon climate have also been proposed.
- For improvement of the climate models, it is important to improve formulation of convection in the GCMs. A focused observational and modeling effort to improve understanding of clouds and its interaction with environment leading to precipitation is proposed. This would involve simultaneous observations of cloud processes and environment involving a cloud and weather radar system, GPS radiosonde, a network of lightning discharge etc.
- A large pool of trained manpower on specialized area is required for success of the above programmes. A multi pronged approach to build this manpower is proposed. Training programme for the existing junior level scientists and research fellows at the IITM will produce a pool of scientists to take up exciting problems and develop necessary skills to address them in the field of atmospheric sciences especially in climate dynamics and development of capabilities in extended range prediction of monsoon. Hence Training Programme is proposed as an integral part of the XI Plan programme. Training to the Institute's scientists within the Institute and at the selected international centres of excellence in other countries, as well as inviting a few internationally reputed scientists to impart training in specialized areas is proposed in this programme. In addition it is proposed to vigorously and proactively recruit a large pool of experts required for different aspects of the programme.
- Development of infrastructure is essential for promoting the research programmes on a sustained long-term basis. An appropriate computing system with very high number crunching capability and having large memory, automatic data storage and retrieval system with sufficient storage capacity is very much needed at the Institute to carry out the work relating to the climate modelling and extended range prediction. Upgradation of the existing laboratories, renovation of workplace, modernization of library, information, publication and other supporting facilities like workshop, and limited Capital Works programme for construction of residential quarters of higher types and a students hostel are proposed in the XI Plan programme.

The total allocation sought for the XI Plan is Rs 300 Crores.

1.3 Scheme wise Outlays For XI Five Year Plan (2007-2012)

A. OCEAN DEVELOPMENT

I. CONTINUING SCHEME

Rs. In crores

S.No.	Scheme	2007-08	2008-09	2009-10	2010-11	2011-2012	Total Budget Provision in XI plan
1.	Polar Science						
1.1	Expeditions to Antarctica – Polar Sciences	25.50	28.50	31.00	33.00	36.00	154.00
2.	Polymetallic Nodules Programme						
2.1	Survey and Exploration	2.00	5.00	5.00	3.00	2.70	17.70
2.2	Environmental Impact Assessment	4.00	5.00	4.00	5.00	4.59	22.59
2.3	Technology Development (Extractive Metallurgy)	10.00	25.00	10.00	6.00	5.48	56.48
2.4	Technology Development (Mining)	24	155	149	143	156	**627**
3.	Ocean Observation and Information System(OOIS)						
3.1	PFZ and integrated PFZ, Tuna forecast(35 cr.) and user interactions(5 cr.)	8.60	10.10	8.10	7.10	6.10	40.00
3.2	Operational coastal ocean wave & current forecast	4.65	6.70	5.30	4.05	3.90	24.60
4	Marine Research and Technology Development						
4.1	Assessment of Marine Living Resources	19.39	29.09	24.25	14.57	9.7	97.00
4.2	Drugs from Sea	10.00	20.00	30.00	30.00	20.00	110.00
4.3	Assistance for Research Projects	15.40	22.40	29.40	39.40	30.40	137.00

	(OSTC & Manpower Training)						
4.4	Coastal Ocean Monitoring and Prediction system(COMAPS)	15.60	23.40	19.50	11.70	7.80	78.00
4.5	Exhibition, fairs etc.(Ocean awareness activities, Seminars, Symposia, Conferences, Lectures, Debates etc.)	10.00	30.00	30.00	15.00	15.00	100.00
4.6	Integrated Coastal and Marine Area Management						
4.6.1	Vulnerability to Shoreline changes, Waste Assimilation Capacity & Inundation Modelling	5.00	10.00	15.00	10.00	10.00	50.00
4.6.2	Ecosystem Modelling	1.00	1.50	1.75	1.75	2.00	8.00
4.6.3	Marine Ecotoxicology	0.60	0.90	0.75	0.45	0.30	3.00
4.6.4	Coastal Risk Atlas	0.40	0.40	0.20	0	0	1.00
4.7	Marine Non-Living Resources (MNLR)						
4.7.1	Studies of Cobalt Crust Exploration	4.00	8.00	20.00	9.00	9.00	50.00
4.7.2	Geological Studies of Indian Ocean Basin	2.00	9.50	9.50	4.50	4.50	30.00
4.7.3	Hydrothermal Sulfides	1.00	4.50	2.50	1.00	1.00	10.00
5.0	Information Technology	4.00	4.00	4.00	4.00	4.00	20.00
6.0	Coastal Research Vessels(CRV) & other Research vessels	51.05	11.44	12.16	62.70	63.61	200.96
7.0	National Institute of Ocean Technology (NIOT)						
7.1	Energy/Desalination	2.00	4.00	5.00	3.00	1.89	15.89
7.2	Deep Seabed Mining	22.00	26.00	28.00	26.00	23.00	125.00
7.3	Coastal & Environmental Engg.	40.0	60.0	60.0	40.0	25.0	225.00
7.4	Marine Instrumentation, sensors, acoustics	35.01	33.77	35.36	16.04	16.05	136.23
7.5	Island Development	24.40	39.20	45.00	29.30	24.10	162.00
7.6	Argo *	0	0	0	0	0	0

7.7	Gas Hydrates*	0	0	0	0	0	0
7.8	NDBP*	0	0	0	0	0	0
7.9	Offshore operations*	0	0	0	0	0	0
7.10	Offshore structures*	0	0	0	0	0	0
7.11	VMC*	0	0	0	0	0	0
7.12	Capacity Building, infrastructure etc	29.00	32.00	47.40	65.0	93.11	266.51
8	Delineation of Outer limits of Continental Shelf	1.00	1.00	1.00	1.00	2.00	6.00
9	Comprehensive Topographic Surveys	5.00	12.00	12.00	12.00	7.00	48.00
10	Gas Hydrate	56.84	98.93	106.61	127.44	234.64	624.46
11	Acquisition of Research Vessel	110.00	15.00	0	0	0	125.00
12	Data Buoy programme/Integrated Sustained Ocean Observations	66.85	86.05	106.00	65.95	42.24	367.09
13	Tsunami & Storm surges Warning System	41.18	20.00	20.00	25.00	20.00	126.18
14	National Centre for Antarctic and Ocean Research(NCAOR)						
14.1	Establishment of New Permanent Indian Base in Antarctica	24.90	19.30	10.80	9.30	9.70	74.00
14.2	Southern Ocean Studies	7.50	5.50	10.00	7.50	11.50	42.00
14.3	In house R&D, infrastructure, capacity building at NCAOR	29.20	44.73	43.46	23.84	25.77	167.00
15	Indian National Centre for Ocean Information Services (INCOIS)						
15.1	Information Bank and Web-bases services	1.00	3.00	3.00	2.00	1.00	10.00
15.2	Ocean Science and techniques Development						
15.2.1	Ocean Modelling and data assimilation	7.30	5.90	5.70	5.85	5.25	30.00
15.2.2	Satellite Oceanography	5.00	6.00	7.00	6.00	6.00	30.00
15.3	Ocean Observations	25.50	17.00	15.50	14.25	12.75	85.00

15.4	R&D in Ocean Science and Informations	13.00	18.00	16.00	16.00	12.00	75.00
16	Seafront facility	25.745	64.045	42.29	37.92	30.00	200.00
	Total	**790.615**	**1021.855**	**1031.53**	**938.61**	**995.08**	**4777.69**

* indicates that while NIOT will be implementing agency the budget provision has been made in the Ministry's programmes

2. NEW SCHEMES PROPOSED DURING XI PLAN

Rs. In crores

S.No.	Scheme	2007-08	2008-09	2009-10	2010-11	2011-2012	Total Budget Provision in XI plan
1.	Expedition to Arctic	5.00	5.00	12.00	12.00	12.00	46.00
2.	Desalination Project	7.00	140.00	43.00	8.00	6.65	204.65
3.	MLR: vessel requirement(Rs. 250 cr) and Dedicated berthing and associated facilities (Rs. 23.50 cr)	34.70	77.05	85.88	53.52	22.35	273.50
4.	National Oceanarium	10.00	40.00	40.00	5.00	5.00	100.00
5.	Demonstration of Shore Protection measures through Pilot project	54.00	81.00	67.50	40.50	27.00	270.00
6.	Integrated Ocean Drilling Programme(IODP)	5.00	18.00	20.00	25.00	32.00	100.00
7.	Ice class Research vessel	40.00	150.00	225.00	30.00	5.00	450.00
8.	Headquarter Building	25.00	20.00	2.50	1.50	1.00	50.00
	Total	**180.70**	**531.05**	**495.88**	**175.52**	**111.00**	**1494.15**

B. ATMOSPHERIC SCIENCES
Scheme wise Outlays For XI Five Year Plan (2007-2012)

I. CONTINUING SCHEME

A. IMD

Rs. In crores

S.No.	**Schemes -**	2007-08	2008-09	2009-10	2010-11	2011-12	Total
1.	Space Meteorology	30.84	33.24	32.50	12.00	18.00	126.58
2.	Meteorological Telecommunication	46.10	33.40	19.15	3.73	1.21	103.59
3.	Observational Organization	101.22	130.80	136.80	129.60	66.00	564.42
4.	Instrumentation Development	41.10	93.03	84.80	25.16	22.88	266.97
5.	Cyclone Warning & Research	42.40	147.66	205.62	243.88	476.40	1115.96
6.	Forecasting Services	65.00	25.00	5.00	5.00	5.00	105.00
7.	Aviation Services	92.80	115.80	172.20	255.80	301.00	937.60
8.	Hydro Met Services	10.36	16.88	9.89	1.81	1.55	40.49
9.	Agro Met Services	141.40	144.92	148.54	152.15	10.58	597.59
10.	Seismology	17.46	26.86	16.78	18.15	8.98	88.23
11.	Seismic Hazard & Risk Evaluation	55.62	57.30	53.10	61.14	71.22	298.38
12.	Environmental Studies	6.00	4.20	3.60	3.60	4.80	22.20
13.	Research	6.94	3.10	2.21	2.21	2.21	16.67
14.	Human Resource Development	8.04	9.84	8.04	6.24	5.04	37.20
15.	National / International Cooperation	0.40	0.40	0.40	0.40	0.40	2.00
16.	Infrastructural Development and maintenance	74.72	109.98	107.93	102.74	28.72	424.09
	Sub-Total I-A	**740.40**	**952.41**	**1006.56**	**1023.61**	**1023.99**	**4746.97**

B. NCMRWF

Rs. In crores

S.No.	Schemes -	2007-08	2008-09	2009-10	2010-11	2011-12	Total
1	Global Modeling and Data Assimilation System	1.38	2.02	2.81	2.91	2.69	11.81
2	Meso-scale Modeling and Data Assimilation System	0.50	0.82	1.10	1.26	1.26	4.94
3	Extended/Seasonal Prediction System	0.27	0.58	0.70	0.67	0.52	2.74
4	Computer/Network Infrastructure and Services	0.50	0.74	1.02	1.10	1.10	4.46
5.	**Agromet advisory**						
5.1	Agro-met Advisory System	1.08	1.23	1.76	1.77	1.62	7.46
5.2	District-level Agro-meteorological Advisory Service	0.54	0.82	0.98	0.98	0.68	4.00
5.3	Grant-in-Aid for AMFUs	12.70	12.70	12.70	12.70	12.70	63.50
	Sub-Total I-B	**16.97**	**18.91**	**21.07**	**21.39**	**20.57**	**98.91**

C. IITM

Continuing Schemes : Research in Tropical Meteorology							
1	Asian Monsoon Variability and Predictability	06.00	03.00	03.00	02.00	02.00	17.00
2	Application of Satellite Data in Weather Fore-casting and Large-Scale Hydrological Modelling	06.00	03.00	03.00	03.00	03.00	18.00
3	Short-Term Climate Diagnostics and Prediction	06.00	03.00	03.00	03.00	03.00	18.00
4	Cloud Modelling	05.00	04.00	04.00	04.00	04.00	21.00
5	Middle Atmosphere Dynamics	05.00	04.00	04.00	04.00	04.00	21.00
6	Aerosol and Climate Studies	05.00	04.00	03.00	03.00	03.00	18.00
	Sub-Total I-C	**33.00**	**21.00**	**20.00**	**19.00**	**20.00**	**113.00**

2. NEW SCHEMES PROPOSED DURING XI PLAN

A. IMD

S.No.	Schemes -	2007-08	2008-09	2009-10	2010-11	2011-12	Total
1	District Meteorological Information Centres	19.20	55.20	30.00	40.80	58.80	204.00
2	Early Warning System	2.95	21.66	23.19	23.16	13.04	84.00
3	Climate Research & Monitoring	2.64	12.78	1.68	1.86	1.92	20.88
	Sub Total 2-A	**24.79**	**89.64**	**54.87**	**65.82**	**73.76**	**308.88**

B. NCMRWF

1	Satellite Radiance Data Assimilation	0.27	0.58	0.74	0.67	0.75	3.01
2	Climate Modeling System	0.69	0.59	0.86	0.56	0.56	3.26
3	Environmental Prediction System	0.23	0.31	0.20	0.20	0.20	1.14
4	Computer/Network Infrastructure Upgradation	80.00	20.00	15.00	65.00	8.00	188.00
5	Infrastructure Development Other Facilities and capacity building	35.60	19.60	18.60	6.60	6.50	86.90
	Sub Total 2-B	**116.79**	**41.08**	**35.4**	**73.03**	**16.01**	**282.31**

C. IITM

New Scheme : Climate Dynamics and Extended Range Prediction of Monsoon							
1	Dynamical Prediction System of Seasonal Mean Monsoon Rainfall	3.00	05.00	04.00	03.50	02.00	17.50
2	Extended- Range Prediction of Active and Break Spells of the Monsoon	1.50	01.00	02.50	02.50	03.00	10.50
3	Science of Climate	01.30	02.00	01.00	00.90	00.50	05.70

	Change and Monsoon						
4	Urban Air pollution and Transport Modelling	02.00	02.00	00.50	00.50	00.50	05.50
5	High Performance Computer	40.00	05.00	05.00	05.00	05.00	60.00
6	Observation Programmes for Studies of Interaction between Clouds and their Environment including acquisition of • Doppler Radar • Lightning Network • Atmospheric Pollution Prediction System • GPS Radiosonde	48.00	01.00	01.70	01.00	01.10	52.80
7	Training Programme	9.00	4.00	4.00	4.00	4.00	25.00
8	Information System in Meteorology and Atmospheric Sciences	3.00	2.50	1.50	1.50	1.50	10.00
	Sub-Total 2 -C	**107.80**	**22.50**	**20.20**	**18.90**	**17.60**	**187.00**

1.4 Yearwise Summary of Financial Requirement

	Scheme	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**Total**
OCEAN DEVELOPMENT	Continuing	790.615	1021.855	1031.53	938.61	995.08	4777.69
	New	180.70	531.05	495.88	175.52	111.00	1494.15
Total (Ocean Development)		**971.315**	**1552.905**	**1527.41**	**1114.13**	**1106.08**	**6271.84**

Atmospheric Sciences-IMD	Continuing	740.40	952.41	1006.56	1023.61	1023.99	4746.97
	New	24.79	89.64	54.87	65.82	73.76	308.88
	Total (IMD)	**765.19**	**1042.05**	**1061.43**	**1089.43**	**1097.75**	**5055.85**
Atmospheric Sciences-NCMRWF	Continuing	16.97	18.91	21.07	21.39	20.57	98.91
	New	116.79	41.08	35.4	73.03	16.01	282.31
	Total (NCMRWF)	**133.76**	**59.99**	**56.47**	**94.42**	**36.58**	**381.22**
Atmospheric Sciences-IITM	Continuing	33.00	21.00	20.00	19.00	20.00	113.00
	New	107.80	22.50	20.20	18.90	17.60	187.00
	Total (IITM)	**140.80**	**43.50**	**40.20**	**37.90**	**37.60**	**300.00**
Total (Ocean Development)		**971.315**	**1552.905**	**1527.41**	**1114.13**	**1106.08**	**6271.84**
Total (Atmospheric Sciences)		**1039.75**	**1145.54**	**1158.1**	**1221.75**	**1171.93**	**5737.07**
Grand Total (Ocean Development+ Atmospheric Sciences)		**2011.065**	**2698.445**	**2685.51**	**2335.88**	**2278.01**	**12008.91**

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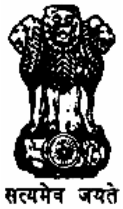
ELEVENTH PLAN
2007-2012

WORKING GROUP DOCUMENT
VOLUME 2
(OCEAN DEVELOPMENT)



Government of India
Ministry of Earth Sciences

2006

VOLUME 1

VOLUME 2
(OCEAN DEVELOPMENT)

VOLUME 3
(ATMOSPHERIC SCIENCES)

2. Achievements during X Plan (2002-07)

2.1. Polar Science & Antarctic Expedition:

The National Centre for Antarctic and Ocean Research (NCAOR), Goa, responsible for plan, execute and launch of annual expeditions to Antarctica on behalf of MOOD, have successfully launched 5 scientific expeditions (XXI – XXV) to the Antarctica, which are multi-disciplinary in nature covering atmospheric science, geology, geophysics and others as in the past.

A survey by National Council for Applied and Economic Research (NCAER) was carried out to assess the Polar Science Activities as per the directive of Cabinet Committee for Economic Affairs (CCEA).

In particular, the following scientific and logistics tasks related to the Indian Antarctic Programme as envisioned by the Expert Committee constituted by the Ministry were undertaken during the X plan period:

(a) 2 Pilot expeditions to the southern Indian Ocean were launched to study Polar Environment and Ecology significant for global processes to contribute to international scientific endeavors for a sustainable management of Antarctica.
(b) Under Development of National Antarctic Data Centre, the data generated through the last 25 odd expeditions were collated, formatted and synthesized for easy accessibility and utilisation by establishing the National Antarctic Data Centre (NADC) at NCAOR.
(c) New programmes on biotechnological potential of Antarctica microbes and biodegradation of organic wastes by employing psychrophilic bacteria were taken up.
(d) Overall 20 out of 100 microbes discovered world over were identified by India.. Activities pertaining to establishment of the Second Indian Permanent Station in Antarctica as well as construction of a new station were taken up.
(e) An ice-core laboratory with state-of-the-art ice core archival and analytical facilities was established at NCAOR to conduct paleo oceanographic studies.
(f) The building infrastructure was expanded to meet increased activities including surveys to explore the possibility of establishing a new station.

Some of the other important achievements include, development of core-competence and initiation of research programs at NCAOR in the fields of Polar Remote Sensing, Southern Ocean Oceanography & Paleoclimatology, Antarctic Global Change Research, Antarctic Atmospheric Sciences, and Polar Environment & Ecology and initiation of studies on the biodegradation studies of organic waste using microbial consortium from Antarctica, and on the biotechnological potential of Antarctic microbes. Further, new experiments in frontier areas, including Total Solar Eclipse studies were undertaken at Antarctica. The major scientific investigations undertaken include:

(a) Ice core drilling in the Central Dronning Maud Land (CDML) area for paleoclimatic and paleoenvironment studies.
(b) Publication of two geological maps encompassing part of the mapped areas of CDML.
(c) Absolute Gravity measurements initiated in the Schirmacher Oasis area.
(d) GPS observations for assessing the inter-plate movement between India and Antarctica
(e) Setting up of a 3-station magnetometer chain for geomagnetic studies.
(f) Evaluation of the bedrock topography of different Antarctic lakes using GPR.
(g) Daytime auroral studies using an indigenously fabricated day glow photometer.
(h) Continuous and periodic ozone profiling by mm wave radio-spectrometer and ozonesonde ascents and Brewer Spectrophotometer.

(i) Surface measurements of the atmospheric electric field, conductivity, and the concentration and size distribution of submicron aerosols.
(j) Studies on the effect of certain established Ayurvedic drugs (rasayana) as food supplements in cold climatic conditions.
(k) A consortium of the psychrophilic bacteria successfully evaluated for their ability to biodegrade human refuse.
(l) Observations of unique extended duration shadow band activity during the Total Solar Eclipse (TSE) of November 23, 2003.
(m) Upgradation of communication links with the mainland by uplinking Maitri with e-mail, real-time picture transmission, and computer-interfaced HF communication.

2.2. Polymetallic Nodules Programme (PMN):

2.2.1 Survey & Exploration

India retained 50% of the allocated 1,50,000 sq. km area to the International Sea Bed Authority upon carrying out detailed surveys as per the requirement of contract signed with International Seabed Authority. Close grid surveys of 6.25 km were carried out using Multiple Frequency Exploration System (MFES) along selected profiles covering pre-identified blocks, deep tow survey for continuous photography at selected profiles based on MFES survey and up gradation of deep tow system with side scan sonar. The Final Relinquishment of 20% of Allocated Area was completed in the prime nodule area of the CIOB. An area having consistently high abundances and grades measuring about 17,500 km2 and which was sufficiently plain in topography, was identified within the Retained Area. This would be investigated in detail using the following pathways for the identification of the 1st Generation Mine Site.

(a) A total of 143 samples were retrieved during one of the 3 cruises although close to 75 Okean grab sampling operations were performed covering 21 blocks during this exercise.

(b) The highest nodule abundance recorded in the operations is 43.6 kg/m2 at one location. Nodules from all the stations occupied were mandatorily analysed for the five critical elements viz., Ni, Co, Cu, Mn and Fe. The overall tonnage of nodules gathered from the abundance data shows a minor reduction so does the average abundance in this region.

(c) Resource evaluation after both the activities would take up at least 6-9 months (i.e., sample identification, sample preparation, analysis, interpretation, integration with the existing data). Slow scan multibeam and backscatter studies and detailed resource evaluation of nodules in the retained area would be continued during the XI plan.

(d) The area selected for the possible location of the 1st generation mine site (17,500 km2) would be mapped using a multibeam system. The micro-topographic features would be revealed during these multibeam surveys at resolutions higher than achieved before.

(e) One cruise using Akademik Boris Petrov was undertaken in May/June,2005 (ABP Cruise 6) wherein approximately 70 % of the delineated area has been mapped using a multibeam system. Further, backscatter data has also been obtained for the area surveyed. The samples from throughout the pioneer area have been isolated, described, and the complex procedure of sample preparation is ongoing and it is expected that the results would be delivered as anticipated by the end of the X Plan.

2.2.2 EIA Study

As a part of Environmental Impact Assessment-Monitoring studies, core samples were collected during all monitoring cruises to study recolonisation aspects. Results of the 4 monitoring cruises during the plan have indicated that whereas the some of the sediment characteristics appear to have regained the conditions similar to that of pre-disturbance stage, the numbers and diversity of benthic organisms showed only marginal restoration. The above parameters indicate that the benthic conditions are steadily moving towards restoration and the effect of disturbance is waning off. Ongoing analysis of environmental parameters would help in establishing the long term restoration processes in the benthic ecosystem. In addition, under environmental impact assessment studies,

(a) sediment plume disbursal studies were carried out for monitoring of recolonisation and restoration of environment in the area.
(b) detailed data on various environmental parameters was collected in the proposed first generation mine site during a cruise in March-April 2005 and these data are being processed at present. It will serve the purpose of application to the Int. Seabed Authority for mining claim.
(c) In order to predict the dispersion of sediment plume in the water column under different conditions, modeling studies were initiated from 2003-2006. The work carried out under the sediment plume modeling has been Dimensional hydrodynamic model and sediment transport model has been developed and integrated with the graphical user interface. Initial runs of the model have been carried out for testing the model setup using constant current flux along the open boundaries.

The environmental database generated during the project was compiled in standard formats specially developed for the purpose. This data can be used in future inputs for design of mining system, planning of pilot mining operations, selection of potential sites for test mining and for submission to International Seabed Authority, which is an requirement on the part of the contractor for filing an application for seabed mining. The samples chosen for the present study are from twenty-four cruises carried out using five research vessels, namely M.V. Skandi Surveyor, ORV Sagar Kanya, M.V. Farnella, R.V. Akademik Boris Petrov and R.V. Akademik Alexander Sidorenko

The morphological analysis of all the 305 stations is completed. The chemical analysis for the total metal content (for regular grade calculation) was carried out for the Boris Petrov (01 & 02) and Sidorenko (40 & 62) cruises, which included 146 stations. Most of the stations among these four cruises are from the area earmarked for demarcation of first generation mine site.

Report comprising resource evaluation of additional elements and the elemental associations have been prepared which can be important while evolving mining strategies and metallurgical extractions.

During the X Plan 36 publications in reputed scientific journals have been produced by the scientists in the project with a total impact factor of 43.475 with a paper/impact factor ratio of 1.2.

Phase III assessment of the project was taken up to monitor the impact of mining on the surrounding areas and to assess the vertical and lateral migration of the plume in the water column, as well as to evaluate the time taken for restoration of benthic

environment, in the test area with respect to reference site. Since its inception, under Environmental Impact Assessment component, 3 of the activities (viz. environment of baseline condition, assessment of benthic impact, and monitoring of restoration) have been completed successfully. Currently, the ongoing activities are collection of environmental data for environmental variability in and around the proposed first generation mine-site, modeling of sediment plume dispersal and creation of database for deep-sea mining.

2.2.3 Technology Development (Extractive Metallurgy)

A semi-continuous pilot plant to process 500 kg of poly-metallic nodules per day for demonstrating the technology for extraction of metals Cu, Ni and Co was commissioned at HZL, Udaipur. Campaigns were conducted for metal extraction requiring about 100 tonnes at Hindustan Zinc Limited (Udaipur) for a total period of 200 days operation after commissioning. Thereafter, campaigns were undertaken to improvise the process based on recent technological development and to reduce number of stages and improve recovery of metals.

Once the process economics for establishing a commercial polymetallic nodule plant is established, it would be necessary to scale up selective process steps for eventual implementation.

The ferrosillicomanganese pilot plant was also commissioned at NML, Jamshedpur successfully to utilize the residues from the HZL pilot plant.

2.2.4 Technology Development (Mining)

Mining & Allied Technology Development work on development of technologies for under water mining were taken up viz., (a) in-situ measurement of soil properties at Indian Nodule Mining Site at 6000m water depth, (b) development of the underwater vehicle for dredging and shallow water mining applications, (c) development of components/studies for deep sea technology systems, (d) remotely operable vehicle (underwater submersible), (e) autonomous underwater vehicle, (f) development of underwater systems for collection and crushing manganese nodules, and (g) development of integrated deep sea mining system for mining nodules from 6000 m depth which are at various stages of development. The shallow bed mining test of indigenously developed crawler was carried out successfully for second time. The Remotely Operated Submersible capable of operating in the water depth of 6000 m has been designed and is in the advanced stage of integration.

2.3. Ocean Observation and Information Services:

The Indian National Centre for Ocean Information Services (INCOIS) established in IX Plan was strengthened by development and commissioning of a new permanent campus for INCOIS with necessary infrastructure facilities. To improve the delivery of ocean information data products such as dissemination of PFZ information three times a week, a variety of media viz., digital display boards, email, Fax, Telephone, TV, Satellite Radio were used in major regional languages including periodical user interaction workshops. INCOIS has generated and disseminated data and data products to user community like fisheries, weather, climate, ports, shipping, etc. The fishermen community found the advisories extremely useful in terms of significant reduction in search time and savings in diesel cost. A dynamic website and ocean portal was commissioned at INCOIS for Ocean Data Mining and Warehousing. A set of 10 information kiosks one each in the coastal states of India was installed in fishing harbours for dissemination of PFZ information. The ocean State Forecast Services on experimental basis was launched for safe operation and travel at sea. The data products available on INCOIS website

from the Ocean State Forecast are waves, swells, mixed layer depth, tidal currents etc.India has established a regional alliance for the Indian Ocean on Global Ocean Observation System (IO-GOOS) at INCOIS, Hyderabad with 21 organizations from 12 countries.. Construction of new campus for INCOIS has been completed and started functioning of certain activities in the new building.

Under Ocean Observing Systems, moored buoy deployment, Argo profiling floats, drifting buoys, XBTs, and their maintenance that entails collection of time series observation of oceanographic and meteorological parameters over Indian Seas which are necessary to improve oceanographic services and predictive capability of short term and long term climatic variability as well to increase the understanding on ocean dynamics.

As a part of validation of satellite products, for the first time, a set of 3 current meter arrays were deployed in the equatorial Indian Ocean at 76, 83 & 93 degrees for obtaining the variability of deep sea currents. Continued XBT surveys were conducted in 3 sectors viz., Calcutta to Port Blair and Chennai to Singapore and Cochin to Lakshadweep. Besides, over 50 drifting buoys have also been deployed in the Indian Ocean for understanding the surface circulation.

INCOIS has been recognized for coordination of the International Argo programme for the Indian Ocean Region. INCOIS has also set up a satellite data reception facility for saving online data from the Indian and International satellite including the data from the Argo floats deployed in the Indian Ocean. By virtue of India's participation in the International Argo programme data acquired from over 600 Argo floats deployed by various countries including India have also been acquired by INCOIS. A set of 12 data products is being made available through INCOIS website for wider accessability and utility of the data. INCOIS has also made operational Ocean State Forecast on experimental basis through website. The parameters currently available include waves, swell, mixed layer depth, tidal currents ete., are being made available for 4 day forecast.

The programme on satellite oceanography envisages development of algorithms, models and related capability for operational retrieval of parameters from Ocean Remote Sensing Satellites. As a logical sequel to the SATCORE Project, it is essential to pursue this activity in the context of newly planned Indian satellite Missions such as Megha Tropiques, Oceansat-II, Radar Imaging Satellite, etc. that are critical for the operational and research applications in the coming years.

Consolidation of the efforts that are underway under the Indian Ocean Modelling and Dynamics (INDOMOD) for operational applications would be one of the priority areas for the early part of the X Plan. A network of 10 institutions is being involved in this programme to develop wide range of models for operational weather forecast and climate including the prediction of Indian Monsoon. The major modules were Ocean and Climate, Coastal Ocean, Hazardous Weather Events, Ocean Data Assimilation and Information Bank ant Obseravation for validation of models. The institutions associated with this programme each having a specific responsibility, are IISC-Bangalore, IIT-Delhi, CMMACS-Bangalore, IITM-Pune, NIO-Goa, NPOL-Kochi, NRSA-Hyderabad, SAC-Ahmedabad, NCMRWF, and SOI-Dehradun. During the X Plan, a new phase of modeling efforts was initiated under this project, focusing towards the end goal of achieving ocean predictability and enabling climate predictability in a mission mode with concomitant efforts in numerical modeling, data assimilation and validation. The projects under this programme, would contribute specially pertaining to validation of ocean-

atmospheric modeling in 5 modules viz., Ocean/climate, Coastal Ocean, Hazardous weather events, Data assimilation models, Validation of models. A significant progress has been achieved particularly with respect to scientific aspects of mathematical modeling towards understanding the ocean atmospheric interactions leading to accomplishment of primary goal of Ocean State Forecast for the seas around India.

Web-based services in near real time were provided to the scientific community and operational agencies. Initiation of value added services to the Industry and other user community in the ocean sector. Implementation of web GIS for Data Mining and warehousing. A regional alliance in the Indian Ocean for Global Ocean Observing System (IO-GOOS) was established to address the issues of common interests of these countries. Currently there are 22 members representing 12 countries of this region. The Secretariat, IOGOOS is located in INCOIS, Hyderabad.

2.4. Marine Research & Technology Development

2.4.1 Assessment of Marine Living Resources and FORV

Survey of fishery resources viz Environment and Productivity Studies, Assessment of deep sea fishery resources of the continental slope, Toxic algal blooms, Benthic productivity studies, Studies on deep scattering layer, Development of acoustic techniques for fish and DSL biomass estimation, Development of predictive models and CMLRE Data and Referral Centre were undertaken.
Further studies were undertaken on Southern Ocean Living Resources through survey and assessment of krill and tooth fish in the Indian Ocean section of the Antarctic waters.

2.4.2. Drugs from Sea

Under this multiinstitutional programme, rodent toxicity testing and clinical trial of three lead compounds were completed and identification of nine other promising leads were taken up for further studies and initiation of toxicity tests etc towards drug development . Clinical trials of anti-diabetic compounds and toxicological test for antihyperdemic have been initiated after obtaining clearances. Drug development of 2 compounds (anti-diabetic and anti-hyper lypidemic) is in advanced stage and the necessary clinical trials are expected to be completed by X Plan.

2.4.3. Marine Research and Capacity Building:

Towards strengthening of marine scientific research in the universities, financial support was extended to 80 ongoing projects and 7 new projects for conducting basic research under 9 Ocean Science and Technology Cells (OSTCs).The programme to foster the concept of stewardship through education, training and human resource development and increasing awareness at all levels. Activities proposed include promotion of research through OSTCs under the basic categories of Marine Ecology, Marine Biology, Marine Microbiology, Marine Benthos, Coastal Marine Culture Systems, Marine Geology/Geophysics, Marine Placer Deposits, and Ocean Engineering & Underwater Robotics. Under Manpower Development, continued support to the ongoing programme of award of research fellowships to students for pursuing higher studies in academic/educational institutions both covered by the OSTC system and outside it, in various disciplines of ocean science and technology. One OSTC located at Annamalai University has been upgraded to centre of Excellence.

2.4.4. Coastal Ocean Monitoring and Prediction System (COMAPS)

The COMAPS programme, to monitor the health of coastal waters, which is being implemented since the 7th Plan period, were continued during the X Plan period at locations identified for annual monitoring along with stipulated parameters and locations identified for studying the diffusion and dispersion characteristics.

(a) Monitoring of Marine Pollution along the Coastline were undertaken at identified locations by involving two institutions in the west coast viz. NIO and CESS and two in the east coast viz. CAS in MB, Annamalai University and RRL, Bhubaneshwar.
(b) Inter-calibration exercise was carried out through RRL, Trivandrum (C-MARS) and pollution monitoring in the A&N waters through the field unit of NIOT at Port Blair.
(c) Development of GIS based database for marine pollution was undertaken through IOM, Anna University. Further, development of oil spill model at selected locations was carried out using hydrodynamic and water quality modelling data.
(d) Intensive monitoring were conducted at 12 selected locations once in three months and undertake modelling of movement of pollutants and their fate in a phased manner in all the 12 hot spots.

The results obtained were disseminated to the Coastal states for remedial action.

The health of the sea at 25 locations, is being monitored once a year. Further, pollution monitoring is being undertaken in the remaining 45 sampling locations of 'no concern' once in two years, to keep a watch on the health of sea in these locations.

2.4.5. Ocean Awareness (Exhibitions, Fairs, Seminars/Symposia,IT & Computers)

The objective of the programme is create ocean awareness and scientific temper specifically targeting the children. With this in view, the Ministry participates in various exhibitions and fairs. During the last plan period, the Ministry participated in Vigyan Rail Project, Indian International Trade Fair, and also the international Trade fairs organized at Hanover, and Syria. In addition, the Ministry participated in national Trade Fair, apart from the regular exhibitions, fairs, seminars, symposia etc.

Several brochures and books were brought out for children. A multicolour booklet specifically designed and developed catering to the children entiltled "Story of Oceans" was published in 8 coastal languages. Further a number of seminars/ symposia/ workshops, etc. were sponsored.

To meet with the IT Policy of the government, purchase of new computer hardware and software for the officers and staff of the Ministry is ensured. The existing hardware and software are to be maintained at the optimum level.

2.4.6. Integrated Coastal and Marine Area Management (ICMAM)

Marine eco-toxicology studies including GIS based system for 3 islands and initiated shore line management studies were carried out under ICMAM project.

The marine environment, which is greatly influenced by a variety of near coast activities and to certain extent the deep inland activities, is governed by the physical, chemical and biological processes. Under Eco-system Modelling Approach for Integrated Coastal and Marine Area Management, as a pre-requisite for Preparation of ICMAM Plans in selected areas by the coastal states/others, the ICMAM Project Directorate were conducted the eco-system modelling studies. The Indian coastline has been subjected to

several geomorphological changes. Relevant aspects of eco-system modelling, namely, physical processes ideally used for Management of the shoreline land, particularly to control erosion and accretion have been carried out. Under Marine Eco-toxicology programme development of criteria and standards for disposal of wastes were undertaken during the X Plan. Under Assistance to Coastal States, coastal States, which are in the beginning stage of coastal environmental planning and management, technical assistance were extended to all the coastal states besides the training programme.

2.4.7. Deep Sea Mineral Resources Exploration

Under these programmes, studies were undertaken to understand seafloor hydrothermal mineralisation, dynamic interaction of heat and chemicals between the lithosphere and the oceans at the global system of divergent plate boundaries and behind volcanic island arcs including at the intra-plate volcanic centres. The Afanasiy – Nikitin seamount, basin and marginal basins of Arabian Sea in the Indian Ocean are potential areas for the formation of cobalt crusts. The MOOD is actively evolving strategy for comprehensive assessment of resource potential of the Indian EEZ including gas hydrates, cobalt crust, etc. Four cruises for collection of additional sample by dredging were conducted. The project is a comprehensive study of the tectonic, geochemical and other studies in the spreading centers in the Indian Ocean carried out as a part of joint MOOD-CSIR project.

2.4.8. Paleo-Oceanographic Studies in the Bay of Bengal Fan (BENFAN)

The BENFAN, though the programme was approved and initiated for a period of 4 years, a major part of it was deferred because of financial constraints. Emphasis was on long coring of the sediments at selected locations. Collection long sediment cores, from various parts of Bengal fan by piston corer onboard MOOD vessel Sagar Kanya. Analysis of core samples for various geochemical, isotope, sedimentological and micro palaeontological proxies by the participating institutes/universities

2.5. National Institute of Ocean Technology:

. The major achievements of National Institute of Ocean Technology (NIOT) are as follows:

(a) NIOT designed and fabricated ‘a floating Ocean Thermal Energy Conversion (OTEC) demonstration plant of 1 MW capacity on board Sagar Shakti’ to demonstrate . Construction of wavepowered desalination Plant at Vizhinjm was completed. Conceptual design of dynamic positing system for coastal engineering works was completed. An experimental desalination plant with 5000 litre/ day capacity was set up at NIOT for demonstration of low temperature thermal prior to setting up of plant in the field. Ejector Driven Vacuum Desalination and Glass house. Demonstration of Low Temperature Thermal Desalination (LTTD) at Kavaratti in Lakshadweep with a of capacity 1 lakh liters per day was commissioned in May, 2005. To meet main land requirements of fresh water, large-scale barge mounted desalination plants have been designed, developed and demonstrated near Tuticorin. For scaling up to such large sized plants it was proposed to set up, design and install a one million liters per day (1 MLD) barge mounted plant in deep ocean waters as an intermediate step. A barge mounted desalination experiment of capacity one lakh liter/day was also carried out for 10 days off Tuticorin and this was also successful. A 1 MLD barge mounted desalination plant moored offshore in deep waters either off Chennai was developed and commissioned and demonstrated in April 2006. Depending on viability higher capacity plants (10 and 25-MLD plant) would be designed and

developed. Besides, design, lab model studies, site surveys and development of a desalination plant using flash evaporation system and commissioning of RO plant at Vizhinjam using wave power.

(b) Under Deep Sea Technology, activities were technologies for direct applications to shallow and deep-water mining upto 500 m depth and development of technology base for deepwater applications in general (NIOT funding) such as Remotely Operable Boat (ROB). Underwater, Crawler for shallow water applications, underwater thruster for operation upto 6000m water depth etc.,

(c) The achievements under Technology for Coastal and Offshore were construction of Dyke at Haldia Port, conducting studies in mega projects like Sethusamudram project, Kalpasar project.

(d) Applications including Environmental Engineering aspects envisages building up necessary expertise for the exploration and recovery of Gas Hydrates, deemed to be the future source of energy, On-line operational Oil spill disaster / storm surge prediction modelling and calibration, enhancing the Mathematical Modelling capability in the areas of pollution, sediment, demonstration of coastal protection device etc.

(e) An Indo-Russian Centre for Gas Hydrate under ILTP has been established at NIOT. Under Technology for Marine Instrumentation System, following programmes a state-of-the-art technology.

(f) An acoustic tide gauge was indigenously developed which received a US patent and installed in 5 major ports. The Beacon lamp for floating platfoms and portable Digital current Meter were developed. Ocean ambient noise measurement analysis and modelling.

(g) Under Institutional Framework: National Institute of Ocean Technology, NIOT had developed institutional cooperation/collaboration for technology development, with the reputed National and International Research Laboratories, Academic Institutions, International Organizations, Private R&D Institutions.

(h) Acoustic Tide gauges were established in Myanmar and Vietanam and developed Storm Surge modeling under the project entitled “Storm Surge Disaster Reduction along the Bay of Bengal bordering India and Bangladesh”.

(i) Acoustic Test Facility was established with fully automated transduces ositioning and calibration system for calibration The State-of-art technology acoustic facility was established at NIOT and calibrated 150 numbers of probes developed by BEL.

(j) Studies on Marine Archaeology in Gulf of Khambat were conducted which led to the discovery of existence of ancient civilization. Lobster Technology for lobster fattening and larval rearing was developed and transferred the technology to the coastal community. Some important consultation projects were undertaken such as navigational channels at Haldia for Kolkata Port Trust. Fixation of Kalpasar dam alignment’ project in the Gulf of Khambat, Gujarat. Two coastal research vessels Sagar Poorvi and Sagar Paschimi for coastal developmental activities have provided uninterrupted support for coastal works and completion of 99 cruises.

(k) Under Ocean Science and Technology for Islands programme, Pilot scale demonstration of fattening of lobster and crabs in A&N Islands and the main land, using different feeds have been completed and technology was transferred to a number of beneficiaries.

2.6. Coastal Research Vessels

CRV Sagar Purvi & Sagar Paschimi were deployed primarily for pollution monitoring both in the east and west coast of India. In addition, the vessel was deployed for physical oceanographic observations & microbiological studies for the waste load allocation project under ICMAM , Observation of critical habitats in Lakshadweep and CTD observations off Chennai for ground water discharge.

2.7. Delineation of Outer Limits of Continental Shelf

The Indian Legal Continental Shelf programme is a multi-institutional national endeavor that seeks to establish the outer limits of the country's legal continental shelf in accordance with certain guidelines of the 1982 United Nations Convention on the Law of the Sea (UNCLOS). As per the provisions of this Convention, coastal states having continental shelves that exceed 200 nautical miles from their territorial sea baselines are required to submit the requisite scientific and technical data in support of their claims for an extended shelf to an international commission. This Commission on the Limits of the Continental Shelf (CLCS) in turn will consider the data submitted and make recommendations in accordance with the provisions of the UNCLOS.

Following India's ratification of the Convention in June 1995, it is now mandatory for the country to lodge her claims for an extended shelf latest by May 2009. The Indian endeavors towards this national goal are coordinated by the Department of Ocean Development and National Centre for Antarctic and Ocean Research (NCAOR) has been assigned the responsibility of undertaking all the scientific tasks for preparation of the submission. Underpinning our endeavors is a comprehensive multi-institutional marine geophysical work programme. The data acquisition as a part of this work programme comprising multi-channel seismic reflection, refraction, gravity and magnetic profiling was initiated on the 17th July 2002 and was completed on the 7th of February 2004. Spread over 385 days of fair-weather period, 27,897 km of seismic reflection and 28,005 km of gravity and magnetic data were collected from the project area. In addition, for the first time in the country, 72 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.

Considering the scope of the work, the post-processing and interpretation of the data was undertaken by three of the leading National Institutes, viz., NCAOR, NGRI and NIO. A comprehensive flow chart for seismic data interpretation incorporating the various scientific and technical guidelines of the CLCS was drawn to have a uniform strategy for data interpretation between these organizations. The interpretation of the seismic, gravity and magnetic data collected has already been completed. Further the final document along with detailed documentation of the scientific results and cartographic work as per the CLCS format is has also been completed at NCAOR, NIO and NGRI.

To archive and retrieve the enormous amounts of data gathered in various media such as IBM 3590 tapes, exabytes, CDs and analog records, a state-of-the-art Data Centre has already been established at NCAOR. In addition, the Data Centre has been equipped with the most-modern geophysical data processing and interpretation facilities.

During April 2006 and October 2005 a five-day training-workshop on delineation of the outer limits of the continental shelf was organised at NCAOR for the scientists from Sri Lanka and Myanmar respectively.

In addition NCAOR initiated as a part of the LCS work programme, a project on "Understanding the plate tectonic evolutionary history of the south-western continental margin of India and the adjoining ocean basins" onboard ORV Sagar Kanya during the period June-July 2005. Bathymetric, gravity and magnetic data collection from the Project area in the Laccadive Basin and to the south of the Laxmi Ridge has already been completed, and interpretation work is in progress.

2.8. Comprehensive Systematic Bathymetric survey in EEZ

The area of our Exclusive Economic Zone is over 2 million sq. km. having various living and non-living resources. This programme entails scientific mapping of this area, particularly to identifying area for future detailed surveys for the non-living resources exploration. The shallow beam geophysical surveys using multibeam system for mapping the bathymetric details at closer grid in the selected locations of EEZ (state of the art) were initiated.

2.9 Gas hydrates:

The gas hydrates with their abundant resource potential is turning out to be an ideal substitute for depleting fossil fuels. National Gas Hydrate Programme (NGHP) under the aegis of ministry of Petroleum has been constituted for investigating gas hydrates in Indian offshore regions. However, major portion of the continental margins have not been explored for this purpose. Based on analysis of samples and interpretation of geophysical & geochemical data, two sites on the east coast of India have been identified as potential sources for Gas Hydrates and further studies. A great deal of Scientific studies were conducted in collaboration with Russia in Lake Baikal. Two joint expeditions were carried out to get first hand experience of gas hydrate samples found in ice cores. Extensive and concerted programme is being proposed to evaluate the resource potential of the gas hydrates and to recommend suitable sites for drilling and ground truth validation. The technology development for exploration of gas hydrate is underway. A Indo-Russian Gas Hydrate Centre was established at NIOT for undertaking detailed studies.

2.10 Acquisition of New Research Vessel:

The Department's focus in the next 5 years will be to develop sustainable technology for the exploitation of various non-living resources. A suitable platform is required to replace the vessels and crafts chartered by the MOOD at present, which caters to the demand for technology services and demonstration programme. This new facility will also cater to shallow water survey, and act as a supply and support platform for the various coastal and deep ocean activities planned by the Department. Acquisition of new multipurpose vessel for Technology vessel serve as a platform for was undetaken which would also serve as a utility science vessel

.The NIOT the nodal agency had prepared specification, floated tender and signed contract after a revision of the initial estimated cost in December 2005. The model tests have been conducted and construction is underway. The Steel cutting has commenced and the vessel is expected to be delivered in September 2007.

2.11. Geophysical Studies of Laxmi Basin

The project on geophysical studies in the Laxmi Basin-Ridge areas was undertaken and completed during the X plan period. The enigmatic Laxmi ridge is a prominent bathymetric feature of the northeastern Arabian Sea located some 300 km oceanwards of the Indian continental shelf and extending in an E-W to NW-SE direction. The origin of this ridge as well as the nature of the crust forming the basement to the ridge and the basin to its east (the "Laxmi Basin") have been topics of intense academic debate for over a decade now. Considering the importance of the Laxmi Ridge and basin in facilitating an understanding of the evolution of the Arabian Sea in its entirety, and to arrive at a logical conclusion on the nature of the basement beneath these geological features, the Department, through NCAOR, initiated during 2002-03, an integrated geophysical study comprising multi-channel seismic reflection, refraction, gravity and magnetic profiling across the Laxmi Basin and the ridge.

The total quantum of work undertaken on completion of the data acquisition during February 2004 comprised 3600 km of seismic reflection, gravity and magnetic profiling and 18 successful OBS deployments.

The analysis of data shows interesting light on the nature of crustal characteristics and the affinity towards the continental structure. The report of the work has been prepared.

2.12 Early Warning System for Mitigation of Oceanogenic Disasters: Tsunami and Storm Surges in Indian Ocean

The coastal states and island territories of India are frequently effected storm surges and occasionally impacted by tsunami such as the Great tsunami of 26th December 2004, occurred due to a large earthquake in the eastern Indian Ocean. This has caused severe damage to the coastal population of India both in terms of property and life. Recognizing the imperative need to put in place an early warning system for mitigation of oceanogenic disasters such as tsunami and storm surges, the Ministry had formulated a proposal in consultation with the Department of Science & Technology, Department of Space and CSIR. It is expected that the system of early warning system will be implemented by end of 2007. All the necessary clearances have been obtained and a project was taken up for implementation with INCOIS, Hyderabad as the nodal agency for overall implementation and coordination of the project. The system will be developed indigenously by Indian scientists. An interim-tsunami Warning System has been made operational on 24 x 7 basis by deployment of a set of tide gauges in selected locations. The seismic network is currently being strengthened. Various activities are progressing as per schedule.

2.13 Data Buoy Programme:

Augmentation of moored buoy network from 12-buoy network established during IX plan, to 40-buoy network by the end of X Plan, with indigenisation of its prototypes. Indigenous productions of data buoys have been completed including setting up of INSAT communication between buoy and shore station for data transfer. Data collected under the programmes have been made available in real-time and delayed mode depending on operational weather forecasting and research activities. Development of Indigenous technology and produce a set of moored data buoys with INSAT communication. Completion of design of buoy tender vessel and initiated construction

work. Established 26-moored buoy network in selected locations to acquire meteorological and oceanographic data. A buoy tender vessel "Sagar Manjusha" has been constructed and commissioned recently at Vishakahapatnam. This will cater to the needs of observation platforms.

3. CONTINUING PROGRAMME

3.1 Polar Science and Antarctic Expedition

Objectives of the programme are given below:

- To ensure a perceptible and influential presence of India in the Polar regions.
- Uphold our strategic interests in the global framework of nations in the Polar regions and the Southern oceans expressed through our consultative status in the Treaty and by conducting substantial scientific activities,
- Pursue a scientific work plan which is dynamic and is aimed towards addressing issues pertinent to our national needs, having potential application and those which have global relevance.

Proposed activities during the XI Plan period**:**

A. METEOROLOGICAL AND ATMOSPHERIC STUDIES

- Aerosol Radiative Flux estimation using Sky Radiometer
- High resolution data acquisition using Automated Weather Station (AWS) and data logger
- Establishment of geomagnetic observatory at Larseman Hill Site (deployment of instruments like DFM, DIM, PPM)
- Continuation of planetary boundary layer studies at interval of 2-3 years to monitor long term changes, if any and also access environmental impact, if any.
- Continuation of Katabatic flow, snow drift and energy balance radiation studies using AWS.
- To study the vertical distribution of aerosol and optical properties of Polar Stratospheric Clouds (PSCs) on continuous basis by micro pulse LIDAR**.** The online measurements will help in understanding the characteristics of different type of the PSCs and polar vortex dynamics.
- To study the temporal variations of CO_2, CH_4, CO, surface O_3 and NO_x gases over Maitri, Antarctica.
- Space-based remote sensing of Polar region (new programme).
- Establishment of radio receiving facility in the 35-125 MHz range

B. GEOLOGY, GEOPHYSICS, GLACIOLOGY AND GLOBAL CHANGE

- Studies of the processes involved in formation of supercontinent Gondwanaland and its fragmentation.
- Closed spaced mapping on large scale, for extensive petrological and geochemical studies.
- Systematic geological mapping to be extended upto 0 degree longitude.
- Glaciological and limnological studies in CDML for paleoclimatic reconstruction and modeling.

- Shallow ice core drilling along a transect starting from Maitri Station upto polar plateau.
- Long-term monitoring of polar ice sheet margin and accumulation / ablation studies in ice shelf areas.
- Mapping of basement topography in ice covered areas
- Lake bed profiling in Schirmacher oasis and Gruber massif.
- Stratigraphic correlation between wide spaced bore holes
- Mapping of Ice shelf – sea water interface, grounding line of ice shelf and calving lines of the ice shelf in the India Bay area.
- Bathymetric/hydrographic surveys at the site of the new Indian base.
- Temporal and spatial variation of energy and mass balance of different snow and ice media in Antarctica using satellite remote sensing, AWS and GPR.
- Correlation between snow drift and snow properties.

C. BIOLOGY

- Biodiversity of sea-ice microbial community.
- Biodiversity and conservation of terrestrial and aquatic biota (fungi, lichens, bryophytes, micro fauna like protozoans, nematodes, tardigrades)
- Biodiversity of microbial community like anaerobic bacteria.
- Microbial bio-prospecting and bio-technological applications- joint ventures with Public and Private Institutions.
- Determination of indicator fauna and their population trends and impact of anthropogenic and other biotic and abiotic factors on the Antarctic ecosystem.
- GIS based wild life census and cataloging of shoreline and pack-ice regions.

D. HUMAN PHYSIOLOGY AND MEDICINE

- Pro-oxidant and anti-oxidant profile in humans exposed to Antarctic environment.
- Bone turnover during residency at Antarctica
- Telemetric monitoring of physiological variables
- Free-radical induced biochemical changes in the human body
- Comparative studies of human behaviour and physiological / psychological changes in Antarctica with that of Arctic region.

E. ENVIRONMENTAL SCIENCES

- Continuous monitoring and conservation of soil, water and air quality.
- Environmental audit and impact of waste management protocol.
- Development of oil handling, storage, spill and other emergency handling protocols.
- Generation of baseline data for EIA.
- Identification of areas of SPA and SSSI on the basis of wild life value.

F. ENGINEERING AND COMMUNICATION

- Maitri as well as the Third Antarctic Base in the Larsemann Hills to be equipped with state of art high speed option of INMARSAT-B facilitating high speed data link between India and the Antarctic research stations.
- Long-term experiment in association for monitoring the effect of geomagnetic activity over High frequency communication.

- Development and application of non-conventional energy sources (wind, solar, fuel cells).
- Development of incinerators, vehicles, life support systems for cold region utility.
- Automatic conditioning monitoring and remotely operated systems.

G. STRENGTHENING OF MAITRI STATION

The structure and service systems of Maitri station have been developed indigenously by DRDO using materials available in the country. The station has already withstood about eighteen years of useful life in a rigorous environment beyond its projected life span of ten years. As a part of our endeavor to maintain a state-of-the-art station in Antarctica, during the XXIII Indian Scientific Expedition, NCAOR had undertaken a comprehensive structural assessment of the Maitri station building as well as of the waste water management system through the scientists of M/s. EIL, New Delhi and SERC, Chennai. Based on the studies undertaken, it is proposed to undertake the following tasks during the XI Plan period, in a phased manner:

- Replacement of the toilets, wall and roof panels of C Block.
- Revamping Block A.
- Establishment of field huts such as the Igloo satellite cabins in the mountains.
- Augmentation of the existing Klargester units.
- Provision of adequate lab. and working space in Maitri as well as in the Summer Huts.
- Development of an online condition and performance monitoring system of various infrastructural facilities operating at Maitri.

Financial requirement : Rs. 154.00 crore

Rs. In crore

Details	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**Total,**
1.Charter of ship/own vessel and helicopters	13.00 3.00	14.00 3.50	15.00 4.00	16.00 4.50	17.00 5.00	**75.00** ****20.00**
2. Expedition to Antarctica	3.00	3.50	4.00	4.50	5.00	**20.00**
3. Res. Station in Antarctica	3.50	3.50	4.00	4.00	5.00	**20.00**
4. Science support to participating organisations	3.00	4.00	4.00	4.00	4.00	**19.00**
Total	**25.50**	**28.50**	**31.00**	**33.00**	**36.00**	**154.00**
** Assuming own ship will be ready by end of XI Plan*						
*** Charter charges for two helicopters*						
Foreign Exchange Component: Rs. 97.50 crores						

3.2. Polymetalic Nodules Programme

On 26th January, 1981 the first nodule from the deep sea floor was picked up by India onboard RV Gaveshani. These nodules were the harbinger of an important programme viz. Polymetallic Nodules(PMN) Programme, formulated by India to explore the Central Indian Ocean Basin (CIOB).

India, an active player the various deliberations in formulation of United Nations Convention on Law of the Sea(UNCLOS) has been instrumental in carrying out of necessary activities pertaining to the research on Polymetallic Nodules available at the sea bottom. In April, 1982 United Nations recognized India as the Pioneer Investor. The UNCLOS was opened for signature in December, 1982. Subsequently, in August , 1987, India was allocated the Pioneer area of 1,50,000 sq. km in Central Indian Ocean Basin. The location of the area is indicated by the box given below. India was the first country to have achieved the status. Consequently, India registered as Pioneer Investor with the United Nations along with IFREMER/AFERNOD, France , Deep Sea Research Development Company Ltd. (DORD), Japan, Yuzhmorgeologiya, USSR (Russian Federation), and Germany. This was followed by registration of China Ocean Mineral Resources and Development Association (COMRA), China, Inter-ocean metal [Bulgaria, Cuba, Check and Slovak Federal Republic (Czech Republic, Slovakia), Poland, USSR (Russian Federation)], and Government of the Republic of Korea, Republic of Korea. In June 1995, India ratified the UNCLOS and the Agreement for implementation of Part XI of the Convention. Today, India is an elected member of the Council under Group B - Investors Category. India also signed a contract with International Seabed Authority in the year 2002 for a period of 15 years. As a part of its obligation, India has relinquished the 50% area upon detailed survey. India also prepared plan of work and has been submitting the annual report to ISBA as a contractor. India is presently in the process of developing a technology for exploration and utilization of Polymetallic nodules from the area of 75000 sq. km., retained in the Central Indian Ocean Basin allotted by the International Seabed Authority. India's nominee is and has also been member of the Legal and Technical Commission and contributed substantially to its work. India continues to support the International Seabed Authority and participates in the meetings of the Council, Assembly, Legal and Technical Commission and Finance Committee of the Authority.

3.2.1 Survey & Exploration

The X plan period had the primary target to identify the 1st Generation Mine site with essential inputs from different types of exploration, analysis etc. Continuing these efforts, the following plan of work is proposed during XI Plan:

- Continue to carry out close-grid sampling at 6.25 km grid in the bottom half of the designated area – occupy 166 stations.
- Determine the grade from all the stations by chemical analysis
- Determine the abundance from the all the new stations
- Integrate the grade and abundance data with the existing data in this part of the retained area and generate a final picture of the best blocks as far as grade and abundance are concerned which would form the nucleus for the 1st Generation Mine Site.
- High resolution mapping of the ocean floor with 1st generation mining site area using an ROV.
- Study and analysis of newly generated grade, abundance data plus the existing data along with the slow scan multibeam maps generated during the X plan to

fine tune the 1ST generation mine site. This activity is expected to be completed by the end of the 1st year of the XI plan.

Financial requirement Rs. 17.70 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
2.00	5.00	5.00	3.00	2.70	17.70

3.2.2 Environmental Impact Assessment

As a result of the exploration for polymetallic nodules, an area of 150,000 sq.km. with promising deposits was identified in the Central Indian Basin (CIB). Arising from the need for evaluation of environmental data for designing a mining system as well as for prediction of potential impact of mining on marine ecosystem, the project on 'EIA studies for nodule mining in CIB' was initiated in 1996, under the national programme on polymetallic nodules of the Department.

Objectives of the program are provided below:

- To evaluate baseline environmental conditions in nodule areas
- To study the effects of sediment redistribution on marine environment.
- To monitor the processes of environmental restoration and recolonisation
- To provide inputs for designing and operation of a marine mining systems
- To develop environmental management plan for deep-sea mining

During the XI plan period, it is proposed to consolidate these into meaningful information and collect detailed data on different environmental conditions in the proposed first generation mine-site, which will help in development of mining system, planning its operation and formulation of guidelines for mining, as per the stipulations of the International Seabed Authority (UN).

The activities proposed include :

- Characterisation of nodule associated sub-surface sediments
- Assessment of nodule associated fauna and other environmental parameters
- In-situ seafloor characteristics investigation
- Contribution of pelagic flux to benthic ecosystem and nodule mining
- Preparation of environmental management plan
- Creation of environmental database -II

Financial Requirement : Rs. 22.59 crores

Rs. In crores

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
4.00	5.00	4.00	5.00	4.59	22.59

3.3.3 Technology Development (Extractive Metallurgy)

Deep-sea manganese nodules are a unique and complex deposit requiring an equally unique extraction process suited to their properties. The extraction processes for recovery of metal from nodules collected from the Indian Ocean are being developed by different National laboratories and R&D Centres in India, funded by Ministry of Ocean Development (MOOD). These laboratories have tested about 15 process routes. After

careful evaluation of the test results of these process routes in early 1986; five potential routes were short-listed for further development on laboratory scale. Further evaluation of these five routes through regular interaction with the participating laboratories enabled MOOD to focus attention principally on three process routes for further development and scale-up.

- Roast reduction ammoniacal leach
- Ammoniacal Sulfur-di-Oxide leach and
- Starch- Sulphuric acid leach.

Polymetallic nodules pilot plant set up by MOOD at Hindustan Zinc Limited, Udaipur is based on a hydrometallurgical process route. The pilot plant was commissioned in March 2002. During the last 3 years, significant quantity of nodules have been processed and large-scale experimental information have been generated.

During XI plan period, Technology Development-Metallurgy programme would be oriented to fulfill the following objectives based on recent technological advancements:

- Testing of all the three process routes at 500kg/day scale.
- Testing of other two process routes - smelting technique and the high pressure high temperature sulphuric acid leaching process.
- Development of suitable process for extraction of metals from crust.
- Recovery of ammonia from liquid effluent containing ammonium sulfate.
- Development of process for safe disposal of solid effluent based on electro-remediation technique.
- Developing/strengthening capabilities in the area of solvent extraction based on the recent developments in this area.
- Development of suitable process for extraction of molybdenum from nodules.
- Development of mathematical model for PMN Process evaluation.
- Development of processes for production of value added products from leached residue.
- Techno-economics studies of different processes based on which final process to be selected for commercial application.
- Distribution of precious metals and rare earth elements in Indian Ocean Manganese Nodules.
- R&D endeavours.

NML(J), RRL(B), BARC, and EIL would be involved in achieving the XI plan objectives.

<u>Processing of ferro-manganese crusts</u>

Less information is available for the cobalt rich ferro-manganese crusts though their resource potential has been of great interest. India has gained sufficient expertise in the area of hydro and pyro-metallurgy due to extensive extractive metallurgy work in the polymetallic nodules implemented by Ministry of Ocean Development. Indian laboratories can utilize this knowledge for development of suitable process for extraction of cobalt and other strategic metals from ferro-manganese crust. The various envisaged activities are as follows :-

· Preliminary technology evaluation
· Preliminary laboratory investigations on selected process routes
· Screening of process routes for detailed investigations

- Bench scale investigations on identified process routes
- Detailed pilot scale investigations on identified process routes

Financial requirement : Rs. 56.48 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
10.00	25.00	10.00	6.00	5.48	56.48

3.3.4 Technology Development (Mining)

The Deep sea technology and Ocean mining group has been actively involved in the development of technology for mining of polymetallic nodules from 6000 m water depth. A major project for development of technology for mining these nodules in collaboration with the Institüt for Konstruktion (IKS), University of Siegen, Germany was taken up by NIOT. An underwater mining system consisting of a crawler based mining machine with a flexible riser system has been developed and tested for operations at 410 m water depth, which is a significant milestone in establishing India's capability to take up the utilization of the resources of the Oceans at all depths. The crawler was tested for second time successfully for operations at a depth of 451 m off Goa coast in March 2006. Based on the results obtained from the tests, design reports have been prepared for a crawler based mining system for mining the manganese nodules from 6000 m depth.

The next phase of the project involves development of Collector and Crusher system for mining Polymetallic Nodules (PMN) from the sea floor and its qualification at 500m water depth by laying artificial nodules. An in-situ subsea soil tester is being developed for precise measurement of soil strength to design and develop the future deep sea mining machine as well as to isolate areas of very low soil strength to prevent the mining machine from sinking in to the sea floor. The soil tester will be used to demarcate the complete first generation mining site by carrying out surveys on continuous basis. To develop a strong knowledge and capability in terms of deep sea technology it is planned to carry out various studies under Hyperbaric and low temperature condition for long-term operations and develop subcomponents for deep sea applications. The studies and subcomponent development will be done through inter institutional R&D. The proposal for the XI five year plan is presented here.

Objective:

- Design and development of a new crawler based mining machine capable of collecting and pumping nodules from 6000 m water depth. To develop a flexible riser system for transporting nodules from the ocean floor to the mother ship/ barge.
- Qualify the underwater mining system at 6000 metres from ship / floating platform equipped with DP system using winches, cable and handling systems.
- Manned submersible to monitor the function of under water mining system at 6000m depth in phases and for sampling purpose.
- Development of small semi submersible floating station.

This would necessitate technology development in the following areas:

- Crawler chassis
- Enhancement of 500m rated collecting and pick up system developed in X plan to 6000m.
- Lateral transport and crusher unit

- Hose coupling
- Hydrotransport studies for nodule size degradation and wear of hoses.
- Slurry pump development for higher pressure
- Underwater cable
- Underwater cable end termination
- Hose cable attachment
- Integrated developmental tests
- Sea tests

The power module for manned submersible could also be diesel based. The possibility of exploring the nuclear power source will also be explored for longer duration.

The development and realisation of Integrated Mining System will be focused around the following:

- Development and realisation of crawler and associated hardware.
- Realisation of umbilical cable, special hose of 7000 m length, along with its coupling.
- Realisation of ship / floating platform along with associated launch facilities.
- Development and realisation of new systems indicated.
- In situ soil testing in the First Generation Mine Site

In addition it is planned to carry out studies on material behavior in hyperbaric and low temperature condition for long term operations and develop sub-components for deep sea applications through inter-institutional R&D efforts.

Detailed documentation of the requirements, qualification and acceptance criteria for new systems to be developed jointly by the industries.

Industrial Participation

Realisation of the project would be through Industrial participation as follows:

- Many of the requirements are high technology, high value, less quantity items made to specific requirements of the project.
- Realisation of mechanical and structural works involving precision fabrication is proposed to be realised mainly through industries.
- During the project many industries are expected to contribute in the development of integrated mining system.
- By this process during operation phase NIOT can concentrate on R&D activities and contract management leaving industries to manufacture and commercialise nodule mining.

Implementing Agency : NIOT

Financial Requirement: Rs.627 crore

S.No.	Title	Yearwise Break up					Estimated cost in crores of Rupees
		07-08	08-09	09-10	10-11	11-12	
1.	Integrated Deep Sea Mining	10	70	60	40	55	**235**

	System for 6000 m						
2.	Development of Small Semi Submersible Floating Station	0	0	35	50	65	**150**
3.	Development of manned Submersible capable of operation at 6000 m water depth	10	80	50	50	35	**225**
4	Offshore operations	4	5	4	3	1	**17**
	Total	24	155	149	143	156	**627**

3.3 Ocean Observation and Information System (OOIS)

3.3.1 Ocean Advisory and Information Services

3.3.1.1 Potential Fishing Zones Advisories

INCOIS has been providing Potential Fishing Zone Advisories generated from satellite retrieved SST and chlorophyll. These advisories are being provided thrice-a-week during the non-monsoon and non-ban period to the entire coastline of the Country using a host of dissemination methods.

It has been proved that PFZ advisories have provided a definite advantage to the fishing community in terms of considerable reduction in searching time to the tune of 30 to 70 %. This in-turn amounts to savings in cost of fuel and valuable human effort. A modest computation of quantitative advantage derived varied between Rs.1.56 lakhs and Rs.6 lakhs per vessel for a 6-month period, depending on the size of the vessel/HP of the engine.

Hence it is imperative to sustain the ongoing PFZ Mission, which is presently being pursued as part of the Common Minimum Programme of the Government of India.

Continuous validation and feedback is imperative for improving the operational forecast of PFZ. INCOIS has already taken up 6 validation experiments along the east and west coasts of India in collaboration with the Academia and other central institutions. It is proposed to extend these validation experiments so as to cover the entire coastline of the Country. User awareness workshops need to be conducted regularly to update the fishing community of the latest advances in the advisories and to solicit their feedback. It

is also necessary to conduct independent market research on scientific lines to get a feedback on the utilisation of the forecasts and to understand the market needs.

During the X Plan, INCOIS has taken up several novel initiatives for dissemination of PFZ information. Once such initiative that became popular among the coastal fishing community is the Electronic Digital Display Boards installed in the major fishing harbours. 20 such boards have been installed that remotely updated from INCOIS in real time. These boards are also capable of providing any other collateral information useful for the fishermen such as market prices, weather, etc. Hence it is imperative to increase the content and coverage of these boards to the entire coastline of the country.
With minimal upgradations in design and communication, these boards could be well used for communicating disaster information to the needy coastal population very effectively. This network will then be a unique mode of communication where selective information could be passed on to specific locations or all locations in real-time from a central node at INCOIS. Considering the vast coastline of India, it is necessary to install at least 200 such boards to cater to a variety of information needs including disasters such as tsunami warnings and storm surges.

INCOIS has been operationally providing Open Ocean Wave forecast to about 60 users, during the X plan. This has proven to be extremely useful for the shipping & oil industry and navy for their safe operations at sea. It is imperative to continue providing this forecast to all the users. It is also proposed to improve the accuracy and spatial as well as temporal resolution of the forecast. It is also proposed to provide user required value added products such as Wave Atlas, optimum ship route Information etc.

Species Specific Forecast for Tuna And Oil Sardine
The Market research survey conducted by INCOIS in 2002, as well as the user feedback had suggested that the fishermen require specific forecasts for commercially important fish species such as Tuna, Sardines, etc. Considering this, as part of the SATCORE Project, MOOD and DOS have pursued research during the X Plan for generating species specific PFZ forecast for Tuna. This is proposed to be made operational at INCOIS by the beginning of XI Plan. In addition, R&D efforts will be mounted during the XI plan for generation of species specific forecasts for other commercially important species such as sardines, etc. It is also proposed to conduct Fish Tagging experiments that will throw light on the migration aspect of fishes as well as the favourable environmental conditions which they prefer.

Integrated PFZ Forecast
Presently PFZ forecasts are issued based on features such as fronts, eddies, meanders, etc that are derived from Sea Surface Temperature and Chlorophyll images. It is well known that these features shift due to effect of local wind-driven Currents. The launch of Scatterometer aboard Oceansat-II will give us the capability to operationally retrieve winds in the Indian Seas. R&D has already been taken up as part of SATCORE Project during X Plan to incorporate this information into the PFZ Forecasts. This will be made operational during the XI Plan.
It is also known that Mixed Layer Depth information is very important for identification of Potential Fishing Zones. This will provide information on thermal fronts in the vertical domain as well as will be useful for operation of fishing gear. Hence it is imperative to pursue R&D during XI plan in this direction.

In addition to the information on fishing locations, fishermen need information on sea state for their safe navigation and operations at sea. It is planned to secure this

information from the appropriate operational agencies and provide to the fishermen in a timely manner along with the PFZ information.
The modelling efforts being mounted at INCOIS will provide the necessary inputs to run local models at high-resolution that will provide local specific sea state information to the fishing community.

Financial requirement: Rs.35.00 crore.

Rs in crores

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
7.60	8.10	7.10	6.10	6.10	35.00

Enhanced User Interaction and Delivery Chain
In order to understand the user requirements and to increase awareness, it is necessary to frequently interact with the users. Hence it is proposed to conduct user meets frequently. The delivery chain needs to be enhanced and extended to offshore.

Financial requirement : Rs.5.00 crore.

Rs in crores

	2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
Value-added Services and Consultancy Services	1.00	2.00	1.00	1.00	0.00	5.00

3.3.1.2 Operational Coastal Ocean Wave & Current Forecast
Presently INCOIS is providing forecast of tidal currents for the North West coast of India. High-resolution Coastal ocean forecast is very useful to the fishing community, search and rescue operations, etc. It is necessary to continue this service. Further, Survey conducted during X Plan revealed that many leading users of OSF require coastal forecast for wave and currents. R&D efforts being mounted at INCOIS as part of Ocean Modelling will provide useful inputs to provide operational forecasts of coastal currents.

INCOIS conducted OSF validation experiment in association with other premier national institutions in the Country. This has provided useful inputs for improving the accuracy of the forecast. These studies need to be continued using both in-situ and satellite data during the XI Plan for better forecast accuracy both in space and time.

The estimated fund requirement would be Rs. 24.60 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
4.65	6.70	5.30	4.05	3.90	24.60

3.4 Marine Research and Technology Development

3.4.1 Marine Living Resources and FORV
The Marine Living Resources Programme [MLRP] was initiated by the Department in 1998 at its attached office 'Centre for Marine Living Resource & Ecology' [CMLRE], with the following objectives;

- Survey and assessment of deep-sea and distant water fishery resources.
- Survey and exploitation of non-conventional resources.

- Monitoring and Surveillance of Harmful Algal Blooms (HAB) in the Indian EEZ.
- To carry out studies on Marine Benthos in the Indian EEZ and to generate advisories on the impact of bottom trawling on the benthic community and the fisheries.
- Ecosystem management of living resources including experimental ecosystem studies.
- Coordination and implementation of Southern Ocean Living Resources Programme.
- Establish FORV Data and Referral Centre.
- Semi Commercial Exploitation of Myctophid Resources of Arabian Sea

To fulfill the above objectives, the Marine Living Resources Programme was implemented during the IX & X plan period as a multi-institutional programme with the active participation of Fishery Survey of India-Mumbai, Central Marine Fisheries Research Institute (CMFRI)-Kochi, National Institute of Oceanography (NIO), Central Institute of Fisheries Technology (CIFT)-Kochi, Central Institute of Fisheries Education (CIFE)-Mumbai, National Bureau of Fish Genetic Resources (NBFGR)-Lucknow, Cochin University of Science & Technology (CUSAT)-Kochi, Andhra University, Kerala University and Annamalai University.

Major themes proposed to be taken up during the XI plan under the MLR Scheme are prioritized below.

3.4.1.1 Monitoring & Surveillance of Harmful Algal Blooms (HAB)

The frequency and extend of Harmful Algal Blooms in the world oceans are reported to be increasing due to various anthropogenic inputs to the sea. These blooms adversely affect the living resources by depleting nutrients and dissolved oxygen, cause Paralytic Shell Fish Poisoning (PSP) in humans which is fatal and destroy coastal aquaculture farms. Taking these into consideration the International Panel on HAB (IP-HAB) has advised monitoring and surveillance of blooms in the world oceans, with a view to developing prediction capabilities and reduce the possible economic loses. Under the MLR scheme, HAB monitoring was initiated during the 9th plan period (1998). The MLR-HAB surveys covered 761 stations in the Indian EEZ in connection with the project on Harmful Algal Blooms. Analysis of the species composition revealed that 392 species of micro-algae consisting of 206 species of diatoms, 164 species of dinoflagllates, 16 species of blue-green algae are the most common ones encountered. Among dinoflagllates 13 species were identified as toxic and 8 species as harmful. The diatoms included 2 toxic species and 14 harmful species. Eight species of Cynobacteria spp., two harmful species of Trichodesmium were common in the population. 16 algal blooms covering extensive oceanic areas were observed from FORV Sagar Sampada. These include 7 blooms of Trichodesmium theibautii, 6 blooms of T.erythraeum and 3 blooms of Noctiluca miliaris. In addition 7 algal blooms were detected along the Kerala coast which included 3 blooms of Gymnodinium veneficum, 2 blooms of Noctiluca scintillans and one bloom each of Anabaena spiroides and Hornettia marnia. As an off shoot of the study the distribution of Chlorophyll-a, diatoms and dinoflagellates in the Arabian sea and the Bay of Bengal was chartered and the patterns delineated.

Monitoring and surveillance of HAB in the Indian waters are proposed to be continued during the XI plan period. Data & information from the open ocean will be gathered

through regular cruises of FORV Sagar Sampda. This activity will be undertaken by CMLRE through its HAB Centre. Studies on the near coastal waters and aqua farms along the east and west coasts of India will be undertaken by CUSAT-Kochi, Andhra University, Kerala University, Annamalai University and Manglore University. Genetic characterization of the major toxic species will be undertaken by the National Bureau of Fish Genetics Research(NBFGR) Lucknow. Satellite algorithms for retrieval of algal blooms will be developed through collaboration with Space application Centre(SAC) Ahmedabad. Major objectives during XI plan are to study the bloom formation, bloom crash, role of algal cysts in the formation of blooms, environmental conditions during formation and crash of blooms and to attempt development of models to explain bloom formation. Work components, agencies involved and estimated cost are given below

3.4.1.2 Marine Benthos of the Indian EEZ

Marine Benthos play a major role in the process of mineralization, forms the food material to demersel fish and also support the pelagic fishery indirectly by way of benthic larval forms contributing to the zooplankton biomass. The benthic community in the shelf area are reported to be affected extensively due to bottom trawling operations. The concept of 'closed fishing seasons' has been adopted by many coastal states to revive benthos and the related fishery.One of the major lacuna was the non-availability of bench mark data to assess the impact of bottom trawling and to evaluate the merits of the closed fishing seasons. Taking this into consideration, the MLR project on Marine Benthos was initiated during the 9th plan period (1998). Under this study the macro benthic fauna and meiofauna of both the east and west coasts and their standing stock have been estimated estimated. This was completed in 2003.The country has now a strong bench mark data on the Marine benthos of the shelf waters. However, with regard to the South East coast, it is necessary to reassess the earlier estimates, as these estimates are based only on limited observations. During the X plan period, marine benthos along the continental slope area (200-1000m depth) are being studied, covering macrobenthos, meio benthos and micro benthos. To fulfill the data base requirements, it is necessary to obtain additional information on marine benthos from Andaman and Lakshadweep and also information on micro benthos of the shelf waters covering both east and west coasts. During the XI plan period it is planned to undertake studies covering the Lakshadweep and the shelf waters of the South East coast. The programme components, agencies involved and fund requirements are given below;

3.4.1.3 Southern Ocean Living Resources

Southern ocean fishery resources are presently being exploited mainly by countries such as Spain, Japan, USA, U.K, South Africa, Russia and Korea. The major living resources of the area are the Antarctic Krill(Euphausia superba) and the Patagonian tooth fish (Dissostichus spp). Ice fish(Champocephalus spp) is also available in moderate quantities. Exploitation of the Antarctic Marine Living resources are regulated by a Commission for Conservation of Antarctic Marine Living Resources (CCAMLR). India is a member of the CCAMLR and has the right to claim catch quotas from the Convention area; subject to undertaking the mandatory scientific surveys and assessment atleast once in two years.

The CCAMLR matters of India are coordinated by the CMLRE. The CMLRE had organized an expedition to the Indian ocean sector of the southern ocean for krill exploitation(FIKEX) in 1995. Further, the meeting of the CCAMLR Working Group on Ecosystem Monitoring and Management(WG-EMM) was organized by CMLRE at Kochi during 1998. The MLR group also participated in the Southern Ocean cruise programme

of ORV Sagar Kanya in 2004. The CMLRE also represented India in all the annual meeting of the Commission held at Hobart, Australia in Oct-Nov, 2005.

Taking into consideration the possibility of promoting commercial scale fishing by Indian fishing industry in the southern ocean, it is proposed to conduct expeditions to the southern ocean, once in two years which is a mandatory requirement to obtain catch quotas from CCAMLR. The first such expedition is planned during Jan-March 2008, under the International Polar Year (IPY). Preliminary discussions on this were held with CCAMLR and the Commission in October 2005. Under the IPY scheme, the CCAMLR will be undertaking a 'core project' for assessment of krill and other fishery resources in the Atlantic ocean sector of the Convention area. The core project, which forms the lead project of the CCAMLR will be carried out in the south west Atlantic covering sub areas 48.5, 48.4, 48.3 and 48.2. Many countries with their ships have volunteered to participate in this effort. As per the discussions held at CCAMLR-2005, the Commission has requested India to cover the 0-30 E sector of the south Atlantic which is adjacent to the Western Indian ocean sector. It is proposed to use FORV Sagar Sampada for the said survey. FORV Sagar Sampada which is an ice-strengthened vessel is equipped with all scientific instruments to meet the survey requirements. The instruments on board are CTD, Simrod EK-60 with 38 KHz, 12 KHz and 200 KHz transducers, MPN, Bongo nets, Auto analyser and fishing winches. However, the limitation will be absence of required facilities for bottom long-lining for Dissostichus spp.on board the vessel. The next expedition to the Southern Ocean is planned in 2010 by chartering a vessel or onboard the new vessel which is proposed to be procured as a replacement for FORV Sagar Sampada. During these expeditions, it is planned to undertake the following activities; Resource survey and acoustic assessment of krill and fin fishes, primary production, abundance and distribution of phyto and zooplankton, distribution of marine benthos, studies on marine mammals, studies on avian fauna and hydrography of Antarctic waters. Proposed agencies and financial implications are as under;

3.4.1.4 Sponsored R & D projects under MLR

Sponsored R & D projects on MLR are proposed in the field of "Application Oriented Research" and "Biodiversity and censors of Marine Life". It is proposed to support these following projects during the XI plan period:

3.4.1.5 FORV Data & Referral Centre

CMLRE has been designated in 1998 as the FORV Data & Referral centre. Accordingly, a data centre has been set up at CMLRE and all available FORV data from cruise 165 onwards of the vessel has been pooled. The primary objective of the data centre is to develop 'National Fishery Oceanographic Data Sets' (N-FODS) by pooling all the information available through FORV and then filling up the gaps through data obtained from other sources. The centre is also involved in the development of annual fishery oceanographic bulletins, covering the fishery and the environment for the respective year.

The FORV referral centre maintains all FORV collections for future use and verifications by experts. The objective is to develop the centre as a National Referencing Station on MLR.These are ongoing activities in CMLRE at present.

3.4.1.6 Survey and Assessment of Deep-Sea and Distant Water Fishery Resources

The estimated potential yield of the fishery resources in the Indian EEZ is 3.93 million tons (Silas etal, 2000). The average annual yield at present is 2.80 million tons. The fishery resources of the shelf area are nearly fully exploited. Additional resources to

meet the National demands could be located only from the oceanic region and the benthic realm. However, deep-sea and distant sea fishing possibilities need to be established before commercial exploitations are recommended. Therefore, there is an urgent need to survey and assess the resources and develop adequate harvesting and post harvesting technologies. The fishery surveys conducted by FSI are mostly in the shelf area (upto 200m depths). FORV Sagar Sampada is the only research vessel currently available which can undertake these surveys.

Demersal fishery survey along the Indian Continental slope area (200 to 1000m depth), was carried out during the IX & X plan periods by FORV Sagar Sampada. After a series of experiments with various types of fishing gears such as Expo model trawl, High Speed Demersal Trawl (HSDT) –Fish version, HSDT-Crustacean version, High opening trawl (HOT) and Long wing trawl, it was found that the performance of Expo model trawl was the best for demersal fishery and the HSDT crustacean version for shrimps and lobsters. Accordingly, these two gears have been chosen as the standard gears for MLR-demersal fishery surveys. Using the above two standard gears, 192 fishing operations were carried out in the deeper waters above 200 to 1000 meters. 30 trawl operations were conducted employing HOT, HSDT-FV and Long wing Trawl. The average CPUE was 185Kg/hour. The findings that most of the ground surveyed have potential for developing commercial fishing for shrimps and lobsters is encouraging. However, before scientific advise on resource availability and maximum sustainable yield (MSY) are transferred to the fishing industry, there is an urgent need to satisfy the following conditions.

(i) Each grid (60x60NM) is surveyed successfully at least thrice using Expo and HSDT trawls per season and for the coverage of one grid, it is suggested to undertake 3x2x3=18 fishing operations. Since the Indian Slope area (200-1000m depth) fall under 32 such grids, the minimum fishery operations required is 576. Of this 192 operations were carried out during the 9th plan period (1998-2002, extended upto March 2003). The X plan survey programs commenced only in July 2005 due to various administrative reasons, and only 85 fishing operations will be possible by end March 2007 due to limitations in vessel availability. The remaining 299 operations are planned to be completed between 2007-2012.

(ii) Earlier surveys used only demersal fish trawls and no effort was made to quantify the cephalopod and other commercially important resources in the water column. This was mainly due to non-availability of standard Rectangular Mid water trawl. Since these trawls have been received in 2005, this gear will be used for the mid water trawl surveys as part of the XI plan activity on the survey of commercially important groups in the deep and distant waters.

(iii) The resource availability at non-trawlable grounds (uneven grounds) are proposed to be undertaken by trap fishing and pot fishing. Bottom long-lining will also be attempted subject to availability of suitable long liners.

(iv) Survey plans for XI plan to be extended upto 1500m depths.

(v) Special efforts are necessary to quantify tuna resources and distant water resources of the Central Indian Ocean. This would be an important work during the XI Plan.

The CMLRE has designed the major theme 'Survey and assessment of deep sea and distant water fishery resources' after conceptualization and following detailed discussions with the CMFRI, FSI and CIFT. Major components of the theme and agencies involved are given below along with the estimated Budget requirements.

3.4.1.7 Semi Commercial Exploitation of Myctophid Resources of Arabian Sea

Myctophids are major resources occurring in the Deep Scattering Layers (DSL) of world oceans. Under the MLR Scheme, preliminary studies on the DSL bio composition and the trophic relations of DSL organisms were worked out covering the Indian EEZ. Studies carried out by the U.S. GLOBEC (Global ocean Ecosystems Dynamics Research) has indicated availability of around 100 millions tons of myctophid (Benthosoma) in the Central and Western Arabian sea. Since the species have only a short life span (less than one year) the bio mass is generated and sustained on an annual basis. The Somalia upwelling and the Findlater's jet perhaps play a major role in sustaining the huge biomass in the Arabian sea. Though not preferred as an edible item due to their high lipid content (HDL) containing esters of wax, the feasibility of utilizing these abundantly available resource, for extraction of crude oil and preparation of animal and aquaculture feed, need to be explored. With adequate post harvesting technologies, it may be possible to refine and make the oil edible. If such R&D attempts are successful, this can lead to high economic returns for the country, as the international demand for oil with HDL is very high.

In the light of the above, semi commercial exploitation of these resources are planned during the XI Plan period. The area of exploration will be the Central and Western Arabian sea. FORV Sagar Sampada is planed to be utilized for these studies. The vessel has recently been equipped with Tucker trawl, Cosmos-RMT and CIFT designed RMT, which can be effectively used for these surveys. Acoustic estimates of the biomass can be undertaken with the EK-60 Echo sounder on-board. The EK-60 has 38KHz ,120KHz and 200KHz transducers to support the proposed acoustic surveys. Agencies involved, work components and estimated cost are as under;

3.4.1.8 Ecosystem Management of Living Resources including Experimental Ecosystem Studies.

The ecosystem approach to the management of living resources is being adopted by many countries. The classic example is the CCAMLR-Ecosystem Monitoring Programme(CEMP) which is considered as a major success by many international organizations. With a view to developing an ecosystem model for our waters, the MLR scheme has been monitoring the physical and biotic components of the Indian EEZ since 1998, through dedicated cruises of FORV Sagar Sampada. The Indian EEZ is surveyed by covering 8 transects(16 diurnal stations and 34 routine stations) along the west coast, 6 transects(12 diurnal stations and 20 routine stations) along the East coast and 5 transects (31 routine stations) in the Andaman sea. In each transect, one diurnal station is selected near the coast and another in the open ocean. Physical parameters such as vertical temperature and salinity profiles, Dissolved oxygen, nutrients (such as phosphate, nitrate, nitrite and silicate), current patterns etc from all the said stations were measured following standard measurement protocols. Biotic components such as primary productivity, chlorophyll concentration, phytoplankton distribution and abundance , zooplankton distribution etc are also measured at each station at standard depths from surface to 1000meters. Information on coastal process including upwelling and mud bank formation are also being gathered through sponsored projects. Based on

these studies, the column productivity for the west coast, East coast, and Andaman waters have been established. The role of microzooplankton in grazing has been established with fairly good accuracy. Also, the distribution of fish eggs and larvae in the Indian EEZ have been worked out under the ongoing scheme.

During the XI plan period, while continuing with the monitoring and survey programs, it is also planned to utilize the available information for the development of Ecosystem models. Development of such models integrating the primary, secondary and tertiary production will help in adopting scientifically designed management strategies for the living resources of our waters. Further, experimental ecosystem studies employing controlled ecosystem experiments in areas already surveyed by Sagar Sampda during the last two plan periods could be an important activity under this programme. The output from this exercise is expected to offer necessary values for the variables to construct and prepare models to estimate the trophic dynamics of the EEZ. Research components, agencies and budget for the study are as under;

Implementing Agency : CMLRE
Financial Requirement: Rs. 97.00 crores.

Activity	2007-08	2008-09	2009-10	2010-11	2011-12	Total
Monitoring & Surveillance Of Harmful Algal Blooms (HAB)	0.90	1.35	1.13	0.68	0.45	4.51
Marine Benthos Of The Indian EEZ	0.70	1.05	0.88	0.53	0.35	3.51
Southern Ocean Living Resources	6.00	9.00	7.50	4.50	3.00	30
Sponsored R & D Projects Under MLR	3.90	5.85	4.88	2.93	1.95	19.51
Survey And Assessment Of Deep-Sea And Distant Water Fishery Resources	0.80	1.20	1.00	0.60	0.40	4.00
Survey And Assessment Of Deep-Sea And Distant Water Fishery Resources	3.30	4.95	4.12	2.48	1.65	16.50
Semi Commercial Exploitation Of Myctophid Resources Of	1.89	2.84	2.36	1.42	0.95	

Arabian Sea						9.46
Ecosystem Management Of Living Resources Including Experimental Ecosystem Studies.	1.90	2.85	2.38	1.43	0.95	9.51
Total	19.39	29.09	24.25	14.57	9.7	97.00

3.4.2 Development of Potential Drugs from the Ocean

Nature has been instrumental in providing effective therapeutic entities. The terrestrially derived therapeutics have laid the foundation of medicine. The marine ecosystem covers more than 70% of the earth's surface but represents 95% of the biosphere. It is known that marine species comprise approximately a half of the total biodiversity, thus offering a vast source for discovering useful pharmacotherapeutics.

The pharmacological exploration of the oceans seriously began over 25 years ago with the advent of scuba diving and submersibles. The important marine derived therapeutics include Manoalide, a non steroidal sesqueterpenoid as a potential anti-inflammatory analgesic. Manoalide is the first inhibitor of phospholipase A2 and its therapeutic potential is being explored in a number of disorders. An impressive immunosuppressive agent, discodermolide is 100-1000 times more potent than cylosporine-A. Interestingly antimalarial compound axinositrile 3 is active against resistant strains. Also new polyesters from marine dinoflagellate demonstrated in vitro 2000 fold activity as compared to anfotericin B. Besides this a number of ion channel, G-protein receptors agonist/antagonists have shown promising activity in certain disorders.

The National project on Development of Potential Drugs from Ocean was taken up for implementation from 1990-91 onwards with a view to harnessing the potential marine flora and fauna for extraction of drugs for medicinal purpose. The programme has been successfully coordinated by Central Drug Research Institute, Lucknow involving 9 other participating centers. The progress includes antidiabetic preparation of successful completion of single dose clinical trial-phase-I in humans. Another antidyslipidemic marine preparation has been found safe in chronic toxicity studies in monkeys and efforts are on for filing IND to DCG(I) for obtaining permission for Phase-I clinical trial in humans. Besides these two more marine fractions having antidiabetic cum antidyslipidemic bioactivities have shown very good promise with wide therapeutic window. The regulatory pharmacology studies of these have been completed and safety toxicity studies are underway. The project has also identified six new leads in the area of antifungal, spermicidal and antidiabetic activities for product development. Six patents and two Patent Cooperation Treaty (PCT) have been filed. There has been isolation of more than one hundred new chemical entities with novel chemical structures for

providing insights into chemical synthesis of diverse molecules of pharmacological interest.

A quarterly bulletin OCEAN DRUG ALERT is regularly published by CDRI containing latest information on marine bioactivity and IPR issues. The steering committee meetings are regularly held to review project progress.

The major objectives of the programme during the Eleventh plan will inter-alia include:-

Exploratory work:-

- Systematic exploration of the entire coast line and collections made from deep sea as well for identification of more flora and fauna having potential for drugs and chemicals.
- Large-scale collection of identified active materials for characterisation and structural determination and for follow-up studies.
- Assessment of neurotoxic potential of marine organisms vis-a-vis for developing new pharmacological tool.
- Collection, extraction and biological evaluation of over 500 species, and evaluation of these leading to possible development of new drug(s), particularly in the area of anticancer, anti-inflammatory and immunomodulation.

During XI Plan the activities are proposed to be expanded in the following areas :

Introduction of new in vitro test systems, enzymes 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 anticancer, anti-inflammatory and immunomodulatory activity of marine samples.

A herbarium museum is necessary to preserve the collected and authenticated specimens for further records and proper identification. CDRI possess one of the largest herbarium of terrestrial plants in India. Establishment/strengthening of marine flora and fauna herbarium at CDRI the nodal institute, will supplement the facilities accessible to scientists in the northern and eastern region of the country.

Establishment of Center of Excellence for drugs from Ocean.

During X Plan progress was made in development of drugs for anti-diabetic and anti-hyper lyperlipdemic. Two more new compoiunds were also discovered for pharmological strudies. The collection of samples, extraction and bio-evaluation for active compounds are being carried out on continuous basis. The Minisstry has inititated action towards involvement of industries under the Programme. The Ministry also felt to give thrust to this programme and prepare for creating a centre of excellence to accelerate the development work in a focused manner.

The estimated fund required for this project would be Rs.110 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
10.00	20.00	30.00	30.00	20.00	110.00

3.4.3 Assistance for Research Projects

The mankind relies on the oceans for food, transport, recreation, minerals, energy, etc. They play an important role in the dynamics and evolution of the global climate and biochemical cycles and are at the same time a major source and sink of

various atmospheric trace gases and aerosols. The quality of the marine environment is influenced by both natural processes and human activities, notably by the discharge of emission via sewage pipelines, rivers, oil spills and by ship motor exhausts, off-shore installations, over-exploitation of the living resources, dredging and dumping, tourism and recreation. The ocean has a limited self-cleaning capacity, but how far can we carry on without jeopardising our future and that of our children? Understanding the system earth through research provides a part of the answer.

Both short-term and long-term applied and management oriented research programmes in the ocean sector are needed to enable the planners and policy makers to formulate the national and international policies for sustainable exploration and exploitation of the vast ocean resources for the socio-economic benefit of the coastal community.

Capacity Building is a basic pre-requisite for monitoring, assessment and exploitation of the marine resources. This should include human resources development through education, training and awareness, as well as enhancement of institutional infrastructures through the provision of laboratory equipment and communication facility such as inter-net connectivity, with a view to updating information and knowledge on marine sciences.

As per the Allocation of Business Rules, policies including co-ordination, regulatory measures and development relating to research (including fundamental research) and the development of oceans are related to the Ministry of Ocean Development. The Ocean Policy Statement enshrines this mandate by identifying human resource development in scientific and technological programmes in the ocean sector.

The concept of stewardship can be fostered only through education and by increasing awareness at all levels. In line with the objectives as envisaged in the Ocean Policy Statement, Ministry of Ocean Development is supporting the frontline areas of research in marine sector, right from its inception with an objective to create excellence in basic and applied marine research and capacity building. The Ministry of Ocean Development has been assisting the Universities to augment the existing infrastructure facilities and building up a skilled human resource base in Ocean Science and Technology and also supporting ocean awareness programmes, by participating in exhibitions and fairs, sponsoring seminar, workshop, symposia, etc. The Vision Document – Perspective Plan 2015 of the Department reflects the need for initiatives to be implemented at primary, secondary and tertiary levels to inculcate an appreciation of the interdisciplinary nature of the ocean at school, college and university levels.

One of the major priorities attached in the country today for ocean management and development is human resource development through training, provision of expertise, etc. The continuing Marine Research and Capacity Building programme not only promotes basic and applied research in ocean management and development, but also provides expertise and training in different disciplines of ocean science to the neighbouring centres/institutes. In a number of other countries also, depending upon the country's need, expertise is being developed in the field of ecosystem management particularly for protection and conservation of coral reefs, mangroves, sea grass beds, pollution monitoring, integrated coastal zone management, global change, sea level variation, air-sea interaction, marine living resources enhancement, coastal and marine ecology, marine biology, marine geology and geophysics, marine minerals and metals,

technology development for tapping the marine resources, underwater application and a number of other areas of concern.

The policies and the overall direction of the programme would continue to be guided by the National Steering Committee chaired by the Secretary, MOOD that comprises of the Vice-Chairmen of the OSTCs, the Research Coordinators of OSTCs and the Programme Director at MOOD Headquarters. The monitoring of the research programmes at the individual OSTCs would be overseen by the Vice-Chairman of respective OSTC – a Departmental nominee – through the mechanism of OSTC Management Board (the Vice-Chancellor of the University being the Chairman of each of these Boards) and actual implementation would rest with the Research Coordinator of the OSTC nominated by the Institute/University.

To promote research in different fields of marine sciences and technology, being pursued in Academic Institutions, National Research Laboratories, R&D Institutions, etc. Under this programme funding support would continue to be provided for both basic and applied research in Ocean Science & Technology, which are not covered under the ongoing programme of establishment of OSTCs. The duration of each of these projects to be sponsored by the Department would be for a minimum of 3 years with a provision to extend the duration by one more year, with specific objectives and goals. The major aspects to be addressed through these programmes would inter-alia include:

Global Change
Polar Science
Bioremediation
Bioactive Compounds, chemicals, toxins etc., from marine organisms
Biofouling
Biological Oceanography
Marine Botany
Marine Chemistry
Paleo-climate and Paleoceanography, etc.

Depending on the expertise available in the academic institutions, national research laboratories, etc., inter-institutional projects will be encouraged.

3.4.3.1 Ocean Science & Technology Cells (OSTCs)

The identified areas fall under the following basic categories:

- Marine Ecology
- Marine Biology
- Marine Microbiology
- Marine Benthos
- Coastal Marine Culture Systems
- Marine Geology/Geophysics
- Marine Placer Deposits
- Ocean Engineering and Underwater Robotics

The main objective of these OSTCs is to undertake front-ranking and applied research in the above areas with a view to provide the base for application of such results for the benefit of mankind.

It is proposed to continue the funding support to these OSTCs by doubling their number, possibly upgrading one or two OSTCs into Centres of Excellence, as a means of promoting research and development and for human resource development, particularly in Academic Institutions.

(a) Marine Ecology:
The major areas of study would cover the ecosystem ecology of the coastal and marine environment representing the ecology of mangroves, coral reefs, sea grass; physical and chemical oceanography with particular reference to pollution monitoring and bioremediation, phosphate solubilisation in marine habitats, biodegradation in marine ecosystems, etc, covering both east and west coast including the island groups.

(b) Marine Biology:
The major areas of study under the MOOD Centre of Excellence on Marine Biology would encompass biology of live feed organisms, eggs and larvae of fin and shell fishes, rejuvenation of corals and mangroves, bio-indicators and sentinel organisms, biology of potentially exploitable, endangered, threatened marine organisms, biology of coastal toxic marine micro-algae, biology of marine ornamental fishes and micro-invertebrates of commercial value, biology of luminescent organisms, etc.

(c) Marine Microbiology:
The main areas of study under this discipline would encompass survey of various microbes in different coastal biotics, their role in biogeochemical, nutrient and element cycles in sensitive ecosystems, bio-leaching of metals, bio-fouling and bio-corrosion of marine structures, marine feed contamination and spoilage of sea feed, extraction of bioactive compounds from marine microbes, use of micro-organisms as biosensors, etc. In keeping with Planning Commission's thrust in this area, the Expert Group (June 2005) on Antarctic and Marine Microbiology recommended establishing an exclusive Antarctic Microbial Reference Centre at NCAOR, Goa and a Marine Microbial Reference Repository at Goa University. NCAOR, Goa would be the agency coordinating Antarctic Microbiology programmes while the OSTC would be responsible for Marine Microbiology supervised by a National Steering Committee for Antarctic and Marine Microbiological Research chaired by the Secretary, MOOD. The key areas to be focussed on are Coastal and Marine Ecosystem including microbial biodiversity & phylogeny of coastal & marine environment, satellite based studies on microbial communities, marine bioprospecting, marine microbial genomics, etc. and Antarctic Microbiology including biodiversity of Antarctic microbes, bioprospecting of Antarctic microbes, molecular basis of cold adaptation, viruses from Antarctica, etc.

(d) Marine Geology and Geophysics:
The major activities under this discipline would include coastal geomorphology oriented towards Natural Hazard Management, creation of core repository/remote sensing laboratory and databank for future studies; Paleo-climatic and paleo-oceanographic studies with reference to global change and climate variability, application of RS & GIS for CZM including coastal geomorphology and related aspects.

(e) Marine Placer Deposits:
The major activities proposed under this OSTC would cover beach placer mineral exploration, techno-economic feasibility of their exploitation, environmental management plan for mining and processes, development and cost effective process technology, etc. The other activities would include establishment of data bank and database management, human resources development through training, preparation of coastal

maps showing the deposits, geo-morphological maps of the coastal zone, modification of the recovery processes and economics for processing, identification of potentially rich placer sites for environmental safe mining, etc.

(f) Marine Benthos:
The major areas of research under this OSTC would include the studies on coastal biomass, study on benthic resources and ecology of coral islands, benthos of the deltaic areas and establishment of a reference centre for benthic organisms.

(g) Coastal Marine Culture Systems:
The studies under this OSTC would focus mainly on breeding and culture of a number of commercially important fin and shell fish species, nutrition and health management of marine cultivable species: Aquaculture engineering and culture system, development of waste water treatment methods for coastal aquaculture systems, etc.

(h) Ocean Engineering and Underwater Robotics:
The major thrust areas identified under this OSTC are design and development of autonomous underwater vehicles, biomimetic underwater vehicles, and underwater sensor network & signal processing. The emphasis will be laid on design, component development and system integration for the vehicle, underwater robotic control system, underwater image and data communication systems and integration of vision and control systems for semi-autonomous and fully autonomous vehicle navigation and manipulation of robots.

3.4.3.2 Manpower Development:
Manpower development is a critical area, which contributes to development of specialised skills in ocean science and technology leading to overall development in the region. The main objective of this programme is to create adequate expertise in various disciplines of ocean sector for management, development, conservation and judicious use of its resources. This is also dealt separately in this document.

It is proposed to continue the ongoing programme of award of research fellowships to students for pursuing higher studies in academic/educational institutions, national research laboratories, ICAR research institutes, etc., in various disciplines of ocean science and technology.

Award of Research Fellowships
The main objective of this new programme is to upgrade the R&D structure under the Marine Research Programmes implemented by OSTCs through provision of skilled manpower at higher levels. For enabling a transformation in quality of research in ocean sector, it is proposed that the present scheme of manpower development is strengthened with enhanced allocation of fellowships under the major thrust areas. The fellowships would cover the 9 disciplines addressed by the OSTCs. The details of such fellowships are as under:
(i) One National Professor (Emeritus status)
(ii) Three Research Scientists
(iii) Five Research Associates
(iv) Fifteen Senior Research Fellows
(v) Thirty Junior Research Fellows

Assistance for participation of Indian Scientists in training, workshops, seminars, symposia, etc., abroad in frontier areas of ocean sector:

A number of scientific institutions and departments in the country are providing financial support to the young scientists for participation in conferences, seminars, symposia, etc., and for undergoing training abroad in different disciplines of arts and science. Such a facility is not available for young ocean scientists, be they from the Department or outside it, in any of the programmes of the Government/Ministry of Ocean Development. It is therefore, proposed that a programme for providing financial support to the young ocean scientists from India in international training programmes and participation in workshops, seminars, etc., abroad is introduced during the XI plan period. It is proposed that atleast 50 young ocean scientists in a year could be identified for providing such assistance.

The fund requirement for this programme would be Rs.137.00

2007-08	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**TOTAL**
15.40	22.40	29.40	39.40	30.40	137.00

3.4.4 Coastal Ocean monitoring and Prediction System (COMAPS)

In brief the following activities will be continued on modified structure

i) Monitoring of marine pollution along the coast line at critical areas identified during X Plan. The frequency of monitoring and other location where changes are not visible would be decided accordingly
ii) Modeling of movement of pollutants and their fate in phased manner in all hot spots
iii) Continuation of development of GIS based information systems for sources of pollution
iv) Continuation of measuring organic pollutants in the sea
v) Continuation of oil spill models at selected locations using hydro dynamic and water quality models/data.
vi) Provide advisory to Govt. industries etc. aimed at evolving pollution controlling measures.

The estimated fund requirement in this project would be Rs.78.00 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
15.60	23.40	19.50	11.70	7.80	78.00

3.4.5. Ocean Awareness(Exhibition, Fairs etc)

One of the activities of the Department is to bring Ocean Awareness among sea users for exploration, exploitation, preservation and conservation of Ocean resources; and to educate them with recent investigations of Ocean Science and developments in Technology that can deliver products for the benefit of social communities who mainly depend on sea for their live-hood. The viable Research and Developmental results on substantial utilization of ocean resources along with the latest information on preservation of marine ecosystem are to be propagated among the sea users through some mechanism viz seminars, symposia, exhibitions, awarding medals etc for conserving the ocean resources. Other propagation media is by displays, special publications such as brochures, books etc, screening suitable films on underwater

resources in schools, collages, News papers and magazines, Television media etc; through Lectures, Debates, Painting competitions etc in public places; by organizing workshops in their local languages. Awareness also aimed at to attract talent through various attractions and grooming them with better facilities to enable them to concentrate more. The topics to be covered are the Marine Living and Non-Living Resources, Climatologically and the dependency by people, Coastal Erosion and Ocean processes, Antarctic Science and their related activities, Socially related activities including preservation of Ocean Resources and safety of fishermen at Sea, Marine Pollution, Marine eco-friendly system mechanisms, OTEC etc. The Department has so far been participating in National and International Exhibitions including Trade Fairs and supporting the Ocean related courses, seminars, symposia, conferences, workshops and strengthening Museums & Planetariums with Ocean themes etc.

OBJECTIVES:

o To create awareness among public for optimal exploitation, preservation and conservation of ocean resources.

o To support the ocean related seminars, symposia, workshops, conferences etc for creating a platform for interaction between Scientists, Experts, General Public and sea users to exchange knowledge and views.

o To create facilities / infrastructure for enabling the people to see the real marine life under sea world environment.

o To propagate the messages in remote coastal villages also, for purpose to bring awareness on Marine Ecosystem and also to create Ocean scientific knowledge among sea users.

o To inculcate scientific temperament among children and others to enable to attract good students towards ocean science studies.

o To create facilities to people for exposing to see real marine life in marine environment.

o To award medals for contributors for preserving and conserving ocean resources.

The Department has been celebrating the Ocean day on the day 27 JULY of every year. Some notable contributors for Ocean activities have been decorated with medals etc. Results achieved during this period are being displayed. Some schoolchildren in Delhi have been participating in the calibrations.

PROPOSED ACTIVITIES FOR THE XI PLAN:

<u>Exhibitions, Fairs etc:</u>

It is proposed :

o to prepare/ get Exhibits including LIVE MODELS etc from the respective MOOD organisations or at Head Quarters of to have uniformity regularly by incorporating the latest knowledge.

o to prepare/get Panels etc through modern display technology preferably in multi-media environment and in the local language to enable the users/ Visitors to understand better.

o to bring suitable and attractive stickers (OST messages), small diaries, pamphlets, video films, photos etc in simple regional languages for distribution among public including school children.

o to print booklets, banners, books on popular Ocean Science and Technology etc in local languages for students, educated people and uneducated mass and also distribute them through State Governments, NGOs, schools and colleges etc.

o to develop Computer based Software Packages for " OCEAN QUIZ" to create enthusiasm and interest among the children, students and General Public and to award certificates and prizes to merit students.
o to participate in selective International Exhibitions and also to organize them in India to have exposure on WORLD ocean knowledge.
o Since State Governments would be organizing Exhibitions in some of its important towns and cities on special occasions, it is proposed to participate in selective exhibitions.
o to establish a permanent Exhibition Pavilion at ITPO, Pragati Maidan with the live working models like the Desalination Plant, Ocean Information Services etc.
o to involve selective Non-Government Organisations for conducting various activities to enable even to have door to door canvassing for the preservation of ocean resources.

WORKSHOPS ON MODERN TECHNOLOGIES AND TECHNIQUES:
o It is necessary to bring awareness on Modern Techniques and Technologies for utilization of ocean resources among traditional and conventional users. As it is not possible to gather them at one fully equipped center, it is proposed to go to their villages with proper material, equipment etc to spread the message in their local Language.

It is proposed :
o to strengthen with at least 10 Mobile Vans and assign this task OSTCs, NIOT, INCOIS, ICMAM, CMLRE, NCAOR and request to take them as part of centre's activity.
o to strengthen the training facilities in Training Schools under Government and NGOs for training traditional users on optimal utilization of Ocean resources, along the coastal line.
o to organize some Training programmes through NGOs', to helping Hands to enable them to conserve the Ocean resources and also to enhance their earnings etc. and to award the best organisation on Ocean's Day function.
o to encourage some active marine fishermen Associations/ Societies for abroad Training on conservation of Ocean Resources and for spreading the safety of fishermen on sea and to award some medals for selective for their outstanding contributions on Oceans Day celebrations at Delhi.

MUSEUMS AND AUGMENTING PLANETARIUMS ETC:
Department has been supporting to built infrastructure on Ocean themes in Planetariums and running some courses and supporting Research also to generate combined knowledge. Some museums were also funded for Ocean Flora and Fauna displays of. It has funded Birla Planetarium, Hyderabad.

It is proposed:
o to establish permanent Museums in MOOD Organisations NIOT, INCOIS, ICMAM, CMLRE, NCAOR including OSTCs to propagate their activities and to popularize in their localities and Districts, and also bring the children and public even with MOOD transportation.
o to display the collections of Marine Resources including Flora and Fauna in museums and to award suitable prizes, certificates for active participants.
o to establish a Museum at MOOD Headquarters, Delhi.
o to keep the OST Exhibition at National Science Museum, Delhi on permanent basis and to display MOOD Exhibitions through National Science Museum in all its centres on rotation basis.
o to strengthen Nehru Planetarium at Teen Murthy Bhavan , Delhi.

MARINE AQUARIA, OCEANARIA:
Number of marine species like horseshoe crabs, olive ridley turtles, few coral species of fish etc live in the coastal and near-shore waters. The marine life in the marine environment is to be shown to the Public to understand better. The advancement of Submarine Structural Technology during the last few years has led to idea for establishment for undersea observations, such as OCEANARIA MARINE AQUARIA etc. This permits the viewers to see the living habitats of the marine animals under the natural conditions. Some State Government have been maintaining Marine Aquaria with few Marine Ornamental Fishes.

It is proposed :
o to set up MARINE AQUARIA, OCEANARIA in the Private Sector and to start such activities in important cities like Madras, Bombay, Visakhapatnam, Calcutta, Goa, Cochin, etc.
o to strengthen MARINE AQUARIA with State Governments suitably as per understanding with respective State Governments.
o to maintain at least about 350 species of marine animals viz. sharks, turtles, rays, colorful fishes, corals etc in various Marine Aquariums.
o to create additional infrastructure for incorporating the possible ocean awareness programmes/ Exhibitions in these places.

OTHER PROGRAMMES:
Department has been conducting OCEAN QUIZ programmes among school children and Public and awarding certificates, medals etc. To attract talent and grooming them from childhood onwards it is the need to support them with attractive schemes and programmes.

It is proposed:
o to conduct a centralized computer based quiz contest on every month and award suitably through their schools/colleges etc.
o to encourage some outstanding students for participation in Antarctica expedition programmes and on short cruise of MOOD Vessels.
o In order to attract the talent from early age and preparing them from primary classes onwards, proposed to introduce at least two to three chapters on OST in secondary and senior secondary subjects.
o to award National Scholarships for selective students from secondary and senior secondary classes onwards till Post Graduation and the students can be selected on all India basis through National Talent Tests and other competitive exams viz JNU entrance test etc. Also proposed to honor merit students with certificates and medals on Ocean Day celebration the 27 July.
o to involve the OSTCs, NIOT, INCOIS, ICMAM, CMLRE, NCAOR in this programme to organize them as per schedule.

a. AWARD OF MEDALS FOR OST PROPAGANDA/ CONSERVATION:
Attraction could be by awarding National medals i) to outstanding students of various classes; (ii) for best project-works at Graduate and Post Graduate students; (iii) for best Ph.D. Thesis and research results, (iv) for works related to ocean resources conservation for NGOs, and for awareness programmes for marine fishermen societies etc for promotion various activities, and (v) decorating the distinguished personalities in Ocean Science and Technology (OST):

b. OCEAN DAY EVENTS AT OTHER PLACES:

Celebrations of Ocean Day are proposed in Academic Institutes including Universities and Non Government Organisations who are involved in activities of Oceans Sciences and Research, in selective colleges and schools, and Coastal States and Union Territories of Marine Fisheries Departments.

c. DEPARTMENT VESSELS' FOR PUBLIC VISITS:

It is proposed:

o to station the MOOD vessels near the Ports/ Harbours around July 27 for few days for the visits of General Public including school children etc and to display OST exhibits on board vessel.

o to notify in newspapers about the of vessels' schedule and their visiting Timings.

SEMINARS, AND SYMPOSIA

Department provides assistance for organizing seminars, symposia, conferences etc to various Institutions, Research Organisations, Non Government Organisations etc for purpose to create a common platform for Scientists, Academicians, Sea users, General Public and Marine Industries to interact with the professionals for exchanging the information. The recommendations generated from these meets would give feedback to formulate new programmes by MOOD for sustained Research in Ocean Sciences and Technology Development as well to derive wider benefits to the society.

It is proposed:

o to support conferences seminars/ symposia etc in the field of OST form Head Quarters.

o to release funds to selective schools and colleges located in coastal places to celebrate oceans' week around the Ocean day 27, July.

o to organize popular Lectures by Experts, Scientists, Social Scientists, retired Academicians etc on ocean themes.

o to organize Essays writing, Debates, Drawing and Painting competitions etc in all possible Schools, Colleges, Universities/ Institutes, just around the Ocean Day July 27 and to present suitable awards for winners. Proposed also the National awards for students selected through these events on the Ocean Day at Delhi for their outstanding contributions.

o to organize the workshops in local languages at various places. During this period proposed to station MOOD Research Vessels in possible nearest Ports/ Harbours which may be available at the time, to attract the local public including school children. and to give wide publicity in the local languages for active participation.

o to organize some of these programmes through selective NGOs in each Coastal States and Union Territories.

o to use Ocean Science & Technology Cells (OSTCs) of MOOD, National Institute of Ocean Technology (NIOT), National Centre for Antarctica and Ocean Research (NCAOR), Indian National Centre for Ocean Information Services (INCOIS), Centre for Marine Living Resources and Environment (CMLRE), Integrated Coastal and Marine Area Management (ICMAM) etc to organize the Exhibitions and to conduct seminar, symposia, workshops, popular Lectures and also to finalize the list of awardees etc.

The fund requirement for this programme would be Rs. 100 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
10.00	30.00	30.00	15.00	15.00	100.00

3.4.6 Integrated Coastal and Marine Area Management Programme

The Integrated Coastal and Marine Area Management (ICMAM) programme of MoES is engaged in the application of scientific tools and techniques to solve the problems of coastal erosion, accretion, pollution etc prevalent along the coastal areas. These help in integrated management of the activities in the coastal areas and ensure their long-term sustenance. The functions of the ICMAM Project Directorate which was formed in Sep 1997 to implement capacity building programmes to start with funding from the World Bank, are being continued from the plan funds provided by the Ministry. Since the activities relating to coastal zone management are long term in nature and and having made significant progress in achieving the objectives of the above activities, it is proposed to convert the Directorate as a permanent R & D centre of the Ministry.

The coastline of the country has been facing severe erosion in the states of Kerala, Tamil Nadu, Andhra Pradesh and West Bengal and in Union Territories of Pondicherry, Andaman & Nicobar and Lakshadweep. Several efforts have been made by the State Governments in protecting the coasts which have been found to be inadequate in terms of design and execution. The major lacunae observed was lack of a holistic approach in developing projects relating to coastal protection. Lack of thorough investigations on the coastal processes while designing the structures led to several cross impacts like erosion of the adjacent coasts and accretion at the nearby river mouths. The ICMAM programme on Shoreline Management presently studied the coastal processes through extensive modeling studies at Ennore, Munambam to Kayamkulam, Vellar and Netharavathi estuary and predicted the likely changes of coastline in future due to existence of ports/construction of sea wall/training jetties at these locations. Such programmes need to be continued along the coastal areas to identify more areas vulnerable for coastal erosion and accretion at river mouths. These outputs are useful for development of Coastal management plans.

The projects on Ecosystem Modelling at Cochin Breakwaters and Chilka Lake have yielded valuable information on the role of physical and chemical parameters in governing the biological regimes. Since these exercises have been taken up in small areas in Cochin Breakwaters and at a Macro scale in Chilka Lake, it is necessary to expand this programme during the Eleventh Plan to cover the entire Cochin Breakwaters and at micro scale in Chilka Lake. Since the Chilka Lake has been subjected to physical changes due to creation of an artificial mouth, a comprehensive long-term perspective on circulation in the lake and consequences on the chemical and biological regimes also need to be covered under the proposed programme during the Eleventh Plan.

The Marine Ecotoxicology programme has helped in determining safe limits for heavy metals like cadmium, mercury and copper in seawater. These limits are useful in coastal water pollution control strategies. It is necessary to continue these activities for determination of safe limits for other heavy metals, insecticides and phenolic compounds that are present in the seawater.

The ICMAM Project Directorate is carrying out modelling of propagation of tsunami waves and their inundation in the coastal areas as a part of the programme on

Tsunami Early Warning System. This programme will be completed in the initial period of 11th Plan. While the outputs from the programme yield the information on vulnerability of an area, a comprehensive map indicating areas vulnerable to natural hazards, status of pollution and safe areas for swimming etc. would help in planning preventive measures. Such maps in the form of Coastal Risk Atlas will be prepared during 11th Plan. Concerned coastal state agencies be trained to develop similar Atlas for other areas in the State/UT.

The activities proposed to be carried out in detail during the 11th plan period would be as follows:

3.4.6.1. Assessment of vulnerability due to shoreline changes

The 10th Plan programme on shoreline Management has helped in prediction of coastal erosion in the coming years at Ennore, Munnambum to Kayamkulam and at Ullal. It has also helped in the assessment of extent of accretion of sediment in the river mouth like Vellar estuary. These information have been found to be useful in developing suitable remedial measures which would minimize the erosion and also accretion at respective locations.

The shoreline of the country is vulnerable to changes especially due to coastal erosion and accretion due to natural and man-made activities. In order to assess the vulnerability of shoreline, the Shoreline Management programme will be extended during 11th Plan period by undertaking similar investigations predicting shoreline changes in future at selected locations along the east and west coast of the country. Few supporting activities like software development for modelling, satellite based sea erosion watch etc will be taken. The outcome like areas vulnerable for erosion will be useful while planning developmental activities, human settlement in and around these areas. In other words, it would be a valuable input to the Coastal Area Management Plans of each state. Preparation of such plans by coastal States/UTs are mandatory under the CRZ Notification (1991).

3.4.6.2. Determination of Waste Assimilation Capacity of coastal waters

The programme of Waste Assimilation Capacity undertaken at Ennore, Tapi and Hooghly during the 9th Plan have helped in the assessment of the extent of assimilation of putrified organic matter in the waters at these locations. A physical oceanography component to study the diffusion and dispersion characteristics of pollution as a part of the COMAPS programme is also being carried out. The coastal states have been planning to set up industrial complexes along the coastal areas of the country and also expanding suburban areas, however, without any prior assessment of the extent of assimilative capacity of coastal waters for the sewage, chemicals and other substances that will be released into the coastal waters. Further there is no cumulative assessment on adverse impact of waste on water quality when more and more industries that dispose waste into the coastal waters are added during the course of time. Such lack of understanding of long-term adverse impact of degradation of coastal waters for chemical elements lead to severe reduction in biodiversity. In order to predict the pollution scenarios of existing waste disposal locations and to help the coastal states to decide addition of more industries, it is proposed to conduct waste assimilative capacity of coastal waters of selected locations during the 11th Plan period. The objectives of the physical oceanographic component of COMAPS programme will also be accommodated under this study. Wherever, the project sites of shoreline changes and the waste assimilative capacity areas are common, an integrated coastal area management plan

will be recommended with appropriate planning strategies for location of ports, industries, human settlement and beach tourism development.

3.4.6.3. Storm Surge Inundation Modelling

During the 10th Plan period, modeling and inundation of tsunami waves and storm surges have been undertaken. Preparation of vulnerability maps for tsunamis and storm surges are also being carried out under this component. For this purpose, software like Tsunami N2 for tsunami and Mike 21 coupled with ADCIRC model for storm surges are being used. These activities will be continued during the 11th Plan period. However, the storm surge models are provided without source code. Due to limited time available to produce the vulnerable maps based on inundation of seawater due to tsunami and storm surges and also development of models would take long time, the above models developed elsewhere are being used. Since these models, especially the one used for inundation of seawater during storm surge is not perfectly amenable for different types of inland water bodies where impact of storm surges during some occasions are significant. Therefore, it is proposed to develop an in-house inundation model for storm surges. This would increase the flexibility of using the model for coastal areas having different geomorphology. This would also improve in prediction of inundation of seawater during storm surges and will also help in updating the storm surge inundation maps in the coming years.

3.4.6.4. Ecosystem Modelling

This is an ongoing project conceived in the 10th plan for ecosystem modeling at Kochi backwaters and modeling of Chilka lagoon with the prime intention of assessing progress towards management objectives and to update decisions on modification of management actions over time in response to system change.

The strategy proposed aims at obtaining insights in the evolution of the lagoon by looking into and comparing historical data (time scale) with recent remote sensing and ground truth information. The approach, which is multidisciplinary, brings together expertise in the fields of marine ecology, marine chemistry, hydrographic and physical oceanography, vegetation science, remote sensing and mathematical modeling not only aimed at improving our knowledge about the lagoon environment but also frame a scheme for such ecosystem based studies to develop the model.

In view of moderate to significant inter-annual variability of system responses, in a small area, the modelling is proposed to be expanded for the entire habitats. The gaps observed in the current studies will be filled from the extension of this study. In-situ experiments are proposed to study the response of phyto and zooplankton, benthic fluxes, growth and grazing efficiencies of the system at spatial scales and temporal scales. Catchment loads will be computed using some established terrain models which can be used to calibrate the already generated model. Similar ecosystem modeling would be undertaken for Sunderbans area also.

3.4.6.5 Marine Ecotoxicology

All over the World, a large number of people live close to the sea coast and make their living from the coastal resources. In all the maritime States of India, coastal and marine ecosystems have been considered as reservoirs of productivity and a massive sink with unlimited capacity to assimilate wastes. The increasing coastal population over the years, associated with the establishment of industries, maintenance of harbours and waterways, growing tourism and multiple uses of coastal land have been the causes for

pollution of coastal waters. Pollutants from both point and non-point sources enter through receiving water bodies and affect the marine biota through food chain.

One of the basic needs to minimise the effect of pollutants on marine organisms is to prescribe the safe limits of chemicals for survival of organisms, since water quality is very important for the survival and well being of living resources in coastal and marine environment. Since most of the contaminants affect the productivity of the ecosystem through food chain, the levels at which the most common pollutants affect these organisms need to be established through ecotoxicology studies. By comparing the levels of these common pollutants, the habitat quality of the ecosystem could be evaluated for their capacity to sustain their productivity. Impacts on marine organisms initially are at the molecular and cellular levels and subsequently at a higher level of biological organization. Some toxicants can cause acute effects and others produce chronic effects. Most of the toxicants affect the metabolism of marine organisms, which will ultimately lead to their mortality. The effects would be greater on larval and juvenile stages. Bioassay tests can be employed for assessing the environmental impact on toxicants alone, mixtures of toxicants, and in combination of temperature, pH, salinity and alkalinity, etc., simulating near field/habitat conditions. The Median Lethal Concentration of pollutants which is commonly referred as LC50 and chronic toxicity values are used to find out the safe limits in the form of water quality guidelines. While the LC50 values are determined through short-term of exposure of animals to toxicants say 96 hrs, the chronic toxicity values are based on long term exposures say about 30 days or until the life cycle of organisms for e.g. marine larvae.

With this background, the Marine Ecotoxicology programme was launched during 10th Plan period and MOOD has established necessary infrastructure for implementation. Under this programme, the sub-projects viz., (a) Determination of water quality criteria for coral reef ecosystem of Gulf of Mannar and (b) Coastal waters of Chennai and Pulicat lake are being implemented to determine the seawater quality criteria and c) Biochemical assessment of impact of toxic/other chemical. The standards would be prescribed for the respective ecosystems. Hence it is proposed to continue the marine Ecotoxicology programme along with these projects to determine the toxic effects of chemicals which were found to be high in the coastal environment and also their demand and consumption will be identified for conduct toxicity studies to derive seawater quality criteria.

During the 11th Plan period, the bioassay experiments will be continued with the addition of heavy metals such as chromium, zinc etc and organic compounds such as phenolic compounds, that are present in seawater. The Continuous Flow through method will be followed for determination of (LC50) and sub-lethal chronic effects and histopathology and biochemical analyses will also be studied as supportive evidence showing the biomarker changes at cellular levels.

3.4.6.6 Web GIS Based Coastal Risk Atlas

Coastal hazards refer to both natural and man made events along coastlines that have the potential of damaging life, property and the environment. India, with her vast coastline, is often struck by natural events like cyclones crossing from land to sea and the resultant coastal storm surges. The recent tsunami in Indian Ocean has forcefully added a new dimension to the natural calamities affecting India. Increasing marine traffic in this region also increases the threat of oil spill and Coastal erosion is a coastal hazard that is both natural and man-made and is definitely a destructive force to be reckoned with. The magnitude of the impact of one of the hazards depends on two parameters:

the impact per unit time and the duration of the hazard. While a tsunami may catch public attention because of its high impact per unit time, coastal pollution may be equally hazardous in the long run because of increase in diseases due to pollution of coastal waters.

The tsunami that hit the coastal and island regions of India on 26 December 2004 has brought into focus the gaping hole that has to be filled up to be able to be better prepared for such events. Preparedness for such hazards depends on: (1) awareness of the hazards (2) appreciation of the vulnerability to the hazard; (3) ability to predict the hazard either by deterministic or stochastic means; (4) readiness of a community to respond; and (5) level of education about the hazards in the coastal community.

Efforts to mitigate the effects of coastal hazards can be complicated by insufficient information concerning coastal vulnerability. Vulnerability factors include the nature of the coast, nature of nearshore bathymetry and swell currents for safe swimming the patterns and characteristics of the built environment, and socioeconomic conditions. Providing a better understanding of these factors to allow communities to undertake the most appropriate mitigation strategies / safe beach tourism provides the rational for developing the Coastal Risk Atlas (CRA) and for wider access it is proposed to deliver it on-line as WEBGIS based Coastal risk atlas. Though this concept is relatively new in our country, CRA are available for Mississippi Gulf Coast and Northeast Florida in the U.S Coast.

In the proposed map, the seawater inundation maps prepared under the programme on modelling and mapping of coastal hazards such as storm surge and tsunami will be used to indicate the extent of vulnerability. Data on pollution levels will be obtained from COMAPS programme and bathymetry data from NHO charts. The socio-economic data will be collected / obtained.

CRA will be made available to users through the ICMAM website at www.icmam.gov.in. It will be served using ESRI's Internet Map Server (ArcIMS), which permits viewing the source data and layers generated for the vulnerability assessment using only a web browser. The map layers may also be downloaded directly through the website for use in a GIS. The data made available for download will be served from a database resident at the ICMAM-PD. The goal is to provide a single source for data and information related to coastal hazards and vulnerability.

Though the work will have to be done for the entire coastline the study will be initially taken up for the selected coastal region representing each Coastal State / UT vulnerable regions to coastal hazards and other details specified as above. The areas will be prioritized on the basis of request and their close participation by the State Government. This phased approach enables identification and resolution of technical issues, better identification of necessary data, and determining data inadequacies that could drive future data collection and coastal research initiatives. The Coastal States /UTs will be trained to prepare similar atlas for other areas of the State / UT.

Financial Summary

(Rs. in crores)

S.No.	Projects	2007-08	2008-09	2009-10	2010-11	2011-12	Total
1.	Vulnerability to Shoreline changes, Waste Assimilation Capacity & Inundation Modelling	5.00	10.00	15.00	10.00	10.00	50.00
2.	Ecosystem Modelling	1.00	1.50	1.75	1.75	2.00	8.00
3.	Marine Ecotoxicology	0.60	0.90	0.75	0.45	0.30	3.00
4.	Coastal Risk Atlas	0.40	0.40	0.20	0	0	1.00
	TOTAL	**7.00**	**12.80**	**17.70**	**12.20**	**12.30**	**62.00**

3.4.7 Marine Non-Living Resources

3.4.7.1 Studies of Cobalt Crust Exploration

Ferromanganese encrustations (Fe-Mn Crust) containing on an average >1% of cobalt metal can be designated as cobalt-crust. Cobalt-crusts accrete at shallow water depth (generally <2500 m) as slabs capping the seamounts. They are 3-6 times more enriched in Cobalt metal than the abyssal polymetallic nodules and deep-water crusts. Ferromanganese crusts are hydrogenous colloidal precipitates (Hein et al., 1992), which are known to record oceanographic conditions contemporaneous to their growth period (Banakar and Borole, 1991; Banakar and Hein, 2000; Banakar et al., 1997 and references therein). It is also worth noting here that the Co-rich crusts do concentrate platinum (up to 2.5 ppm; Hein et al. 1992) than the deep-water Fe-Mn nodules. Therefore, the seamount ferromanganese crusts have attracted the attention of mineral explorers.

Exploring for new mineral deposits generally depends on its utility, cost, and availability on the land. As far as India is concerned, no workable land deposits of cobalt have been located. Although India produced over 500 tonnes of Co during 2004 (www.thecdi.com), this production of metal is from imported scrap and by product residue concentrates, and hence cannot be considered as our own naturally occurring resources. Thus the Co metal appears to be of strategic importance to our country. It may be essential for our country to know about the possibility of occurrence of cobalt enriched offshore natural resources. A rough estimate suggested that seamount crusts and deep-sea nodules in Pacific alone contain around 5 million tonnes of Co metal. Thus seamount Fe-Mn crusts obviously are going to be the next targets for this metal if the world demand increases due to its increasing industrial application.

In view of its industrial importance, the preliminary exploration for cobalt-enriched seamount ferromanganese crusts was launched during the X-Plan, and here we propose to extend the work into XI-Plan Period also. This extension would generate important data to understand the areas of occurrences of Co-deposits in our marine regime and the significance of their occurrence to the oceanographic science. It may also be possible that the generated data on Co-resource would help the Ministry of Ocean

Development to decide on a possible claim for a cobalt-resource site in international waters.

ACHIEVEMENTS DURING PHASE-I OF X PLAN

a) Detailed study on extensive occurrence of Fe-Mn crust deposits in the ANS region. A rough estimate indicated 0.4 million tonnes of Co-metal in survey area.

b) Recovery of Fe-Mn crusts from Lakshadweep Sea and Laxmi basin seamounts, which are within our waters.

c) Generating first multibeam bathymetry map of the part of the northern-ANS region.

d) Productivity, nutrients, suspended matter, biomarker analysis, microbial activity data generated for the ANS region as part of the water column studies.

PROPOSED PLAN OF WORK FOR XI-FIVE YEAR PLAN PERIOD (2007-2012)

It is proposed to explore the entire Afanasiy-Nikitin Seamount (ANS) region for the occurrence of cobalt-enriched crusts. This region occupies ~60000 sq. km. area on the seafloor. Exploring the entire ANS region forms the primary part of the plan. In addition, there are several submarine topographic features in the vicinity of- and within-the EEZ of India, which probably host cobalt enriched crusts, as indicated by very preliminary sampling. Our single station sampling in Laxmi Basin Seamount region in fact has yielded samples from one seamount, where the Co-content is ~0.5 %. This sample is from the basal slope, and hence there is a possibility of higher enrichment in the upslope regions.

It is also proposed to generate simultaneously information on the baseline environment in all the regions to be explored. These data would include, dissolved oxygen profiles, surface productivity, suspended matter, microbial inventory, nutrient and lipid distribution, temperature and salinity profiles, benthic organisms, current patterns etc.

EXPECTED OUTPUT

a) First complete multibeam bathymetric map of the Afanasiy-Nikitin Seamount region.

b) Identification of regions hosting the cobalt-enriched crusts in the ANS region, and Northern Indian Ocean, and the Central Indian Ocean.

c) Preliminary estimation of Cobalt-crust and hydrothermal sulfides deposits in those study regions.

d) Generating baseline environment data for the seamount regions hosting Cobalt-enriched crusts and hydrothermal sulfides. The data would include, vertical distribution of nutrients, dissolved oxygen, suspended matter, biomarkers, surface productivity, current patterns, temperature-salinity profiles, organic-flux, microbial activity etc.

e) Preliminary characterization of cobalt crust, hydrothermal sulfides & conceptual plan sheet with laboratory test results.

f) Addition of scientific understanding such as genetic aspects of the cobalt-enriched crusts and hydrothermal sulfides, paleoceanographic reconstructions, biogeochemical aspects of the water column, microbial community inherent to cobalt-crusts etc.

g) Preparation of document to claim sites for the cobalt crust exploration and hydrothermal sulfides and developmental activities.

The output depends upon the availability of ship time throughout the XI-Five Year Plan at regular intervals.

The estimated cost requirement for this project would be Rs. 50.00 crores

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
4.00	8.00	20.00	9.00	9.00	50.00

3.4.7.2 Geological and Tectonic Evolution of the Arabian Sea and Bay of Bengal Sectors

Background: As the first major step in India's endeavors in laying claims to an extended continental shelf as per the provisions of UNCLOS 1982, the National Centre for Antarctic and Ocean Research (NCAOR) on behalf of the Ministry of Ocean Development (MOOD) initiated a comprehensive multi-institutional work programme of marine geophysical surveys ("LCS surveys") in and off India's EEZ during 2002-04. The data acquisition work undertaken with the active participation and the direct supervision of scientists from some of the leading national geoscientific organizations and institutions comprised nearly 28,000 lkm. of multi-channel seismic (MCS) reflection, gravity and magnetic data profiling. In addition, 72 Ocean-bottom seismometers (OBS) were successfully deployed along some of the critical seismic sections to constrain the MCS velocities as well as to develop a crustal model of the study area. Considering the enormous amount of invaluable scientific data sought to be collected, the data acquisition programme was planned in such a way that the data collected would not only substantiate the country's claims for an extended shelf, but will also form a corner stone for India's future endeavors in the marine domain.

Complementing the above programme was another major multi-institutional endeavor of gathering critical marine geophysical data from the Laxmi Basin- Ridge areas off the western offshore aimed at deciphering the type and nature of the crust flooring the ridge and the basin. This data acquisition programme which was undertaken concurrently with the LCS surveys, comprised 3600 kms. of seismic reflection, gravity and magnetic profiling in addition to 18 OBS deployments. The post-processing and interpretation of the data collected under the two programmes have been undertaken at NCAOR, NGRI and NIO and currently the documentation work is in progress. The initial scientific document of the LCS work programme is proposed to be submitted to the Department by December 2005, while the final report of the Laxmi basin studies is scheduled to be submitted by March 2006.

As the nodal agency responsible for the implementation of both the programmes, NCAOR has already created at the Centre state-of-the-art archival and retrieval facilities for all the raw and processed data gathered during the surveys as well as for the results generated during the interpretation work in the different institutions. Considering the sensitive nature of the LCS Programme, the entire data set is being treated as Classified till such a time India's claims are submitted to the UN and are accepted.

Against the above background and in the context of the exercise of planning for the XI five year plan, a brain storming session was organized in September 22005 under the auspices of NCAOR and MOOD to crystallize ideas on the marine geoscientific programmes that could be implemented by the MOOD in and off Indian EEZ as major multi-institutional initiatives during the XI plan period.

Based on the deliberations at the brain storming it was decided that the major thrust area of marine geophysical studies during the XI plan period should be a comprehensive

evaluation of the geological and structural evolution of the Arabian Sea and the Bay of Bengal sectors of the northern and north-western Indian Ocean. However, since this would necessarily call for extensive use of the LCS data and its objective - oriented reprocessing, the studies can be implemented in their entirety only after the LCS claims are made and accepted. Despite this apparent difficulty, with the background scientific knowledge and the expertise developed in the course of the LCS work, it may be possible to develop the programme during the XI Plan period itself by initiating such studies (see below) which may call for only selective use of the LCS data and which at the same time would help substantiate the country's shelf claims.

The following aspects which constitute some of the vital elements of a comprehensive study of the geological and structural evolution of the Arabian Sea and the Bay of Bengal sectors are being proposed during the XI Plan period:

1. The study of the Gulf of Mannar – its origin, whether it is a simple pull-apart basin or a nascent ocean developing as Sri Lanka is drifting away.
2. Delineation of the continental/ oceanic crust boundary on the Indian plate, both off the Western and Eastern offshore.
3. Structural evaluation of the 850 Ridge.
4. Offshore extension of the Deccan Volcanics.
5. Formation of Chagos-Laccadive Ridge as a consequence of reunion hot spot trail.
6. Imprint and implications of hot spots on the Indian continental margin.
7. Structural highs and gravity lows in the Bay of Bengal – the reasons for their association.
8. Fan sediment development vis-à-vis Himalayan orogeny.
9. Geophysical studies of the tsunami generating areas off the Western Andamans.

Each of the above objectives constitutes an independent work programme by itself. However, considering the linkages of these objectives to the LCS work programme and the fact that together they contribute to a holistic assessment of the evolution of the northern and north-western Indian Ocean, it is proposed to consider the entire work programme as one entity with different distinct domains of work.

The Arabian Sea and the Bay of Bengal basins are the two oceanic domains extending the Indian passive margin. Despite sustained efforts by scientists from several of the leading national and international geoscientific organizations, a coherent picture of the sequence of geological and tectonic events leading to the development of these ocean basins characterized by many prominent seabed and sub-seabed structural elements is as yet to emerge. All of the studies enumerated under the proposed objectives of the programme continue to be topics of intense academic debate. Partly this is on account of the highly complex tectonics of the area. But more significant is the paucity of high resolution geophysical data from these regions. Barring some studies undertaken on poorly-constrained single-channel seismic reflection and sonobuoy data collected during the eighties and early nineties, most of the interpretative works of relevance from a scientific point of view have been carried out on the gravity and magnetic data collected from these areas. The first major effort at a systematic collection of seismic reflection, refraction, magnetic and gravity data deploying state-of-the-art techniques and instrumentation and encompassing most of the Arabian Sea, the Bay of Bengal and the western Andamans has been made only as a part of the LCS work programme. Considering the cost-intensive nature of marine geophysical data acquisition, the data acquisition during the LCS surveys was planned in such a way that the data collected would not only substantiate the country's claims for an extended legal shelf, but would

also constitute the nucleus for future marine geoscientific studies. A systematic and properly planned integrated effort at understanding several of the scientific questions pertaining to the geological evolution of the Indian offshore realm is of paramount importance not only from an academic point of view, but is also critical in an evaluation of offshore mineral resources.

The proposed studies have two other important aspects:

- A proper delineation of the continental/oceanic crust boundary could be vital in the context of the possibility of a geological (non-bathymetric) delineation of the foot of the continental slope (FoS) as being more advantageous to demarcating the outer limits of the continental shelf than a bathymetrically-definable FoS. A typical instance is afforded by the studies on the nature of the crust flooring the Laxmi Basin, which indicate that the continental-ocean transition (and hence the FoS) is further offshore than the bathymetrically-defined foot.

- It has been established that seaward-dipping reflections identified on multichannel seismic reflection data from many passive continental margins consist of vast subaerial outpourings of lavas rapidly emplaced during the time of final continental separation and the initial formation of ocean basins. The presence of such SDRs on some of the seismic sections off the Western offshore raises the possibility of the "basement" identified in these areas being a seismic expression of the offshore extension of the Deccan volcanics. If so, this could be indicative of the presence of syn/pre-Deccan sedimentary rocks below the identified (acoustic) basement-vital for LCS purposes.

Marine geological/geophysical studies of both volcanic and non-volcanic rifted margins concentrating on their evolution, mantle dynamics and lithosphere recycling, large-scale magmatism associated with continental rifting and its influence on the environment, the coupling between solid-earth processes and their influence on surface processes including sedimentation, drainage patterns and fluid flow, the processes controlling temporal and spatial variability of rifting, and how rifting ultimately transitions to seafloor spreading, the relationship between rifting and sedimentary basin development, the influence/imprints of hot spots on the formation of LIPs such as the Deccan volcanics etc. are among the thrust areas of current intense scientific research the world-over (e.g.www.largeigneousprovinces.org,www.margins.wustl.edu, www.ldeo.columbia.edu/ margins, www.mantleplumes.org, Crustal processes Group at Southampton). The Indian passive margin is among the least understood compared to the extensive work carried out in the U.S. East Coast passive margin, Western Equatorial Atlantic, Mozambique Basin, Scandinavian Atlantic Passive margin etc.

Considering that NCAOR as the nodal agency for the implementation of the LCS Progress is the archival centre for the entire marine geophysical data gathered in fulfillment of the Progarmme, the proposed studies would be undertaken at NCAOR. This would also help ensure the Confidentiality of the data gathered for the LCS purposes. It is also proposed to develop a core group comprising scientists from NCAOR, NIO and NGRI to undertake selective re-processing of the data to meet the various objectives of the envisaged studies. No results from the studies which might prove to be disadvantageous to the country's endeavors in laying claims to an extended shelf would be published till such a time the LCS claims are made by India and are accepted.

In addition, it is proposed to collect swath bathymetric, gravity and magnetic data along certain critical areas, as for instance in the Gulf of Mannar, south-west coast of India and western Andamans, and dredging along some of the bathymetric highs and seamounts to address some of the objectives of the planned studies. This data acquisition would be undertaken on board ORV Sagar Kanya. It is also planned to request for hard-rock samples from the Ninety East Ridge and Laccadive areas available with the DSDP/ODP core repository for geochemical and petrographic studies. Selective sampling of onland Deccan volcanics and the Rajmahal Traps are also being proposed. Once all the enumerated objectives are fulfilled, it is proposed to undertake a holistic assessment of the geological and tectonic evolution of the two ocean basins.

The estimated fund requirement is Rs.30.0 crores.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
2.00	9.50	9.50	4.50	4.50	30.00

3.4.7.3 Studies on Hydrothermal Sulfides

Although submarine hydrothermal activity and mineralization have not been well documented at many locations in the Pacific and Atlantic oceans, even less is known of their occurrence in the Indian Ocean. Originally, the Indian Ocean ridges were considered to represent less favourable targets for exploration because of the low to medium spreading rates, although this view has changed with the discovery of massive sulphide and vent biota in the TAG area of the Mid-Atlantic Ridge in 1985. During a series of GEMINO cruises by R.V. Sonne, a hydrothermal field was discovered on the Central Indian Ridge about 200 km NW of the Rodriguez Triple Junction. This led to new discovery of marine sulfide in this area in 1993 Dee by P. Halbad group.

One group that is potentially prospective for hydrothermal mineralization is the Andaman Sea (Roonwal, 1994). Already, anomalous concentrations of Cu (upto 500 ppm), Zn (upto 500 ppm) and Pb (900 ppm) have been reported in the coarse fraction (800 mesh) of clay sediments taken at c. 1500 m along the toe of a submarine valley 12 km west of Narcondam Island.

The work would consist of undertaking research cruises in the Andaman Sea and study the minerlisation of hydrothermal sulfides and estimate the resource potential in the region.

The estimated fund requirement is Rs.10.0 crores.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
1.00	4.50	2.50	1.00	1.00	10.00

3.5 Information Technology

Considering the need for the upcoming and cutting edge technologies for integration in the implementation of various programmes, a separate budget provision has been kept in the XI plan period.

Financial requirement Rs. 20.00 crores

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
4.00	4.00	4.00	4.00	4.00	20.00

3.6 Coastal Research Vessels and Other Research Vessels

In order to overcome the shortcomings, the MoOD has acquired two Coastal Research Vessels namely Sagar Purvi and Sagar Paschimi in 1996. The vessels would continue to be operated by NIOT with additional instrumentation required from time to time to support COMAPS and ICMAM programmes. The budget requirement for running vessel during XI Plan of Rs. 200.96 crores is provided in NIOT budget as follows:

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
51.05	**11.44**	**12.16**	**62.70**	**63.61**

The cost of 200.96 is inclusive of running of CRVS, BTV Manjusha and replacement of CRV and the phasing of the replacement (102 cr) for Monitoring of oil pollution along the international tanker route especially around the islands. to be put under the 4th year of plan.

At present the levels of pollutants along the coastal waters of the islands of Lakshadweep and Andaman and Nicobar are being monitored in one or two islands only due to lack of research vessel facilities. As the Lakshadweep and Nicobar group of islands are situated close to the international oil tanker route, it is imperative to monitor the levels of oil pollution on a continuous basis. The present coastal research vessels of MOOD, namely, Sagar Purvi and Sagar Paschimi are small vessels and have low endurance. Since the survey of the Andaman and Nicobar and Lakshadweep islands would take at least 15 days for each island group, it is essential to have a dedicated ocean going research vessel for this purpose. As the two CRVs are likely to reach a stage of replacement at the end of XI Plan, one of the vessels will be replaced with a Ocean going vessel. Therefore, it is proposed to acquire a new research vessel of 65 to 70 m long with an endurance of 20 days.

3.7. National Institute of Ocean Technology (NIOT)

National Institute of Ocean Technology (NIOT) is involved in developing technologies for ocean related areas. The main areas of interest are Energy and Fresh water from sea, Deep Sea Mining, Coastal and Environmental Engineering, Marine Instrumentation, Ocean Science & Technology for islands, ROSUB and Gas Hydrates, ARGO floats. The Institute also has the Vessel Management Cell and National Data Buoy Programme. During the XI plan period these areas will continue with new prospects. In addition to these, new technology development areas such as Ocean Acoustics, off shore structures, marine sensors and electronics, mechanical design of underwater components will be taken up. New laboratory and field facilities are also being planned.

A new campus is also being proposed on the sea front. This sea front facility will house laboratories and aid in carrying out field experimentation.

This document summarises all technology development activities proposed to be taken up during XI five-year plan period enumerating the objectives, time frame and budget. The details of the financial requirement for programmes implemented by NIOT are provided against the respective programmes.

3.7.1 Energy and Fresh Water from Sea

The main focus of this programme is to develop technologies for tapping renewable energies from the ocean. Research on caisson type fixed Wave Power plants has been completed and it has been proved that floating Wave Powered devices would be more cost effective with smaller power ratings. A small rating Backward Bent Ducted Buoy was studied in the X plan and larger Floating Wave Powered devices will be taken up. NIOT has already demonstrated a desalination plant at Kavaratti Island with the capacity of 1 lakh litre per day and also 1 million litre per day barge mounted LTTD plant was successfully commissioned. While most of the work pertaining to the setting up of 10 MLD desalination plant will be completed, its commissioning may spill over to XI plan period. This technology has advantages over conventional technologies like reverse osmosis such as easy operation and maintenance, low scaling, fouling etc. In the process of utilizing the deep-sea water for desalination, air-conditioning and aqua culture are also envisaged. The cold water drawn may also be utilized for production of Lithium and hydrogen.

It is also intended to establish a facility to meet the requirements of the fabrication and machining works for the above mentioned projects. For smaller islands large-scale desalination plants are not really required and hence a small solar desalination using multi effect humidification may be preferred by avoiding the task of using deep-sea cold water for condensation. Equally an integrated facility has been intended i) to demonstrate and compare desalination plants with various capacities with optimum yield and to test & evaluate the heat exchangers for various desalination plants. Thus theXI plan envisages that NIOT will have all the facilities for designing, testing and evaluating the various technologies for obtaining energy and freshwater from the ocean.

Objectives

- To install a floating Wave powered device to power a small rated Reverse Osmosis plant to generate fresh water
- To establish a technology for development of technology for the recovery of Hydrogen and Lithium from sea water
- To establish a facility to demonstrate and compare desalination plants with various capacities with optimum yield conditions. Generation of experimental data for suitable adoption to exploit commercially the desalination technology utilizing low-grade heat and ocean temperature difference.
- To establish a facility to develop and demonstrate the extraction of renewable energies from the Ocean. Generation of experimental data, for suitable adoption to exploit commercially the extraction of renewable energies.
- To establish a facility to test and evaluate the heat exchangers used for various desalination applications.
- To establish a facility to meet the requirements of the fabrication and machining facilities and material handling requirements in offshore and on the shore

Projects

- Commissioning of 10 MLD desalination plant
- Solar desalination using multi-effect humidification
- Floating wave powered device
- Recovery of Hydrogen and extraction of rare metals (Lithium) from sea water
- Integrated facility for desalination technology development
- Establishment of machine shop and material handling facility

Budget: Rs. 15.89 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
2.00	**4.00**	**5.00**	**3.00**	**1.89**

3.7.2 Deep Sea Mining

NIOT has been given the task of developing technology to mine Manganese nodules from a depth of 6000 m. As part of this programme an underwater crawler available with Institüt for Konstruktion (IKS), University of Siegen, Germany, has been refurbished and various tests have been conducted successfully. The latest test incorporating the locomotion and slurry pumping at a depth of 451 meters was done in the Arabian Sea off Goa. The next phase of the project involves development of Collector and Crusher system for mining Polymetallic Nodules from the sea floor and its qualification at 500 m water depth by laying artificial nodules. An insitu subsea soil tester is being developed for precise measurement of soil strength to design and develop the future deep sea mining machine.

It is also proposed to develop manned submersible. The primary advantage of the manned submersible is that it permits the trained mind and eye to work in situ at great depths of the sea. Presently, manned submersibles are used extensively by the offshore oil companies in support of survey, drilling and production operations. The possibility of nuclear power source would also be explored. Semi submersible platforms are also to be developed for the support of the crawler and for long term commercial mining, with all facilities for the launching, retrieval, and operation of crawler. Infrastructural facilities for development and testing of deep sea systems is also highly essential for the smooth and safe execution of the projects.

Objectives

- Design and development of a new crawler based mining machine capable of collecting and pumping nodules from 6000 m water depth.
- Development of a flexible riser system for transporting nodules from the ocean floor to the mother ship / barge.
- Detailed survey at the Central Indian Ocean Basin (CIOB) to assess soil property. Micro level demarcation of the mine site will be carried out to isolate sites of very low soil strength properties to avoid sinkage of crawler in to sea floor.
- Studies in areas such as material under high pressure and low temperature condition for long-term operations, Sub-sea control systems and Acoustic Positioning and imaging systems
- Development of manned submersible capable of operation at 6000 m water depth

- To develop a small semi submersible platform that will be used for the Launching and Retrieval of mining system.

Budget : Rs. 610 crores

S.No.	Title		Yearwise Break up					Estimated cost in crores of Rupees
			07-08	08-09	09-10	10-11	11-12	
1.	Integrated Deep Sea Mining System for 6000 m		10	70	60	40	55	**235***
2.	Soil Testing in the Central Indian Ocean Basin		10	10	10	10	10	**50**
3.	Inter Institutional (R&D) & In house Development		12	16	18	16	13	**75**
4.	Development of Small Semi Submersible Floating Station		0	0	35	50	65	**150***
5.	Development of manned Submersible capable of operation at 6000 m water depth		10	80	50	50	35	**225***
6.	Offshore operations		4	5	4	3	1	**17***
	Total							**752***

* Total of Rs. 627crores budgeted under PMN programme and rest Rs 125 crores (item 2 and 3) to be met from institute funds

3.7.3 Coastal and Environmental Engineering

This group focuses on development of capacities in areas required to sustainably develop coastal areas in line with the economic requirements of the nation. Reference material for such development in most coastal stretches are targeted in the XI- plan proposals.

Objectives

- To enable site characterisation for marine infrastructure development.
- To link the model of real time data collected by various proposed MoOD monitoring system such as weather monitoring stations, HF radars and data buoys.
- To develop substantial capabilities in marine survey that allow rapid scanning of the seafloor and sub seabed.

Projects

- Demonstration of Coastal Protection Measures
- Technical Criteria Atlas
- Sediment transport atlas for east and west coast of India
- National Oil Spill Modeling and Prediction System
- Creation of technology for Marine Archaeology

- Monitoring and Modeling of Thermal and Desalination effluents
- Kinetic rate coefficient estimation for mathematical models

Budget : Rs. 225 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
40.0	**60.0**	**60.0**	**40.0**	**25.0**

3.7.4 Marine Instrumentation, marine sensors and ocean acoustics

This group focuses on engineering and technological skills to design and develop different types of marine instruments and accessories that are necessary / useful for observation, survey, communication and deep water applications.

This group also plans to develop Underwater Electronics Support Facility, underwater electronics development component and development of autonomous surface vehicle.

Objectives

- In-house development of sea Glider System (SGS)
- Fabrication of 5 Benthic station and establishing a network with real time data transmission to shore station-using surface buoy
- Establishment of a comprehensive tide gauge & automatic weather station networking program along Indian coast.
- To explore techniques for Acoustic communication for point-to-point communications in vertical deepwater channels
- Development and deployment of automated noise measurement system at different locations in shallow waters
- Development of automated measurement systems consisting of vertical array of hydrophones
- Application of waveler transform for identifying tonal/ transients in an ambient noise data, particularly by marine organisms.
- To design and develop the multi function data acquisition and control system qualified for marine environment.
- To establish a facility of excellence to provide electronics support to various activities and projects of NIOT
- To create infrastructure for reducing the development time and facilitate rapid prototyping
- To develop specialized non-off-the-shelf components (in Indian markets) for underwater applications in association with industry.
- To develop small size, low weight acoustic and magnetic sensors , sensor technologies etc
- To develop infrastructure to study ocean acoustics.
- To develop technologies using theories of underwater acoustics for various engineering applications.

Projects

- Development of Sea Glider System (SGS)
- Development of expendable CTD (XCTD) and expendable sound velocity (XSV)
- Development, production and setting up of underwater benthic station network
- Design and development of pressure based & open type tide gauge
- Development of acoustic modem, electromagnetic current meter, ultrasonic current meter and automated noise measurement system & networking in shallow waters
- Geo acoustic inversion using vertical array of hydrophones
- Development of wavelet based de-noising algorithm for underwater signal detection
- Development of inductive modem (1 m)
- Design and development of under water lamps for fishing
- Development of Multi-function data acquisition and control system for marine applications
- Establishment of infrastructure for facilities such as, geo technical / hydrographic / oceanographic survey
- Underwater electronic support facility
- Underwater electronic component development
- Development autonomous surface vehicle
- Marine sensor & technology development
- Acoustic emission
- Time reversal acoustic
- Marine animals and acoustics
- Shallow water measurements for ambient noise
- Acoustic daylight imaging
- Active structural – Acoustic control of ship hulls infrastructural facility

Marine Instrumentation

Budget : Rs. 51.14 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
15.11	**13.57**	**12.51**	**3.95**	**6.00**

Marine Sensors

Budget : Rs. 31.05 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
9.9	**8.2**	**4.85**	**4.05**	**4.05**

Ocean Acoustics

Budget : Rs.54.04 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
10.0	**12.0**	**18.0**	**8.04**	**6.0**

3.7.5 Island Development

NIOT has been successful in creating the requisite infrastructure for carrying out technology development activity in the island for the benefit of island community, monitoring the health of seas, analysis of data on ocean parameters, enhancement of Marine Living Resources through mariculture, biofouling control, etc. Utilizing those infrastructures and expertise already developed by NIOT, the programmes such as mud crab farming and open sea cage culture of lobsters, fish aggregation devices around Lakshadweep islands, biofouling study of marine structures, completion of life cycle of two species of lobsters and experiments study on Deep Ocean water were successfully being implemented during the X Five Year Plan period, for overall economic development of island and coastal community. During the XI five year plan period, this group is focussing on the following major programmes

a. Production of commercially useful microalgal species and extraction of biochemicals using deep ocean water.
b. Demonstration of open sea cage culture of fin and shellfish for the societal benefits
c. The introduction of coastal mariculture activity will help eradicating poverty among the coastal fishers and provide alternate employment.
d. Reduction in the uncontrolled fishing in coastal areas will indirectly help in enhancing the marine natural resources. Additionally, the cage operational sites will serve like a better settling and feeding sites for young ones of various marine species.
e. A systematic GIS database will be available on spatial and temporal changes in coastal water quality, mangrove vegetation, coral cover.

Objectives

- State-of-the-art training facilities for eco-friendly cage culture for live fish trade.
- Participation of Women and Self Help Groups (SHG) in socioeconomic development of selected villages.
- Fish aggregation devices for tuna fishing
- A systematic GIS database on spatial and temporal changes in coastal water quality, mangrove vegetation, coral cover.
- Creation of data model on various water quality parameter using existing database.
- Dissemination of information for developmental projects which requires environmental clearance.
- Selection of site suitable for aquaculture including crab, lobster farming.

- Short listing of potential strains of microalgae for heterotrophic production from Indian waters.
- To integrate the laboratory based research facilities, computer hardware with networking facilities to analyse and distribute the databases of biodiversity, molecular sequence and structure, particularly for marine organisms.
- To evolve biofouling & corrosion potentials at different points along the Indian coast.
- To develop test protocols for evaluation of fouling, corrosion, biocorrosion & performance of equipments / coatings Insitu for developing standards.

The field unit of NIOT at Port Bliar Andaman & Nicobar Centre for Ocean Science & Technology (ANCOST) has started functioning from 1999 as a part of Ocean Scientific and Technology for Islands. During this period, the Centre has worked on various R&D project and societal activities and is also supporting Island administration on post-tsunami rehabilitation reconstruction activities.

Earlier the Department of Ocean Development requested the Marine Products Export Development Authority, Ministry of Commerce, during the year 1987 to demonstrate the possibility of shrimp culture in the acid sulphate conditions prevailing at A & N Islands for the socio-economic up-liftment. The MPEDA developed the facility during the year 1989 and 1990 with the fullest financial support of the DOD. They demonstrated the farming techniques and trained around 200 islanders in the shrimp farming techniques. After the completion f the project period, the MPEDA handed over the assets and liabilities back to DOD, New Delhi. The DOD directly maintained the Centre for a period of 18 months before they took a decision to hand over the same to NIOT during the year 1999.
It is proposed to upgrade Andaman & Nicobar center for ocean science and technology as a national centre of the national institute of technology

The Programme being implemented are

- Coastal Ocean Monitoring and Prediction system (COMAPS)
- Commercialization and extension of mud crab fattening technology
- Implementation of extraction of bioactive compounds from marine organisms
- GIS based model for the land use land cover change for Nicobar group of Island
- Environmental impact assessment programme

The centre is also supporting the Institutional activities like Tide Gauge installation and monitoring, Data buoy programme by coordinating with Administration, Navy and Coast Guard.etc., Under the XI five plan new activities are proposed as per the need of Island. Administration. It may be noted that developmental activities at A&N is being pursued by the Government on a priority basis. Hence NIOT's presence has to be strengthened to work on Ocean Technology related activities as given below:

*Marine micro algal biotechnology (MAB):*This involves promotion of research in the line of identification of commercial important marine microalgale species in Indian waters, developing, extraction and optimization of biochemical production, development of transgenic microalgal strains for maximizing production of biochemical compounds of interest

Fish Cages for Alternative Livelihood (Fish-CAL): The marine capture fishery potential of A&N Islands, as revalidated by Ministry of Agriculture during 2000, is about 246,000 tonnes. However the current level of fish production is estimated to be only 28,000

tonnes. The groupers and snappers have high commerical value in international market if sold in live condition. The proposed project aims at distribution of cages to selected Self Help Groups (SHGs). It is initially planned to encourage wild-collection of commercial sized grouper and snapper, following the recommended legal size restrictions proposed by state administration. Later on, the programme plans to lay importance only on culture of hatchery-produced juveniles up to marketable size for live fish trade.

Island Resource Marine Information System (IRIS): Any Plan, should lead to an integrated and environmentally sound development based on science and technology. These programmes should be primarily meant for the benefit of the islanders, at the same time, fitting into the overall strategy of our nation's economic development. A Geographical Information System (GIS) based resource inventory will be most suitable for this purpose as this will provide a powerful platform to integrate multiple resource information in the form of multi-layered Geo-database. This will help the resource managers and policy makers evaluate the natural resources in a holistic manner through a very user-friendly and interactive interface to take appropriate decisions for various developmental activities in these islands. It can also be used as a powerful tool to synthesize all the data, for comprehensive Interpretation and forecasting of marine environmental ecosystems for the islands region.

Commercialization and extension of mud crab breeding, larval rearing and fattening/culture technology: Mud crab is one of the highly priced seafood commodities because of its nutritional value and it's potential as an export commodity. Due to faster rate of natural stock depletion, over fishing and fluctuation in catches, the landing is insufficient to meet the export demand, has stimulated mud crab aquaculture venture in Indian sub continent. Culturing crabs in captivity could be one of the strategies to cope up with the ever-increasing demand. However at present no commercial mud crab farming is undertaken in India. Even though there is good scope for commercial crab farming in India, the crab culture depends overwhelmingly on wild caught brood stock and seed. Hence crab culture practice faces a critical bottleneck effect in seed production due to the lack of quality brood stock and viable breeding and larval rearing technology. Hence it is proposed to develop technologies for captive brood stock development and larval rearing of the mud crabs belonging to the genus Scylla.

Major infrastructure facilities planned are

Construction of new Staff quarters: The exiting quarters were constructed by MPEDA. when they were executing a project for DOD in 1990 and these buildings are damaged after earth quake and they are not actually quarters constructed with different category as per Government norms rather they are much like temporary living facilities.

Andaman has a peculiar long rainy season of almost 8 months in a year and our work involves staff moving to different islands for sampling and hence these Quarters would be benefits to staff

Mud crab farming: The ongoing mud crab farming and fattening work is done with wild caught crabs. In order to sustain this activity mud crab farming facility with state of the art hatchery system is planned for this centre.

Projects planned:

- Sea cage culture of lobster and crabs and open sea aquaculture
- Island resource information system
- Marine Micro-algal Biotechnology
- Development of Marine Bioinformatics applications
- Materials for marine applications

Infrastructure facilties for upgradation of centre at Port Blair

	Rs Crores
Mud crab hatchery with seawater intake system	*5.00*
Staff Quarters	*3.00*
GIS Laboratory facility –	*3.00*
Algal culture facility	2.00
Fis-cal laboratory	3.00

Total	16.00

Additional 16 personnel would be required minimally.

It is felt that wider reach is required along the west coast and east coast and the present structure is not able to cater to these requirements. 2 extension centres of NIOT are, therefore proposed to be set up in each of the above coastlines as detailed below. :

3.7.5.1 West Bengal (East Coast)

Ministry of Earth Sciences (MoES) proposes to open a center in the eastern region of India, possibly at Rajarhat, Kolkata. The focus of the center will be to develop science and technologies in the marine sector targeting sustainable long term economic development. The region has number of specific requirements, given the presence of Kolkata Port, which a prime driver for the local economy; the Sunderbans and Chilka Lake as major natural resources; Orissa as a growing investment location; and environmental protection for critical resources like Sunderbans and turtle breeding grounds.

Technologies and environmental resource management specific to the regions of West Bengal and Orissa are:

(a) Sediment transport and geomorphology with an emphasis on navigation, dredging and erosion
(b) Shoreline Protection methods for coastal areas on coasts of Orissa and West Bengal, as well as bank protection along the estuarine stretches of High River and Sunderbans.
(c) Aquaculture for shellfish (prawns, crabs, mussels) and fish (catfish, perch) on combination of each particularly in mangroves and inter-tidal areas.

(d) Mangrove propagation and biodiversity enhancement approaches.
(e) Waste water treatment using constructed wetlands to generate economically useful by products (seaweeds, aquaculture feed)
(f) Tidal energy
(g) Desalination and water treatment given the high arsenic and iron content in water.
(h) GIS and Remote sensing for identification of areas for economic development of environmental protection, addressing natural resources and natural hazards.
(i) Biotechnology for doing research.
(j) Oceanographic measurements for long term understanding of interaction of Ganges- Brahmaputra basins to bay of Bengal
(k) Evaluation of land based inputs during dry and wet (monsoon) season for estuarine environmental quality to control sediment inputs.
(l) Consolidation of above efforts for Coastal Zone Management Plans.

Investment for initial 5 year period

Sl.No.	Description	Rs. In Crores
	Non recurring	
A.	Equipment - Oceanographic measurements, currents, Tides, waves, salinity, temperature, wind, pressure	2.00
B.	Water quality based – DO, BOD, pH, nutrients, etc	1.00
C.	Computers for GIS & RS, Office, Networking	1.50
D.	Building, Infrastructure, maintenance, furniture	2.50
E.	Projects	20.00
	Recurring	
E.	Core manpower and services	3.50
G.	Operating costs (Electricity, transport, travel, stationeries, etc.)	1.00
H.	Contingencies	1.00
	TOTAL	**32.50**

Additional 30 personnel would be required minimally.

3.7.5.2 Gujarat (West Coast)

Gujarat is focused on economic development through the port and harbour sector. Maharashtra is also stepping up efforts to develop coastal infrastructure. Port, coastal industries and fisheries have been key focus areas with several vision documents, policy statements. Key projects, both existing and future are:

Ports and loading / unloading facilities at Kandla, Mundra, Pipavav, Shell (Hazira), Petronet (Dahej), Sikka (Reliance), Vadinar (Essar), Jakhau (Good Earth)

Kalpasar project for generation of energy & freshwater

Industrialization from Mumbai to Ahmedabad.

Spurt of activity along the Mumbai-Goa coastal stretch with privatization of Jaigad & Dighi sites, Dabhol near Ratnagiri, NPCIL project at Vijaydurg, Finolex at Ratnagiri.

The focus of the center needs to join hands with the states in meeting their requirement while encouraging the need for environmental sustainability. The center may act as a proactive facilitator rather than a regulator or a non-participant.

Focus areas

- Coastal zone management at a macro level using GIS and Remote. ICMAM already has a plan for Gulf of Kutchch which needs to be extended and consolidated with the rest of Gujarat state. Similar exercise can be extended to Maharashtra.
- Ship breaking yard monitoring and management studies
- Fish processing and related waste management.
- Salt water intrusion.
- Mangrove afforestation, biodiversity enhancement and propagation
- Dredging.
- Intake and outfall designs.
- Marine Archaeology
- Oceanographic and Geomorphology studies for Gulf of Khambhat and inner areas of Gulf of Kutchch..
- Oceanographic measurements for long term understanding of regimes changes due to upstream freshwater control.

Investment for initial 5 year period

Sl.No.	Description	Rs. In Crores
	Non recurring	
A.	Equipment - Oceanographic measurements, currents, Tides, waves, salinity, temperature, wind, pressure	2.00
B.	Water quality based – DO, BOD, pH, nutrients, etc	1.00
C.	Computers for GIS & RS, Office, Networking	1.50
D.	Building, Infrastructure, maintenance, furniture	2.50
E.	Projects	30.00

	Recurring	
E.	Core manpower and services	3.50
G.	Operating costs (Electricity, transport, travel, stationeries, etc.)	2.00
H.	Contingencies	1.00
	TOTAL	**43.50**

Additional 30 personnel would be required minimally.

Total requirement under the programme is given below:

Item	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	Total
Projects at Port Blair	12.40	13.20	16.00	14.30	14.10	70.00
Upgradation of centre at Port Blair	2.00	6.00	5.00	2.00	1.00	16.00
Requirements for East coast centre in West Bengal	5.00	7.00	8.00	7.00	5.50	32.50
Requirements for West coast centre in Gujarat	5.00	13.00	16.00	6.00	3.50	43.50
	24.40	39.20	45.00	29.30	24.10	162.00

3.7.6 Argo Floats

To study the variability in the heat content in the upper layers of the ocean for the understanding of global scale changes in the climate. The recent research indicates that upper ocean heat content influences the inter-annual variability of monsoon rainfall-over India. These data sets will provide immense help in predicting tropical cyclone track and intensity. These data will help to obtain an unprecedented dataset for model initialization, data assimilation and dynamical consistency testing of the next generation of global ocean and coupled models.

Objectives

- Deploying 50 floats per year with different sampling strategies covering Northern Indian Ocean
- Deploying floats with additional sensors like Oxygen, Chlorophyll, wave current, rainfall and windfall in addition to CTD sensors
- Design optimization of indigenized float systems to reduce power consumption for increasing the useful life
- Augmentation of indigenized floats with additional / alternate sensors

Projects

- Procurement of Floats
- Deployment of Floats
- Augmentation of existing design

Budget : Rs. 30.8 crores to be met from ISOON/NDBP programme of HQ

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
6.85	**6.05**	**6.00**	**5.95**	**5.95**

3.7.7. Gas Hydrates

Development of underwater technology leads to the growth of different tools which are required to map, observe and explore the deep ocean resources and play vital role as supporting tool for deep water engineering operations in coming decades.
Remotely operated submersibles are used primarily in the area of marine science research. The AUV with docking station increases the operating time at the depth. Also it may be possible to develop wet recharger for unlimited operations. The Hybrid Remotely Operated Vehicle is a unique system which combines the advantages of ROV and AUV. The AUV can operate independently in deep waters.

Identification & quantification of gas-hydrates along the continental margins of India are very essential to evaluate the resource potential followed by technology development to validate the ground truth and exploit the new energy reserves.
As gas-hydrates are not stable at standard temperature and pressure like other minerals/resources, they cannot be exploited with the existing technology. The technology for commercial production and transportation of gas-hydrates from seafloor to sea surface is in its infancy and remains a major challenge. Lot of collective efforts are on throughout the world to tap this non-conventional source of energy. The successful development of the remote coring system will be the first step towards establishing unique functioning technology for exploiting ocean resources. The need to further this technology will be the natural corollary. The concept of the technology will establish the basis of the pilot plant technology.

Objectives

- Developing suitable technology devices for supporting offshore activities
- Developing skill base and infrastructure to support and maintain the systems
- Developing a suitable technology device for understanding the behavior of gas hydrate seepages and sampling at sea bed

- Developing exploitation strategy for gas hydrates
- Developing transportation, storage and processing facilities for gas hydrates
- Creating facilities viz. hyperbolic pressure chamber to test the underwater vehicles as a whole

Projects

- Autonomous Underwater vehicle (AUV) with docking station
- Development of Hybrid Remotely operated Vehicle (HROV)
- Utilizing the upgraded support submersible for Gas hydrate exploration
- Fine tuning and utilizing the Support Submersible for gas hydrate exploration
- Development of Remote coring system with enhanced capability
- Pilot plant for production of Gas from the Gas Hydrate rich zone
- Storage, Transportation & Processing Gas Hydrate

Budget : Rs. 564.46 crores to be met from Gas hydrate programme of HQ.

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
44.84	**86.93**	**164.61**	**145.44**	**122.64**

3.7.8 National Data Buoy Programme (NDBP)

Upper ocean dynamics has tremendous influence on both short- and long-term atmospheric changes. Observing these properties of the ocean and incorporating relevant data into models is essential to the prediction of our future climate, the onset of the monsoon, the longer term decadal changes linked to the Indian ocean dipole mode and propagating long waves. The recent reports indicate that there is an increase in the nature's fury and the episodes of natural hazards like Tsunami, Cyclones and Storm surges calls for the need of systematic observation of various oceanographic and meteorological parameters and the timely dissemination of information to public and other related agencies for mitigation. Therefore, the accuracy of future climate forecasts will depend on improvements in our ocean observations like temperature, salinity, and currents within the upper layers of the ocean.

The vision guiding the development of an **Integrated Sustained Ocean Observation Network (ISOON)** is to provide the information needed by governments, industry, science and the public to deal with marine related issues, including the effects of the ocean upon climate. It needs to be supported by a unified network to systematically acquire, integrate and distribute oceanic observations and to generate analysis, forecasts and other useful products.

Objectives

- Time series met-ocean data and data products from a wide network of various observational platforms located in coastal, within the EEZ and open ocean region in the North Indian Ocean.
- Near realtime retrieval and dissemination of various met-ocean parameters to various end users and user specified observational programmes with a wide network of observational platforms.

- Facility to validate/ calibrate various met-ocean sensors in marine environment.
- Time series data to validate satellite observations and model evaluation of various met-ocean parameters.

Projects

- Indian Coastal Ocean Observational Network (ICOON)
- Indian EEZ Observational Network (IEON)
- Open Ocean Observational Network (OOON)

Budget : Rs. 336.29 crores to be met from programme on ISOON/NDBP

(Rs. In crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
62.81	**73.14**	**64.26**	**67.53**	**68.55**

3.7.9 Offshore Operations

Offshore operations group is mainly to link for carrying out the various experiments at sea. This group will co-ordinate the activities of offshore and shall have the full infrastructure to implement the trial and demonstration of technology. Certain infrastructure will be created for the same.

Objectives

- Creation of infrastructure for safe and smooth execution of various operations.

Projects

- Reconnaissance and survey boat
- Hydra and lifting appliances
- Deep sea lifting and mooring winches

Budget : Rs.17 crores to be met from Technology Development(Mining) programme of HQ

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
4.0	**5.0**	**4.0**	**3.0**	**1.0**

3.7.10 Offshore Structures

Introduction

This group focuses on modelling and testing of different types of structures for offshore applications, offshore platforms for wind energy desalination plants and cyclic load test facility for offshore applications.

Objectives

- Modelling, analysis, design and model testing of different types of offshore structures.

- Powering of offshore desalination plants by renewable energy like wind energy.
- To set up a cyclic testing facility to test different objects of different materials like pipes and rope subjected to time varying loads.

Projects

- Modelling and testing of different type of structures for offshore applications
- Offshore platforms for wind energy driven desalination plants
- Cyclic load test facility for offshore applications

Budget : Rs.54.65 crores to be met from Desalination project of HQ programme

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
2.0	**20.0**	**18.0**	**8.0**	**6.65**

3.7.11 Vessel Management Cell (VMC)

The vessel management cell has the following mandate:

- Operation, maintenance and technical management of existing research vessels Sagar Purvi, Sagar Paschmi, Sagar Shakthi, Sagar Manjusha and the proposed technology demonstration vessel.
- To conduct swath bathymetry survey in the East coast of India under EEZ programme.
- Design, detailed engineering and construction of technology demonstration vessel
- Establishment of autonomous underwater data and positioning network in the East coast
- Acquire an autonomous underwater vehicle capable of carrying out survey at deep waters of 3000 m.

Objectives

- To continue operation, running and maintenance of the existing research vessel and augment them to have pollution control capability and replacing them after their useful life.
- To build a new multipurpose vessel for technology services and demonstration to cater to the ongoing and new programmes of NIOT and act as a supporting platform for various research activities of the department.
- Preparation of comprehensive bathymetric map of Exclusive Economic Zone of India across eastern coast between 10 m water depth and 500 m water depth.
- To establish an autonomous underwater data and positioning network in the East coast.

Projects

- Continuing programme for operation, running and maintenance of the existing research vessel
- Acquisition of technology demonstration vessel Sagar Nidhi
- Swathe bathymetry survey of the exclusive economic zone of India
- Acquisition of an autonomous underwater vehicle, survey of deep water (>3000 m) natural resources and autonomous underwater data and positioning network.

Budget : Rs. 150.96 crores to be met from the provision under the programme on Coastal Research Vessel of HQ.

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
101.05	**11.44**	**12.16**	**12.70**	**13.61**

3.7.12 Capacity Building, Infrastructure, operations etc

3.7.12.1 Mechanical Design (Integrated fluid dynamic laboratory facility)

To serve the long term and short term needs of the institute, it is necessary to establish an integrated fluid dynamics laboratory. This will help in arriving at optimal designs for various applications in frontier areas.

The facility will have laboratory for testing scale models as well as computational tools for simulating real systems.

It is necessary to establish a test facility with the state of the art equipment to conduct studies on scale models that can help arrive at the optimum design and a computational facility with the state of the art modelling tool to handle the design and operational issues in the general area of fluid dynamics and convective heat transfer.

Objectives

- To provide a set of tools at the Institute's disposal to carry out system level analyses in the general areas of fluid and thermal sciences
- To develop an expertise in the experimental and numerical modelling area to carry out the process enhancement, design optimisation and feasibility studies for optimal design
- To provide the institute with the basic tools to conduct scale model analyses, as in the case of changing the design from a small-scale model to a commercially feasible large scale model.

Projects

- Integrated test facility
- Computational fluid dynamics laboratory

Budget : Rs. 8.40 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
4.0	**2.0**	**2.40**	**-**	**-**

3.7.12.2 NIOT Institutional frame work – Administration, campus development and maintenance including manpower and operational expenses

NIOT is successfully carrying out the assigned task within the stipulated time supported by adequate infrastructure and administrative and supporting staff. Administrative and supporting staff works closely with the scientific and technical staff in fulfilling all the requirements of implementing the various projects. So the provision under this is used

for purchase of technical books for library, procuring computers, printers, software and other equipments, administration group, human resource development group, development and maintenance of existing campus.

Objectives

- To impart appropriate training to staff on different fields for improving the work output and to create virtual university on ocean technology (Human Resource Development)
- To take care of the maintenance of the existing computers, NIOT web server, network and other IT related products of NIOT by the existing computer maintenance cell (Computer maintenance cell)
- To create, alter, maintain, quality infrastructure facilities to cater to the fullest utilization of the facilities created in a NIOT campus (Estate and Security).
- To meet expenses towards domestic / foreign travel expenses, medical reimbursement, salaries including perks, maintenance of plant and machinery and institute vehicle and purchase of technical books and hindi books, etc (Establishment, Administrative and Campus maintenance expenses including library).

Budget : Rs.258.11 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
25.0	**30.0**	**45.0**	**65.0**	**93.11**

3.8 Delineation of Outer Limits 0f Continental Shelf

Continental shelf as defined in Article 76 of United Nations Convention on Law of the Sea (1982) is required to be delineated by the States Parties in accordance with the provisions of the Convention. While Territorial Sea and Exclusive Economic Zone follows essentially from the baseline, the formulation for establishing the outer limits of the continental shelf involves interplay of various criteria. Claims in relation to the outer limits of the Continental Shelf have to be submitted by the States Parties to the Commission on the Limits of Continental Shelf (CLCS). It is expected that India may gain a significant area beyond the existing Exclusive Economic Zone.

In this context, it is important to point out that our claims would be based on Statement of Understanding provided in Annex II of the Final Act of the Third United Nations Conference on Law of the Sea which is applicable to Sri Lanka and India only. For this purpose, discussion with Sri Lanka in respect of technical and policy issues regarding the Delineation of Outer Limits of Continental Shelf between India and Sri Lanka is required to be taken up. Simultaneously, boundary delineation issues also need to be taken up with Bangladesh, Pakistan, Myanmar, Indonesia, and Maldives.

While, the data acquisition and processing including the interpretation of data has been completed and final report and submission is in advanced stage of completion, we need to continue this programme which is of strategic importance till our claims are accepted in the UN. While we need to keep a token provision, there may arise the need to take up more survey to support and justify our claims, which will be known from the response of the UN Commission on the Limits of the Continental Shelf upon examination of India's submission. We have already created data archival facility at NCAOR for 32000 line km

of geophysical data and expertise exclusive to this programme. This needs to be optimally utilized and secured.

Token Financial Requirement during XI plan: Rs. 6 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
1.00	**1.00**	**1.00**	**1.00**	**2.00**

3.9 Comprehensive Topographic Surveys

India with a coastline of over 7516 km and 1197 islands, is traditionally a seafaring country. The adoption of the Convention of the UN Conference on the Law of the Seas has established a new international order for the oceans. This extends the economic jurisdiction of coastal states to an area ranging from 200 to 350 nautical miles from the coastline. As of now, 200 nautical mile is our Exclusive Economic Zone (EEZ). According to this regime, in 2.02 million square kilometers of EEZ area, which is nearly two-thirds of the landmass, India has the exclusive right to utilize living and non-living resources.

The seabed below our EEZ is the repository of hydrocarbons and other potential mineral resources. While the search and research for mineral and hydrocarbon and fishing resources is being pursued by the various agencies, the knowledge about topography/geomorphology of the seafloor remains very sketchy. Our knowledge of the seafloor morphology is on the basis of single beam echosoundings and spot measurements obtained over a long period of time for the navigation purposes and by merchant navy ships. The variety of geological features i.e. submarine channels, canyons, volcanoes etc. remain to be studied in detail.

As of now, there is a specific requirement of detailed topographic maps in the following areas:

- Mineral exploration and development
- Deployment of research instrumentation on or near seafloor including submersible operations
- Fishing operations using deep trawl or bottom fishing gear
- Sub-sea pipe line or cable rooting
- Identification of ocean waste-disposal sites
- Port and Harbor Development
- Fish habitat research
- Marine archeological studies

Considering the importance of the work from national perspective, a project on " Surveys of the Exclusive Economic Zone of India" was formulated. The main objective of the project is to prepare a comprehensive morphology/topography map for the entire EEZ which would be useful in addressing the areas listed above. Sampling by grabs and sediment coring will enhance our knowledge on sedimentation, paleo-climate, non-living resources etc. Besides, the detailed morphology on the basis of seamless topography of EEZ will help us refine our understanding of the endowment of resources. Prevalent state of art technologies enables us to obtain morphology of long swaths of seabed in single cruise tracks, with multi-beam sonar.

The mission mode programme was accordingly reformulated by the department in association with the participating institutes, GSI (marine wing) and Naval Hydrographic Offfice(NHO) for obtaining morphology of the entire EEZ together with the sonar imaging of the seabed. Sampling of the area is also proposed considering its importance for endowment assessment. The implementation of the programme has now been compressed for to duration of six years from the earlier proposal of nine years in view of suggestion made by the Planning commission. Services of a chartered vessel have been commissioned by a Russian vessel, in addition to the Research Vessel Sagar Kanya, coastal vessels with the institutes engaged in the programme namely, NIOT, NIO and NCAOR. It is proposed to complete all the data acquisition with the help of four vessels using multibeam sonar in five years. The state of art multibeam system today can provide a coverage up to 3.5 time the depth (in deep waters) and up to 7 times the depth (in shallow waters). Further, data collection through multibeam echosounder is faster, cost effective and more accurate. Total estimated ship days required for the work is 1238 days out of which shallow depth survey (10 m to 500m) of 5 lakh sq. km area is estimated to be completed in 638 days and deeper water (>500m water depth) is estimated to be completed in 600 shipdays. The data analysis processing and digitization would be made simultaneously and would extend up to 6th year of the programme. The Steering Committee comprising of MOOD, NHO,GSI,NIO,NIOT,NCAOR would be monitoring the project covering all aspects.

While, the surveys for waters under 500 m depth are continuing using the Departmental vessels, the deep water surveys beyond 500 m would not be completed within IX plan period and would be continued during XI plan period. Further, data inventory and archival facility will have to be created during the XI plan period. This would have to be supplemented with adequate computational and memory.

Financial requirement **i**n XI plan : Rs. 48 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
5.00	**12.00**	**12.00**	**12.00**	**7.00**

3.10 Studies on Gas Hydrates Exploration & Technology Development for Its Assessment.

Gas-hydrates have attracted the attention of whole scientific community because of their
(i) Widespread occurrences in polar and outer continental margins and
(ii) Future potential energy resources.

Gas hydrate program was envisaged to get basic understanding on the occurrence, distribution, formation mechanism and exploitation strategy for gas hydrates by Ministry of Ocean Development involving Science and technology for qualification and quantification of gas hydrates in Indian continental margins.

<u>Science Component</u>
This involves:
1. Development of basic infrastructure facilities for geophysical modeling studies
2. Established geophysical modeling techniques for assessing gas hydrate occurrence (sites with BSR and without BSR)

3. Infrastructure development for Synthesis and characterization of gas hydrates using Raman Spectrometer
4. Equipments such as Ocean Bottom Seismometer and Heat probe were purchased for the gas hydrate studies
5. Development of infrastructure for gas hydrate program
6. Laboratory Equipments for analysis
7. Sediment storage facilities
8. analytical techniques for gas hydrate, pore water chemistry etc (methanogenesis, Sulphide Methane interface etc)
9. Techniques to study ecological aspects at gas hydrate study involving benthic and microbial studies

Two sites of 100km x 100km with high potential of gas hydrate occurrence in East coast of Indian were selected after detailed data processing of Multi-channel Seismic data collected during Legal Continental Shelf program for gas hydrate study by NGRI and NIO

Technology Component

This involves :

1. Development of Support Submersible 2500 and Coring System)
2. Autonomous Coring System

The development of the Support Submersible is in the integration phase and is expected to be ready for sea trials by May 06. The Autonomous Coring System is at the design stage.

The sequential development in this regard is as follows:

- Subcomponents qualification test for integration of SS2500
- Integration of all components for shallow water testing
- Testing the submersible at medium depth
- Ground truth validation of gas hydrate sites using suitable sensors for
- Basic design of Autonomous Coring system
- System integration will be completed for initial testing

Indo – Russian Centre for gas Hydrates

1. Centre started during February 2004 under Integrated Long term Program (ILTP) of DST to cater the need of gas hydrate activities in India
2. In total Nine program had been identified and approved with three each to NIO, NGRI and NIOT
3. First Visit of Indian Scientists to Russia was completed during April 2005. Technology development and gas hydrate research in Lake Baikal projects were formulated and under implementation

Science Component (NGRI & NIO)

This involves:

Multidisciplinary data acquisition and Collection of long (~20m) sediment cores at selected two locations namely Godavari (17,875 sq.km) and Mahandi offshore (12,220 sq.km)

Following detail survey will be performed at selected sites :

1. Sparse grid Multi channel seismic study – NGRI
2. Swath Bathymetry survey – NIO

3. Deep tow digital sides scan survey – NIO
4. High resolution sparker Survey – NIO
5. Deep tow digital video imaging – NIO
6. CTD and Heat flow measurement – NIO & NGRI
7. Close grid Multi channel seismic study – NGRI
8. OBS survey along with short streamer – NGRI
9. Sediment and water sampling – NIO & NGRI

The data will be analysed

a. to infer geophysical and non geophysical proxies (gas charged sedimentary columns, contrasting acoustic impedance horizons, gas escape features etc besides geochemical and biological proxies

b. to establish geophysical modeling techniques for resource estimation

c. to identify the benthic communities and quantification of methanogenes, sulphate and nitrate reducing bacteria and other microbes which thrive on methane and other gases

d. to characterize gas hydrates bearing sediments

e. to select few best suitable sites for ground truth validation by technology devices

Activities under XI plan period

The present gas hydrate programme through its science and technology components will lead to a better understanding of the gas hydrate characteristics vis a vis the environment and handling. This will lead to the ultimate target of evolving suitable science and technology for the production and maintenance of the ecology.

The successful development of the remote coring system will be the first step towards establishing unique functioning technology for exploiting ocean resources. The need to further this technology will be the natural corollary. The concept of the technology will establish the basis of the pilot plant technology.

Technology development

To meet the objectives laid out above, the technology development and requirement would consist of the following, though not confined to them :

1. Pilot plant for production of Gas from the Gas Hydrate rich zone.
2. Manned submersible to monitor the functioning of the Pilot plant.
3. Development of further unmanned remotely operated submersibles and Remotely operated coring and drilling systems to build up spare capacity.
4. To upgrade existing Remote coring system for capability enhancement.
5. Storage, Transportation & Processing Gas Hydrate

1. Pilot plant for production of Gas from the Gas Hydrate rich zone

Though gas-hydrates are a vast storehouse of natural gas, commercial production of gas from gas-hydrates has been a distant prospect. Three methods such as (i) thermal stimulation, (ii) depressurisation and (iii) inhibitor injection can be considered for production of gas from gas-hydrates.

However, no method has been proved economically viable so far. With the fast growth of technology, it is expected that methane trapped below the gas-hydrates can be exploited economically. Therefore, we should look into ‘gas traps in hydrate-seals’ at places of seafloor hills, domes extending from below towards the seafloor, dipping strata intersecting the seafloor.

Depending on the success of the Remote operated automated coring system, the technology will be advanced to initially tap the gas below Gas Hydrate layer where ever found suitable. The system may either be based on offshore platform or sea floor based (may be in further future). Putting a suitable offshore platform at 2000 to 2500 meters depth is the technological challenge and it needs to be evolved before embarking on a long term and large-scale solution.

Initially the system will consist of ship mounted production unit to prove the technology and the success of it would lead to establishment of large scale plants for commercial productions.

2. Manned submersible to monitor the functioning of the Pilot plant.

Going by the trends of the world in the research of Gas Hydrates and related technologies, the use of remotely operated unmanned submersible and subsequently manned submersibles are expected to play a major role in defining the deep sea technologies of the future. In similar programs, United States of America and Canada have been using the service of ALVIN (manned submersible of Woodshole Institute) extensively in areas like Blake Ridge etc. for validating the survey data. The monitoring of the coring & drilling system and the future process of converting the Remotely operated Drilling and Coring systems to sea bottom based production and power generation centers will depend largely on the successful usage of the manned and unmanned submersibles.

India has already embarked on developing un-manned submersibles and it would be prudent to continue its advancement in the form of manned submersibles. The idea of using nuclear power source would also be explored depending upon the feasibility.

3. Development of further unmanned remotely operated submersibles and Remote coring and drilling systems to build up spare capacity.

Considering the spread of the Gas Hydrate resources in Indian waters and in the likelihood of the attempt to explore the full potential of the resources, it will be required to have the services of quite a few numbers of support submersibles and remote coring systems. This will lead to building up the spare capability and reduce idle time between downtimes.

4. Upgrade existing Remote coring system for capability enhancement.

The present drilling and coring system would have the capability of drilling up to 50 meters (upgradeable to 150 meters) whereas the expected Gas hydrate layers can occur up to 400 to 500 meters below the sea floor. To realize the full usefulness of the system it is necessary, as the next step, to enhance the drilling capacity to around 500 meters. The modalities of enhancement of the capabilities need to be examined taking into account the size, weight, available infrastructure and modular enhancement capability.

5. Storage, Transportation & Processing Gas Hydrate

Through the production of Gas Hydrates, the skill, confidence and capabilities would increase. This would lead to newer thinking on the qualification & quantification of gas hydrate.

The process will also include recovery of gas from solid Gas Hydrates disassociated through active agents and thereby enhancing the production capacity. The quality of the gas from the Gas Hydrates also needs to be monitored control and processed to make it suitable for transport, storage or energy conversion. The present idea is to have the processing, controlling and monitoring unit atop the offshore production ship.

Financial implication for XI plan : Total Rs. 624.46 crores
(Technology Component : Rs. 564.46 crores
Science Component: Rs. 60 crore)

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
56.84	98.93	106.61	127.44	234.64

3.11 Acquisition of New Research Vessel

The Department's focus in the next 5 years will be to develop sustainable technology for the exploitation of various non-living resources. Under New Research Vessel, suitable platform is required to replace the vessels and crafts chartered by the MOOD at present, which caters to the demand for technology services and demonstration programme. This new facility will also cater to shallow water survey, Data buoy maintenance, and act as a supply and support platform for the various coastal and deep ocean activities planned by the Department. A new multipurpose vessel for Technology services and demonstration is presently under construction. Upon completion of design, the agreement for construction of the vessel has been signed on 31.12.2005. This vessel will serve as a platform for the programme envisaged in the X Plan and also serve as a utility science vessel which will augment the capacity needs of the marine living and non-living resources programme of the Department including the ongoing and the new programmes of the Ministry of Ocean Development during the Tenth Five Year Plan and thereafter, namely: Deep Sea mining, Remotely Operated Vehicle (ROV), Autonomous Underwater Vehicle (AUV), Gas Hydrates, surveys to support technology demonstration programmes etc. and to act as a support platform for various research activities planned by the Ministry of Ocean Development. The NIOT is the nodal agency to implement this programme and to operate and maintain the vessel.
The following activities would be completed during the present plan period
(i) 50% construction of the vessel. (Keel laying is already completed.)
(ii) procurement of outfitting for the vessel including Special Purpose Deck Machinery and scientific equipment
Since, the construction activity is likely to be spilled over to the next plan period, the programme would be continued in XI plan period.

Financial Requirement during XI plan : Rs. 125crores

(Rs. in crores)

2007-2008	2008-2009
110.00	**15.00**

3.12 Data Buoy programme / Integrated Sustained Ocean Observation Network (ISOON)

The ISOON has been designed, considering the existing observational networks and future possible observational requirements to address the ocean atmospheric processes in an integrated way. The Data Buoy Programme being implemented since 9th Plan is one of the components of the ISOON programme. Thus there would be no separate programme as Data buoy Programme during XI Plan. The vision guiding the development of an Integrated Sustained Ocean Observation Network (ISOON) is to provide the information needed by governments, industry, science and the public to deal with marine related issues, including the effects of the ocean upon climate. It needs to be supported by a unified network to systematically acquire, integrate and distribute oceanic observations and to generate analysis, forecasts and other useful products.

The proposed Integrated Sustained Ocean Observation Network is classified into three networks namely, ICOON, IEON and OON. Different work packages are proposed to cater the region specific requirement of the observation network. The status of each work package with details of sensor fit, end application and the proposed locations are furnished below.

Indian Coastal Ocean Observational Network (ICOON) Work Packages
ID Work Packages
WPC1 Coastal Weather Stations
WPC2 HF Radars
WPC3 Tide Gauges
WPC4 Environmental Buoys
WPC5 Port Buoys
WPC6 Moored Profilers
WPC7 Expendable Buoys
WPC8 Validation Platforms

Indian EEZ Observational Network (IEON) Work Packages:
WPE1 Ocean Buoys
WPE2 Current Meter Moorings
WPE3 Reference Platforms
WPE5 Glider Floats
WPE6 Autonomous Vehicle
WPE7 Tsunami Buoys
WPE8 GPS & Hydrophone Buoys
WPE9 Geophysical Observatory

Open Ocean Observational Network (OOON) Work Packages:
WPO1 Met Buoys
WPO2 Drifter Buoys
WPO3 Argo Floats
WPO4 XBT Profilers
WPO4 Ocean Odyssey Buoys
WPO5 Ice Buoys
WPO6 – Work Packages for Open Ocean Observation

In each of the three working packages some components are continuing in nature and some are new initiatives in XI Plan. Accordingly, these component are grouped into the followings two groups giving details on responsibility of various institutes, : .

CONTINUING COMPONENTS:

Implementing Agency : NIOT /INCOIS

1	Tide Gauges	NIOT
2	Environmental Buoys	NIOT
3	Port Buoys	NIOT
4	Moored Profilers	NIOT
5	Expendable Buoys	NIOT
6	Validation Platforms	NIOT
7	Ocean Buoys	NIOT
8	Current Meter Moorings	NIOT
9	Reference Platforms	NIOT
10	XBT Profilers	NIO
11	Met Buoys	NIOT
12	Drifter Buoys	NIO
13	Argo Floats	NIOT/INCOIS

NEW COMPONENTS

1	Glider Floats	NIOT
2	Autonomous Vehicle	NIOT
3	Tsunami Buoys	NIOT
4	GPS & Hydrophone Buoys	NIOT
5	Geophysical Observatory	NIOT
6	Ocean Odyssey Buoys	NIOT
7	Ice Buoys	NIOT/ NCOAR
8.	Coastal Weather Stations	NIOT
9	HF Radars	NIOT

Budget : Rs. 367.09 crores

The year-wise budget requirement for Continuing and New schemes each of the component is as follows:

	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	TOTAL
A. Continuing databouy and other buoys	40.00	50.00	50.00	40.00	20.00	200.00
B. ARGO	6.85	6.05	6.00	5.95	5.95	30.80
C. New Components	20.00	30.00	50.00	20.00	16.29	136.29

3.13 Tsunami & Storm surges Warning System

MOOD is the nodal Department for setting up Early Warning System for Tsunami and storm surges. INCOIS is the responsible agency under MOOD for setting up of Tsunami Warning Centre. The warning system is planned to be made operational by September 2007.

During the operational phase the Early Warning Centre needs to be operated on 24x7 basis, which calls for technical infrastructure as well as computational infrastructure with hot standby, thus eliminating chances for any single point failures. It is essential to maintain and replace (as and when necessary) all sub-systems including the deep ocean assessment and reporting system, tide gauges, radar network, communication systems, etc.

PERIODIC REHEARSALS

A scheme for periodic rehearsals will be worked out to ensure that the entire system is functioning normally. This will involve exercising the individual sub-systems (seismic, water level, communication, dissemination, etc) and total system. This Drill will ensure 24x7 upkeep of the entire system.

CAPACITY BUILDING AND AWARENESS

Appropriate training programmes will be taken up to keep the technical manpower abreast with the standard operating procedures at the Warning Centre as well as latest advances in the field. Periodic workshops will be organised for the user community to familiarize them with the use of tsunami and storm surge advisories as well as inundation maps. Publicity material on Earth quake, Tsunami and storm surges will be generated in vernacular languages to be distributed to general public.

IMPROVE & MAINTAIN ACTIVE DISSEMINATION CHAIN

Timely dissemination of tsunami and storm surge advisories to all stakeholders (MHA and coastal population) is very critical. This requires a strong failsafe network of dissemination equipment to be installed along the entire coastline. It is necessary to use all available communication modes such as TV, Radio, IMD cyclone network, mobile phones as well as introduce advanced Digital display Boards (with satellite communication capabilities and ID based multicasting) and new technological interventions that may be available.

R&D IN OCEAN SCIENCE, SEISMOLOGY, MODELLING

Basic research in Seismology will be pursued to extract information related to source dynamics, rupture velocity, direction and displacement through a suite of modelling and wave form inversion techniques.

R & D in ocean sciences will be focused on evaluation of existing Tsunami and storm surge models. Studies will also be undertaken to assess the effectiveness of natural and artificial defence mechanism for mitigating the impact of Tsunami and storm surges.

The estimated fund required for this project would be Rs.126.18 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
41.18	20.00	20.00	25.00	20.00	126.18

3.14 National Centre for Antarctic and Ocean Research (NCAOR)

3.14.1 Establishment of New Permanent Indian Base in Antarctica

For the past 25 years the Indian activity has been concentrated in the Central Dronning1 Maudland (CDML) area of Antarctica. Considering the fact that it is necessary to generate detailed and comprehensive data base which has both scientific and strategic significance, it is envisaged to establish a new Indian permanent station in Antarctica. This has become pertinent keeping in view the growing significance of Antarctica and the Southern ocean as modulator of global climate change and other intrinsic processes, which directly control the sustenance of humankind on the planet earth, and as a potential sourcing of resources.

Keeping in view the above, during the XXIII Indian Scientific Expedition to Antarctica (2003-04), a Task Force constituted by the Department of Ocean Development had, after reconnaissance traverses in the coastal oases of the Vestfold Hills, Rauer Islands and Larsemann Hills, tentatively identified a rocky promontory in the Larsemann Hills, East Antarctica, as a possible site for India's new permanent Antarctic base. Subsequently, a team of scientists had visited the new site during the XXIV Expedition and had initiated preliminary geological, glaciological, limnological and upper atmospheric studies at Larsemann.

Based on the studies carried out, a timeframe for the various activities leading to the establishment of the new Indian Antarctic Base in the Larsemann has been chalked out. This includes a Comprehensive Environmental Evaluation of the proposed station as per the provisions of the Environmental Protocol to the ATS, a detailed site and building/infrastructure plan to be readied by 2007 and obtaining the requisite approvals of ATCM for the Project. The construction work of the new station is planned to be initiated during the XI Plan.

Financial Requirement: Rs. 74.00 crores

Details	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**Total, Rs. crore**
1. Basic engineering set-up/structure at the new site/new research station	10.00	10.00	3.00	1.00	1.00	**25.00**
2. Laboratory facility/ instrumentation	5.00	2.00	1.00	1.00	1.00	**10.00**

3. Life support system (Communication, vehicle, crane,dozer, gen. set, fuel storage containers)	5.00	2.00	1.00	1.00	1.00	**10.00**
4. Satellite field camps/living modules	0.30	0.20	0.20	0.20	0.10	**1.00**
5. Financial support to scientific programmes	0.60	0.60	0.60	0.60	0.60	**3.00**
6. Logistics support (team mobilization, food, kit clothing etc.)	4.00	4.50	5.00	5.50	6.00	**25.00**
Total	**24.90**	**19.30**	**10.80**	**9.30**	**9.70**	**74.00**
** Assuming own ship will be ready by end of XI Plan*						
Foreign Exchange Component: Rs. 60.00 crores						

3.14.2 Southern Ocean Studies

The agenda for research in the Southern Ocean realm underlines the sensitivity of the Southern Ocean region to climatic variabilities and its importance in our understanding the global environment. Basic and advanced research programs proposed to be undertaken during the XI Plan period in the Southern Ocean Sector will primarily include determination of the dynamics of the formation & distribution of water masses, currents and sea ice, investigating the relationship between oceanic & atmospheric circulation systems and the physical basis for biological productivity, assessment of the distribution, sources and sinks of carbon, deciphering paleoclimatic records preserved in the sediment cores from the southern Ocean and the periglacial freshwater lakes in the continent, through integrated sedimentological, paleontological and geochemical studies, and delineation of space-time variables of the APF and STC in the Indian Ocean Sector of the Southern Ocean, and as assessment of the constraints of interhemisphere climatic forcing functions.

Considering the need for an oceanographic research vessel in mounting the Southern Ocean `experiments, it is planned to delink the Southern Ocean studies with the regular Antarctic Expeditions. It is proposed to charter a state-of-the-art oceanographic vessel during alternate years of the Plan period for this purpose, with ORV Sagar Kanya being deployed in the Southern Ocean waters north of 58^{o}S during the intervening years. Although the Southern Ocean studies will be an integrated effort involving several of the leading national laboratories, the primary responsibility for planning and implementing the research programs in this sector as well as for the planning and co-ordination of all activities related to mounting multi-disciplinary cruises in the Southern Ocean will be vested with NCAOR.

FINANCIAL Requirement : Rs. 42 crores

Details	2007-08	2008-09	2009-10	2010-11	2011-12	Total, Rs. crore
1. Chartering of Ship	4.00	0.00	5.00	0.00	6.00	**15.00**
2. Scientific instrumentation	1.00	2.00	0.50	2.00	1.00	**6.50**
3. Logistic support (team mobilization, food, kit clothing etc.)	1.50	2.00	2.50	3.00	2.50	**11.50**

4. Finance support to scientific programmes	1.00	1.50	2.00	2.50	2.00	**9.00**
Total	**7.50**	**5.50**	**10.00**	**7.50**	**11.50**	**42.00**

3.14.3 In house R&D, infrastructure, capacity building at NCAOR

With the establishment of state of the art instrumentation facilities at NCAOR like cold laboratory, ultra clean (Class 100) room, SIRMS, ICPMS, AAS, SEM etc. the center has fully geared up to take up well-focused scientific R & D activities in following scientific disciplines and themes of polar/oceanographic research.

1. Ice-core studies & Paleoclimatology
2. Chemical /Geological/Biological Oceanography of the Southern Ocean
3. Satellite application and Remote Sensing in Polar Regions
4. Microbiological/ Biotechnological potential of Antarctic microbes
5. Antarctic Environment Studies
6. Paleoclimatic studies
7. Marine Geophysical studies
8. Development of National Antarctic Data Centre and its networking

Proposed activities during the XI Plan:

A brief outline of the objectives of the various research programs and activities proposed to be undertaken by NCAOR during the XI Plan period is provided below: -

1. Ice-core studies & Paleoclimatology: It is proposed to collect short (<200 m long) ice-cores from geographically distinct regions in Antarctica

2. Chemical/Physical/Biological Oceanography of the Southern Ocean: It is proposed to undertake at least two cruises in the Southern Ocean during the XI Plan period for undertaking R&D activities in different domains of Oceanography.

3. Satellite application and Remote Sensing in polar regions: During the XI plan, the characterization of sea ice in Arctic and Antarctic using satellite data from Indian/foreign satellites will be undertaken.

4. Microbiological/ Biotechnological potential of Polar microbes: In order to explore the biopotential of different cold-temperature microbes/bacteria, systematic studies shall be initiated in both the polar regions.

5. Antarctic Environment Studies: Systematic environmental monitoring around the Indian Base in Antarctica as well as at the site of the new station in the Larsemann Hills are proposed to be regular features of the Indian Antarctic Programme during the XI Plan period.

6. Pale-oclimatic studies: Antarctic lake sediments, Southern Ocean sediment cores and cores from the Arctic region represent some of the most reliable archives of paleo-climatic conditions. Therefore, an integrated sedimentological, geochemical and microplaeontological study of the sub-surface sediments from these regions is proposed to be initiated for understanding the natural short-term climatic perturbations of the past. Concrete efforts shall be made in this direction during the XI Plan to reconstruct the millennial-scale climatic changes, with special reference to the Holocene.

7. Marine Geophysical studies: In order to explore the possible linkage of the Indian sub-continent with Antarctica, a comprehensive geological/marine geophysical investigation is proposed to be initiated during the XI Plan period in the East Antarctic

region around Prydz Bay. The thrust areas of the studies being proposed are (i) Understanding the structure and evolution of the East Antarctic Margin including crustal architecture and possible rift processes, (ii) Determination of the spatial and temporal partitioning of strain across the rifted margin, and (iii) understanding the type and nature of the basement.

8. **Development of National Antarctic Data Centre and its networking:** Under International obligation of ATS, the National Antarctic Operator needs to operate its own data Center with linkages to the Antarctic Master Directory. Initial efforts in this direction have already been made at NCAOR during the current plan period. These shall be continued during the XI Plan with the ultimate aim of developing an exhaustive Indian Antarctic Data Centre with uplinking to the Antarctic Master Directory.

Some of the above studies are already in progress and are proposed to be continued in a phased manner spread over the XI plan period. To cater to the requirements of these research activities as well as for its other mandated activities, NCAOR has drawn up a comprehensive blue print for scientific manpower development at the Centre concomitant with the phased expansion of the research areas. Besides specialists in different disciplines to be recruited as scientists, the scientific complement under different research programs will also include research fellows/ associates who will support the various scientific activities at the Centre. In addition, the Centre also proposes to support advanced research projects related to Polar Sciences being initiated by other premier institutes in the country through a system of research fellowship programs / GIA.

Financial Requirement : Rs. 167 crores

(Rs. 39.35 +Rs .127. 65 crores)

Details	2007-08	2008-09	2009-10	2010-11	2011-12	Total, Rs. crore
1. Ice-core studies & Paleoclimatology	0.80	0.32	0.83	0.84	0.85	**3.64**
2. Chemical/ Physical/ Biological Oceanography of the Southern Ocean	0.45	0.46	0.50	0.75	1.00	**3.16**
3. Satellite application and Remote Sensing in polar regions	0.10	0.12	0.13	0.14	0.15	**0.64**
4. Microbiological/ Biotechnological potential of Antarctic microbes	0.20	0.21	0.24	0.25	0.26	**1.16**
5. Antarctic Environment Studies.	0.20	0.21	0.24	0.25	0.26	**1.16**
6. Paleoclimatic studies	0.65	0.12	0.13	0.14	0.15	**0.19**
7. Marine Geophysical studies	0.30	0.27	0.26	0.28	0.30	**1.41**
8. Development of NADC	0.25	0.27	0.28	0.29	0.30	**1.39**
- Other NCAOR Expenses						
9. Other lab. expenses related to R&D	0.50	1.00	1.50	1.60	2.00	**6.60**

10. KBCAOS	0.75	0.75	1.00	1.00	1.00	**4.50**
11. Microbiology Centre at CCMB	1.00	1.00	0.50	0.50	0.50	**3.50**
12. Expenses related to LCS submission	1.00	1.00	1.00	0.00	0.00	**3.00**
13. Scientific Equipt. For Sagar kanya	2.00	1.00	1.00	2.00	2.00	**8.00**
Total	**8.20**	**6.73**	**7.61**	**8.04**	**8.77**	**39.35**

9. Construction of a Jetty at NCAOR , Capacity Building, Office and Operational Expenses

Considering that (i) NCAOR is the nodal agency responsible for the handling of ORV Sagar Kanya and other vessels chartered by the Ministry (ii) Goa is the launching pad for the annual Antarctic Expeditions as well as those being proposed for the Southern Ocean, the need is being felt for a dedicated jetty abutting the NCAOR Complex, as an extension of the current port facilities being managed by the Mormugao Port Trust (MPT). Preliminary discussions in this regard with the officials of the MPT indicate that the Port Trust is also keenly interested in this Project, as it will help reduce the traffic at the Port to a great extent.

Office and operational expenses						
1. Salary, wages etc.	3.00	4.00	5.00	6.00	7.00	**25.00**
2. Other office expenses including establishment, campus maintenance, electricity, water, POL, transport etc.	5.00	5.00	5.00	7.00	8.00	**30.00**
3. Civil works comprising:a - Visiting scientists' lab; Director's Office; Data Centre; research Scholar's Hostel, Guest House	6.00	5.00	4.60	0.80	0.00	**16.40**
b - Construction of a Jetty	4.00	22.00	20.00	2.00	2.00	**50.00**
c - Purchase of land & construction of residential accommodation	3.00	2.00	1.25	0.00	0.00	**6.25**
Total	**21.00**	**38.00**	**35.85**	**15.80**	**17.00**	**127.65**

3.15 Indian National Centre for Ocean Information Services (INCOIS)

3.15.1 Information Bank and Web-based Services

Need-based User Projects for Coastal and Offshore applications

With the vast amount of data available in the Information Bank of INCOIS, Ocean models could be fruitfully utilized to undertake need based user projects for coastal and offshore applications.

Development of an active network of institutional and project-oriented data centres

INCOIS has the mandate to generate and provide data and value added data products to user communities. In accordance with this, INCOIS has been providing data and data products, advisory services to several users.

During the XI plan, it is proposed to have a strong organisational arrangements with all the agencies involved in ocean observational programmes, so that there is real-time /near real-time flow of data to Ocean information Bank.

INCOIS will make the data and data products available to all users in appropriate formats. This will facilitate optimal and proper utilization of data for both operational oceanography and other research purposes.

National Oceanographic Data Centre

Recently, INCOIS has obtained the formal status of being the National Oceanographic Data Centre for India, which will be the centralized facility that provides continuous ocean data and information in usable form to user community. The data flow to NODC from ocean information bank will follow national data policy.

Data Warehousing & Data Mining Applications for in-situ and remote sensing data & data products.

INCOIS has implemented state-of-the-art data base driven user friendly dynamic web site with multilingual capability, Web-GIS facilities for providing ocean information and advisory services such as PFZ, OSF, Argo data and products, etc. This has been widely used web site among wide spectrum of users.

To improve the functionality of the Website and maintain a centralised repository of enterprise data, INCOIS has initiated the development of data warehouse and data mining facility. Towards this, INCOIS has designed a data warehouse data base using Oracle for managing in-situ as well as remote sensing data. Also a GIS based interface for selection and retrieval of data from various observing platforms in the Indian Ocean has been developed. During the XI Plan it is proposed to make this as a full fledged data warehousing with data mining capabilities using on-line analytical processing (OLAP) and on-line transaction processing (OLTP).

The entire web site will be maintained and upgraded from time to time with contemporary technologies in ICT and marine realm.

Ocean Data dissemination to operational agencies

Web interface developed by INCOIS will provide timely, reliable, up-to-date ocean information to various users in appropriate formats to meet their requirements.

Global Telecommunication System (GTS)

It is imperative to get a dedicated GTS access from IMD for National oceanographic activities. This will facilitate to receive oceanographic data disseminated by International communities in Indian Ocean. Also, as a part of International commitment, we could disseminate oceanographic data collected outside EEZ from Indian observing system to other operational agencies.

The estimated fund requirement in this project is Rs.10.00 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
1.00	3.00	3.00	2.00	1.00	10.00

3.15.2 Ocean Science and Techniques Development

3.15.2.1 Ocean Modelling and Data Assimilation for (a) Ocean and Climate, (b) Coastal Ocean and (c) Hazardous events

Setting up of High-performance Computing (HPC) facility at INCOIS as a national facility

INCOIS was called upon to be the prime mover for Ocean modelling by INDOMOD-SATCORE steering committee (Oct, 2001). Governing Council of INCOIS in its 9th meeting recommended that INCOIS will set up a high-performance computing facility to run coastal, regional and global model in operational mode. This will also serve as a National facility for other R & D in ocean modelling. This facility will be setup in a phased manner.

Ocean Modelling with Data Assimilation for providing description of past, present & future state of Ocean at appropriate spatial & temporal resolutions.

The plan is to (a) assemble long-term climatic data sets to describe past states and time-series showing trends and changes (Hindcast), (b) provide a description of the present state of the sea, including marine living resources with optimal accuracy (Nowcast) and (c) develop efficient data assimilation technique in the model to provide a description of the future condition of the sea as far ahead as possible (Forecast)

Contribute to Weather/Monsoon/Climate forecast by providing forcing for Atmospheric Models

Daily, monthly and seasonal thermo-haline field from Ocean model will help in forcing atmospheric model in order to predict weather, monsoon and climate. Hourly fields for a specific domain required for forcing meso-scale model for predicting cyclone intensity and track, and decadal thermo-haline fields will help for long term monitoring of climate and its change.

Understanding the variability of Ocean & Marine environment

Observing system will ever be so intensive that a mere contouring of the data would present a usable product for most customers, since every user tends to need very local site-specific information. By assimilating new data into numerical models, whenever possible and generating products based on the diagnostics and predictions of the models, Numerical model will deliver high quality information whilst keeping observation costs within practical limits.
The data acquired from ocean observations will be used in a wide range of ocean models to summarize the best quantitative understanding of different processes operating in the oceans and their interactions. Since the models are the most concise and complete representation about state of knowledge on ocean processes, they will serve as a link between observations and advance its ability to predict future ocean conditions.

Simulation experiment to optimize the observation system

Modeling is required to understand where and what frequency the sensors and platforms are required to deploy to capture better spatial and temporal sampling to resolve

scientific objective. This simulation experiments will also help in cost-benefit analysis for limited observations for optimal ways in a realistic budget. Though the ocean will always be under sampled, Models containing a proper representation of the ocean with assimilating data can supplement and extend observational data that are necessarily limited in space or time.

The estimated fund requirement in this project is Rs.30.00 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
7.30	5.90	5.70	5.85	5.25	30.00

3.15.2.2 Satellite Oceanography

Technology transfer of Species specific PFZ forecast (Tuna) as well as Wind-based Forecast for operationalisation at INCOIS
R & D being pursued at SAC as part of X Plan under SATCORE project will be operationalised at INCOIS after necessary validation and technology transfer.
Technology transfer of Advanced OSF for operationalisation at INCOIS
R & D being pursued at SAC as part of X Plan under SATCORE project will be operationalised at INCOIS and NRSA after necessary validation and technology transfer
Mount efforts for retrieval of geophysical parameters from Oceansat 2, Megha-Tropiques, RISAT and other Foreign Satellites
Several ocean remote sensing satellites are planned for launch during the XI Plan period by India and other space agencies. Some of them are Oceansat-II, Risat, Meghatrophiques, SMOS, etc. with various sensors for ocean and atmospheric applications. It is necessary to develop appropriate methodologies for atmospheric corrections and retrieval of geophysical parameters from radiometers, Scatterometer, Altimeter and Radars instruments. Also, it is imperative to develop regional algorithms for better retrieval accuracies in the Indian Seas.
Mount studies using high-resolution satellite data (Resourcesat, Cartosat, etc) for coastal processes, coastal habitat mapping, etc
Data from high resolution satellites need to be fruitfully utilized to study coastal processes and coastal habitats. This data will be useful to prepare coastal zone maps and disaster management.
R&D for incorporating additional parameters in PFZ Forecast; Species-specific forecast (Sardines, etc);
It is known that Mixed Layer Depth information is very important for identification of Potential Fishing Zones. This will provide information on thermal fronts in the vertical domain as well as will be useful for operation of Fishing gear. Hence it is imperative to pursue R&D during XI Plan in this direction.
Make satellite data products available at appropriate spatial & temporal resolutions
Satellite data fields such as wind, sea surface height anomaly, SST, chlorophyll, etc need to be archived and made available for use in Ocean modelling.

Financial Requirement : Rs.30.00 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
5.00	6.00	7.00	6.00	6.00	30.00

3.15.3 Ocean Observations

INCOIS has taken up the following International responsibilities during X plan period and these need to sustained further in the XI Plan with appropriate enhance Financial and Manpower support:

- Regional Argo Coordination and Argo Data Centre for Indian Ocean
- Indian Ocean GOOS: IOGOOS is the regional alliance for Global Ocean Observing System in the Indian Ocean with 25 Institutions form 14 Countries as Members. INCOIS is the Secretariat of IOGOOS during 2002 – 2008.
- NODC/IODE: National Oceanographic Data Centre, a centralized facility that provides continuous ocean data/Information in usable form to a wide user community.

Further, keeping in view the responsibilities of INCOIS, we need to have collaboration with other major international programmes/bodies such JCOMM, GODAE, IOCCG, IOTWS, etc.

Oceans play a significant role in the national development process as (a) the driving force for the monsoons, (b) a potential source for food, drug and energy, (c) a cost-effective medium for transport and (d) a strategic space. Disasters such as cyclones originate in oceanic region. Knowledge and information about the oceanic processes is of paramount importance in (a) improved forecast of weather and climate, (b) harvesting the marine living resources consistent with the principles of sustainable development, (c) development and management of the coastal seas and (d) preservation of critical marine and coastal ecosystems.

Further, combined marine meteorological and oceanographic advisories and services, generated with the above knowledge base and enabling technologies (such as IT) need to be delivered to a wide range of users, satisfying the economic, social and political needs of the country. An Ocean Information Bank accessible to the scientific community and operational agencies in real-time or near-real time is imperative for enrichment of knowledge base and effective generation of forecasts and advisory services.

MOOD has dedicated programmes for Ocean Observation, Ocean modelling, Ocean Information and Advisory Services. MOOD has institutional arrangements for implementing these programmes through its autonomous institutions. Ocean observations programmes include Argo profiling floats, moored buoys, drifting buoys, XBT lines, Current meter moorings, Ships of opportunity and observations using dedicated research vessels (CRV, ORV and FORV). Currently, INCOIS is the nodal agency for implementation of Drifting Buoys, Current Meter Moorings, XBT's, Ships of Opportunity and Argo Floats through NIO and NIOT. Ocean modelling activities are implemented through INCOIS as part of INDOMOD project with participation from premier national Institutions aimed at understanding the Ocean dynamics and thermodynamics of Indian Ocean. Operational services such as Potential fishing zone advisories and Ocean state forecast are being provided by INCOIS.

GOOS is an internationally coordinated system for systematic operational data collection (measurements), data analysis, exchange of data and data products, and technology development and transfer. The objective of GOOS is to ensure the establishment of a permanent system of global and systematic observations adequate for forecasting climate variability and change; for assessing the health or the state of the marine environment and its resources, including the coastal zone; and for supporting an improved decision-making and management process, which takes into account potential

natural and man-made changes in the environment and their effects on human health and marine resources.
The Global Ocean Data Assimilation Experiment (GODAE) is a GOOS pilot project that is a practical demonstration of near-real-time, global ocean data assimilation that provides, regular, complete descriptions of the temperature, salinity and velocity structures of the ocean in support of operational oceanography, seasonal-to-decadal climate forecasts and analyses, and oceanographic research.

Satellite Data Calibration and Validation Sites

Several ocean remote sensing satellites are being planned for launch during the XI plan period by India and other space agencies. Some of them are Oceansat-II, Risat, Meghatrophiques, SMOS, etc. with various sensors for ocean and atmospheric applications. These data sets need to be continuously validated, which calls for dedicated platforms with necessary in-situ sensors.

SOOP Lines

Though the efforts and investments in ocean data collection are huge, the available data from the aforementioned observational systems are still inadequate to draw meaningful conclusions on annual and inter-annual variability. Hence, additional observational systems and other possibilities also need to be explored to enhance the data availability from the oceans. To obtain surface meteorological data (air temperature, SST, relative humidity, atmospheric pressure, radiation, winds etc.), automated weather systems (AWS) may be installed onboard commercial ships if they volunteer to carry them around in the Indian Ocean during their voyages. This will provide sufficient surface data on synoptic scales.

INCOIS will be the prime agency for implementation of the scheme in active collaboration with the following institutions/agencies for each of the modules
Potential Fishing Zones
SAC, NRSA, FSI, State Fisheries Departments, Academia, other central research institutions, NGO's
Ocean State Forecast
NCMRWF, NIO, NIOT, ICMAM, SAC, DNOM, Coast guard, Navy, Shipping & Oil Industry, Academia
Early Warning for Tsunami & Storm Surges
IMD, SOI, NIOT, ICMAM, ISRO, NRSA, NIO, NGRI, BARC, Academia, MHA
Value-added Services including Consultancy Projects
NIOT, NIO
Ocean Information Bank and Web-based Dissemination
Active Collaboration with all the institutions implementing Ocean Observing systems in the Indian Ocean and other National/Global Data Centres
Ocean Modelling and Data Assimilation
CAOS, IIT-D, IITM, NIO, NPOL, NRSA, C-MMACS, NCMRWF.

Establish international knowledge networking with GOOS and GODAE Centres/ Satellite Oceanography
Schemes will be taken up with joint funding from DOS and MOOD under the direction of NNRMS-Standing Committee on Ocean Resources. Active Collaboration with SAC, NRSA, NIO etc. will be ensured for implementation

Ocean Observations
NIOT and NIO as well as Academia

Financial Requirement : Rs.85.00 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
25.50	17.00	15.50	14.25	12.75	85.00

3.15.4 R&D, infrastructure and Capacity Building

In order to maintain the computer systems in good working condition and 100% up time, the operation and maintenance of computer systems, equipment, peripherals, and networking needs to be continued. Further the procurement of high end servers, storage systems, Web and data base servers, Networking components, e-library etc are required to cater the XI Plan programmes

Technical Support Services (TSS) which include operation, maintenance and up-gradation of electrical, AC plants, Security, House keeping, Canteen, transport, etc would be needed.

It is proposed to construct residential accommodation, Hostel and Guest house in the INCOIS campus essentially to cater to the staff working for 24x7 operations, research/Project staff and Guests. This is an essential requirement since INCOIS is located at the outskirts of the City.

INCOIS will pursue R & D projects that will especially support its operational activities and other cutting edge science programmes of national relevance. These projects will be taken up in association with institutions/academia with core competence in the relevant areas. One such study that is planned to be taken up in the XI Plan is the Integrated study of Biogeochemical processes in the Northern Indian Ocean. The focus will be to enhance observations that are relevant to identify the bio-geochemical processes and its impact on climate change.

To pursue the proposed programmes, it is highly essential to build capability in core scientific areas such as Ocean Modelling, Data Assimilation, etc for which it is proposed to have collaborations with premier national/international centres for exchange programmes.

While it is proposed to induct core manpower for pursuing the XI plan activities of INCOIS, it is imperative to impart necessary training to the project personnel to be positioned on projects at INCOIS and collaborating institutions.

It is proposed to improve awareness on Oceans among the general public, School Student, Colleges, etc. This could be done by conducting lectures, exhibitions, publicity material, etc aimed at specific target groups.

Budget: Rs.75.00 crore.

	2007-08	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**TOTAL**
R & D in Ocean Science	5.00	6.00	6.00	5.00	3.00	25.00
INCOIS-Infrastructure development and capacity building	8.00	12.00	10.00	11.00	9.00	50.00

3.16 Sea Front Facilities

The Ministry of Ocean Development is implementing various oceanography research related programmes (both scientific and technology development). The major programmes of the ministry are implemented by its autonomous institutes like NIOT, Chennai; NCAOR, Goa and INCOIS, Hyderabad and two attached offices like ICMAM, Chennai and CMLRE, Kochi. The Ministry is also in the process of formulation of XI plan programmes and its major programmes have been proposed to be taken up duringthe next plan. The technology development work mainly would be taken up by NIOT, Chennai which needs various sea-front facilities for creation of integration bay, test ponds, test bed for tow vehicles, mariculture and research labs, etc.

A number of major technology demonstration programmes are given below:

i. Energy / Fresh Water
ii. Costal Process and Modelling
iii. Oceanographic Hydrographic and Geophysical Surveys
iv. Design of Offshore Structures
v. Development of submersibles
vi. Deep Sea Mining Activities
vii. Gas Hydrates Programme
viii. Integrated Sustained Ocean Observation Network (ISOON)
ix. Argo Programme
x. Programme on Ocean Science and Technology for Islands
xi. Vessel Management Cell
xii. Oceanographic Instrumentation
xiii. Marine Sensors and Electronics
xiv. Ocean Acoustics

The above said programmes are initiated in the X Five Year Plan and going to geared up in XI Five Year Plan.

The special facilities need to carryout the above activities are given below:

- Berthing facilities for Research vessels
- Test Ponds, Test bed for tow vehicles etc.,
- Desalination research laboratory
- Ocean acoustic laboratory
- Mariculture and research labs.
- Deep sea mining facilities
- Validation platform (Test reference area in the sea for vehicle platform, Sample Instrument Platform etc.,)
- Transit facilities such as Large Guest House for scientists, research fellows etc.,
- External and Internal service facilities and other peripheral facilities.

The scope of the work for the present proposal is to create a sea front facility to meet the research requirements of various programmes of NIOT. The work includes identifying the land having sea front area, procurement of Land, establishing sea front facility with external services.

Objectives

To establish sea front facility to carry out the above activities are as follows

Berthing facilities for Research vessels

- Test Ponds, Test bed for tow vehicles etc.,
- Desalination research laboratory
- Ocean acoustic laboratory
- Mariculture and research labs.
- Deep sea mining facilities
- Validation platform (Test reference area in the sea for vehicle platform, Sample Instrument Platform etc.,)
- Transit facilities such as Large Guest House for scientists, research fellows etc.,
- External and Internal service facilities and other peripheral facilities.

Implementing Agency : NIOT

Budget : Rs 200 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
25.745	**64.045**	**42.29**	**37.92**	**30.00**

4. New programmes

4.1. Expedition in the Arctic

In the modern world, the problem of political, economical, military – strategic, scientific and demographic characters are apparently closely interrelated in Polar Regions. As far as Antarctic and surrounding regions are concerned, India has strongly underlined her presence in Antarctic matters. However, so far the Northern hemisphere has not been paid attention by Indian scientific community. The Arctic region offers many scientific challenges. The Arctic is of special importance to the world. Due to climate changes such as; sea ice changes, coastal erosion and the thawing permafrost. Arctic is changing rapidly and thus climatic changes in this region present a major and growing challenges to the world scientific community at large. Possible changes in the global oceanic circulations, changes in storm intensity, and abrupt changes in temperature could also pose a threat to Arctic region. Since any change in extreme Northern hemisphere (Arctic region) affect the global climate, sea level, biodiversity etc. therefore any human induced changes in Arctic are being widely felt. World wide scientific community is embarking upon these regions to assess the impact of climatic changes.

The understanding of climatic changes in the Arctic region and their consequences on global climate changes has relevance to Indian subcontinent as well. Therefore, efforts need to be initiated to address some of these scientific challenges in details. It is therefore proposed that during the ensuing XI Five Year Plan concrete efforts need to be made to launch the First Indian Scientific Expedition to the Arctic and future emphasis would be laid on bi-hemispheric approach in understanding the vital issues related to environment/climatic changes. Accordingly efforts will also be made to initiate scientific programmes in the Arctic realm in consonance with the international endeavors in the Arctic being mounted under the Svalbard Treaty, SCAR etc.

Implementing Agency : NCAOR

Financial Requirement : Rs. 46. 00 crore

D - Expedition to the Arctic	2007-08	2008-09	2009-10	2010-11	2011-12	Total, Rs. crore
1. Chartering of expedition vessel/own vessel and Chartering of helicopters	0.00	0.00	8.00	8.00	8.00	**24.00**
2. Procurement of various scientific equipments	0.00	0.00	1.00	1.00	1.00	**3.00**
3. Logistics support (team mobilization, food, clothing etc.)	0.00	0.00	3.00	3.00	3.00	**9.00**
4. Collaborative programs to be mounted with other Arctic Teams in Spitzbergen (to be undertaken during the 1st	5.00	5.00	0.00	0.00	0.00	**10.00**

and third years of the Plan)						
Total	**5.00**	**5.00**	**12.00**	**12.00**	**12.00**	**46.00**

4.2 Desalination project

The main focus of this programme is to develop technologies for tapping renewable energies and generating fresh water from the ocean. NIOT has already demonstrated a desalination plant at Kavaratti Island with the capacity of 1 lakh litre per day and also 1 million litre per day barge mounted LTTD plant was successfully commissioned. In the XI plan, it is proposed to establish an offshore plant with 25 million liter per day capacity. This technology has advantages over conventional technologies like reverse osmosis such as easy operation and maintenance, low scaling, fouling etc

Objectives

- To establish an offshore plant with capacity of about 25 MLD

Implementing Agency : NIOT

Total Financial Requirement : 204.65 crores

(a) Budget: Rs. 150.00 crores

(Rs. in crores)

2007-2008	2008-2009	2009-2010
5.00	**120.00**	**25.00**

(b) Offshore structures Budget Rs.54.65 crore

(Rs. in crores)

2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
2.0	**20.0**	**18.0**	**8.0**	**6.65**

4.3 MLR and FORV Sea Front Facilities and Infrastructure

4.3.1 Dedicated berthing and associated facilities

CMLRE will have to co-ordinate all the national programmes funded by MoOD through CMLRE in the mean future. For this purpose considerable expansion both in infrastructure facilities and scientific, technical and managerial personnel are anticipated. Keeping these objectives in mind the following proposals are submitted for physical facilities in the area of land and buildings.

Land & Building: The CMLRE is functioning at present from an central pool building of the CPWD at Kakkanad. The office is provided with 750 sq.mt. area on the 6th floor of the said building. This office is approximately 25 kms away from the waterfront, where FORV Sagar Sampada reaches after every cruise. This makes the

transport of samples, maintenance of live culture etc and coordination of FORV activities extremely difficult. Further, Fishing gears and accessories etc are stored in a godown at Mattanchery (35 kms from the present office). Similarly, as against the requirement of approximately 4000 sq.m. area for the effective functioning of the Centre, the area available now is only 750 sq.m.

The CMLRE has approached GCDA(Greater Cochin Development Authority) to obtain land near the water front at the Valarpadam area. The construction cost of the Dedicated berthing and associated facilities of Rs. 23.50 crores.

Budget: Rs. 23.50 crores

2007-08	2008-09	2009-10	2010-11	2011-12	Total
4.70	7.05	5.88	3.52	2.35	23.50

Implementing Agency : CMLRE

4.3.2 Vessel Requirements

The Expert Committee constituted by the Department to work out the vessel requirements of MOOD had recommended research and coastal fishery Oceanographic vessels to meet the requirements of MLR Schemes.
However, during the meeting for formulation of XI plan programme held at New Delhi on 19.11.2005, it was decided that the vessel requirements for southern ocean MLR surveys be met by chartering of vessels and to restrict the number of coastal fishery oceanographic vessels. Accordingly, budget has been proposed as under:

Implementing Agency : CMLRE

Budget: Rs. 250. 00 crores

2007-08	2008-09	2009-10	2010-11	2011-12	Total
30.00	70.00	80.00	50.00	20.00	250.00

4.4 National Oceanarium

As a logical sequel towards the creation of a scientific temper in ocean sciences amongst children, the demand of the hour is for the development of a dedicated Oceanarium in the country. This necessarily would require the involvement of private enterprise who are already involved in real estate development and entertainment industry of the country as major stakeholders. The government has already evolved clear guidelines for Public Private Partnerships (PPP) in the infrastructure sector. This part of ocean science infrastructure is badly missing and immediate steps ought to be taken to redress the lacunae in our economy. The main objective of this programme is to make learning about the oceans a family experience by means of promoting science tourism so that young children are motivated to opt for an ocean career later on as adults. The government would provide seed capital and the expertise to the interested parties under this scheme.

Budget : Rs. 100.00 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	Total
10.00	40.00	40.00	5.00	5.00	100.00

4.5 Demonstration of Shore Protection Measures through Pilot Project

During X plan, the projects on Shoreline Management and Management of Tidal Inlets to understand the cause of erosion and siltation were initiated at inlets along the Indian coast. The experiences of the studies indicate that the two major areas of research are

- Protection of coast from Erosion caused by natural and man-made interventions through systematic understanding of the process responsible for its cause
- Prevention of Siltation at tidal inlets through analysis the dynamics of tidal inlets, which accounts forces from land as well as sea

The feedback from implementation of the projects on Shoreline Management and Management of Tidal Inlets during the X Plan and the outcome of the brain storming session conducted involving various State/Central Government Departments reveal the need of integrated shore protection strategies on site to site basis, where local hydrodynamics and coastal morphology is taken into account. The project will be implemented through pilot project at selected sites along the Indian Coast and its performance is monitored.

Objectives

- To develop shore protection/stabilization strategies that have minimum cross impact on adjacent coast, considering natural coastal processes and geomorphological setting of the site.
- To evaluate the performance of the shore protection strategy for its repeatability at other locations
- To develop wave information atlas required for shoreline management

Major components of the project

- To assess the present status of coastal defence and identification of vulnerable areas of erosion
- Identification of socioeconomic implications of erosion/siltation
- Monitoring processes responsible for erosion/siltation such as waves, tides, currents, sediment characteristics, beach profiles and morphology etc.,
- Development of strategies (Shoreline Management Plan) for coastal protection or prevention of siltation through model and prediction of its cross impacts
- Design of flexible structure that can be adaptable to changes in process or strategy or to be removed.
- Testing of the Structure for its stability through Physical Model
- Installation of Structure at field
- Monitoring the condition and performance of proposed coastal defence strategy, to assess their interaction with coastal processes to carry out strategic forward planning of maintenance, upgrading and replacement
- Developing methodology for implementation these techniques which can be used by local authorities for protection of coast/ prevention of siltation at other locations

Implementing Agency : NIOT

Budget: Rs.270.00 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
54.00	81.00	67.50	40.50	27.00	270.00

4.6 Integrated Ocean Drilling Programme

The Integrated Ocean Drilling Program (IODP) is an international marine research program established in October 2003 that explores Earth's history and structure recorded in seafloor sediments and rocks, and monitors sub-seafloor environments. IODP builds upon the earlier successes of the Deep Sea Drilling Project (DSDP, 1968-1983 using the *Glomar Challenger*) and Ocean Drilling Program (ODP, 1985-2003 using the riserless vessel *JOIDES Resolution*), which revolutionized our view of Earth history and global processes through ocean basin exploration. IODP greatly expands the reach of these previous programs by using multiple drilling platforms, including riser, riserless, and mission-specific, to achieve its scientific goals.

The IODP Science Plan: IODP's scientific objectives are organized into three major themes: The Deep Biosphere and the Subseafloor Ocean; Environmental Change, Processes and Effects; and Solid Earth Cycles and Geodynamics. Within these three themes, the following eight initiatives have been identified that are ready to be addressed within the first decade of IODP drilling:

- Deep Biosphere
- Extreme Climates
- Rapid Climate Change
- Continental Breakup and Sedimentary Basin Formation
- Large Igneous Provinces
- Gas Hydrates
- 21st Century Mohole
- Seismogenic Zone

Against the above background of IODP operations and science plan and in the context of the front-ranking scientific endeavors being planned/being undertaken by the country in the ocean domain, it is felt that there is an imperative need for India to be in the forefront of the consortium of nations involved in oceanographic research. This could be sought to be achieved by the country's membership in the IODP.

Objectives:
Development of a science plan and initiation of deep-drilling through the IODP, in at least three scientifically significant sites, one each in the Arabian Sea, the Bay of Bengal and in the western Andamans.

In the context of our ongoing exercise of delineation of the outer limits of the Indian continental shelf, an immense amount of invaluable marine geophysical data has been collected. The dataset will not only help not only to substantiate the country's endeavors at defining the outer limits of her continental shelf, but will also form the cornerstone of our future scientific forays into the marine domain. As a sequel to the LCS programme, a comprehensive study of the geological and tectonic evolution of the Arabian Sea and the Bay of Bengal basins of the northern Indian sector is being proposed to be initiated during the XI Plan period. The deep-coring upto the basement will be of immense advantage in constraining the geophysical data both for the LCS purposes as well as for the studies planned during the XI plan period.

Compared to the exhaustive deep-sea drilling data available for the oceans the world over, the Arabian Sea-Bay of Bengal sectors are marked by very few DSDP/ODP operations. The lack of critical basement data has been a major constraint in our endeavors at unraveling the history of the geological evolution of our ocean basins.

The IODP being a very recent international program, with the first riser-vessel due to be put in operation only by 2007, this would provide India with a unique opportunity to be a part of the international oceanographic fraternity.

Scientific participation in IODP programs anywhere in the world is largely restricted to scientists from member nations, excepting in cases where the drilling operations are in the contiguous sea of a non-member nation. Indian membership in IOPD will therefore provide a more effective participation of Indian scientists in international endeavors.

With our envisaged plans for initiating scientific programs in the Arctic region during the XI Plan period, membership in IODP will provide an avenue for Indian participation in the mission-specific operations being undertaken in the Arctic.

The major initiatives of the IODP such aș the Gas Hydrates, paleo-climatologcial studies, Continental Breakup, Large Igneous Provinces and Seismogenic Zone are in fact some of our current/proposed thrust areas of research. Currently, only ODP technology is capable of retrieving and maintaining gas hydrates samples from the subseafloor marine environment at *in situ* pressures.

As one of its inaugural activities, IODP is planning to drill through a seismogenic fault zone to characterize the composition, deformation microstructures and physical properties of the rocks at *in situ* conditions. This assumes significance in the context of our plans to undertake a study of the tsunami generating areas off the Western Andamans.

It is proposed to implement the program in two stages:

1. Initiation of action for Indian membership in IODP. This could be a National initiative.

2. Constitution of a core group to bring out an initial science plan prioritizing the deep-sea drilling in the Bay of Bengal/Arabian Sea/western Andamans. Since the drilling programs of IODP are finalized years in advance, the detailed science program needs to be generated at the earliest, if the first deep-sea drilling operations under the Indian initiative are to be undertaken during the XI Plan period.

It is envisaged that the initiative for Indian involvement in IODP would start during 2006-07 and that the formalities would be completed before the start of the XI Plan period. Concurrently with this initiative, the Initial Science Plan document would be readied. Once these initial activities are completed, the scientific programme for Ocean Drilling could be finalized. The actual dates for the initiation of drilling program are however, subjected to the acceptance of the Indian proposal and time-slotting by the IODP.

Implementing Agency : NCAOR

Financial Requirement: Rs. 100 crores

Details	2007-08	2008-09	2009-10	2010-11	2011-12	Total, Rs. crore
1. Assoc. membership n IODP	5.00	5.00	15.00	15.00	15.00	**55.00**
2. Expenses towards scientific projects to be taken up	0.00	13.00	5.00	10.00	17.00	**45.00**
Total	5.00	18.00	20.00	25.00	32.00	**100.00**

4.7 Construction of an Ice-class Research Vessel for Oceanographic studies

Ever since the First Indian Scientific Expedition to Antarctica, India has been depending on chartered ice-class vessels or ice-breakers for catering to the entire gamut of expedition related activities. However, considering the fact that the vessels were primarily meant for the transportation of men and material from India/Cape Town to Antarctica and back, The ships chartered over the years have been mainly freight container vessels with accommodation/space for the crew and expeditioners. The lack of oceanographic equipment and laboratory space on such vessels has prevented the participant scientists from carrying out any underway oceanographic/ hydrographic measurements during the ships transit to and from Antarctica. With the proposed plans for undertaking multidisciplinary scientific programmes in the Southern Ocean, initiation of activities during establishment of a new permanent Indian base in the Larsemann hills and plans to expand Indian scientific endeavors to the Arctic region/northern hemisphere, it is felt that its time for India to have her own Ice class research vessel which will (a) serve as a medium for transportation of men and material to Antarctica; (b) serve as a platform for the Indian scientists to undertake oceanographic studies in the sub Artic and sub Antarctic regions and (c) serve the needs of the Indian scientific community year-round in the tropical waters as well as in the sea-ice conditions of the polar regions.

Implementing Agency : NCAOR

FINANCIAL PROJECTIONS

Details	2007-08	2008-09	2009-10	2010-11	2011-12	Total, Rs. crore
1. Construction of the vessel	10.00	50.00	200.00	60.00	30.00	**350.00**
2. Instrumentation/ deck machinery	0.00	25.00	50.00	25.00	0.00	**100.00**
Total	**40.00**	**150.00**	**225.00**	**30.00**	**5.00**	**450.00**

4.7 Headquarter Building

The Ocean Development subject of the ministry is significant considering the coastline of over 7500 km length and about 2.02 million sq. km area within the Exclusive Economic Zone that offers immense scope for exploration and exploitation of the living and non-living resources. The vastness, complexity and uncertainty of the ocean environment calls for a coordinated, centralised and highly sophisticated development response. The Department of Ocean Development (DOD) was created in July 1981 as a nodal and independent department under the direct charge of PM for organising, coordinating and promoting ocean development activities. While the Department has grown manifold and has now major 16 programmes and converted into a full-fledged Ministry of Ocean Development in the beginning of 2006, (which later changed into Ministry of Earth Sciences) there is no increase in the infrastructure allocated to the Department since its establishment. The present requirement is of full-fledged Building with a campus in Central Delhi of about 15000 sq. m for Ocean Developmental activities The present space in the Ministry is about 1300 sq m.

Budget estimate of Rs. 50 crore is projected for the purpose.

Budget: Rs.50.00 crore.

2007-08	2008-09	2009-10	2010-11	2011-12	TOTAL
5.00	20.00	20.50	3.50	1.00	50.00

5. Manpower Development

5.1 It is evident from the XI plan proposals that manifold growth in the multifarious programmes and capacity building relating to our oceans The Department of Ocean Development has come long way since its inception 1981. It has many achievements to its credit and it has contributed in several ways to 7500 km long coastline and over 7 million coastal fishing community of the country. The challenge before us to understand the oceans in totality for the benefit of national economy and welfare of ocean dependent society. The plan allocations for the Department has been steadily growing consistent with these expectations.

5.2 However, the Department and its autonomous Institutions have been functioning with a severe constraint of inadequate manpower. Being a young Department and with its recently established autonomous Institutions, it is essential to ensure that the Department has the core critical mass of scientific, technical and administrative manpower as well as is able to attract and retain, competent Scientists and Technocrats as Directors of these autonomous Institutions. It is noted however, that such growth in scientific and technical manpower has not been commensurate with the increase in projectised activities funded by the DOD. This aspect needs to be addressed in detail in light of recent amalgamation of Ministry of Ocean Development and India Meteorological Department and will be dealt separately.

5.3 The existing manpower (X plan) and projected manpower requirements as at the end of the XI Five Year Plan is indicated for the 3 autonomous organizations at Table 5.1. It would be seen that in order to accomplish the objectives of the ambitious maritime projects of the XI Plan, the existing skilled manpower will have to be increased significantly during the next 5 years. The manpower projections relate to the 3 autonomous institutions under the Ministry along with the 2 attached offices and the Headquarters set up of the Ministry. The approach to bridging the gaps in skilled technical staff is indicated in this Chapter in a consolidated manner.

5.4 Though it is appreciated that the major build-up of scientific and technical competencies in oceanic activities has to be from actual job experience in different ongoing projects, it is being increasingly felt that core groups of systematically trained people will have to be inducted on a continuing basis. A time has come when such growth has to be institutionalized. By working out the gaps between the existing and incremental manpower required in the future, the educational & training facilities can be created/augmented accordingly. Only such gaps will have to be identified with the help of specialists, as would be deployed on a continuing basis by the concerned Institutions and not temporarily to meet the needs co-terminus with any individual project. It is also imperative that the educational and training facilities to be augmented will have to be more and more job oriented so that the candidates selected for such courses will have the necessary motivation and career opportunities ahead of them. They should be able to chart out meaningful service careers in Oceanography and related subjects.

5.5 The most practicable base for building institutional facilities for such training and development will be the well established R&D Organisations like NIO, NCAOR or Technical Institutions like NIOT etc. These are the service centers that are already operating in the ocean-related activities. But for the purpose of conducting such specialized educational/training courses, support from academic Institutions like IITs or

University Depts, already dealing with these subjects or presently conducting graduate level courses in marine sciences, needs to be sought and funded. The marine Institutions can provide practical training and research facilities to these post-graduate students. The graduate-level background qualifications to be prescribed for admission to these specialized courses will have to be carefully worked out to suit the specializations expected from these candidates when trained. Like wise, the training modules for various courses in these facilities will have to be carefully evolved to meet the job requirements called for. For certain specialized short term courses, candidates could also be duly sponsored by the various organizations and after acquiring the required specializations, these trained candidates will go back to the parent organizations and man various projects.

5.6 The facilities to be actually created may have to be in excess of the actual national requirement of trained technical manpower. Experience gained in the past in building up skilled manpower in Shipping, I.T. etc. shows that there is bound to be a high rate of turn-over of such skilled manpower, what with an ever increasing global demand for such trained and experienced hands. In such cases, India has contributed liberally in other fields to mutual benefit. In maritime courses in particular, we could perhaps tap the international career opportunities for science graduates and engineers of Indian origin by providing educational and training facilities in various technical disciplines, for which the global demand at large is growing rapidly. India, being one of the pioneering countries in ocean development, it is just as well that trained manpower of Indian origin is made available for career pursuits in the international arena also. Of course, the primary attention will be to cater to the indigenous requirement of additional manpower as explained above.

5.7 Selected University Departments, autonomous technical institutions like IITs would be persuaded to create/augment facilities for graduate level courses in ocean related subjects. Taking a cue from what Department of Atomic Energy, Ministry of Environment & Forests, etc. have been doing to build up adequate core competencies in their respective fields, the same would be created in appropriate educational centres of ocean science & technologies and specific courses and training facilities created. More and more graduate level students would to attracted to pursue these career oriented post graduate training courses and make a career in ocean sciences. Job orientation of these post-graduate courses would be the key to success.

5.8 It is clearly understood that the development of human resources will necessarily have to be institution-specific. In the instant case, most of the scientific and service organizations working in this field are in the public domain. Thus, the necessary guidance and financial support may have to be provided by the Ministry of Ocean Development itself. The core facilities for such training and development would be entrusted to relevant University Departments and will be adequately supported by the Ministry. The field training facilities will be provided and staffed by the national institutions like NIO, NIOT and other Organisations/Departments reporting to Ministry of Ocean Development. Incidentally, bulk of the products from such augmented training facilities are meant to cater to the growing needs of these organizations themselves but not necessarily so.

5.9 In due course the development and management of our oceans may have to be entrusted to a dedicated cadre as in the case of forest development. The intended manpower developmne will be similar to the successful efforts made by Department of

Atomic Energy and Department of Space.

TABLE 5.1 Manpower Requirement

	Scientific and Technical Posts		**Admin Posts and Support staff**		**TOTAL**	
	Current Manpower	XI plan Reqmt-Additional	Current Manpower	XI plan Reqmt-Additional	Current Manpower	XI plan Reqmt-Additional
INCOIS, Hyderabad	25(38)	150	3(3)	26	28(41)	176
NIOT, Chennai	66(115)	521+ 12+25+25	19(24)	67+ 4+5+5	85(139)	588+ 16+30+30 *
NCAOR, Goa	22(26)	154	19(24)	7	41(50)	161
PD-ICMAM Chennai	10 (15)	13	7 (8)	0	17 (23)	13
CMLRE Kochi	12 (18)	30	6 (7)	20	18 (25)	50
HQ DOD	17(25)	40	118 (122)	68	135(147)	108
Total	**152(237)**	**908 +62**	**172 (188)**	**188+14**	**326(425)**	**1096+76**

( ) indicates original sanctioned strength
* includes requirement of 62(12+25+25) scientific and technical posts and 14(4+5+5) admn and support staff for island centre at Port Blair, West Bengal and Gujarat respectively.

6. Scheme wise Outlays For XI Five Year Plan (2007-2012)

I. CONTINUING SCHEME

Rs. In crores

S.No.	Scheme	2007-08	2008-09	2009-10	2010-11	2011-2012	Total Budget Provision in XI plan
1.	Polar Science	0	0	0	0	0	0
1.1	Expeditions to Antarctica – Polar Sciences	25.50	28.50	31.00	33.00	36.00	154.00
2.	Polymetallic Nodules Programme	0	0	0	0	0	0
2.1	Survey and Exploration	2.00	5.00	5.00	3.00	2.70	17.70
2.2	Environmental Impact Assessment	4.00	5.00	4.00	5.00	4.59	22.59
2.3	Technology Development (Extractive Metallurgy)	10.00	25.00	10.00	6.00	5.48	56.48
2.4	Technology Development (Mining)	24	155	149	143	156	**627**
3.	Ocean Observation and Information System(OOIS)	0	0	0	0	0	0
3.1	PFZ and integrated PFZ, Tuna forecast(35 cr.) and user interactions(5 cr.)	8.60	10.10	8.10	7.10	6.10	40.00
3.2	Operational coastal ocean wave & current forecast	4.65	6.70	5.30	4.05	3.90	24.60
4	Marine Research and Technology Development	0	0	0	0	0	0
4.1	Assessment of Marine Living Resources	19.39	29.09	24.25	14.57	9.7	97.00
4.2	Drugs from Sea	10.00	20.00	30.00	30.00	20.00	110.00
4.3	Assistance for Research Projects (OSTC & Manpower Training)	15.40	22.40	29.40	39.40	30.40	137.00
4.4	Coastal Ocean Monitoring and	15.60	23.40	19.50	11.70	7.80	78.00

	Prediction system(COMAPS)						
4.5	Exhibition, fairs etc.(Ocean awareness activities, Seminars, Symposia, Conferences, Lectures, Debates etc.)	10.00	30.00	30.00	15.00	15.00	100.00
4.6	Integrated Coastal and Marine Area Management	0	0	0	0	0	0
4.6.1	Vulnerability to Shoreline changes, Waste Assimilation Capacity & Inundation Modelling	5.00	10.00	15.00	10.00	10.00	50.00
4.6.2	Ecosystem Modelling	1.00	1.50	1.75	1.75	2.00	8.00
4.6.3	Marine Ecotoxicology	0.60	0.90	0.75	0.45	0.30	3.00
4.6.4	Coastal Risk Atlas	0.40	0.40	0.20	0	0	1.00
4.7	Marine Non-Living Resources (MNLR)	0	0	0	0	0	0
4.7.1	Studies of Cobalt Crust Exploration	4.00	8.00	20.00	9.00	9.00	50.00
4.7.2	Geological Studies of Indian Ocean Basin	2.00	9.50	9.50	4.50	4.50	30.00
4.7.3	Hydrothermal Sulfides	1.00	4.50	2.50	1.00	1.00	10.00
5.0	Information Technology	4.00	4.00	4.00	4.00	4.00	20.00
6.0	Coastal Research Vessels(CRV) & other Research vessels	51.05	11.44	12.16	62.70	63.61	200.96
7.0	National Institute of Ocean Technology (NIOT)	0	0	0	0	0	0
7.1	Energy/Desalination	2.00	4.00	5.00	3.00	1.89	15.89
7.2	Deep Seabed Mining	22.00	26.00	28.00	26.00	23.00	125.00
7.3	Coastal & Environmental Engg.	40.0	60.0	60.0	40.0	25.0	225.00
7.4	Marine Instrumentation, sensors, acoustics	35.01	33.77	35.36	16.04	16.05	136.23
7.5	Island Development	24.40	39.20	45.00	29.30	24.10	162.00
7.6	Argo *	0	0	0	0	0	0
7.7	Gas Hydrates*	0	0	0	0	0	0
7.8	NDBP*	0	0	0	0	0	0
7.9	Offshore operations*	0	0	0	0	0	0
7.10	Offshore structures*	0	0	0	0	0	0
7.11	VMC*	0	0	0	0	0	0

7.12	Capacity Building, infrastructure etc	29.00	32.00	47.40	65.0	93.11	266.51
8	Delineation of Outer limits of Continental Shelf	1.00	1.00	1.00	1.00	2.00	6.00
9	Comprehensive Topographic Surveys	5.00	12.00	12.00	12.00	7.00	48.00
10	Gas Hydrate	56.84	98.93	106.61	127.44	234.64	624.46
11	Acquisition of Research Vessel	110.00	15.00	0	0	0	125.00
12	Data Buoy programme/Integrated Sustained Ocean Observations	66.85	86.05	106.00	65.95	42.24	367.09
13	Tsunami & Storm surges Warning System	41.18	20.00	20.00	25.00	20.00	126.18
14	National Centre for Antarctic and Ocean Research(NCAOR)	0	0	0	0	0	0
14.1	Establishment of New Permanent Indian Base in Antarctica	24.90	19.30	10.80	9.30	9.70	74.00
14.2	Southern Ocean Studies	7.50	5.50	10.00	7.50	11.50	42.00
14.3	In house R&D, infrastructure, capacity building at NCAOR	29.20	44.73	43.46	23.84	25.77	167.00
15	Indian National Centre for Ocean Information Services (INCOIS)	0	0	0	0	0	0
15.1	Information Bank and Web-bases services	1.00	3.00	3.00	2.00	1.00	10.00
15.2	Ocean Science and techniques Development	0	0	0	0	0	0
15.2.1	Ocean Modelling and data assimilation	7.30	5.90	5.70	5.85	5.25	30.00
15.2.2	Satellite Oceanography	5.00	6.00	7.00	6.00	6.00	30.00
15.3	Ocean Observations	25.50	17.00	15.50	14.25	12.75	85.00
15.4	R&D in Ocean Science and Informations	13.00	18.00	16.00	16.00	12.00	75.00
16	Seafront facility	25.745	64.045	42.29	37.92	30.00	200.00
	Total	**790.615**	**1021.855**	**1031.53**	**938.61**	**995.08**	**4777.69**

* indicates that while NIOT will be implementing agency the budget provision has been made in the Ministry's programmes

2. NEW SCHEMES PROPOSED DURING XI PLAN

Rs. In crores

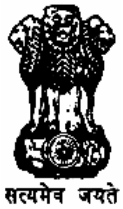
S.No.	Scheme	2007-08	2008-09	2009-10	2010-11	2011-2012	Total Budget Provision in XI plan
1.	Expedition to Arctic	5.00	5.00	12.00	12.00	12.00	46.00
2.	Desalination Project	7.00	140.00	43.00	8.00	6.65	204.65
3.	MLR: vessel requirement(Rs. 250 cr) and Dedicated berthing and associated facilities (Rs. 23.50 cr)	34.70	77.05	85.88	53.52	22.35	273.50
4.	National Oceanarium	10.00	40.00	40.00	5.00	5.00	100.00
5.	Demonstration of Shore Protection measures through Pilot project	54.00	81.00	67.50	40.50	27.00	270.00
6.	Integrated Ocean Drilling Programme(IODP)	5.00	18.00	20.00	25.00	32.00	100.00
7.	Ice class Research vessel	40.00	150.00	225.00	30.00	5.00	450.00
8.	Headquarter Building	25.00	20.00	2.50	1.50	1.00	50.00
	Total	**180.70**	**531.05**	**495.88**	**175.52**	**111.00**	**1494.15**

Summary of Financial Requirement

	Scheme	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**Total**
OCEAN DEVELOPMENT	Continuing	790.615	1021.855	1031.53	938.61	995.08	4777.69
	New	180.70	531.05	495.88	175.52	111.00	1494.15
Grand Total		**971.315**	**1552.905**	**1527.41**	**1114.13**	**1106.08**	**6271.84**

ELEVENTH PLAN
2007-2012

WORKING GROUP DOCUMENT
VOLUME 3
(ATMOSPHERIC SCIENCES)



Government of India
Ministry of Earth Sciences

2006

VOLUME 1

VOLUME 2
(OCEAN DEVELOPMENT)

VOLUME 3
(ATMOSPHERIC SCIENCES)

7. Achievements during X Plan (2002-07)

7.1 India Meteorological Department (IMD)

Under the successive five year plans, IMD has endeavored consciously and systematically to meet the growing and varying user's demands by upgrading its infra-structure, including contemporary technology and generating quality products and services. The Thrust areas of X th Plan were as follows:

1. Space Meteorology
2. Metorological Telecommunication
3. Observational System
4. Cyclone Warning and Research
5. Forecasting System
6. Service oriented schemes (Aviation, Agriculture)
7. Research
8. Seismology
9. Human Resource Development
10. National/ International cooperation
11. Positional astronomy
12. Infrastructure Development

Some of the major achievements of IMD in the tenth Plan period are highlighted below:

7.1.1 Space Meteorology

A new National Satellite Data Centre (NSDC) has been established at IMD, New Delhi. All types of satellite data and products are being archived in this center for utilization by different users. Web-based service is also being provided for easy access of data and products to the users. Old INSAT data of more than last 25 years archived on 30,000 magnetic tapes has been transcribed on latest media i.e. Digital Linear Tapes (DLTs) which are being integrated with NSDC.

100 nos. of Digital Cyclone Warning Dissemination Systems (DCWDS) have been established in the coastal areas of Andhra Pradesh, as part of the World Bank funded project of Govt. of Andhra Pradesh, for direct reception of cyclone warnings in local language to the coastal areas likely to be affected by the cyclones. This is a direct satellite based broadcast service operating through Indian Satellite INSAT-3C. Uplink for transmission of cyclone warnings to the satellite has been established at Area Cyclone Warning Centre (ACWC), Chennai.

A new scheme on establishment of a ground segment for reception and processing of meteorological data from advanced meteorological payloads on the next satellite of INSAT-3 series i.e. INSAT-3D, has been approved at an estimated cost of Rs. 37.59 crores. Two MOUs have been signed with M/s ANTRIX Corporation, the commercial wing of ISRO, for establishment of earth station and data processing segments sometimes before end of 2007 by which time INSAT-3D satellite is also expected to be launched. This scheme will, therefore, be implemented with a very high priority right from the beginning of 11th Five Year Plan period.

7.1.2 Meteorological Telecommunications

Four old and obsolete Automatic Message Switching System (AMSS) computers operating at New Delhi, Mumbai, Kolkata and Chennai were replaced with new state-of-art systems to improve the efficiency of generating aviation related meteorological products for operational use. Old HF broadcast service was replaced with new satellite based broadcast service using L-band. In addition, 3 international circuits were upgraded to 64 Kbps links for better efficiency of operations.

Four new schemes viz. Replacement of old RTH, new AMSS for Guwahati and Nagpur, data terminals for remote stations and new Interactive Voice Response System (IVRS) were approved by the CMAS. These are currently under implementation.

7.1.3 Observational System

The Department has made concerted efforts to modernize its basic observatory network. While the aim is to maximize the number of Departmental observatories, financial and staff constraints have come in the way of its realization. During the 10th Plan more thrust has been given to the automation of observations. With this approach it has been possible to collect meteorological data from a limited number of remote and inaccessible areas in real-time using the satellite based transponder. After having established the usefulness of data obtained by this means, the Department has gone ahead with the replacement of 100 Nos. of old and obsolete Automatic Weather Stations (AWS) installed during 1985 under the INSAT-1 programme. During 10th plan order was placed for supply of 100 numbers of state-of-art AWS systems alongwith an earth station for real-time reception of AWS data at Pune. A number of other agencies are also operating AWS for meeting their operational requirements. During 11th plan the network of AWS will be further augmented.

Four numbers of state-of-art Doppler Weather Radars (DWRs) have been inducted in the IMD's radar network. The old conventional types of S-band cyclone Detection Radars (CDRs) installed at Kolkata, Chennai, Machalipatnam and Visakhapatnam have been replaced with new Doppler Weather Radars during 10th five year Plan. These new type of radars provide digital data alongwith a large number of quantitative products for use in real-time operational weather forecasting. In addition, one indigenously developed Doppler Weather Radar was also commissioned at Sriharikota (SHAR). It is being currently operated in a Test and Evaluation mode. During the 11th five year Plan it is planned to further augment the radar network of the Department by providing a large number of Doppler Weather Radars.

Seven nos. of old and obsolete 1680 MHz Radiotheodolites have been replaced with new state-of-art radiotheodolites of much improved technology. In addition, three more such radiotheodolites have been installed under the mountain meteorology programme at Jammu, Manali and Sasoma for collection of upper-air data for operational use by Snow and Avlanche Study Establishment (SASE) of DRDO located at Chandigarh. In addition, during the 10th Plan a new Mark-IV radiosonde has been introduced. The semi-automatic computing system at RS/RW stations has also been replaced with the fully automatic computing system. As a result of all these changes in the upper-air network, the quality of operational upper-air has also improved to a certain extent. Major thrust has been given during 10th Plan for further improving the quality of upper-air data. A new radiosonde with semi-conductor based sensors is being developed by SCL, Chandigarh under an MoU between IMD and SCL. In addition, a modified version of Radiosonde has also been developed using a new semiconductor based pressure sensor. A few test flights taken with this radiosonde have shown very

encouraging results. Many more test flights (˜ 150) will be taken before end of the 10th Five Year Plan.

7.1.4 Cyclone Warning & Research

Although the topical cyclones which form in the Bay of Bengal and Arabian Sea are fewer in number than such storms in other parts of the world, they are the ones which are most deadly. It has always been IMD's aim to provide timely warnings in order to minimize the loss to life and property and help relief agencies in organizing disaster mitigation work by constant surveillance of the cyclones through satellites and radars.

During the 9th & 10th Plans, Department had started replacement of the existing S-Band Cyclone Detection Radars (CDR) by Doppler Weather Radars (DWR) which are capable of providing an insight into the cyclone structure and velocity field. So far only four old radars have been replaced with Doppler radars. During the 11th Plan, it is proposed to replace the remaining 6 old CDRs with the new DWRs. The Doppler radars will make available a large volume of data to researchers for further studies in the movement and intensity of tropical cyclones which in turn will lead to better warning services.

During the passage of a cyclone, ordinary anemometers usually get blown off. In order to estimate the actual wind velocities, it is necessary to install special wind recorders designed to withstand such high speeds. During 9th and 10th five Year Plans, Department had installed 20 nos. of high wind speed recorders in the cyclone-prone coastal areas. During the 11th Five Year Plan, it is proposed to install high wind speed recorders at 10 more locations on the coastal areas.

The INSAT-based Cyclone Warning Dissemination system which was introduced in the North Tamil Nadu and South Andhra Pradesh coasts in 1982, has since been progressively expanded to cover the entire coastline of the country. This service provides a means for warning the coastal population directly in the local language, through selectively tunable receivers even when terrestrial communication links fail during a cyclone. It has been acclaimed by the media, public, and relief agencies. During the 10th Plan, 100 nos. of state-of-art Digital Cyclone Warning Dissemination System (DCWDS) receivers were installed in the coastal areas of Andhra Pradesh. During the 11th Five Year Plan, the old analog receivers installed in the early phase at 250 locations will be replaced with the state-of-art DCWDS receivers.

7.1.5 Forecasting System

The old and obsolete computer system Cyber 2000U has been discarded. A new SGI based machine has been installed in its place for running the Limited Area Model (LAM) of IMD. With this the computational speed has increased considerably and now the LAM model can be run much faster than before. The NWP products generated from LAM are now available at a faster speed for operational utilization by the end users. The forecasting system has been further augmented by adding another ALTIMA machine of state-of-art. With these upgradations, IMD has also started running Mesoscale Model (MM-5) on an operational basis.

The Northern Hemispheric Analysis Centre is functioning as the Regional Specialised Meteorological Centre for Tropical Cyclones in the north Indian Ocean Area as designated by the WMO to act as such a center.

7.1.6 Aviation Services

Latest state of art transmissometers were installed at International Airports of New Delhi and Kolkata for making automatic Runway Visual Range (RVR) assessments at critical points on the runways. These equipments are providing real-time RVR data for operational use by IMD and AAI. Ten Laser Ceilometers were installed at various important airports to obtain real-time data for height of low clouds which is important for aviation related operations. The data obtained from these new equipments is being used operationally at the Airports.

A detailed plan for modernization of Airport Meteorological Services in the country has been prepared by an Inter-departmental Committee of experts from IMD, DST , Ministry of Civil Aviation and AAI.

7.1.7 Hydrometeorological Services

Raingauge networks of State governments which are included in an overall District Rainfall Monitoring network has been integrated under a World Bank aided scheme where IMD is the receipient of the data in an offline mode. Drought monitoring, Monsoon activity studies and water resources assessments are conducted with the help of this data. In Phase I which has been implemented in the X th plan period includes all the peninsular states.

7.1.8 Agricultural Meteorology

Agromet. Advisory Services continued to be operated from various State capitals during the 10th Plan. The evapotranspiration and soil moisture measuring stations established during the 9th Plan have been continued and further expanded. An Agromet Co-ordination Cell formed in IMD to co-ordinate with the National Centre for Medium Range Weather Forecasting for establishing field units in 127 different agroclimatic zones of the country during earlier plan periods continued to provide useful service using new equipments established for this purpose. New website for agrometeorological services has also been launched.

7.1.9 Research

IMD encouraged research activity in-house and it also supported research in atmospheric sciences outside, through Grants-in-aid to Universities/Research Institutes on the basis of recommendations of the Research Committee. The VAX 4000/300 computer installed at NDC, Pune continued to support management and storage of meteorological data for research and study.

Status of major research and developmental activities in IMD is given below :

<u>Long Range Forecasting</u>

Indigenous investigational efforts have resulted in the development of improved statistical models for Long Range Prediction of seasonal monsoon rainfall. Forecasts based on improved models were started on an operational basis from the year 2003. Main feature of improved model is that it is possible to issue first stage forecast for

country as a whole, in the month of April using 8 parameters. Subsequently, in the 2nd stage (end June), it is possible to further update the forecast using 2 additional parameters. It is also now possible to issue the forecast separately for the four broad homogeneous regions of the country instead of three regions.

IMD also developed new models indigenously to prepare forecasts for monsoon onset over Kerala. In 2005, for the first time, IMD issued a forecast for the monsson onset over Kerala. In addition, IMD for the first time introduced in 2003 a forecast, exclusively for the monthly rainfall of July. For this purpose, a separate new model was indigenously developed.

Monsoon Dynamics and Variability

IMD implemented a dynamical prediction system at IMD Pune by adopting the seasonal forecast model developed by Experimental Climate Prediction Centre (ECPC), USA. The model climatology was prepared by running the models for 26 years (1979-2004) using observed SST data. The model output showed encouraging skill over the Indian region. Experimental forecasts have been generated for 2005 and 2006 seasons using this model.

Several research studies examining monsoon teleconnections with North Atlanatic Ocean (NAO), Indian Ocean Dipole (IOD), Sea surface temperatures (SSTs), global air temperatures , were completed and research papers were published in national and international journals. Similarly other studies VIZ: probable causes for weakening of ENSO and monsoon relationship, assessing peak warming in EL-Nino events, and cloud climatology over North Indian Ocean, were also completed. Some studies relating to climate change viz. effect of urbanization on meteorological parameters, discontinuity in temperature, discomfort conditions, Decadal variation in hot and cold water days, atmospheric turbidity, were also completed and papers were published.

Research in NWP Models

Further developmental work on limited area Numerical Weather Prediction Models for forecasting storm movement was continued. Improved regional models for short range weather prediction are now being operationally used to provide advisories to the field forecasting centers. Continued efforts are being made to further improve these models.

Good progress has been made for assimilation of satellite derived soundings products in the Limited Area Models being run by the Department. Studies have brought out positive impact of satellite soundings on the model forecasts.

Local Severe and Tropical Storms

Studies relating to the prediction, development and movement of local severe storms and tropical storms were continued during 10th Plan.

Climate and Climate Change

A National Climate Centre was made fully functional by merging the activities of Investigation and Development (I&D) section and Long Range Forecast section. In addition to long range forecasting activities, climate monitoring and climate diagnostics is one the main responsibilities of the centre. NCC has brought out Monthly and seasonal

climate diagnostics bulletins regularly. In addition, detailed scientific reports on drought of 2002 and 2005 monsoon (including special section on heavy rain over Mumbai on 26/27 July) were published. For the first time, annual climate summaries were published in 2004 and 2005 highlighting the major climate anomalies that occurred over the country.

Environmental Meteorology

Air Pollution Section maintains a network of ten Global Atmospheric Watch (GAW) stations of regional category. The Indian GAW network includes Allahabad, Jodhpur, Kodaikanal, Minicoy, Mohanbari, Nagpur, Portblair, Pune, Srinagar and Vishakhapatnam. At these stations chemical composition of precipitation and atmospheric turbidity is studied. Following equipment have been procured to bring the chemical analyses of rainwater at par with other WMO GAW stations : (i) Atomic Absorption Spectrophotometer with Graphite furnace, (ii) Ion Chromatograph, (iii) Microprocessor based PH and Conductivity Meters (iv) Ultra pure water purification System. Air Pollution Laboratory also participated in WMO's laboratory intercomprison programme conducted twice in a year. One set of gas analysers (SO_2 and Nox) for ambient air monitoring was installed at Pune.

Aerosol Optical Thickness which indicates the columnar aerosol load of the atmosphere is measured at GAW stations. Single channel volz's sunphotometer has been replaced with Microtop-II multi-channel sunphotometer (wavelength 368, 500, 675, 778 & 1028 nm) at Allahabad, Jodhpur, Kodaikanal, Nagpur, Portblair, Srinagar and Pune. One such Sunphotometrer was also installed at Maitri, Antarctica.

The data from GAW stations provide reliable long-term observations of the chemical composition of the atmosphere and related parameters in order to improve our understanding of atmospheric chemistry and to organize assessment in support of formulating environmental policy. Chemical composition of precipitation is useful in quantifying the level of pollution due to increasing anthropogenic activities.

Climatological Services

To meet the requirements of users, many climate data products/ atlases were also brought out. Revision of climatological summaries of some states was also taken up. To fulfill the long lasting demand from the research community, National Climates Centre brought out a high resolution daily gridded rainfall data set for the Indian region for 1951-2003 periods. About 30 institutes in India and abroad have purchased this important data set,

7.1.9 Seismology

India Meteorological Department (IMD) is maintaining the national seismological network consisting of 51 stations spread over the country for monitoring the seismic activity in and around the country. The network consists of 24 stations equipped with state-of-the-art broad-band seismic and communication equipments capable of providing facilities for immediate processing of data and dissemination of earthquake information to various state and central government agencies dealing with disaster management related matters. Ten of these broad-band observatories (of Global Seismic Network Standards) have been provided with V-SAT based communication systems to enable fastest mode of data transmission between the field stations and the Central Receiving Station (CRS) at New Delhi.

Fifty strong motion accelerographs were procured and installed in various seismological observatories of the national network to record strong ground motions

during large magnitude earthquakes. The existing network has enabled generation of very useful data sets and timely dissemination of earthquake information to government functionaries during the recent significant earthquakes such as Bhuj (2001), Sumaatra (2004) and Pakistan (2005). Detailed technical reports on these and various other significant earthquakes were prepared and submitted to Government of India. The digital data is also being archived systematically in a database and made available to various user agencies for R&D purposes.

As part of Tsunami Warning System being set up by Government of India, IMD is also in the process of setting up a 17 station Real Time Seismic Monitoring Network for monitoring Tsunami-genic earthquakes from the two potential source areas, viz. Andaman-Nicobar-Sumatra island area and Makran coast in the north Arabian Sea area.

An Indo-Russian Centre for Earthquake Research (IRCER) has been established in IMD for providing a multi-institutional platform for carrying out research on earthquake prediction related topics.

The network of Seismological observatories was further strengthened by establishing more observatories. Present strength of the network is 51 observatories. Studies in the Seismicity and Seismo-tectonics were continued.

During this plan period the Earthquake Risk Evaluation Centre has been established. It has completed microzonation studies of Delhi and Jabalpur at 1:50,000 scale giving geotechnical and engineering parameters of seismic induced damages.

7.1.10 National / International Cooperation

Research schemes on atmospheric science and cyclone prediction implemented at Centre for Atmospheric Science at IIT Delhi and Jadavpur University Kolkata were supported. In the area of International cooperation several WMO activities were pursued as follows:

WORLD WEATHER WATCH PROGRAMME (WWW)

1. Global Data-Processing System
2. Global Observing System
3. Global Telecommunication System
4. WWW Data Management
5. WWW System Support Activity
6. Operational Information Service
7. Instruments and Methods of Observation Programme
8. Tropical Cyclone Programme
9. WMO Antarctic Activities

WORLD CLIMATE PROGRAMME (WCP)

1. Climate Programme Co-ordination
2. Support Activities, including IPCC on climate change, Biodiversity and Desertification.
3. Global Climate Observing System
4. World climate Data and Monitoring Programme
5. World Climate Applications and Services Programme, including the CLIPS project.
6. World Climate Impact Assessment and Response
7. Strategies Programme.
8. World Climate Research Programme

ATMOSPHERIC RESEARCH AND ENVIRONMENT PROGRAMME (AREP).

1. Global Atmosphere Watch including support to ozone and other environmental oriented conventions.
2. World Weather Research Programme including
   i.THORPEX
   ii.Tropical Meteorology Research Programme
   iii.Programme on Physics and Chemistry of clouds and
   iv.Modification Research.

APPLICATIONS OF METEOROLOGY PROGRAMME

1. Public Weather Services Programme
2. Agricultural Meteorology Programme
3. Aeronautical Meteorology Programme
4. Marine Meteorology and Associated Oceanographic
5. Activities Programme

HYDROLOGY AND WATER RESOURCES PROGRAMME

1. Programme on Basic System in Hydrology
2. Programme on forecasting and Applications in Hydrology.
3. Programme on water-related issues
4. Programme on sustainable Development of Water Resources.
5. Programme on capacity building in Hydrology and Water Resources

EDUCATION AND TRAINING PROGRAMME (ET)

1. Human Resouces development
2. Training activities
3. Education and Training fellowships
4. Support to training events under other
5. WMO major programmes

TECHNICAL CO-OPERATION OGRAMME

NATURAL DISASTER PREVENTION AND MITIGATION PROGRAMME.

W M O SPACE PROGRAMME

7.1.11 Positional Astronomy Centre

The Indian Asronomical Ephemeris used by Navigators, Astronomers and Survey of India for Tidal computations is prepared and published by this center. In addition to that the centre also issues the National Calendar and Rashtriya Panchang on behalf of the Government of India. During the X th plan period the entire activities were reviewed by a high power National Committee and completely modernized. The products are now made available on the Website and 5 years in advance to help all possible applications in the country.

7.1.12 Human Resource Development

The training unit of IMD was established in 1947.1. Various disciplines covered are: General Meteorology, Instrumentation, Agrometeorology, Telecommunications and computerised data processing. In addition, a number of advanced refresher courses on

highly specialized subjects, including a number of SAARC seminars, have also been conducted.

The training facilities of the department have been recognized as a Regional Meteorological Training Centre (RMTC) of the WMO in 1986 which is among the 22 such centres of the WMO. Several WMO sponsored training seminars have also been organized by IMD in the field of tropical meteorology, storm surge, agrometeorology and monsoon. The training facilities of the department consist of well-equipped laboratories, class rooms with modern audio-visual equipments, well-furnished residential hostels and training school building.

During the last five years the training centes of the department have trained nearly 1184 trainees in various disciplines including 22 foreign trainees mainly from developing countries in Asia and Africa.

7.1.13 Infrastructure Development

New office buildings have come at Hyderabad and Jaipur Meteorological Centres replacing rented ones. Residential quarters have been built at Jaipur, Ajmer Observatory and Palam Met Office. Land has been purchased for Met Centre Chandigarh, Mangalore RSRW station. A Radar building has been constructed at Vishakhapatnam. Maintenance of existing buildings at Mausam Bhavan , New Delhi, Pune office, RMC and MC buildings at all centres have been carried out by CPWD. New Guest house for visiting scientists and Officers has been constructed at Shivaji Nagar,Pune.

7.2 National Centre for Medium Range Weather Forecasting (NCMRWF)

7.2.1 Operational

NCMRWF continues to be the only Organization in the country for Real-time Global Data Assimilation & Medium Range Weather Forecasting.

In addition, several Mesoscale Models and Data Assimilation system are run on operational basis to provide forecasts for high-impact weather.

The medium range forecasts are made available to India Meteorological Department(IMD), and a number of other user agencies(Ministry of Agriculture, IAF, Indian Navy, SASE, DAE, DOD etc.). Through in-house effort, the Centre has developed its Web Page. Its data and products are also kept on this page and are accessible to user agencies and public.

Established a network of 107 Agro Advisory Service(AAS) units out of planned 127 units, one in each of the Agro Climatic Zones(ACZ) of the country..

Provide Quantitative location specific medium range weather forecasts to AAS units regularly.

Forecast products are also provided to other countries for example Sri Lanka, Kenya, Qatar, Nepal etc.

7.2.2 Experimental/Semi-Operational

Experimental Extended Range (monthly) and seasonal Predictions are issued during monsoon seasons.

7.2.3 Research & Development

7.2.3.1 Global Modeling & Assimilation System

A new high-resolution Global Model & Data Assimilation System (T170/L28) has been developed in-house at NCMRWF.

A new and improved Planetary Boundary Layer (PBL) scheme has been implemented in-house in the NCMRWF global model.

A new and improved Radiation scheme has been implemented in-house in the NCMRWF global model.

A new Ensemble Prediction System has been developed in-house to make ensemble medium range weather forecasting.

A new objective criteria based scheme for medium range prediction of onset, progress and withdrawal of southwest monsoon has been developed.

New Convection schemes have been implemented and test runs have been carried out.

Schemes have been developed in-house to assimilate passive microwave radiometer data (total precipitable water, wind speed) from MSMR, SSM/I sensors from Remote Sensing Satellites.

Schemes have been developed in-house to assimilate Advanced TOVS (ATOVS) Satellite data.

Schemes have been developed in-house to assimilate Wind data from QUIKSCAT Satellite data.

Schemes have been developed in-house to assimilate data from Meteosat Satellite.

Schemes have been developed in-house to assimilate data from ACARS system.

Comprehensive Quality Control system is regularly updated to account for new types of satellite data.

Schemes have been developed to effectively utilize Indian RS/RW data which otherwise does not get assimilated in other operational global NWP centers.

A Rainfall Analysis scheme has been developed to analyze merged rain gauge and satellite data over the Indian region.

A statistical interpretation (SI) prediction system has been developed in house for improved location specific forecasts.

Crop weather models have been calibrated and validated for different crops cultivated in different agro-climatic zones of the country.

A low-resolution version of the forecast system has been implemented on a workstation to meet the emergency situation if entire computing infrastructure collapses due to some accident or other reasons.

Model & assimilation codes have been re-written so that they run on every computing platform at NCMRWF.

7.2.3.2 Regional Modeling & Assimilation System

Research works on Mesocale models (MM5, ETA, and RSM) are being carried out to improve short-range predictions.

Schemes have been developed to assimilate Doppler Radar data in Mesoscale models.

7.2.3.3 Extended-Range/Seasonal/Climate Prediction System

The NCMRWF Extended-range/Seasonal prediction system has been developed in-house.

Skill of this prediction system is comparable to that from other leading seasonal prediction centers.

Long integrations have been made using the NCMRWF global model to understand and alleviate the model systematic errors.

A Chemical forecast & Long-range aerosol transport Model has been developed and implemented.

7.2.3.4 Publications

The scientists of the Centre have published a large number of research papers in journals of international repute. 90% of the scientists of the Centre are Ph.D. degree holders, some of them have worked for their degree while serving NCMRWF. Many scientists have supervised Ph.D. students of various universities/institutions.

7.2.4 Supercomputer Establishment and Upgradation

To meet the increasing demands of NWP, the Centre established supercomputing and networking facilities and regularly upgraded the same.

Recently, a 64-processor Cray X1e system has been installed. An indigenous parallel processing computer system PARAM PADMA from CDAC has been installed.

The bandwidth of internet connectivity has been raised to 4 mbps.

The Centre contributed to development of indigenous parallel computing capabilities in the country in the field of weather and climate modeling.

7.2.5 Other Important Achievements

Initial and boundary conditions from global model are provided to various agencies to enable them to run their regional models.

Customized forecasts are provided from time to time for special requirements which include defence exercises, adventure sport, tourism, entertainment, power sector etc.

Crop Weather Models have been developed, training imparted and technology has been transferred to various Agriculture Universities

A number of training programmes have been organized for scientists/users from within the country and abroad in NWP, use of NWP products, and their applications. NCMRWF scientists serve as faculty in various national training programmes.

The Centre has organized many national and international conferences, workshops, and symposiums.

7.2.6 Participation in International/National Coordinated Programs

NCMRWF participated in WMO/WGNE/MONEG program on seasonal monsoon prediction; in WMO/WCRP/AMIP program on global model intercomparison; in WMO Australia Monsoon inter-comparison project and INDOEX.

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NCMRWF participates in

- WMO/WWRP THORPEX and CEOP programme.
- BOBMEX, ARMEX, LASPEX, and other programmes
- STORM, CTCZ, PROWNM and other programmes

NCMRWF is a collaborating institute with NCAR, UK Met Office, and LMD France, Florida State University, University of Maryland, University of Washington, MPI Germany.

7.3 Indian Institute of Tropical Meteorology (IITM)

The IITM has its research programme under the scheme 'Research in Tropical Meteorology' against its Tenth Five Year Plan (2002-07). Research work under this scheme was organized under five major areas viz., (i) Monsoon Prediction, Climate Dynamics and Modelling, (ii) Environmental Meteorology, (iii) Cloud Physics and Atmospheric Electricity, (iv) Scientific Computing for Atmospheric Research, and (v) Strengthening of Infrastructure. Research work carried out under the 10^{th} Five Year Plan has contributed to the studies relating to severe weather systems affecting Indian subcontinent, Asian monsoon variability and predictability, application of satellite data in weather forecasting, climate modelling and dynamics, regional aspects of global climate change using instrumental and proxy climate records, short-term and long-term climate diagnostics and prediction, hydrological modelling, cloud modelling, theoretical understanding of atmospheric and oceanic circulation, atmospheric monitoring and air pollution studies through LIDAR, radiometric and spectrometric remote sensing systems, middle atmosphere and chemical climate, atmospheric boundary layer experiments,

atmospheric electrical characteristics, development of simulation techniques in cloud physics and surface observations of atmospheric electricity and electrical properties of clouds.

The research has also contributed to the progress of some of the international programmes such as World Climate Research Programme (WCRP), Climate and its Variability (CLIVAR), International Geosphere - Biosphere Programme (IGBP), Intergovernmental Programmes of Climate Change (IPCC), United Nations Framework Convention on Climate Change (UNFCCC), etc. The IITM has also been part of many national research and observational programmes such as Indian Climate Research Programme (ICRP) of the Department of Science and Technology, Indian Ocean Modelling (INDOMOD) programme of the Department of Ocean Development, IRSP4 Application Programme of the Indian Space Research Organisation, Environmental Information System of the Ministry of Environment and Forests, Climate Change Projects of The Energy Resources Institute (TERI) etc. IITM participated in several multi-Institutional observational programmes like ARMEX, CTCZ and STORM of the Department of Science and Technology, ISRO-GBP Programmes like ARBS, ICARB and Nation-wide Land campaign, Southern Ocean expeditions of the National Centre Antarctica and Ocean Research, Goa, and 24th Expedition to Antarctica and research programmes being actively pursued by several observational and theoretical scientists working in the field of Atmospheric Sciences in different countries.

The scientists of IITM have also collaborated with leading scientists of other nations through several bilateral research programmes such as Indo-UK programme on impact of climate change on water resources, Indo-France programme for the study of sensitivity of the Indian summer monsoon to anthropogenic climate change, Indo-US (DST-NSF) projects on aerosol studies, Asia-Pacific Network (APN) for global change research, Indo-Bulgaria Programme of co-operation in Science & Technology, Indo-Swedish collaborative programme on Composition of Asian Deposition (CAD), etc.

A review of the achievements of the 10th Five Year Plan programmes of the IITM is summarized below:

7.3.1 Monsoon Prediction, Climate Dynamics and Modelling

- Discovered a coupled feedback between the tropical Indian Ocean circulation and the southwest monsoon winds, on sub-seasonal / intra-seasonal time-scales, which is pivotal in forcing long-lasting breaks in the monsoon rainfall over India and occurrence of droughts over the subcontinent. This new understanding should foster major improvements in our ability to predict the monsoonal rains on time-scales of days-to-weeks.

- Demonstrated the role of Indian Ocean SST boundary forcing in influencing the monsoon intra-seasonal variability and the seasonal monsoon rainfall over India through atmospheric GCM simulation experiments.

- Improved understanding of the ENSO-monsoon teleconnection through convection changes over Northwest Pacific has been obtained that has major implications on predicting the seasonal mean monsoon.

- Experimental Long-Range Forecasts of seasonal mean monsoon rainfall based on various statistical and dynamical techniques were sent, every year, to the India Meteorological Department (IMD). In issuing the national seasonal forecast for the All India Monsoon Rainfall, the IMD takes guidance from IITM forecasts together with their own empirical model results.
- Typical analysis of pixel-by-pixel OLR data, performed through digitized Kalpana-1 IR observations showed unique characteristic feature highlighting the persistence of very deep convection (OLR ~ 85 W/m) at Santacruz and surrounding area for a period 09 UTC of 26 July to 03 UTC of 27 July 2005. This analysis, along with integrated approach of multiple satellites specifying the details of integrated water vapour, cloud liquid water content and precipitation rates gave the signature of occurrence of excessive rainfall over Santacruz.

- An integrated effect of NAO and ENSO has been found to give a signal 3 to 4 months in advance for the prediction of excess/deficient monsoon rainfall over the Indian region.

- A method to predict the onset date of Indian monsoon over Kerala, about six weeks in advance, has been developed. The method is based on the observed relationship between Thiruvanathapuram, Cochi, Alapuzha and Kodaikanal during pre-monsoon months (March - June) for the period 1961 – 1992. Based on the highly significant skill demonstrated by the method on hindcast mode, it is being validated on operational mode for the recent monsoon years (2001 onwards).

- East Indian Ocean SST over the region 5ºS - 5º N, 85º - 95º E has been identified as a new predictor for both all India summer monsoon rainfall and annual rainfall. April SST over the region helps predict the annual rainfall and June SST is useful in prediction of the monsoon rainfall.

- POM model simulated subsurface circulation indicated that reversal in the direction of Somali current is present only in the shallow upper layer up to 50 to 70 meter depth. Subsurface Somali current is found to be northward through out the year.

- IITM has taken a national lead in generating high resolution regional climate change scenarios for two time slices, one corresponding to the present (1961-90) and the other for the future (2071-2100), using Hadley Center Regional Climate Model (PRECIS). These scenarios, developed based on the future projections of SRES GHG emissions, form the basis for the impact assessment studies being carried out by different research groups in India relating to agriculture, water resources, human health etc.

- Quality controlled data sets on all-India and macro-regional scale monthly rainfall and surface air temperature developed and updated every year by the Institute are highly sought after and extensively used by many researchers in India and abroad for understanding monsoon variability and global teleconnections.

- A set of four Atlases depicting the Spatial and Temporal Variations in rainfall during 1813-2003 over India have been prepared. These atlases can serve as an excellent reference material for understanding intricate monsoon rainfall variations during the last century.

- For the first time, tree ring chronologies spanning more than 5 centuries of *Tectona grandis* based on extensive sample collections from Narange Forest, Kerala have shown to be useful in the reconstruction of monsoon climate over the Peninsular India.
- Tailor-made Hydrometeorological products generated at the Institute based on hourly and daily rainfall data from a dense network of stations in India have extensively been used by several central and state agencies dealing with water resources management, flood control and hydropower generation.

7.3.2 Environmental Meteorology

- Argon-ion lidar derived aerosol loading in the ABL over Pune showed a significant increasing trend in the last 14 years due to urbanization and a well defined seasonal variation. Multi-site aerosol optical characterization has been made using multiwavelength radiometers, and aerosol radiative forcing estimates at the surface and at the top of the atmosphere have been made for an urban location using sun/sky radiometer.

- Precipitation chemistry studies in different environments in India showed that rain is alkaline in nature at most of the locations except at some industrial and forest locations. This is due to neutralization of acidic components of rain by soil originated components.

- State of the art atmospheric chemistry model to study the long-term trends in the atmosphere from surface to 100 km and a tropospheric ion chemistry model have been developed and also an Environmental Information Center (ENVIS Centre) for creating database and inventories of acid rain and atmospheric pollutants over the Indian region has been established at the Institute.

- A rotating drum automatic UV-visible spectrometer for monitoring stratospheric/ tropospheric NO_2, O_3, H_2O and O_4 has been developed indigenously. Observations with this spectrometer compared well with those by the Dobson Spectrophotometer and satellite observations.

- An automatic twilight photometer has been utilized to obtain vertical profiles of aerosols up to 120 km altitude and observations during meteor shower periods showed enhancement of aerosols at mesospheric levels and their subsequent downward transport to lower altitudes.

- Sustained observations from an instrumented tower set up at the NCAOR campus during ARMEX experiment reveals that(i) the surface layer profile has an internal boundary layer at the site extending up to ~ 2 m above surface due to coastal terrain, (ii) analysis of water vapour and CO_2 data showed significant negative

correlation coefficient (> -0.8) existing in the unstable atmospheric conditions corroborating inverse phase relationship in variation of CO_2 and water vapour (August – October 2002) in moderate and light winds, and an increase in water vapour and decrease in CO_2 during sea breeze, and (iii) micrometeorological spectra depicted -5/3 power law in the inertial sub-range.

- Unusual changes in surface ozone and NO_X concentrations (day time minima and night time maxima) have been observed during 3 January to 20 February 2005, a week after the giant Tsunami wave struck Tranquebar, Tamilnadu on 26 December 2004.

- Measurements on surface ozone along and across the Coromandal coast of Tamilnadu, in December (2000 and 2002) and in April (2001 and 2003) have shown higher ozone concentration along the coastline than 20 km inland possibly due to oxidation of hydrocarbon by chlorine radicals from sea.

7.3.3 Cloud Physics and Atmospheric Electricity

- Based on the experience gained in the Institute's warm cloud modification experiments, assistance to various State Governments in their respective rain enhancement programmes has been provided and extensive Radar data collected during these programmes are being analyzed to study the cloud microphysical characteristics.

- Isolated thunderstorms occurring over Pune region have been observed to have an extensive Lower Positive Charge Centre (LPCC) which can last for more than 75% of the lifetime of the storm. These LPCCs are strong enough to initiate/trigger an intracloud (IC) or cloud-to-ground (CG) lightning discharge. Shape of the surface electric field recovery curves of such CG lightning discharges has strong signatures of the influence of corona charge accumulated in the sub-cloud layer.

- Some lightning discharges in thunderclouds deposit enough charge in one part of the thundercloud so as to trigger another lightning discharge of opposite polarity in a remote area of the thunderstorm.

- Thunderstorms occurring over Pune region frequently exhibit 'End-of-Storm-Oscillation (EOSO)' in surface electric field. A novel case of an inverted EOSO is reported in a thundercloud of inverted polarity in our observations.

- Atmospheric electric conductivity over sea surface near west coast of India undergoes approximately a three-fold increase at the time of the onset of southwest monsoon. The observed increase is proposed to occur due to the generation of multiply charged large ions generated due to wave-breaking in the high wind speed regions over the Arabian Sea.

7.3.4 Scientific Computing for Atmospheric Research

- Augmented the computational facilities at the Institute by acquiring workstations, PCs, printers, scanners, data storage devices, intranet and internet, and necessary softwares.

7.3.5 Strengthening of Infrastructure

- Carried out face-lifting of the Institute's surrounding, Constructed two ultramodern Conference Halls and one Seminar Hall for national and international events like meetings, conferences, etc. Improved horticultural activities at the Institute's campus.

7.3.6 Number of Research Publications in peer reviewed journals during 10th Five Year Plan

Total 250 papers published during the 10th Five Year Period (4 years i.e. 2002-03 to 2005-06) out of which 135 papers have been published in journals with Impact Factor. Cumulative Impact Factor of 135 Papers is 216.11717

Number of Research Publications in peer reviewed journals during 10th Five Year Plan with Cumulative Impact factor : Please see Annexure I

8. CONTINUING PROGRAMME

1.1 India Meteorological Department(IMD)

For defining the directions in which IMD should proceed in the next ten years, it is necessary to look into the emerging global scenario in meteorology as well as to envisage our own national requirements. The global trend is towards issues related to improved public weather services, Disaster Management, NWP models, climate change, global warming, ozone depletion, research focus, human resources development etc. Also, as India industrialises, the requirements of meteorological service are becoming more demanding. Environment related issues have now assumed even greater importance as they are affecting significantly the quality of life in major cities
IMD's perspective plan for the next decade presented in this section has been derived from the following considerations:

- Global scene in Meteorology
- Requirements of meteorological services to keep pace with the transition of our society in 2020 timeframe.
- Availability of expertise and capabilities within the country.
- Research trends in atmospheric sciences and allied fields.
- Maximum utilization of state of art technology in observation system, instrumentation, space-based systems, computers and telecommunications
- The need for more accurate and timely prediction of high impact weather events of extreme nature (For example Mumbai Rainfall of 26 July,2005) .
- The need for providing more precise weather information for economically important sectors such as agriculture, aviation, shipping, power generation etc.
- Providing more precise and accurate information for better preparedness against weather related disasters and for disaster mitigation related operations.
- Improved outreach of weather related information and products to a vast variety of end users in a most effective and efficient manner.
- To cater to the weather/climate information related needs of general public in view of the changing scenario in the country.

In the recent past, some of the high impact weather events of extreme nature have attracted the attention of public at large and media persons. Particularly after the unprecedented heavy rainfall spell recorded at Mumbai on 26th July, 2005, inadequacy of meteorological infrastructure has been felt. General feeling is that availability of more sophisticated equipments and better communication facilities for real-time collection of meteorological data and dissemination of information would have resulted in increased capability of weather forecasters to provide weather related information and forecasts with more lead time. Key to minimizing losses due to such unprecedented weather events is "better information and adequate preparedness". As an aftermath of this event, general policy guideline that has emerged from the high level functionaries in the Govt. is "to make meteorological services in India of World-class standards". It is, therefore, absolutely necessary at this stage to take right direction and put in sufficient thrust backed by strong commitment and adequate resources to augment the infrastructural facilities in the department. As a sequel to the initiative taken in middle of the year 2004 from very high level in the Govt. stressing the urgent need for upgradation of forecasting

and observation systems of the Department, lot of spade work has already been done by the Department. As a first step in this direction a feasibility report spelling out detailed requirements of upgradations required in IMD has already been sent to the Planning Commission. It is, therefore, essential that projections for 11th Five Year Plan made in this document are in consonance with the projections made in the feasibility report.

Ministry of Civil Aviation has recently announced its large scale plans for modernization of a number of airports in the country. Since provision of meteorological services at the airports forms an essential component of airport services, IMD will be required to make corresponding upgrades in the aviation related meteorological equipments and the meteorological services in accordance with the guidelines given by ICAO. A detailed review in this regard has been conducted jointly by a team of offices from MCA, AAI, DST and IMD and a report prepared. This will form the basis for projecting requirements of upgradation of airport meteorological services in accordance with priorities suggested by the users (MCA and AAI). A large chunk of financial resources will, therefore, to require in the 11th Plan to meet this commitment by the Department.

Most of the existing radars operating in the IMD's network of weather radars are old and obsolete and are difficult to maintain due to non-availability of spares. All these radars need to be replaced with state-of-art Doppler Weather Radars with capabilities of generating digital data and a large number of operational products for use by the field forecast offices. Existing network of radars also needs to be augmented further to provide adequate coverage for real-time weather monitoring at all places in the country. A high level national committee of experts has given recommendations on the type of radars required their approximate numbers, frequency band of operation and strategy of inducting new type of radars in the IMD's network. A large chunk of financial resources will have to be allocated to meet this national commitment of vital importance from the point of view of real time weather monitoring over all parts of the country. Projections in the 11th Five Year Plan document have been made keeping in view the recommendations of above mentioned committee of experts. These are also in accordance with the feasibility report referred in the above para..

WMO Long-term Plan

World Meteorological Organizaion, in consultation with various member countries, has formulated Long-Term Plans which discusses in depth the broad sectors or issues which would have to be addressed during the decade 2006-2015. Sixth WMO long-term plan for the period 2004-2011 and 7th WMO long-term plan for the period 2012-2019 have been prepared by the WMO. Its major objectives for the next decade are the following

Global Observations: To foster the effective integration of global and regional programmes for comprehensive and reliable observation of the state of the global atmosphere and the entire earth system; and to support the following major objectives through the international exchange of these observations.

Public Services, **welfare and safety**: To ensure that, in all countries, the general community improves its understanding of the value of, and is better assisted to benefit from the basic public information, weather forecasts and warning services provided by National Meteorological and Hydrological Services.

Natural Disaster Mitigation: To contribute to the goals of the internationally co-ordinated programme for Natural Disaster Reduction through the implementation of detection, prediction and warning systems.

Specialised meteorological and hydrological services: To assist members to satisfy the requirements of the growing number of users of specialized meteorological and hydrological services and to give specific attention to transportation safety, provision of food, fibre and fresh water.

Climate: To ensure that WMO exerts effective international leadership in climate monitoring, research and applications including global climate prediction.

Environmental quality: To contribute, through scientifically sound monitoring and research to understanding, arresting and reversing the degradation of the atmosphere and the marine and hydrological environment.

Sustainable development : To contribute through the meteorological, hydrological and oceanographic monitoring, research and prediction facilities and programmes of National Services, to environmentally and economically sustainable development in all countries.

Capacity building: To bridge the gap between national Meteorological and Hydrological services of developing and developed countries.

Commercial activities : To build an effective harmonious and mutually supporting relationship between public and private sectors of the meteorological and hydrological communities in the provision of commercial meteorological services.

From the above, it is clear that issues relating to climate and environment have been designated as thrust areas where considerable efforts are required to be put by member countries subject to the capabilities as well as availability of respective national resources. In many developing countries, a major part of resources are still to be apportioned for updating the existing activities to bring them at par with other member countries.

A proper examination and research in issues related to climate variability pre-supposes a high quality of data. The accuracy requirement of data for climate study is much more stringent as compared to what is required for meso-scale/synoptic scale weather forecasting. The importance of high quality of data is now being fully appreciated as we attempt to grapple with problems such as definition and management of climate change and variability. It is now being realized that the number of sites which have long term records of sufficient quality to give meaningful data are less than what are optimally required. The data we collect now is for posterity and we must ensure that it is going to be of high value. While accepting this principle, we should also keep in mind that data for other purposes such as research or forecasting and warning services would continue to be required.

Another area, where considerable efforts are required is timely availability of data. In many developing countries, the telecommunication network is still in nascent stage due to which data which is acquired at considerable effort and resources is simply not useful for meso-scale forecasting as it is not available in time. Therefore, there is an urgent need to update the telecommunication network standards. Since considerable resources would be required for this purpose, it may be necessary to examine diversion of funds by closure of such observation stations whose data cannot be made available in

time. However, the requirement of climate research would dictate continuation of such observations for the purpose of long term record.

The requirements of high quality of data put pressure on the observation system to induct newer technology and other methods. For instance for recording surface observations, automatic weather stations need to be essentially inducted which would remove errors due to human intervention. However, they may not replicate manual observations in respect of averaging times and the different sensors used. These can make small but significant changes in the record. Newer systems like Doppler Weather Radars, wind profilers, automatic weather stations, global positioning system soundings and advanced Space-based systems are at the leading edge of technology. Most of the staff and officers do not have the necessary skills for the operation and maintenance of such sophisticated equipment. Increased attention will have to be given to redeployment of staff by retaining them in the appropriate fields. Continuing training of observers in newer fields has to be organized in future.

Research in environment related issues would require establishment of expanded monitoring network of atmospheric pollutants like SO2, NO2, CO2. Continuous monitoring of ozone, particularly in tropical regions where it is produced is essential to understand fully the mechanism of its production, transport and its destruction by pollutants.

Increased attention is required to be paid for natural Disaster Mitigation, including seismology, during the next decade. Effective and timely communication of the occurrence of earthquake to the mitigation agencies is very essential for reduction of loss of life.

Thrust Areas

The proposed "Major Thrust Areas'' and "Sub-thrust Areas" for the Eleventh Five Year Plan for IMD are as follows:

MAJOR THRUST AREAS:

(1) Observational and Met. Telecommunication system.

Sub-Thrust Areas.

1. Space Meteorology -continuing programme
2. Meteorological Telecommunication. -continuing programme
3. Observational System -continuing programme
4. Instrument Development. -continuing programme

(2) Weather Forecasting System.

Sub-Thrust Areas

5. Cyclone Warning and Research. - continuing programme
6. Forecasting Services. - continuing programme
7. District Meteorological Information Centers (DMIC). - new programme
8. Early Warning System. - new programme

(3) Specialised Meteorological Services.

Sub-Thrust Areas:

9. Services to Aviation. - continuing programme
10. Hydromet. Services. - continuing programme

11. Agro Met. Services. - continuing programme

(4) Seismology and Earthquake Risk Evaluation .

Sub-Thrust Areas:

12. Seismology. - continuing programme
13. Seismic Hazard and Risk Evaluation. - continuing programme

(5) Climate & Environment Monitoring & Research.

Sub-Thrust Areas:

14. Climate Research and Monitoring. - new programme
15. Environmental Studies. - continuing programme
16. Research. - continuing programme

(6) Human Resource Development. **-** continuing programme

(7) National and International Co-operation. **-** continuing programme

(8) Infrastructural Development and Maintenance **-** continuing programme

Programme Goals

Within each thrust area, the programme goals and the benefits that would result from their realization are discussed in the subsequent paragraphs. Full details, including year-wise phasing of expenditure under different heads, are given in a separate document appended at appropriate place in this report.

Major Thrust Area (1) - Observation and Meteorological Telecommunication

3.1 Space Meteorology

A very high priority is to be given right in the beginning of the 11th five year Plan for establishment of new ground segment for reception and processing of meteorological data from the next meteorological satellite of INSAT-3 series i.e., INSAT-3D, to be launched before end of 2007/early 2008. It will be a dedicated meteorological satellite with advanced payloads of multi-channel imager and a 19 channel atmospheric sounder. The multi-channel imager will have capability of providing 1 km. resolution imagery in visible band and 4 km resolution in the Thermal infrared bands. The sharper images of weather phenomena provided in the visible and IR bands will allow better discrimination of features. Also, they will provide better insights into the structure of tropical storms, thus further helping in issuing accurate cyclone warnings. The INSAT-3D payload will demand an upgradation of the ground system in terms of high bit rate data handling and additional softwares for derivation of new products.

Beyond the INSAT-3 D time frame, the Indian Space Programme envisages advanced satellites like Megha-Tropiques, OCEANSAT-2 etc. which will be expected to further improve IMD's forecasting capabilities over land and ocean and provide data for climate studies and atmospheric research. Preparatory work on the definition of these satellites which are likely to be launched during 11th Five Year Plan, has already commenced. As the system definition get clarified, IMD has to initiate parallel actions for building up its ground infrastructure. The ground processing systems also need to be suitably augmented for receiving data from U.S. earth observation and meteorological satellites which would monitor weather and environment parameters on higher spatial

resolutions than the Indian Satellites. For all these satellites, ground processing software for deriving products and the utilization of products for various applications will have to be developed in R&D mode.

Some of the services of satellite INSAT have an added provision for broadcasts of meteorological data and warnings. Under the MDD (Meteorological Data Dissemination) system, INSAT imagery, facsimile weather charts and weather data are being broadcast in near real time to IMD's forecasting centers throughout the country. In the 11th Plan, it is proposed to enhance the capability at the field units by adding to the number of receiving stations and by resorting to digital transmission of INSAT imagery. The INSAT based Cyclone Warning Dissemination System (CWDS) which has proved to be highly successful in conveying warnings of approaching cyclones directly to affected areas, will be strengthened during the 11th Plan by replacing the old equipments installed first in mid 1990s and by making technological improvements to ensure smooth operations during cyclone situations. Digital Cyclone Warning Dissemination System (DCWDS) receivers will be installed in place of old analog systems. Already 100 nos of DCWDS are working in coastal areas of A.P.

The INSAT-based Data Collection System will be augmented and utilized more efficiently during the 11th Plan period by using the spare transponder capacity for transmission of meteorological data from a large number of Automatic Raingauge and Automatic Weather Stations proposed to be deployed in the field areas for real time data collection..

Budget Requirement

Rs in crores

Sub-Thrust Area	2007-08	2008-09	2009-10	2010-11	2011-12	Total
Space Meteorology	30.84	33.24	32.50	12.00	18.00	126.58

8.1.2 Meteorological Telecommunications

It is IMD's mandate to provide, operate and manage the basic telecommunication system necessary for collection of weather observations from various types of observing stations, their transmissions to the analysis centers, dissemination of processed outputs to various field units in the shortest possible time and to meet the present and future national and international communication requirements related to weather service.

During the 11th Plan, it is proposed :

(v) To provide satellite based communication links at all surface, upper air, radar and other observation stations through creation of new Hub station at New Delhi.
(v) To provide computer based current weather display system at all important airports.
(v) To establish maintenance centers for telecommunication equipment at Regional Offices.
(iv) To replace old and obsolete communication equipment including HF receivers, AMSS computers etc.

The need to develop a dedicated satellite-based telecommunication system for IMD in the 11th Plan arises from the sheer volume of digital data from satellites, radars

and computer products that would require to be handled during this period. A networking of computers at Delhi, Pune and other places would provide immediate access to the field centers to the latest computer derived products and climatic information. Moreover, while in a broadcast mode, all types of information is disseminated, taking a longer time, in a computer access mode the users can selectively and speedily obtain only that information which is of interest to them. With digital transmission of satellite imagery planned for the 11th Plan, and the expansion of the national radar network with digital processing, exchange of radar and satellite imagery and products could be realized through an efficient telecommunication system, as the image processing work stations at the field units would commonly handle various types of data.

Budget Requirement

Rs in crores

Sub-Thrust Area	2007-08	2008-09	2009-10	2010-11	2011-12	Total
Meteorological Telecommunication	46.10	33.40	19.15	3.73	1.21	103.59

8.1.3 Observational Systems

IMD maintains a dense network of upper air and surface observatories to obtain data on vital atmospheric parameters. Besides the observatory network, IMD also has a network of X-Band and S-Band radars. During the 11th Plan, the following upgradation to the observing systems are proposed :

(i) Replacement of all old analog based X-Band radars with state of art Doppler radars having digital capability is planned. This will enable processing of large amount of data with a computer, generate quantitative products and image & products display which can be subjected to detailed analysis which is not possible with the present analogue-type of radars. The digital data and products can also be transferred from the radar station to other radar stations and field forecasting offices in real-time for operational use.

(ii) All old ground equipments of SAMEER make being used operationally for tracking of radiosondes.

(iii) During 10th Plan, Department had commissioned the first wind profiler at Pune as part of a development programme of DST. This profiler was designed and developed indigenously by SAMEER, Mumbai. Five more wind profilers are proposed to be introduced in the upper-air network. These systems do not need consumables like balloons or gas and are capable of providing very frequent upper air wind observations. They are also useful in studies of clear air turbulance.

(iv) A large number of observatories are proposed to be upgraded/departmentalized. Automatic weather stations will be set up where manned stations can be operated with difficulty. Satellite-based transmission of data to the analysis center will be started.

Budget Requirement

Sub-Thrust Area	2007-08	2008-09	2009-10	2010-11	2011-12	Total Rs lin crores
Observational system	101.22	130.80	136.80	129.60	66.00	564.42

8.1.4 Instrumentation Development

To ensure the quality of observations, standardization and calibration of instruments has to be improved. Also, the instrument design itself has to be reviewed from time to time and modifications introduced. For this purpose, it is proposed to set up R&D centers for instrumentation at New Delhi and Pune and to upgrade the test, calibration and standardization facilities. The Radar Laboratory at New Delhi will be equipped with facilities in tune with the new types of radars that are being installed and would have to be maintained. The IMD workshops and New Delhi and Pune which are engaged in instrument manufacture on a large scale have to be modernized by replacing obsolete machinery with fully automatic/semi-automatic machines which will help to turn out quality products in a more efficient manner.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total Rs lin crores
Instrumentation Development	41.10	93.03	84.80	25.16	22.88	266.97

Major Thrust Area (2) - Weather Forecasting System

8.1.5 Cyclone Warning and Research

Although the topical cyclones which form in the Bay of Bengal and Arabian Sea are fewer in number than such storms in other parts of the world, they are the ones which are most deadly. It has always been IMD's aim to provide timely warnings in order to minimize the loss to life and property and help relief agencies in organizing disaster mitigation work by constant surveillance of the cyclones through satellites and radars.

During the 9th & 10th Plans, Department had started replacement of the existing S-Band Cyclone Detection Radars (CDR) by Doppler Weather Radars (DWR) which are capable of providing an insight into the cyclone structure and velocity field. So far only four old radars have been replaced with Doppler radars. During the 11th Plan, it is proposed to replace the remaining 6 old CDRs with the new DWRs. The Doppler radars will make available a large volume of data to researchers for further studies in the movement and intensity of tropical cyclones which in turn will lead to better warning services.

During the passage of a cyclone, ordinary anemometers usually get blown off. In order to estimate the actual wind velocities, it is necessary to install special wind recorders designed to withstand such high speeds. During 9th and 10th five Year Plans, Department had installed 20 nos. of high wind speed recorders in the cyclone-prone coastal areas. During the 11th Five Year Plan, it is proposed to install high wind speed recorders at 10 more locations on the coastal areas.

The INSAT-based Cyclone Warning Dissemination system which was introduced in the North Tamil Nadu and South Andhra Pradesh coasts in 1982, has since been progressively expanded to cover the entire coastline of the country. This service

provides a means for warning the coastal population directly in the local language, through selectively tunable receivers even when terrestrial communication links fail during a cyclone. It has been acclaimed by the media, public, and relief agencies. During the 10th Plan, 100 nos. of state-of-art Digital Cyclone Warning Dissemination System (DCWDS) receivers were installed in the coastal areas of Andhra Pradesh. During the 11th Five Year Plan, the old analog receivers installed in the early phase at 250 locations will be replaced with the state-of-art DCWDS receivers.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total Rs in crores
Cyclone Warning & Research	42.40	147.66	205.62	243.88	476.40	1115.96

8.1.6 Forecasting Services

(i) During the Eleventh Plan, it is proposed to modernize the 11 major field forecasting offices of the department by providing them real time access to the main new supercomputer proposed to be established at HQrs office, New Delhi. This will enable the field offices to obtain high level products for use in day to-day operational weather forecasting.

(ii) Considering the ever increasing amount of meteorological information/data required to be handled at the field offices, it is necessary to introduce auto-plotting and analyzing at all field forecasting centers.

(iii) To strengthen the public relation activities of the department and to further enhance the public image, it is proposed to establish separate media support centers for information, publicity and extension activities. At present this activity is being carried out by the operational forecasters, who are always hard pressed for time and are therefore, unable to carry out their duties efficiently.

(iv) The forecasting manuals of the department, which are a useful reference material for all field offices need to be updated and revised suitably by incorporating latest information and data.

(v) Forecasting set-ups at Bangalore, Thiruvananthapuram and Pune are to be upgraded to cater to growing requirements.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Forecasting Services	65.00	25.00	5.00	5.00	5.00	105.00

Major Thrust area (3) – Specialized Meteorological Services

3.7 Aviation Services

Service to aviation is a major operational activity of IMD. During the 11th Plan, the following areas of growth are proposed in this sector :

a). Modernisation of airport instruments at all major airports to provide accurate and timely information on parameters crucial to aircraft operations and aviation safely.

b). Establishment of appropriate type of Doppler Radars at two international airports to provide warnings for wind shear and microburst phenomena.

c). Exploitation of new Doppler Weather Radar systems for providing warnings against severe weather.

d). Upgradation of aeronautical observatories keeping in view the expansion of aviation sector and introduction of air services to new airports.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Aviation Services	92.80	115.80	172.20	255.80	301.00	937.60

3.8 Hydrometeorological Services

Hydrometeorological information is very important for water resources management.

IMD is providing very important technical inputs for evaluating design criteria for construction of hydraulic structures. Other services given by IMD include support to the flood forecasting centres and monitoring of rainfall all over the country.

(i) Work will be continued during 11th plan for preparation of generalized probable maximum precipitation (PMP) maps for different areas/duration. Suitable techniques will be evolved for this purpose. Such maps will be of immense use for the hydrological engineers engaged in the construction of hydraulic structures.

(ii) It is also proposed to augment the network of permanent snow observatories Western Himalayas. This is necessary in view of the inadequate snow cover information for hydrological purpose and for use in long range models for monsoon predictions.

(iii) Two more Flood Meteorological Offices (FMOs) will be set-up in the catchment areas prone to flash floods in order to provide better meteorological support to Central Flood Forecasting Divisions (CFFDs).

(iv) Meteorological component of an externally aided (funded by World Bank) Hydrology Project (Phase-II) will also be implemented by the Department during the 11th Five Year Plan. The main objective of this project is to improve the quality and service of Hydrometeorology data in selected states of India. The project envisages training of observers, creation of data centres in the states and upgradation of IMD's observation and calibration/test facilities.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Hydro Met Services	10.36	16.88	9.89	1.81	1.55	40.49

8.1.9 Agrometeorological Services

Agrometeorological services of the Department have a direct impact on the agricultural production. It is necessary to further improve the services during the 11th Plan by expanding the observational network and having closer co-ordination with state government authorities. Suitable research/study projects will also be initiated in order to provide better services to users in particular :

(i) Network of soil moisture observatories will be augmented to 42 (from existing 12 nos.) during 11th plan. Data will also be recorded for use in developing rainfall budgetary methods for applicaion to agricultural problems.

(ii) The existing Agromet Advisory Services of the Department will be strengthened by incorporation of additional information on soil temperature, cloudiness, dry spell/ wet spell etc. which will be better suited to the requirements of the farmers/end users.

(iii) In order to enhance the accuracy of agrometeorological measurements, it is proposed to modernize the Central Agromet. Observatory (CagMO) at Pune and at 3 Agromet Research Units located at Bangalore, Anand and Rahuri. With this, it would be possible to measure the energy and water balance components in the crop canopy. Using this data it would be possible to develop crop growth simulation models.

(iv) Use of remote sensing data will continue be made in Agricultural Meteorology and further research work will be undertaken for development of crop-specific growth and yield models. More interaction will be done with other research groups, particularly at SAC and NRSA who are doing similar work.

(v) Greater interaction with the agricultural agencies is envisaged, particularly in data exchange and research in inter-disciplinary areas. Interaction with State Departments of Agriculture and Agricultural Colleges would be brought under an institutional arrangement to produce farmer oriented advisories for direct application.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Agrometeorological services	141.40	144.92	148.54	152.15	10.58	597.59

Major Thrust Area (4) – Seismology and EREC

8.1.10 Seismology

It is proposed to strengthen the existing seismological network by upgrading 20

existing stations and setting up 20 new observatories.It is also proposed to add 50 more new seismological observatories to the national seismological network, as part of a major proposal to setup an optimum seismological network consisting of 177 stations to improve the detection threshold of locating earthquakes of magnitude 3.0 and above occurring anywhere in the country. To meet the ever increasing requirements of seismological data transmission/reception, processing, handling and storage, it is proposed to setup a modern National Seismological Database Centre in IMD, by deploying state-of-art computer hardware and software and communication equipment for immediate processing, easy access and safe archival of valuable seismological data sets.

It is proposed to take up work related to archival and digitization of old seismic analog charts. A pilot project is proposed for scanning and vector digitization of a few significant seismic analog charts to establish a technically viable approach.

It is necessary to give more thrust in human resource deveolopment for Seismology. It is proposed to create a specialized center for training in Seismology .

It is also proposed to set up a modern state-of-art Operational Center for real-time monitoring of earthquake activity in the country on 24x7 basis and to house the Operational Center in a well designed ground-floor building to withstand maximum earthquake forces likely to be expected in Delhi (corresponding to Zone-IV). This would not only ensure safety to the operational staff but also ensure minimal damage to the structure due to earthquakes for uninterrupted continuation of operational activities of the department.

This is another very important service area of the Department which has recently attracted attention of the public at large and the publicity media in the country particularly after the Bhuj Earthquake of 26 January, 2001 and Sumatra Earthquake of 26 Dec., 2004 leading to vast destration on the Coastal areas due to Tsunami. There have been many reviews and discussions at higher levels in the Government on this service of the Department. There is an urgent need to further improve this service during the 11th Plan.

(i) To improve serviceability of seismic equipments, a modern testing and calibration facility will be established a New Delhi. Seismo Workshop at Delhi will also be modernized by providing state-of-art machines and other equipments needed for improving quality of seismic recorders being fabricated there.

(ii) In order to take up more efficiently the works related to micro-earthquake survey after the major earthquake it is proposed to procure and set up an eight element telemetry array system. This will help taking up survey at short notice. Existing arrangements for such type of activities are not adequate and efficient.

(iii) For better monitoring of seismic activity over the Gangetic Plan and Peninsular India, it is proposed to upgrade the network of observatoeies in the country. New observatories will also be set up and suitable telecommunication facilities will be created for more efficient data collection.

(iv) To improve the technical competence of officers and staff for seismology related works it is also proposed to set up during 11th plan a seismological

training centre at New Delhi. This centre will provide three levels of training courses and will be equipped with latest teaching aids.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Seismology	17.46	26.86	16.78	18.15	8.98	88.23

8.1.11 Seismic Hazard and Risk Evaluation

As per seismic zoning of the country over 59% of India's land area is under threat of moderate to severe seismic hazard. Damage to life and property can be greatly reduced by proper land use planning, engineering approaches, strengthening of existing structures etc. Seismic hazard and risk microzonation is an essential and important tool for disaster mitigation planning.

Seismic microzonation of Mumbai, Guwahati, Ahmedabad and Dehra Dun on 1:10,000 scale and creation of national Database for Seismic Hazard and Regional Risk appraisal are proposed for the XI th Plan.

The benefits of microzonation can be summarized as improved –

- Resource allocation for remedial upgradation
- Information for planning and mitigation efforts
- Education of the public, land use planning for policy makers, designers and disaster managers

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Seismic Hazard & Risk evaluation	55.62	57.30	53.10	61.14	71.22	298.38

Major Thrust Area (5) – Climate & Environment Monitoring and Research

8.1.12 Environmental Studies

(i) Considering the importance of carbon dioxide in global warming, it is necessary to establish facilities in India for systematic monitoring of concentration of the gas in the atmosphere. At present only one station in India is in the process of commissioning for making such measurement on a routine basis. More stations are proposed to be opened in this planperiod to cover major geographical areas of the country to get a good estimate of CO2 sources and sinks in the region. Long time records of this data will be useful for future studies related to global warming.

(ii) In view of the impact of different atmospheric constituents on climate change, it is also proposed to upgrade ozone monitoring and BAPMON activities during 11th Plan by establishing additional stations in the data gap regions and to provide capability for monitoring other gases such as SO2 and NO2 and laying stress on aerosols which are now considered to have not only serious health effects but also significant climate forcings. Aerosol stations would be opened at around 20 locations covering areas of dust rising, agricultural burning and urban/ industrial emissions.This data will be useful for systematic environmental studies. Monitoring of micromet weather parameters will also be strengthened in view of their importance for boundary layer related studies.

(iii) Systematic studies on environmental urban meteorology and Bio-meteorology will also be started during 11th Plan to establish relationship between meteorological parameters and different human activities. Under this programme calculations of comfort index of various places of interest will also be done for different seasons. This information will be of direct applications in tourism.

(iii) A data centre would be opened for archiving observational data and metadata that are useful their interpretation and providing derived products to users of different categories

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Environmental Studies	6.00	4.20	3.60	3.60	4.80	22.20

8.1.13 Research

Systematic research on a continuous basis in meteorology is essential as it has direct bearing on the weather forecasting services. It is, therefore, proposed to give additional thrust during 11th Plan to a few important research areas :

(i) In order to improve Long range Predictions of monsoon rainfall which has a direct impact on the Agricultural production, it is proposed to develop improved models for predictions of rainfall on seasonal, part seasonal and monthly scales over State and Sub-divisional scales. Further studies on use of a suitable ocean-atmosphere Coupled General Circulation Model (CGCM) for long range forecast of different elements will also be undertaken.

(ii) Considering the increasing importance of harnessing conventional source of energy for various sectors of national economy, it is proposed to further strengthen the network of wind observations, collect systematic data and make a systematic analysis in order to assess wind energy potential.

(iii) Upgradation of Drought Research Unit will also be done during the 11th Plan to map drought prone areas using remote sensing data. The main objective is to monitor district-wise agricultural droughts and to evolve integrated drought index based on meteorological, climatological and agricultural parameters.

(iv) For better consideration of overall research activities of the Department and to evaluate various research proposals received by the Department through various

institutions, it is also proposed to establish a research monitoring cell in the Office of ADGM(R), Pune during the 11th Five Year Plan.

(v) With a view to provide better research facilities to the Indian scientists, it is proposed to construct during 11th Five Year Plan a separate library building in Pune and to equip it with latest user friendly systems for more efficient and easy access to the facilities. Present library building is quite old and is inadequate to handle large number of publications.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Research	6.94	3.10	2.21	2.21	2.21	16.67

8.1.14 Human Resources Development

IMD will continue to provide and maintain training facilities for imparting the necessary professional skills to IMD personnel to enable them to meet the growing demands of work. The increasing sophistication in their work arising out of the induction of modern technology has to be matched with the creation of expertise through specialized training in satellite, radar, communication s and instrumentation. Computer-aided Learning would be introduced in a big way. The Central Training Institute at Pune will be supported by specialized training centres to be set up and/or upgraded at Pune and New Delhi and regional centres. Advanced refresher courses would be organized periodically for in-service staff besides ab initio training courses for fresh recruits. This would provide opportunities to them for career advancement and professional satisfaction.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
HRD	8.04	9.84	8.04	6.24	5.04	37.20

1.1 National and International Cooperation

Meteorology, being an inter-disciplinary science, opportunities for national and international cooperation have to be utilized for its development. Also, IMD would promote further research efforts within India through grants-in-aid to universities and institutes for pursuing research projects in atmospheric sciences, the result from which would benefit both the Science and profession of meteorology.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
National /International Coop	0.40	0.40	0.40	0.40	0.40	2.00

8.1.16 Infrastructure Development and Maintenance

As a continuing effort towards capacity building, it is proposed to modernize the Hydrogen Factory, Agra, where the gas required for balloon flights is generated. It is also proposed to create a similar facility at one more place to reduce transportation delays and to set up gas-generation facilities at some of field units of operational importance.

IMD has over the years, added to its infrastructure in terms of office buildings, staff quarters, trainees' hostel etc. This aspect needs to be pursued in the coming years as required for implementing various 11th Plan schemes such as construction of Radar buildings at Paradeep, Bhuj, Mumbai and renovation of the existing Radar base structures. Construction of office buildings of newly created meteorological centres viz. Shimla, Dehra Dun, Raipur, Ranchi and Itanagar will also be completed.

Budget Requirement

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Infrastructure Development and Maintenance	74.72	109.98	107.93	102.74	28.72	424.09

8.2 NCMRWF

The demands for accurate, reliable, and customized forecast products are increasing continuously and various sectors of economy are increasingly factoring weather based advisories in decision making. Numerical modeling forms the back bone for all weather and climate forecasting systems, all around the world. At the time of establishment, NCMRWF became the unique global NWP Centre which not only computed weather but also demonstrated applications.

During the XI Five Year Plan, our main goal is to further improve the accuracy, reliability and range of medium range weather forecasts, provide regional forecasts at very high resolution for high impact weather systems, provide modeling support in early warning systems for weather and climate based disasters, and significantly enhance outreach. In view of the requirements of the country, particularly the agricultural and economic planning sectors, complementary goals of extended range/seasonal prediction will also be vigorously pursued.

Keeping in view the developments and trends in the field internationally and emerging requirements, it is proposed to focus on the following thrust areas during the eleventh five year plan:

1. Global Modeling and Data Assimilation System
2. Meso-scale Modeling and Data Assimilation System
3. Extended/Seasonal Prediction System
4. Climate Modeling System
5. Environmental Prediction (Aerosol, pollution, chemical etc.) System
6. Agromet Advisory Services
7. Computing Resources
8. Infrastructure

8.2.1 Global Modeling and Data Assimilation System

Activity 1: Global Modeling System

Objective: To improve the dynamics and physics of the NWP model. These improvements will be incorporated in the operational global Model, to enhance quality of deterministic medium range weather prediction.
This involves the following targets:

- Increase horizontal resolution to T354: (approx. 40 Km) for operations and T511 (approx 25 km) for research
- Increase vertical resolution to 60 Layers
- Semi-Lagrangian Schemes
- Improve the Parameterization of Physical Processes:
  - Boundary Layer
  - Radiation (Short-wave & Long-wave)
  - Cumulus Convection
  - Land Surface Processes
  - Air-Sea Interaction
  - Mountain Drag
- Implement a Real-time Ensemble Prediction System
- using Perturbation Breeding Method

Present Status
*Resolution***:** Both horizontal and vertical resolutions have been increased & T170/L28 model has been developed. Test runs with newer version of the global model are being carried out.
*Ensemble Techniques***:** An 8 member ensemble prediction system at coarse resolution has been implemented. This system is based on breeding vector technique and is able to take into account uncertainties in the initial condition.
*Radiation Parameterization***:** A new shortwave radiation parameterization scheme based on NASA/Goddard has been implemented in the NCMRWF operational model. The new shortwave radiation scheme replaced the old-generation GFDL shortwave radiation scheme. The new scheme takes care of scattering and absorption processes in the cloudy atmosphere. Zenith angle dependent surface albedo computation is also a part of the new shortwave scheme. A dust aerosol model has been developed at NCMRWF. It shows better energy balance between incoming and outgoing fluxes. CCM3 radiation scheme (shortwave and longwave) is implemented in the NCMRWF global model. This scheme includes the radiative effects of sulfate aerosols and trace gases like methane, NO_x, CFCs in addition to water vapor, CO_2 ,O_3 and clouds. Studies indicated that CCM3 radiation scheme is able to produce more realistic surface fluxes and heating rates compared to the operational radiation scheme.
*Convection/ Cloud Parameterization***:** The Global weather prediction model of NCMRWF was integrated using two different convection parameterization schemes, namely, the Simplified Arakawa-Schubert scheme (SAS) and, the Relaxed Arakawa-Schubert Scheme (RAS). These schemes show a strong monsoon flow and better prediction of rainfall over the Indian subcontinent as compared to the Kuo scheme. Comparison between SAS and RAS indicated that the former scheme produces relatively better forecast skill scores in terms of systematic and root mean square errors.
A study was carried out for the utilization of CLW derived from the MSMR on board IRS-P4 satellite in the NCMRWF model. The analyzed CLW data from IRS-P4 was compared with similar products from SSM/I on DMSP satellites. Results indicated that

the model derived CLWP values were within acceptable limits, where as the (MSMR) observations showed slightly larger values.

Planetary Boundary Layer Processes: Parameterization of the PBL in the NCMRWF model uses a simple first-order local closure approximation. Impact studies over Indian region using a more sophisticated TKE closure scheme showed positive results on the formation and movement of monsoon depressions. The precipitation distribution pattern also improved to a great extent. Later, a non-local closure approximation for the PBL was implemented in the NCMRWF model. The overall impact of the non-local scheme was found to be positive compared to the local scheme. The precipitation distribution pattern was improved to a substantial extent.

Studies are on to ascertain the sensitivity of the global model towards utilization of different roughness lengths for heat and momentum and compare the boundary layer structure with the data from various field experiments over Indian regions. Work on developing unified boundary layer scheme by assigning weights to various schemes depending on their individual performances is near completion.
Air-Sea Interaction: It has been shown that coupled evolution of the upper ocean is significant for medium range weather forecast over the Bay. An upper-ocean model was coupled to the global circulation model and exploratory simulations were carried out. On the basis of these works it was felt that work on an ocean data assimilation system for Bay of Bengal has to be pursued. The use of observed sea surface temperature on the analysis-forecast cycle was implemented

Proposed activities Higher resolution models with improved physics and dynamics shall be developed and inducted into operations. Improved ensemble prediction system in terms of model resolution, ensemble technique, and number of members shall be developed. Increasing the detail of the radiation parameterization scheme is essential to improve the forecast of temperature and fluxes. The future modification are to introduce more accurate cloud-radiation interaction, aerosol-radiation interaction schemes in the NCMRWF models.

Increasing the detail of schemes that parameterize physical processes, like convection is essential to improve the model forecast with a realistic prognostic cloud scheme. Understanding PBL dynamics and developing PBL parameterizations compatible to very high resolution global model will be undertaken. High resolution Boundary Layer Model for simulating ABL Eddies (Nested in a High Resolution Mesoscale NWP Model) is another field on which research work will be carried out that would specifically focus on utilization of data from field campaigns.

A more detailed land-surface model will be implemented with the corresponding land-surface assimilation scheme to initialize the surface boundary fields of the global model

Activity 2 : **Global Data Assimilation System**

Objective : Major objectives of this activity are the following:

- Improved algorithm for 3-DVAR Assimilation
- Development of 4-DVAR Schemes and test runs
- Utilization of all available satellite data
- Assimilation of Radar data
- Land Surface Data Assimilation
- Assimilation of Special Data from Field Experiments/IOP

Present Status : At present, a three-dimensional variational (3D-VAR) scheme is operationally implemented at NCMRWF, which utilizes satellite derived observations, apart from conventional meteorological observations also. Data processing techniques including decoding, quality-control etc. and assimilation methods have been devised for new satellite observations (viz. METEOSAT, ERS, MSMR/SSMI, ATOVS, QuickScat) for its real-time utilization in operational global data assimilation system. Schemes have been developed in-house to assimilate data from ACARS system. Extensive Observation System Experiments (OSE) are carried out to determine optimum use of satellite data. Comprehensive Quality Control system is regularly updated to account for new types of satellite data. Schemes have been developed to effectively utilize Indian RS/RW data which otherwise does not get assimilated in other operational global NWP centers. At present there is no land surface data assimilation. A Rainfall Analysis scheme has been developed to analyze merged rain gauge and satellite data over the Indian region.

Proposed activities:

- Improved algorithms for better quality control and assimilation of observations.
- Implementation of a land surface data assimilation scheme.
- Implementation of 4-D VAR assimilation system by the end of the XI Five year plan

Activity 3 Observation Data Reception, Monitoring, Processing & Quality Control System

Objective : Major objectives of this activity are to

- Develop tools for data Reception/ Monitoring/Processing, Quality Control of Data using Comprehensive Quality Control Procedures Examine Data Rejection Statistics and develop innovative Methods to improve better Quality data Ingestion into the Assimilation System

Present Status : Though NCMRWF receives ~80% of conventional data as compared to that received by other leading NWP centers of the world but in case of satellite observations it is one order less. It is required to establish bilateral arrangements for data transmission with some of these agencies for quick acquisition of these voluminous data sets. Continuous monitoring of data acquisition status is also a very important task and due to lack of manpower the same could not be dealt with proper importance

Proposed activities : Observation pre-processing such as data selection, thinning, daily monitoring of different types of observations are some key issues attached with success of any operational data assimilation system. NCMWF is sharing its monthly data monitoring report with other NWP centers. Extensive resources have to be deployed for data monitoring in operational mode. Studies to evolve proper data selection and thinning criterion over our region of interest have to be undertaken.

Activity 4 Model diagnostics and Verification System

Objective Tools for model diagnostic and model verification will be developed. R & D works on new verification metrics will be carried out. Research on model systematic errors will be carried out and models will be improved based on these studies.

Present Status At NCMRWF, a set of diagnostics, which include forecast systematic errors and standard verification scores suggested by WMO/CBS are generated every month on a routine basis. The NCMRWF operational forecasts compare well with those of the other centres and have demonstrated an acceptable level of forecast skill. The aim of the verification process is to provide skill and accuracy reference against which the impact of the subsequent changes in the analysis-forecast system can be measured. During the recent years several changes have been implemented in the NCMRWF analysis-forecast system and the model performance has been evaluated.

Proposed activities The efforts at NCMWRF would continue in understanding the origin of the systematic errors and reduce them to the extent possible. We also aim to add some more parameters in the list of diagnostics at NCMRWF.

Total of above activities	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**Total**
Global Modeling and Data Assimilation System	1.38	2.02	2.81	2.91	2.69	11.81

8.2.2 Mesoscale Prediction System

Activity **R&D on mesoscale modeling system and data assimilation for short range weather prediction**

Objective Major objectives of this activity are as follows:

- Retrieve high spatial-density data from Satellite/ GPS data,
- Assimilate measurements from radars, aircraft and conventional surface based networks,
- Utilize a 3D-VAR approach,
- Utilization of fine-mesh mesoscale models
- Generate and validate high-resolution weather predictions, using boundary conditions from a large-scale global model.

Present Status High impact weather system are manifestation of meso-scale weather systems embedded with in large scale flow. These cause severe loss to life and property. Mesoscale models are run routinely to dynamically downscale global model predictions and to provide accurate weather forecasts for high impact weather systems.

At present, three meso-scale models (MM5, WRF & ETA) are being regularly run at NCMRWF at different resolutions (10km, 32km, etc.) Data assimilation system (3D-VAR) compatible to MM5 and WRF have been acquired from National Center for Atmospheric Research (NCAR) under MOU and installed at NCMRWF. Mesoscale data assimilation in turn needs high resolution observations. Conventional as well as satellite observations obtained through GTS are being assimilated in this scheme.

Research on impact of physics parameterization in mescoale predictions are being carried out. Assimilation of Doppler Radar data has been carried out for the first time in India using a mesoscale data assimilation system. For Mountain Meteorology

programme of India, special R&D works are being carried out using the mesoscale models and predictions are prepared for Himalayan regions.

Proposed activities Higher resolution mesoscale models with improved physics and dynamics shall be developed and inducted into operations. High density observations will become available from meso-net, satellite and radar system and will be assimilated using a 3D-VAR approach.

Hurricane WRF(HWRF) is the next generation meso-scale model suitable for simulating tropical cyclones. Forecast demonstration project relating to land falling tropical cyclone over Indian region has been initiated recently and several experiments using different combination of resolutions/nesting, observations, model-physics have to be carried out over our region to achieve an optimal configuration of the meso-scale modeling system over our region. This task also require considerable computing resources

Budget Requirement

	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
MESO-SCALE PREDICTION SYSTEM	0.50	0.82	1.10	1.26	1.26	4.94

8.2.3: Extended-Range/Seasonal Prediction System

Activity **R & D on extended-range and seasonal prediction system**

Objective Major objectives of this activity are as follows:

- Develop a Multi-Model Ensemble (MME) Prediction System for Extended-range/Seasonal forecasting of Rainfall & Temperature
- Test runs with Dynamic MME Schemes
- Dynamically downscale the global model predictions for regional domain
- Statistical downscaling methods for improving the long-range forecasts

Seasonal **Pr**ediction and **A**pplication to **S**ociety (SEAPRAS) program at NCMRWF aims to improve the capacity in India's resource management to cope with the impacts of increasing variability of the world's climate, by establishing a platform through which policymakers and resources managers have better access to, and make better use of, information generated by climatologists and meteorologists. The objective is to provide the planners with more reliable seasonal climate prediction information and guidance to facilitate suitable applications.

Present Status The Seasonal prediction system has state-of-the-art global models as its major component. The skill of the NCMRWF seasonal prediction system is comparable to those of other international operational prediction centers around the world. R&D works are underway to include several other global models in the seasonal prediction system to generate a multi-model ensemble system to provide the policy

makers and resource managers a probability distribution function (pdf) prediction of future climate events. Research works on seasonal prediction for monsoon rainfall are being carried out at NCMRWF and other research institutions in India. However, an operational system for seasonal prediction for all the seasons, with an aim to meeting the demands of several socio-economic sectors is not at place in the country.

Proposed activities Extended/Seasonal predictions are made routinely at a number of meteorological centres around the world, using comprehensive coupled models of the atmosphere, oceans, in conjunction with, or as an alternative to empirical methods. Present-day skill of climate predictions needs to be examined from a social and economic perspective and attempts to be made to effectively utilize the climate prediction information. Economic value of seasonal predictions is measured by the increase in social welfare arising from the use of the prediction in economic decision making. One of the major concerns with a potential climate change is that an increase in extreme events will occur. Results of observational studies suggest that in many areas, extreme precipitation and temperature events have become frequent. Climate model simulations show changes in extreme events for future climate, such as increases in extreme high temperatures, decreases in extreme low temperatures, and increases in intense precipitation events.

Following activities will be carried out to make SEAPRAS a successful program.

(i) Development of the multi-model ensemble prediction system will be completed in the first year.

(ii) Development of a well-calibrated probabilistic prediction system will be completed in the second year.

(iii) Development of application systems for water resource management, energy demand management will be completed by fourth year.

(iv) Drought Monitoring & prediction system will be developed and completed in the fourth year.

(v) Verification will be carried out from users' perspective in the fifth year.

Budget Requirement

	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Extended Range/Seasonal Prediction System	0.27	0.58	0.70	0.67	0.52	2.74

8.2.4 Computer/Network Infrastructure and Services

Activity **Computer/Network Infrastructure and Services**

Objective Major objectives are:

Planning; Procurement; Maintenance of computer systems
Graphics/visualization; Software application support, system
Analysis, web design, GIS, Networking
Archival and Retrieval, Data Services
Programme Monitoring and Implementation, Coordination

Present Status At present the Centre has Cray X1e, Param Padma, Cray SV1,Origin, Dec-Alpha, O2 systems. Each scientist has been provided a desktop. The Centre has LAN and internet connectivity. Many of the systems need phasing out/replacement/upgradation.

Proposed activities Desk tops for additional man power, new desk tops as replacement of obsolete systems, new servers for data processing, web services, archival, storage, and periodic upgradation of supercomputing facility and network bandwidth

Budget Requirement

	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Computer/Network Infrastructure and service	0.50	0.74	1.02	1.10	1.10	4.46

8.2. 5 Agromet Advisory

Activity 1 Opening 20 new Agromet. Advisory Service (AAS) Units

Objective To start AAS from all 127 agroclimatic zones of the country

Present Status At present there exist 107 AAS units which are functioning under different State Agricultural Universities/ Institutes of Indian Council for Agricultural Research (ICAR). NCMRWF provide grant-in-aid to these collaborating agencies to defray salary of one scientist, expenditure on TA/DA, contingencies and development of infrastructure. No grant-in-aid is provided to two of these units as they are opened on special request by collaborating agencies that are bearing the expenditure themselves. Also, they are functioning with overlapping domains of the given agroclimatic zones.

Proposed Activities NCMRWF has to cover all the 127 agroclimatic zones and provide forecast to theses units on a bi-weekly basis. This will require additional grant-in-aid to be provided to collaborating university/institute for their functioning

Activity 2 : **Crop modeling & Decision support system (DSS)**

Objective : To develop and use crop model and Decision support system in farm decision making in AAS

Present Status : Upon the receipt of weather forecast from NCMRWF, a group of agricultural Scientists at AAS units translate, in a subjective manner, the current and forecast weather into farm management decisions and advise the farming community accordingly. Dynamic crop model based Decision Support System (DSS) can be used as an objective tool efficiently in farm decision making. In this direction NCMRWF has been demonstrating the use of crop models at some of the AAS units to help in farm

decision making such as deciding cultivar selection, optimum sowing window, irrigation scheduling, etc.

Proposed Activities : There is wide variability in terms of intercultural operations in farm management with in agro-climatic zone, which is not addressed properly in the present level of advisory. Besides this, availability and use of spatial data/information at smaller spatial domain scale on crop, soil and other interactive parameters at regular interval will allow to address the variability present in the farming system and make the farm advisory more efficient, objective and meaningful. This needs development/ calibration/validation of Crop model and Decision Support System on crop, pest & disease and livestock management in different agro-climatic zones. This will require additional manpower and more crop information to be generated at zone level.

Activity 3 Statistical interpretation of NWP model output

Objective To develop SI models for rainfall, temperature, wind speed & direction for all 107 AAS units for all seasons of the year

Present Status SI models have been developed for rainfall and temperature for 45 stations in monsoon season and for 20 stations in winter season

Proposed Activities SI models to be developed for additional 62 stations in monsoon season and for additional 87 stations in winter season. SI models to be developed for other surface parameters like wind speed, wind direction, fog etc for the all-107 stations for all seasons.

Activity 4 Diagnosis & Synoptic Interpretation of NWP model products

Objective Production and customization of weather forecast in medium range.

Present Status At present customized medium range weather forecast in a subjective manner is produced for 107 Agromet. Advisory service units, Min. of Agriculture, Indian Army, other Govt. agencies, electronic and print media and other user agencies on daily basis.

Proposed Activities There is need of such customized forecast for smaller spatial domain and different temporal scale for different purposes. Sectors like power, tourism and surface transport etc. require it for their regions of concern. Further these forecasts need to be verified on regular basis. The work requires 15 manpower for the purpose.

Budget Requirement

Total of above 4 activities	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Agro-met Advisory System	1.08	1.23	1.76	1.77	1.62	7.46

District-level Agrometeorological Advisory Service

Activity 1 Preparing District Level Weather Forecast

Objective
1.Compilation of observed and NWP model data for the last 3-4 years

2.Development of SI models for essential surface parameters like rainfall and surface temperatures, for different seasons

3.Validation and Implementation of these SI models for operations.

Present Status Presently NCMRWF, is preparing forecast at agro-climatic zone level, using deterministic methods. The variability of meteorological elements, particularly rainfall, with in a zone (comprised of 4-5 districts) is so great that more than often farmers of the country are unable to reap the benefit of the forecast though it may be correct in broader terms. This necessitates further down scaling the domain of applicability of the given forecast.

Consequent upon declaration by Hon'ble Minister for Science & Technology to provide district level forecast for the Monsoon 2005, NCMRWF took lead to generate weather forecast for districts of India, which is the basic administrative unit for managing the natural resources. NCMRWF has developed the procedure though which forecast for all 604 districts is being generated on daily basis and placed on its web page (www//:ncmrwf.gov.in). The district level forecast will have multifarious usage in different sectors of economy e.g. reservoir management, power generation/distribution, avalanche forecasting, flood forecasting, transportation, tourism, defense activities etc.
Status of SI models at NCMRWF: Perfect Prog Method (PPM) based SI models have been developed for monsoon(kharif) and winter(rabi) seasons. At present PPM models are used for rainfall and temperatures (maximum and minimum) for 45 stations in monsoon and for 20 stations in winter located in different agricultural climatic zones. SI forecasts are superior over the DMO forecast by about 10-20%.

Proposed Activities Development of Statistical Interpretation (SI) models for district level forecast will be undertaken. Other techniques such as bias removal, Kalman filter etc will also be developed to further improve the forecast skill. They also need to be intensively validated and verified before they are put to operational use. Hence there is a need for the procurement of meteorological data at district level.

Activity 2 District-level Agrometeorological Advisory Service (DAAS)

Objective District-level Agrometeorological Advisory Service will be established..

Present Status The NCMRWF in collaboration with the State Agricultural Universities (SAUs) is providing Agrometeorological Advisory Service (AAS) at the scale of Agroclimatic Zone (total 127, each comprised of about 5 districts) based on location specific Medium Range Weather Forecast. The forecast is prepared by using global, regional and meso-scale NWP models which are run in operational mode. Model out put is

subjected to synoptic and statistical interpretation to prepare the zone specific forecast employing man-machine approach. Agromet Advisory Bulletins comprising of crop/animal/soil/pest/disease specific expert advise on cultural practices to be carried out by the farmers of the zone in view of prognosticated weather situations are made available to the farming community.

NCMRWF has so far established 107 AAS Units and have plan to cover all 127 agro-climatic zone in near future. The center is providing agro-climatic zone specific day to today weather forecast for next 4 days twice a week i.e. Tuesday and Friday. On receipt of the forecasts at the AAS unit, they prepare the medium range weather forecast based Agrometeorological Advisories in vernacular language in consultation with a panel of experts in various subject matters of Agriculture. These agro-advisories are disseminated to the farmers through all possible mass media like newspaper, radio, television and also through personal contacts by extension workers. In addition, these bulletins are also provided to authorities of concerned departments like those of agriculture, horticulture, irrigation, soil conservation, animal husbandry etc. to enable them to take necessary measures for effective utilization of weather sensitive farm inputs and practices. During 2004, NCMRWF has also started issuing an All India agro-advisory bulletin on every Monday during monsoon season for dissemination and utilization by various departments and agencies both at centre and state levels. Ministry of agriculture and ICAR have institutionalized several follow up action based on these reports. A Web based agro-advisory system was also implemented in 2004.

Proposed Activities: Although quite successful and useful in terms of benefits accrued, the present agro-advisory system at the agro-climatic zone scale is inadequate to deal with issues related weather sensitivity of sustainable agricultural production owing to larger variability of farming systems as well as weather and soil, within the agro climatic zone. In a way, farm production is reflected by the signature of climatic (rainfall) variability present at sub-district (taluka) scale or even at sub-taluka scales. Present system lacks in terms of including observations on spatial variability in farm operations due to non-availability of information on weather, soil condition, sowing decision taken by farmer, irrigation, fertilizer and chemical application etc. within the zone. Keeping these considerations in view, NCMRWF plans to expand the farm advisory network from agroclimatic zone scale to district level in the country. Significant components are listed below:

Weather & Climate: Current information on various high impact weather events such as extreme temperatures, heavy rains, floods, and strong winds etc. are desirable to be included in advisory. Using historical climate data, climatology of various kinds need to be prepared for each and every location to support the agricultural decision making. There is a need for the procurement of historical and real time meteorological data at district level.

Agro-advisory: Development of dynamic model based Decision Support System (DSS) on crop, pest & disease and livestock management for use of spatial data to increase the timeliness of planting, spraying operations, irrigation applications, fertilizer applications, etc will be undertaken. Advisory content shall vary with location, season, weather, crop condition, and local management practices. The advisories is also envisaged to serve as early warning system for alerting producers to the implications of various weather events such as extreme temperatures, heavy rains, floods, and strong winds.

Information dissemination system: Timely dissemination of weather observations, forecasts, advisory bulletins to the end users is critical for their beneficial use in farm management. Besides the existing communication network between NCMRWF and its AAS units at ACZ level, it is envisaged to use the reliable communication facility of National Informatic Centre (NIC) operating at district level for information transfer among NCMRWF, AAS units and all the districts. This uninterrupted information transfer includes reception of agrometeorological observations at NCMRWF from AWS, dissemination of Medium Range Weather Forecasts from NCMRWF to AAS units and centers at district level, and dissemination of weather forecast based advisory from AAS unit to respective district centers and NCMRWF. District level advisory may further reach down the line to the block/sub-taluka level using communication system under the control of district authorities.

Budget Requirement

	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
District-level Agrometeorological Advisory Service	0.54	0.82	0.98	0.98	0.68	4.00
Grant-in-Aid for Agrometeorological Units(AMFUs)	12.70	12.70	12.70	12.70	12.70	63.50

8.1 IITM

The Research in Tropical Meteorology is the ongoing scheme which involves the following :

- Asian Monsoon Variability and Predictability
- Application of Satellite Data in Weather Forecasting and Large-Scale Hydrological Modelling
- Short-Term Climate Diagnostics and Prediction
- Cloud Modelling
- Middle Atmosphere Dynamics
- Aerosol and Climate Studies

8.3.1 Asian Monsoon Variability and Predictability

Land-surface processes over the northern hemisphere mid-latitudes and the air-sea interaction over the tropical oceanic region play an important role in the interannual/decadal variability of monsoon rainfall. Hence to better understand and predict monsoon rainfall variability studies on global connections are essential. The study will be continued in the 11^{th} Plan Period.

Objectives

- To understand and predict the Indian monsoon rainfall (IMR) variability on intraseasonal, interannual and decadal time scales and its connection with low-frequency phenomena such as the El Nino Southern Oscillation (ENSO), North

Atlantic Oscillation (ENSO), North Atlantic Oscillation (NAO), Pacific/North America (PNA) pattern and West Pacific Oscillation (WPO) using conventional and advanced statistical/empirical techniques.

- To isolate regions which are more closely linked for the snow-monsoon connections in relation to monsoon variability using historical Soviet snow depth and INSAT derived Himalayan snow cover data.

- To understand the causes of the decadal variability of monsoon rainfall over the Asian domain.

- To explore connections of IMR variability within the Asian monsoon domain and other monsoonal regions of the world.

8.3.2 Application of Satellite Data in Weather Forecasting and Large-Scale Hydrological Modelling

Numerical Weather Prediction requires complete and accurate description of atmospheric state. For the detailed study of weather system developed on oceanic region from its initial state to its dissipation state, hourly/half hourly data are required frequently on real time basis. In order to alleviate data sparsity problem over oceanic region, it is better to use satellite observed data for obtaining the vertical temperature profiles etc. Also, through four dimensional data assimilation the past data can be used in optimum way for the analyses of meteorological parameters.

Importance of hydrological modelling for practical purposes as well as scientific purposes while it is useful to understand the sustainability of natural ecosystem is of great help in planning, management and implementation of agricultural activities. Knowledge of basin scale hydrological cycle is of great significance in the exploration and management of the water resources. There is tremendous emphasis in the modern meteorological research to understand the role of hydrological processes on the weather and climate of different spatial and temporal scales.

Objectives

- To acquire the satellite data like moisture/precipitable water, satellite observed winds, surface winds over oceanic region, outgoing long wave radiation (OLR) snow cover, soil moisture, vegetation index and sea surface temperature (SST) from the INSAT, GMS, METEOSAT, IRS-P4, NOAA, TOVS, archive and process the data for research applications. To use the IRS-P4 MSMR data for understanding the features of cyclones and monsoon depressions.

- To develop hydrological model for large-scale estimation of run-off and soil moisture using satellite derived rainfall, vegetation distribution and soil moisture for selected (hydrologically, agriculturally, ecologically and tectonically important) river basins of the country and understand the role of surface wind stress and spatial shift in the rainfall activities on the vagrancy of the courses of river.

8.3.3 Short-Term Climate Diagnostics and Prediction

Climate has now been globally recognized as one of the most critical factors in socio-economic development, present as well as future. Therefore, a concerted effort will be made in the present research scheme to orient climate research being done at this Institute towards development of specific climate applications in the areas of agriculture, water resources and public health etc. This is believed to help the Indian population at large in coping with the climate variability in a much better way by effectively incorporating the seasonal climate information into the decision making processes at different levels.

Objectives

- To develop the necessary background and capability for true end-to-end application of seasonal climate forecasting in the areas of agriculture, water resources, public health, etc.
- To develop climate forecast products tailored to suit the user requirements and to demonstrate the value of seasonal forecasts for the decision making in the areas of agriculture, water resources, etc.

8.3.4 Cloud Modelling

Theoretical investigations relating to cloud modelling would help simulate precisely the physical and dynamical processes representative of the natural conditions in real clouds and investigate the seeding effects in warm and cold clouds. Similarly, modelling of fog**/**hail processes under a variety of atmospheric conditions and simulation of the effect of existing techniques for their modification would facilitate not only for understanding the microphysics and dynamics but also for evaluating the efficacy of different seeding techniques in improving visibility, particularly for air traffic operations and to minimize the losses to crop production activities. These studies are essential for advancing the present knowledge of numerical simulation of cloud**/**precipitation processes existing in monsoon clouds, and also to modify the fog**/**hail forming under different meteorological conditions over specific regions in the country.

Objectives

- To carry out numerical simulation of cloud and precipitation processes for the study of the physical and dynamical properties of natural conditions in real clouds and to compare with the satellite-derived cloud observations.
- To undertake mathematical modelling and computer simulation of fog/hail processes under different atmospheric conditions and documentation of techniques available for their suppression.
- To undertake simulation of silver iodide/salt seeding of cold/warm clouds and investigate the seeding effects.

8.3.5 Middle Atmosphere Dynamics

For understanding the variations in rainfall and associated meteorological phenomena, the troposphere-stratosphere coupling and the influence of middle atmosphere dynamics on tropospheric circulation systems would be essential. Similarly the middle atmosphere responses to solar and geomagnetic activities are considered to be important for the physical understanding of meteorological phenomenon in the troposphere.

Objectives

- To study the long-term changes and trends in ozone and other climate forcing parameters, and global change scenarios.

- To investigate interactions between tropospheric circulation, ozone and lower stratospheric temperature over tropics.

- To study stratosphere-troposphere coupling/ exchange processes.

8.3.6 Aerosol and Climate Studies

An understanding of the role of atmospheric aerosols and gases in the forcing mechanism and the forecasting of changes in global climate and in geosphere biosphere processes is necessary. In order to understand the role of these constituents in the climate system in influencing the atmospheric radiation regular and systematic measurements of aerosols and trace gas distribution is essential.

Objectives

- To monitor atmospheric aerosols, trace gases up to stratospheric altitudes using optical and solar radiometric remote sensing techniques and build aerosol and trace gas climatology for assessing long-term climatic impacts and trends for the study of troposphere-stratosphere exchange processes.

- To carry out measurement of greenhouse gases using ultraviolet, visible and infrared spectrometers.

- To develop atmospheric correction schemes for satellite data retrieval and comparison of aerosol and trace gas observations from LIDAR, Radiometer Spectrometer with *in-situ* and satellite observations.

- To study radiative forcing parameters due to aerosols and trace gases and their role in climate and climate change.

- To measure air pollutants and undertake studies relating to atmospheric chemistry and acid rain for assessment of the impact of air pollutants on the environment vis-a-vis climate system.

Upgradation of the following Existing Facilities is envisaged :

Stable Isotope Laboratory

The dendroclimatology work is handicapped by the lack of a stable isotope laboratory. It will be equipped with mass spectrometers and other necessary equipments. This would also be an important new palaeoclimatology activity.

Instrumented Tower for continuous Boundary Layer Measurements

For continuous measurements of the boundary layer turbulence parameters the existing micrometeorological tower will be augmented with new instruments. With this tower sustained high resolution measurements of turbulent parameters in the boundary layer will be made for development of parameterization of surface fluxes, based on understanding of relationship between turbulent fluxes and large scale environments.

Restructuring of Existing Workshop Infrastructure Facilities

The workshop facilities will be modernized for advanced needs of the Institute by restructuring of the mechanical facilities and by initiating Electronic section. Specialized instruments required for observational experiments will be fabricated at this Workshop.

Budget Requirement

Rs. in Crores

Programmes	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**Estimated cost**
Asian Monsoon Variability and Predictability	6.00	3.00	3.00	2.00	2.00	17.00
Application of Satellite Data in Weather Forecasting and Large-Scale Hydrological Modelling	6.00	3.00	3.00	3.00	3.00	18.00
Short-Term Climate Diagnostics and Prediction	6.00	3.00	3.00	3.00	3.00	18.00
Cloud Modelling	5.00	4.00	4.00	4.00	4.00	21.00
Middle Atmosphere Dynamics	5.00	4.00	4.00	4.00	4.00	21.00
Aerosol and Climate Studies	5.00	4.00	3.00	3.00	3.00	18.00
Total	33.00	21.00	20.00	19.00	20.00	113.00

9. New programmes

9.1. IMD

The new schemes are based on demands that have been received from various quarters in some cases as a result of the Governments policy of unifying Disaster Management and in some cases for establishing a single window system of meteorological forecasting and in some for packaging products for media dissemination involving latest technologies like DTH, Mobile phones etc.

The schemes that have been identified are as follows:

Major Thrust Area – Forecasting System

Sub Thrust Areas
7. District Meteorological Information Centers (DMIC). - new programme
8. Early Warning System. - new programme

Major Thrust Area – Climate & Environment Monitoring & Research

Sub Thrust Areas
14 Climate Research and Monitoring. - new programme

9.1. 1 District Meteorological Information Centers (DMIC)

Meteorological information is sought at District levels which can be supplied in a customized manner with location specific value additions. This responsibility falls on the State Met centre to prepare such products and use IT infrastructure to network adequately with local Governments. The District is also a revenue unit requiring representative climatology. In addition the District level liason man shall also work as the representative to collect crop related information to hand over to the Pune Agromet office for generation of crop advisories. Thus the work at location would involve inspection of installations, collecting data and liasoning. The cost of networking IT equipment and supplementary cost of office maintenance have been projected.

Budget Requirement:

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
DMIC	19.20	55.20	30.00	40.80	58.80	204.00

1.1.1 Early Warning System

This scheme seeks to generate capability of the IMD to generate media compatible information products at all forecasting office levels ie State Governments and Headquarter Delhi. Visuals, Audio and movies capabilities will be built up. There would be media centres at all levels mentioned above. In addition there would be digital communication based warning services that would be activated at forecast centres and would reach various levels of Disaster Management Authority instantaneously.

Budget Requirement :

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Early warning System	2.95	21.66	23.19	23.16	13.04	84.00

1.1.2 Climate Research and Monitoring

During the 11th Plan, it is proposed to take up studies of various biological and chemical processes involved in global change as part of IMD contribution to the International Geosphere Biosphere Programme (IGBP). Efforts of international scientific community will focus on the CLIVAR (climate variability) Programme as a major thrust area of the World Climate Research Programme (WCRP). Under this programme, as part of India Climate Programme, IMD will conduct further studies on Monsoon and its Predictability, Stratospheric Processes and their role in climate and impact of anthropogenic aerosols. These studies will lead to better understanding of physical processes involved in global and climate change which is one of the high priority area of research all over the world.

Application of neural network for prediction is increasing in recent years in various disciplines and it continues receiving attention of World Scientific Community. Extensive research in this area will be conducted during 11th Plan to explore possibility of weather prediction by this technique. Further studies on use of chaotic theory to forecast meteorological parameters in different time scales will also be undertaken.

Existing computer system installed in the National Data Centre (NDC),Pune would be inadequate to meet the future demands of climate data users as 5 million additional records of data are being added every year. It is, therefore, proposed to replace the present system during 11th Plan with a new system to meet future increased requirements of various users including use for various research projects. In order to meet regional demands more expeditiously, it would also be necessary to establish 6 small separate regional data centers.

Department is maintaining daily meteorological data records of past 110 years on magnetic media. This data set will be transferred on latest type of suitable media so as to manage the data in a more efficient manner consistent with the ever increasing demands of users.

It is also necessary to properly archive analysed weather charts of past 100 years which is a valuable data source for future work. In order to increase the utility of these charts it would be useful to store them on latest type of media in easily accessible form after digitization.

A National Climate Centre is functioning in the Office of ADGM (R), Pune since last several years. During the 11th Plan the activities of this center will be further expanded for monitoring climate over India and neighbourhood and for carrying out diagnostic studies. Suitable climate model will also be adopted and operationalised after detailed studies. With these expanded activities it will be possible to organize a climate information service for users.

Budget Requirement:

Sub-Thrust Areas	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Climate Research & Monitoring	2.64	12.78	1.68	1.86	1.92	20.88

9.2 NCMRWF

9.2.1: Satellite Radiance Data Assimilation System

Activity: R&D on schemes to assimilate satellite radiance data and subsequent use in operations

Objective: Assimilation of all satellite radiance data

Present Status : At present, a three-dimensional variational (3D-VAR) scheme is operationally implemented at NCMRWF, which utilizes satellite derived observations, apart from conventional meteorological observations also. Data processing techniques including decoding, quality-control etc. and assimilation methods have been devised for new satellite observations (viz. METEOSAT, ERS, MSMR/SSMI, ATOVS, QuickScat) for its real-time utilization in operational global data assimilation system. Schemes have been developed in-house to assimilate data from ACARS system. Comprehensive Quality Control system is regularly updated to account for new types of satellite data.

Proposed Activities : As generally large uncertainties are associated with satellite derived products, all the leading NWP centers of the world are assimilating satellite measured radiances directly, instead of derived products.
Satellite observations are continuous in time (asynoptic) and the best way of assimilating asynoptic observation is 4D-Var (space & time) technique. 4D-VAR expects basic radiance as input from various satellites. A 4-D var assimilation system with radiance data assimilation will be implemented.
Mechanism to receive and monitor high volume satellite data in real time from national and international satellite application Centres like NOAA NESDIS, EUMETSAT SAF, CIMSS, KNMI, NASA, ISRO SAC, IMD, INCOIS etc. shall be established.

Budget Requirement

	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
SATELLITE RADIANCE DATA ASSIMILATION SYSTEM	0.27	0.58	0.74	0.67	0.75	3.01

9.2.2 Climate Modeling System

Activity 1 R&D on 'climate modeling' part of climate change science

Objective Major objectives of this program are to develop an 'Earth System Climate Model' to be used in climate time scale simulations and predictions. It will comprise of the main modules of atmosphere, ocean and land. The dynamics and physics in each of these components will be in accordance with the climate scale as the target. It should be able to simulate the 21st century climate realistically. The representation of monsoon and its teleconnections to other major climate components of the earth climate system has to be realistic in climate scale. This model will have the capabilities to project future climate scenarios under various possible conditions and the extremes.

Present Status The atmosphere and land components of the model are available. The atmospheric data assimilation system is also available. The major modeling centers of the world are moving in the direction of the concept of 'Seamless Suite' of models.

Proposed Activities A more sophisticated version of the land model with land assimilation has to be developed. A global ocean model and the corresponding assimilation system (projected separately under independent head) will also be linked to this climate model. A proper strategy of coupling the three models will be developed and tested.

Activity 2 Ocean State Modelling, Data Assimilation & Coupled Modeling System

Objective Main objectives of this activity are :

- To build a global ocean model/assimilation System to be coupled with the atmospheric model for dynamical extended/seasonal prediction
- Improvement of the currently used Ocean Wave Model

Present Status Ocean State Forecast System has been implemented at the Centre. Ocean Wave Height Forecasts are issued to INCOIS and other agencies. A Stat-of-the-Art of Global Ocean Model is being implemented. A new Ocean-Data Assimilation System (and model) is being developed. An operational Ocean Data Assimilation system is a critical and essential component for any further progress in including ocean-atmosphere coupled interaction in the forecast process for extended and seasonal prediction.

Proposed Activities A new Ocean-Data Assimilation System will be available. A new coupled ocean-atmosphere model will be developed for medium range to long- range predictions. A better ocean state analysis will be available. Implementation of an ocean-data assimilation system which will try to use every available information from the seas around India available from DOD and other international sources. As mentioned earlier this is and essential component for including two-way interaction in coupled ocean atmospheric forecasting in medium or seasonal scales. It is essential that in the coming 1-2 years an experimental system is put in place and in 5 years time a fully functional system is used for providing initial conditions for coupled models.

Activity 3 R&D on weather & climate monitoring

Objective Major objectives of this program are to develop a system for Weather Monitoring: Extreme Events- Heavy Rainfall, Avalanches, Cloud bursts, Cyclones etc. Climate Monitoring:: Droughts, Floods, MJO, Aerosols, Development of Indices to monitor Extreme Climate events

Present Status Currently this activity is carried out as a low-key affair due to lack of adequate man power. A monitoring & prediction system for MJO is being developed. Drought monitoring over India is being carried out on weekly basis. Some studies have been initiated for large-scale transport of aerosols.

Proposed Activities A new monitoring system will be developed for weather & climate system. This system will be for global weather & climate. Indices will be developed for extreme climate events. Monthly report on weather & climate monitoring will be brought out. This report will be helpful in medium-range and seasonal prediction. This activity will also supplement the examination of frequency of occurrence of extreme weather and climate events.

Budget Requirement

	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Climate Modeling System	0.69	0.59	0.86	0.56	0.56	3.26

9.2.3 Environmental Prediction System

Activity R&D on Environmental Prediction (Aerosol, pollution, chemical)

Objective Main objectives of this activity is to develop an Environmental Prediction (Aerosol, pollution, chemical) System

Present Status The problem of trace gases and aerosols in the atmosphere is important from the point of climate change and weather forecasting. Seasonal and medium range forecasting may have to include the present day distribution of such materials in the atmosphere rather than long term averages as done now. In addition to that the forecasting and simulation of long range transport of tracers is of practical application as a weather forecast product, in relation to catastrophic release of radioactive material, volcanic dust and intercity-transport of pollutants. NCMRWF have been engaged in capacity building in this area for the last 8-9 years. During this period we have achieved the following:

(i) Built up systems for calculating air-trajectories.
(ii) In collaboration with the Max-Planck Institute for Chemistry, Germany we have studied the climatology of the global distribution of trace gases. Carried out studies on transport processes of soluble, insoluble idealized tracers and chemical tracers over India.
(iii) The interface for running the MATCH-MPIC Model with NCMRWF products was developed .

Proposed Activities**:** A global chemical forecast system to simulate the ambient air-quality will be made operational in 2-3 years time. A forecast system for intercity transport and regional transport of idealized tracers will be set up. This will be run at varying spatial resolutions for use in emergency response. In the next five year period work on assimilation of observations of trace gases will be initiated.

Budget Requirement

	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Environmental Prediction System	0.23	0.31	0.20	0.20	0.20	1.14

9.2.4 :Computer/Network Infrastructure Upgradation

Activity Computer/Network Infrastructure Upgradation

Objective Major objectives are

- Upgrade the Supercomputer depending upon the model resolution and number of members of the Ensemble Forecast system. Upgrade the desktop systems.
- Establish a dedicated communication link between NCMRWF and 107 AAS units.
- Upgrade the Internet Leased Line (ILL) depending on the requirement of reception of Satellite Radiance Data and establish Internet Private leased Line Circuit (IPLC) between NCMRWF and Satellite Data Centres in US and Europe.
- The data and NWP products are going to be so voluminous that NCMRWF will need to establish a Data warehouse that shall be much different from the Data archive. Explore the possibility of Grid Computing and Distributed Database.
- Upgradation of all associated infrastructure like UPS, Diesel Generator, Network bandwidth commensurate with the requirement of Compute Power. Establish a Gas based Captive Power Plant.
- Establish a Microwave link between NCMRWF and Mausam Bhavan for uninterrupted Data reception.

  This activity involves developing and implementing practical algorithms, making the best use of the available computer resources and continuously upgrade the compute infrastructure.

Present Status At present the Centre has Cray X1e, Param Padma, Cray SV1,Origin, Dec-Alpha, O2 systems. Each scientist has been provided a desktop. The Centre has LAN and internet connectivity. Many of the systems need phasing out/replacement/ upgradation.

Proposed Activities :Replacement of obsolete systems, new servers for data processing,

web services, archival, storage, and periodic upgradation of supercomputing facility and network bandwidth

Budget Requirement

	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Computer/Network Infrastructure Upgradation	80.00	20.00	15.00	65.00	8.00	188.00

9.2.5 Infrastructure Development and other facilities

Activity **Capital expenditure in respect Infrastructure Development and Other facilities**

Objective

- Existing Office Interior Furnishing; modular furniture; partitioning for space utilization and Seating Arrangement for optimal usage of floor area;
- Auditorium Interior Finishing and Furnishing; Augmentation of Conferencing and Meeting Rooms with Audio and Visual Support
- Multi-Story Building for accommodating additional Manpower and
- BIMSTEC Centre for Weather and Climate; Housing Complex
- Hiring of Professional Services/ Surveys and Programme Implementation Analysis/ Value Added Services
- Planning, Procurement, Commissioning and Maintenance of appropriate Supportive Infrastructure – Gas Based Captive Power Source; UPS; Air-conditioning; House Keeping; Office Automation; Internet Bandwidth for Video Conferencing and Web casting; Visualization and Visual Application Environment; Security etc.
- Capacity Building, International Exchange Programmes, Strategic Partnership, Promotion of R&D on Weather & Climate Modeling in the country
- Strengthening of Library and Documentation Facility

Budget Requirement

	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Infrastructure Development Other Facilities and capacity building	35.60	19.60	18.60	6.60	6.50	86.90

9.3 IITM

Climate Dynamics and Extended Range Prediction of Monsoon

The agricultural prediction and water resources of the country depend primarily on the monsoon rainfall. Therefore, prediction of monsoon climate, namely the seasonal mean rainfall over the country has major influence on the country's economy. While prediction of seasonal mean all Indian rainfall (AIR) about a season in advance is useful for making some policy decisions, it is not so useful for agricultural planning due to (i) large inhomogeneity of rainfall within the country and (ii) requirement of temporal evolution of rainfall within the season. Therefore, it is even more important to predict the active and break spells of the monsoon about 3-4 weeks in advance. Hence, two specific requirements for extended range prediction of monsoon are:

a) Long-range prediction (about a season in advance) of seasonal mean monsoon rainfall, and
b) Region specific prediction of active and break phase of the monsoon 3-4 weeks in advance.

Indian meteorologists in particular IITM have made significant contribution in developing empirical models for long-range prediction of seasonal mean monsoon rainfall. However, all such models have an intrinsic limitations, namely they are unable to capture the extremes. Hence, it is recognized that the logical alternative is to use dynamical climate models based on physical laws to predict the monsoon.

Over the last two decades, the conceptual basis for climate prediction has been established. Considerable research on predictability of the monsoon (including some pioneering work by IITM scientists) 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. However, all the climate models, from anywhere in the world, currently have either zero or negative skill in predicting the monsoon rainfall. The challenge is to improve the prediction system (including the model, the data assimilation and forecast strategy) to achieve the potentially achievable skill.

In India, we are still experimenting with short runs of atmospheric GCMs and we have a long way to go even to reach the level achieved elsewhere. But if we want to achieve the goal of reaching the limit on potential predictability, we have to better the efforts made elsewhere in the world. IITM proposes to develop such a system. However, it would require (i) massive investment on computing infrastructure (ii) induction of a number of experts on different aspects of coupled modeling including data assimilation and (iii) investment on training and physical infrastructure.

Regarding the prediction of active and break spells, IITM scientists have done some pioneering work on developing empirical method for such prediction. It is proposed that such a technique is made operational and dynamical method is developed for

predicting these spells. It may involve also a coupled model and innovation in data assimilation and initialization.

Improvement of forecast skill depends on improvement of models which in turn depends on improvement of parameterization of physical process in these models. Such improvement can come only through basic research in these areas. Therefore, vigorous basic research is essential for improvement of forecast skills of prediction models. One area where most models are deficient is, in the formulation of convective processes. A better understanding of interaction of small scale convective process with its large-scale environment can go a long way in improving parameterization of cumulus convection in GCMs. For this, specialized observations and modelling are required. Therefore, we are proposing a project on 'Interaction betweencloud and environment and formation of precipitation'.

The new scheme of 11th Five Year Plan of the Institute consists of the following three components:

- Science Plan
- Infrastructure
- Manpower

9.3.1 Dynamical Prediction System of Seasonal Mean Monsoon Rainfall

This would involve development of coupled ocean-atmosphere-land models, testing them for simulation of the mean climate, developing data assimilation techniques and developing prediction methodologies. It would require hundreds of years of simulations with a coupled model. It would also require plenty of simulations of the individual component models (e.g. the atmosphere model, the ocean model etc). The computing infrastructure for such activity does not exist currently at IITM. It is proposed to establish a major high performance computing facility as a central facility at IITM during this plan that will cater to computing needs of this activity as well as that of other activities. In addition to the major computing infrastructure, we would require at least 15 additional senior scientists with various expertise to achieve the goal of this project.

Such a prediction system is crucial for the IMD but does not exist in the country. Once established, we shall be in a position to train some scientists and transfer the system to the IMD. Once fully developed, the system will give us a lot of spin-off science. For example, we should be able to study the role of air-sea interactions on monsoon variability and predictability.

<u>Objectives</u>

- Selection and testing of atmospheric and oceanic components for integrating in to a coupled model.
- Development of a coupling strategy.
- Evaluation of simulation of global climate and monsoon climate by the coupled model and diagnosis of systematic bias.
- Development of techniques of assimilating in situ as well as remotely sensed data in to the coupled model.

- Development of a strategy for forecast of seasonal mean monsoon.
- System for experimental forecast of seasonal mean monsoon.
- Study of air-sea interaction and monsoon predictability.

1.1.1 Extended- Range Prediction of Active and Break Spells of the Monsoon

While the prediction of the seasonal mean is important, the predictability of the seasonal mean may be limited. Also, seasonal all India mean rainfall may not be very useful and meaningful when the mean is close to normal. This is because the regional distribution of rainfall anomalies is very inhomogeneous when the all India mean is close to normal. On the other hand, prediction of active and weak spells of the monsoon even 3 weeks in advance could be very useful for sowing, harvesting and water resources management. It is proposed to develop a system to predict the active and break spells 3-4 weeks in advance. It will involve empirical techniques as well as dynamical coupled models. The models developed under (4.1.1) will be useful for this purpose also.

Objectives

- Development of an empirical method for predicting active and break monsoon.
- Use of daily rainfall data along with other parameters.
- Study of air-sea interaction associated with monsoon intraseasonal oscillation (ISO).
- Attempt to use an atmospheric general circulation model (GCM) to predict the phases of the ISOs.
- Use of a coupled model for predicting the ISO phases.
- Data assimilation and slow manifold initialization for improving the forecasts.

1.1.2 Science of Climate Change and Monsoon

Some interesting work on monsoon under climate change scenarios has been done at IITM. In the next few years, we shall endeavour to establish a multi model mean and the range of uncertainty in simulation and prediction of regional monsoon rainfall under different scenarios. The coupled model platform indicated in (4.1.1) will extensively be used here.

Objectives

- Estimation of monsoon climate under different climate change scenarios through downscaling using a regional climate model.
- Sensitivity of the estimate of monsoon climate under climate change due to downscaling of the output from a large number of global models.
- Quantification of uncertainty in estimation of monsoon climate under climate change scenarios.
- Roles of internal variability and external forcing in predicting the future monsoon climate.

1.1.3 Urban Air pollution and Transport Modelling

Some work on air-pollution studies and chemical transport modelling exists in the Institute. It is proposed that bringing this expertise together and a comprehensive urban air pollution and transport model would be developed. For developing and testing such a modelling platform a meso-net may be developed around Pune and special intense observations during some specific periods may be planned.

Objectives

- Development of a regional model with active chemistry for many pollutants embedded in a large scale transport model.
- Collection of data of chemical components over urban locations.
- Verification of model simulation and predictions.
- Estimation of impact of some of these pollutants (e.g. ozone) on regional climate.

9.3.5 High Performance Computer and Data Centre

The existing computing infrastructure at IITM is very insufficient. The proposed modelling work needs to develop a state of the art monsoon prediction system. The development process requires a computing system with about 3 teraflop number crunching capabilities with appropriately large memory and an automatic data storage and retrieval system with about 100 terabyte storage capacity. This central facility will cater to the need of all the scientists from different modelling groups.

Development of a coupled model requires quick turn around (within a few days) of

- Multiple multidecadal integration of a global Atmospheric General Circulation Model (AGCM) with approximate resolution of T63 and 30 levels in the vertical.
- Multiple multidecadal simulations with a global ocean general circulation model (OGCM), with 1º resolution in zonal direction and variable in meridional direction (about 1/3º near the equator going to about 2º after about 20º latitude).
- Coupling of the AGCM and OGCM and testing the model for long integration, evaluation of the “climate drift”.
- Based on the nature of the “climate drift” (i), (ii), (iii) may have to repeated many times before the drift is brought under control and the simulation of the coupled climate is reasonable.
- Running the data assimilation programs for many cases involving running the model and its adjoint.
- Multidecadal integration of the high resolution Regional Climate model corresponding to a large number of global climate state for the future climate from large number of global climate models.

- Chemical Transport modeling involving a global GCM and embedded in it is regional model with chemistry.

- Ensemble hindcast (may be 40 members) of past 30 monsoon seasons made by the coupled model, and their verification and evaluation of the hindcast skill.

- Running of tropical cyclone coupled model and data assimilation.

- Simulation and prediction of intense rainfall events using a high resolution non-hydrostatic mesoscale model.

- Multicentury run of the coupled model to study the dynamics and predictability of monsoon multidecadal oscillation.

9.3.6 Observation Programmes for Studies of Interaction between Clouds and their Environment

There is considerable expertise at IITM in making observations of various atmospheric parameters. In particular, considerable work has been done on measurement of cloud microphysical properties, aerosols, cloud electricity, etc. using variety of techniques. However, simultaneous measurements of environmental parameters (e.g. winds, temperature, humidity profile, etc.) were not available. As a result interaction between those microphysical processes and the environment could not be studied. A new focused problem for study is the interaction between cloud and environment for formation of precipitation.

In order to understand the interaction between clouds and their environment as well as to estimate cloud contribution to the redistribution of energy and water in the climate system, simultaneous measurements of cloud microphysical parameters (e.g. drop size spectrum, liquid water content, phase of hydrometeors, etc.) are required together with measurements of environmental parameters (e.g. 3-d wind). So far such measurements are being taken in isolation. It is proposed to put together a system of Doppler precipitation cum weather radar on a mobile platform. Therefore, it would be a multiparameter system. It could be a continuation of a Ka band radar at 35.35 GHz and a W-band radar 95.13 GHz with Doppler and polarization capabilities. A Mobile Doppler Precipitation cum Weather Radar will serve the purpose. An expert committee has been constituted to work out the details of the configuration required for the purpose. It would be extremely helpful in developing 3-D cloud models and its interaction with the environment. Following activities will be taken up with the acquisition of the Mobile Doppler Precipitation cum Weather Radar.

- Make simultaneous measurements of cloud microphysical parameters and wind and precipitation rate for a complete monsoon season at Pune. Archive the data at high resolution.

- Study of formation, growth and evolution of clouds and its interaction with the environment.

- Collection of similar data on a number of sits under different weather conditions. For example a campaign may be carried out some where in Mumbai (heavy rains from shallow clouds) and in our Delhi Branch (for convective clouds in the absence of orography).

- Use of the facility during national field experiments like STORM and CTCZ.
- Use of this data base to develop and verify cloud resolving models (CRMs).

ii) Setting up a Lightning Location Network for Thunderstorm Dynamics and Prediction consisting of a central processor and several sensors which are spread over an area of several hundred square kilometers is proposed to be set up. Each sensor linked with the central processor through satellite detects the occurrence of a lightning flash within about 250 kms of its location. After detecting the occurrence of lightning, each sensor transmits this information to central processor which then processes the data to compute the position, polarity and number of strokes in each lightning flash and plots it on a given map. The network can detect intra-cloud, cloud-to-ground or total number of flashes in a given area. Therefore, the network will be useful to detect, locate and map the lightning activity occurring in a storm and follow its development in real time. In addition, this information can be transmitted to different users by the central processor. The end-products of a lightning flash occurring anywhere in the area are transmitted to the users within a few seconds. Initially it is proposed to setup a network of 10-15 different sensors and a central processor. The central processor can be located at the IITM, Pune and the sensors can be installed in different areas of activity. Since such a network will be very useful in the national projects such as Severe Thunderstorm – Regional Modeling and Observations (STORM), Continental Tropical Convergence Zone (CTCZ) etc. currently being undertaken by the Department of Science and Technology, it is proposed to set up this network in the northeast India along the Indo-Gangetic plains. Additional sensors can always be added and thus the area of investigation be expanded by adding more sensors to the network. Alternately, these sensors can be shifted to different areas. The system will be useful for the following activities:

- To study the spatial and temporal distribution of lightning through the life-history of a thunderstorm as the storm moves from one place to other.
- For the development of theoretical models for very short range forecasting (nowcasting) of the weather.
- To study the relationship of lightning activity with the development of microphysics and dynamics of the thunderstorm.
- In several areas of practical importance such as aviation, power generation, forest fires, recreation, defence and for the protection of the life and property on the ground.

iii) Simultaneous measurements of large scale environment are essential for measurements of cloud microphysics, cloud electricity and aerosols. This was not possible due to lack of availability of a dedicated GPS radiosonde. The GPS radiosonde would be useful for various national campaigns and also across the divisions. For the activities mentioned below:

- To take atmospheric soundings simultaneously with measurements of electrical parameters, cloud microphysical measurements, aerosol characteristics

measurements at Pune. Pune is not a IMD regular Radiosonde station. This will fulfill a long lasting need for simultaneous soundings required for many studies.

- To take the instrument in to the field campaign and take soundings along with other measurements.

- Such simultaneous measurements are going to be valuable in resolving many issues that could not be resolved in such field campaigns.

iv) Observational Network for Urban Air Pollution Modelling is proposed in order to develop and validate the urban air pollution model, continuous measurements from a mesonet of stations is proposed. Setting up of around 10 pollution monitoring stations within the model domain (initially within local grid of radius 50-100 km around Pune) for validation and baseline model input (NOx, CO, O_3, Hydrocarbons, Suspended Particulate matters, and SO_2) is proposed.

9.3.7 Training Programme

For the monsoon prediction programme of the country to be successful anytime in the future, a large pool of very well trained scientists are required who will be strong in modelling, conversant with coupled models and also have good knowledge of oceanic and atmospheric observations and tropical dynamics. IITM is well placed to train such a pool of scientists for the nation. For this purpose, an extensive and sustained training programme is required. A two pronged approach is proposed.

i) In-house Training

An in-house in depth structured training is proposed to be given to the Research Fellows and young scientists (Senior Scientific Assistants and Scientists B). This will expose the young scientists to the important and exciting problems and develop the necessary analytical skills to address them. A core course programme is already planned to be started from August 2006. This will primarily be taught by IITM scientists with a few specialized invited lectures from eminent scientists. A Training Laboratory equipped with multimedia and audiovisual tools for interactive training will be developed As this training requires demonstration with computer models, visualization and analysis of large volume of data, such a facility will be very helpful.

ii) Specialized Training

While the in-house training is essential, it would take time to create experts in different areas required to achieve the goal of focused programmes. For this, it is proposed to select a set of about 40 young scientists (B & above level) for specialized training in different areas required to achieve the goal of the focused programmes. They would be trained in international centres of excellence, if necessary, at the Institute's cost. Few internationally reputed scientists would also be invited at IITM to spend some time and train some scientists in specialized areas. Necessary expenses for inviting such scientists will be part of this programme.

9.3.8 Information system in Meteorology and Atmospheric Sciences

The Library, Information and Publication Division of the IITM serves as the comprehensive Information Resource System in the field of Meteorology and Atmospheric Sciences. Scientists, academicians and students from the field of meteorology and atmospheric sciences from all the corners of the country use the library of the Institute extensively. With the increasing research activities of the Institute, growth of research community in the field of meteorology and the impact of interdisciplinary studies demand has considerably been increased for the sophisticated and instant library & information services. To cope with this situation the existing library, information and publication activities in the Institute will be enhanced and modernized with latest equipment and advanced information technology for storage, retrieval and dissemination of information. Moreover, a programme for science popularization like summer training, experts' lectures, exposure to research activities etc. especially for students of high schools and junior colleges to attract them towards meteorology as their professional career is considered to be essential. Latest science communication equipment will be acquired and science popularization kits, models and exhibits will be prepared for such programmes.

New Scheme : Climate Dynamics and Extended Range Prediction of Monsoon						
Components	2007-08	2008-09	2009-10	2010-11	2011-12	Total (Rs in crores)
Dynamical Prediction System of Seasonal Mean Monsoon Rainfall	3.00	05.00	04.00	03.50	02.00	17.50
Extended- Range Prediction of Active and Break Spells of the Monsoon	1.50	01.00	02.50	02.50	03.00	10.50
Science of Climate Change and Monsoon	01.30	02.00	01.00	00.90	00.50	05.70
Urban Air pollution and Transport Modelling	02.00	02.00	00.50	00.50	00.50	05.50
High Performance Computer	40.00	05.00	05.00	05.00	05.00	60.00
Observation Programmes for Studies of Interaction between Clouds and their Environment including acquisition of • Doppler Radar • Lightning Network • Atmospheric Pollution Prediction System • GPS Radiosonde	48.00	01.00	01.70	01.00	01.10	52.80
Training Programme	09.00	0.4.00	04.00	04.00	04.00	25.00
Information System in Meteorology and Atmospheric Sciences	03.00	0.2.50	01.50	01.50	01.50	10.00
Total of B (New Scheme)	**107.80**	**22.50**	**20.20**	**18.90**	**17.60**	**187.00**

10. Manpower Development

For the continuation of the existing schemes under the X Five-Year plan and implementation of the new schemes in the XI Five-Year plan, it is very essential to ensure that the centre has the critical mass of scientific and technical manpower.

At present IMD has 4300 personnel posted in scientific and technical cadres out of which 278 are under Plan Schemes and the remaining 4022 under various Non Plan Schemes. These people are engaged in different scientific activities viz. meteorological reporting, data processing, analysis, forecasting, preparation of products for specialized services, environmental monitoring, R&D, QA/QC exercises, information handling, instrument calibration, inspection, maintenance of monitoring and communication equipment etc. Most of the activities pertain to work introduced in earlier schemes and continue as mainstay operations.

Qualifications for manpower recruitment are science graduation at the lower levels and post graduation in Physics, Mathematics and specializations such as Agronomy, Agrometeorology, Engineering graduation for Instrumentation and Hydrology etc at higher levels. Training programmes of IMD target three different levels. The first is of junior level operators who are made conversant with basics of atmospheric science and standard practices in information preprocessing for the purpose of predictions. They are made adept in handling computers and monitoring equipment. At the second level the training includes specialized subjects of meteorology and caters to the requirements of supervision of technical functions including quality control and maintenance. The advanced level includes forecasters, specialized service providers and instrumentation personnel. The subjects are taught to them in great depth and include all the frontier areas of the science. Further, there are several refresher courses for selected personnel for updating knowledge content in specific areas. Finally, with each major acquisition of a new generation of operational equipment personnel are trained in their handling and retrieval of scientific information.

In the new scenario sophisticated instrumentation will be introduced in a big way, data retrieval from satellites and Radars will become very significant and complex numerical modeling at global and regional levels will be used as principal methods. Thus, adequate manpower will have to be provided to handle these responsibilities. At present absence of recruitments over an extended period of time for various reasons has depleted the number of available manpower and has increased the average age thereby constraining capacity building. Thus new schemes in the XI th plan must be complemented with appropriate staff requirements and a strengthening of the training programmes. The additional manpower requirements have been worked out after consideration of redeployment of existing staff with rehabilitative training.

IMD will continue to provide and maintain training facilities for imparting the necessary professional skills to its personnel to enable them to meet the growing demands of work. Computer-aided Learning would be introduced in a big way. The Central Training Institute at Pune will be supported by specialized training centres at Pune, New Delhi and regional centres. Capsule courses offered on the network will give opportunities to individuals to improve their knowledge in various disciplines through self study.

In a supportive role the IMD presently has 2073 personnel who are engaged in administration, documentation, housekeeping and manual help. With a large number of

functional units at different locations the proportion of support staff to the scientific and technical ones is bound to be some what high. However, in the incremental projection for the XI Plan the number has been kept to a small figure of ~8% because the new schemes would generally be supported by existing establishments.

While the manpower requirement of IMD has been stipulated above, NCMRWF and IITM have requirements specific to their mandate and changing requirements in their respective fields viz. computational/ numerical modeling/ services and research in tropical meteorology/ climate dynamics/ monsoon prediction respectively.

The overall position of manpower is provided below:

	Scientific and Technical Posts		**Admin Posts and Support staff**		**TOTAL**	
	Current Manpower	XI plan Reqmt-Additional	Current Manpower	XI plan Reqmt-Additional	Current Manpower	XI plan Reqmt-Additional
IMD	4300	1243	2073	103	6373	1346
NCMRWF	34	219	10	25	44	244
IITM	163	56	84	--	247	56
Total	**4497**	**1518**	**2167**	**128**	**6664**	**1646**

11. Scheme wise Outlays For XI Five Year Plan (2007-2012)

1. CONTINUING SCHEME

A. IMD

Rs. In crores

S.No.	**Schemes -**	2007-08	2008-09	2009-10	2010-11	2011-12	Total
1.	Space Meteorology	30.84	33.24	32.50	12.00	18.00	126.58
2.	Meteorological Telecommunication	46.10	33.40	19.15	3.73	1.21	103.59
3.	Observational Organization	101.22	130.80	136.80	129.60	66.00	564.42
4.	Instrumentation Development	41.10	93.03	84.80	25.16	22.88	266.97
5.	Cyclone Warning & Research	42.40	147.66	205.62	243.88	476.40	1115.96
6.	Forecasting Services	65.00	25.00	5.00	5.00	5.00	105.00
7.	Aviation Services	92.80	115.80	172.20	255.80	301.00	937.60
8.	Hydro Met Services	10.36	16.88	9.89	1.81	1.55	40.49
9.	Agro Met Services	141.40	144.92	148.54	152.15	10.58	597.59
10.	Seismology	17.46	26.86	16.78	18.15	8.98	88.23
11.	Seismic Hazard & Risk Evaluation	55.62	57.30	53.10	61.14	71.22	298.38
12.	Environmental Studies	6.00	4.20	3.60	3.60	4.80	22.20
13.	Research	6.94	3.10	2.21	2.21	2.21	16.67
14.	Human Resource Development	8.04	9.84	8.04	6.24	5.04	37.20
15.	National / International Cooperation	0.40	0.40	0.40	0.40	0.40	2.00
16.	Infrastructural Development and maintenance	74.72	109.98	107.93	102.74	28.72	424.09
	Sub-Total I-A	**740.40**	**952.41**	**1006.56**	**1023.61**	**1023.99**	**4746.97**

B. NCMRWF

Rs. In crores

S.No.	Schemes -	2007-08	2008-09	2009-10	2010-11	2011-12	Total
1	Global Modeling and Data Assimilation System	1.38	2.02	2.81	2.91	2.69	11.81
2	Meso-scale Modeling and Data Assimilation System	0.50	0.82	1.10	1.26	1.26	4.94
3	Extended/Seasonal Prediction System	0.27	0.58	0.70	0.67	0.52	2.74
4	Computer/Network Infrastructure and Services	0.50	0.74	1.02	1.10	1.10	4.46
5.	**Agromet advisory**						
5.1	Agro-met Advisory System	1.08	1.23	1.76	1.77	1.62	7.46
5.2	District-level Agro-meteorological Advisory Service	0.54	0.82	0.98	0.98	0.68	4.00
5.3	Grant-in-Aid for AMFUs	12.70	12.70	12.70	12.70	12.70	63.50
	Sub-Total I-B	**16.97**	**18.91**	**21.07**	**21.39**	**20.57**	**98.91**

C. IITM

Continuing Schemes : Research in Tropical Meteorology							
1	Asian Monsoon Variability and Predictability	06.00	03.00	03.00	02.00	02.00	17.00
2	Application of Satellite Data in Weather Fore-casting and Large-Scale Hydrological Modelling	06.00	03.00	03.00	03.00	03.00	18.00
3	Short-Term Climate Diagnostics and Prediction	06.00	03.00	03.00	03.00	03.00	18.00
4	Cloud Modelling	05.00	04.00	04.00	04.00	04.00	21.00
5	Middle Atmosphere Dynamics	05.00	04.00	04.00	04.00	04.00	21.00
6	Aerosol and Climate Studies	05.00	04.00	03.00	03.00	03.00	18.00
	Sub-Total I-C	**33.00**	**21.00**	**20.00**	**19.00**	**20.00**	**113.00**

2. NEW SCHEMES PROPOSED DURING XI PLAN

A. IMD

S.No.	Schemes -	2007-08	2008-09	2009-10	2010-11	2011-12	Total
1	District Meteorological Information Centres	19.20	55.20	30.00	40.80	58.80	204.00
2	Early Warning System	2.95	21.66	23.19	23.16	13.04	84.00
3	Climate Research & Monitoring	2.64	12.78	1.68	1.86	1.92	20.88
	Sub Total 2-A	**24.79**	**89.64**	**54.87**	**65.82**	**73.76**	**308.88**

B. NCMRWF

1	Satellite Radiance Data Assimilation	0.27	0.58	0.74	0.67	0.75	3.01
2	Climate Modeling System	0.69	0.59	0.86	0.56	0.56	3.26
3	Environmental Prediction System	0.23	0.31	0.20	0.20	0.20	1.14
4	Computer/Network Infrastructure Upgradation	80.00	20.00	15.00	65.00	8.00	188.00
5	Infrastructure Development Other Facilities and capacity building	35.60	19.60	18.60	6.60	6.50	86.90
	Sub Total 2-B	**116.79**	**41.08**	**35.4**	**73.03**	**16.01**	**282.31**

C. IITM

New Scheme : Climate Dynamics and Extended Range Prediction of Monsoon							
1	Dynamical Prediction System of Seasonal Mean Monsoon Rainfall	3.00	05.00	04.00	03.50	02.00	17.50
2	Extended- Range Prediction of Active and Break Spells of the Monsoon	1.50	01.00	02.50	02.50	03.00	10.50
3	Science of Climate Change and Monsoon	01.30	02.00	01.00	00.90	00.50	05.70

4	Urban Air pollution and Transport Modelling	02.00	02.00	00.50	00.50	00.50	05.50
5	High Performance Computer	40.00	05.00	05.00	05.00	05.00	60.00
6	Observation Programmes for Studies of Interaction between Clouds and their Environment including acquisition of • Doppler Radar • Lightning Network • Atmospheric Pollution Prediction System • GPS Radiosonde	48.00	01.00	01.70	01.00	01.10	52.80
7	Training Programme	9.00	4.00	4.00	4.00	4.00	25.00
8	Information System in Meteorology and Atmospheric Sciences	3.00	2.50	1.50	1.50	1.50	10.00
	Sub-Total 2 -C	**107.80**	**22.50**	**20.20**	**18.90**	**17.60**	**187.00**

Yearwise Summary of Financial Requirement

Rs. In crores

	Scheme	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2011-12**	**Total**
Atmospheric Sciences-IMD	Continuing	740.40	952.41	1006.56	1023.61	1023.99	4746.97
	New	24.79	89.64	54.87	65.82	73.76	308.88
	Total (IMD)	**765.19**	**1042.05**	**1061.43**	**1089.43**	**1097.75**	**5055.85**
Atmospheric Sciences-NCMRWF	Continuing	16.97	18.91	21.07	21.39	20.57	98.91
	New	116.79	41.08	35.4	73.03	16.01	282.31
	Total (NCMRWF)	**133.76**	**59.99**	**56.47**	**94.42**	**36.58**	**381.22**
Atmospheric Sciences-IITM	Continuing	33.00	21.00	20.00	19.00	20.00	113.00
	New	107.80	22.50	20.20	18.90	17.60	187.00
	Total (IITM)	**140.80**	**43.50**	**40.20**	**37.90**	**37.60**	**300.00**
	Grand Total	**1039.75**	**1145.54**	**1158.1**	**1221.75**	**1171.93**	**5737.07**