Annual Report
2006-2007

Ministry of Earth Sciences

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ATMOSPHERIC SCIENCES

Introduction

Government of India, in its Cabinet meeting held on 9th May 2006, have approved formation of the Earth Commission and re-organisation of the Ministry of Ocean Development as Ministry of Earth Sciences. Earth Commission has been patterned on the lines of Atomic Energy Commission/ Space Commission for delegation of functions and authority.

The 21st century is likely to be dominated by concerns of water, global climate change, environment, land use and ocean resources. The need for taking up an integrated view of Earth System Sciences, *i.e.* land-ocean-atmosphere is being recognised across the world. The Indian efforts till recently, were being independently made by individual agencies like Ministry of Ocean Development (now Ministry of Earth Sciences), India Meteorological Department (IMD), research institutes like Indian Institute of Science, Indian Institutes of Technology (IITs), a few laboratories of Council for Scientific and Industrial Reasearch (CSIR), etc. There is need to integrate these activities.

The Ministry of Earth Sciences aims to create a framework for understanding the complex interactions among key elements of the Earth System, namely ocean, atmosphere and solid earth, by encompassing the existing national programmes in meteorology, climate, environment and seismology. The Earth System Organisation (ESO) will act as an executive mechanism under the Ministry of Earth Sciences, consisting of two major entities – (i) Ocean Science and Technology Department, and (ii) India Meteorological Department. In addition, the Earth System Organisation would have, at its Headquarters, the Ministry of Earth Sciences office and the Programme Offices for coordination among the constituent organisations and units engaged in similar work in other departments, academic institutions and research bodies. The Ocean Science and Technology Department consists of the existing Centres and Attached Offices of the erstwhile Ministry of Ocean Development. The Indian Institute of Tropical Meteorology (IITM) and National Centre for Medium Range Weather Forecasting (NCMRWF) would be active partners of the ESO.

The Ministry of Earth Sciences will provide the nation with best possible services in forecasting the monsoons and other weather/climate parameters, ocean state, earthquakes, tsunamis and other phenomena related to earth systems through well integrated programmes and utilising world class science and technology resources. In addition, the Ministry will work on science and technology for exploration and exploitation of ocean resources (living and non-living), and play nodal role for Antarctic/Arctic and Southern Ocean research. The Ministry would closely work with other agencies both public and private to provide them scientific and technical support and assist in ensuring adequate preparedness for handling natural disasters.

Ocean Science & Technology

National Centre for Antarctic & Ocean Research (NCAOR)

Silver Jubilee - Indian Scientific Expedition to Antarctica

The Vessel "M.V. Paardeberg" with 50 members (27 summer and 23 winter members) of the 25th (Silver Jubilee) Indian Scientific Expedition to Antarctica on board, was flagged off on 29th December 2005. The team comprised scientists from 18 Organisations/Academic Institutes, 13-member Logistic Team from Indian Army and 2 cooks from Indo-Tibetan Border Police (ITBP). With the joining of 2 Medical officers as winter members, the strength rose to 52.

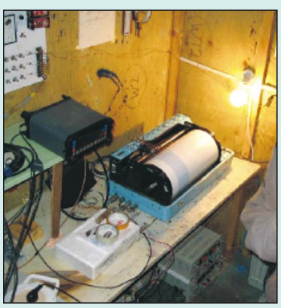
The 25th Indian Antarctic Expedition (IAE) members reached Antarctica on 9th January 2006 and the first helicopter sortie and summer period scientific and logistics activities commenced from 10th January 2006. The winter team of the 24th expedition along with the summer team of the 25th Expedition shifted to the vessel M.V. Paardeberg on 24th February 2006.

Achievements During Winter Period of 24th Indian Scientific Expedition to Antarctica

The Antarctic Programme during the 2005-06 winter-over period comprised various scientific research projects pertaining geomagnetic, limnological, glaciological, geological, meteorological and physiological studies. Magnetic data collected with Digital Fluxgate Magnetometer was helpful in understanding the relation between magnetic storms and sub-storms. Proton Precession

Magnetometer was used to monitor the declining trend of the total field value and long wire antenna was used to measure the weak current (Maxwell currents) in the atmosphere. At various climatic and magnetic conditions, the vertical electric field of the atmosphere was also measured.

The project of raising lake bottom sediment cores for multi - disciplinary investigations including palaeoclimatic, palaeontological, sedimentological, geochemical and palynological studies along with TL dating of the glaciolacustrine sediments met success with a record retrieval of 21 sediment cores from the different lakes of Schirmacher Oasis.



Maitri has a state-of-the-art Digital Broadband Seismological Observatory established as a part of Global Seismographic Network in Antarctica. Preliminary analysis has been done for the earthquakes recorded by the instruments at Maitri and data have been communicated to USGS Data centre.

Synoptic weather data were collected for global telecommunication system as a contribution to the international efforts for weather forecasting. Regular stratospheric ozonesonde ascents were undertaken to study the vertical distribution of ozone, ozone hole phenomenon and effect of depletion of ozone in global climatic changes. Measurement of atmospheric total ozone, ground reaching UVB, NO_2 and SO_2 was done with the help of Brewer Spectrophotometer.

For the first time a systematic and thorough study of the human sleep patterns, melatonin secretion and biorhythm changes was carried out at Maitri. Physiological research related to Human Circadian Rhythm that regulates the temporal organisation of the physiological functions and sleep pattern based on the Melatonin hormone were also carried out.

Scientific Achievements during the Summer Period of the Silver Jubilee Indian Antarctic Expedition

The following scientific observations were carried out during the 25th Indian Antarctic Expedition:

- GPR Study
- Ice Core Drilling
- Depth Profiling and Bathymetry
- GPS Study and Mapping

- Palaeoclimatic Study
- Geological Sampling
- Seismic and Electric study
- Geomagnetic Study
- Installation of RRTS System
- HF and VHF communication set-up
- Weather Observations
- Vertical Structure of Atmosphere
- Ionospheric Study
- Algal Sampling
- Soil/organic waste sampling
- Lichen study
- Penguin and Skua study
- Psychological Study

Scientific Progress of Winter Team of 25th IAE

The following Observations are in progress in Antarctica.

- Regular operation of Seismological observatory systems
- Regular operation of Permanent GPS Tracking Station
- The Magnetic observations
- Collection of the Global Electric Circuit (GEC) data
- Synoptic observations of meteorological parameters
- Radiation studies
- Ozone depletion study
- Measurement of Atmospheric turbidity
- Psychological assessment
- Snow and Avalanche Study Establishment
- Management of communication system

26th Indian Antarctic Expedition

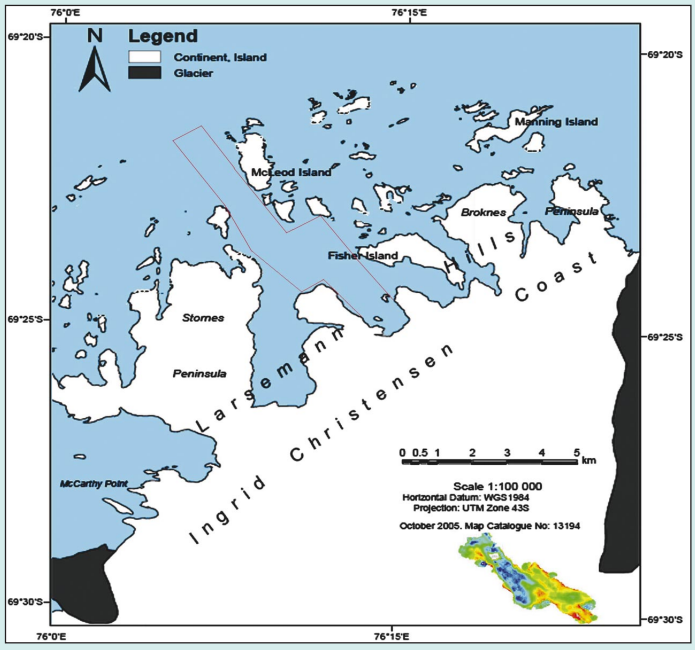
The XXVI Indian Antarctic expedition is planned in three phases: launching of Ist and IInd phases by the Air from Cape Town and IIIrd phase by Ship. The Ist phase and II phase were launched in November 2006 and the members have started working in Antarctica. The IIIrd and final phase of

the XXVI expedition was planned for launching at the end of December 2006 from Mormugao Harbour, Goa on board "Emerald Sea" to Larsemann Hills and Maitri *via* Mauritius. For the members of the 26th Indian Antarctic Expedition, snow and ice craft training was conducted at Auli during September 2006.

Ice Core Drilling

After arrival of the Ist phase, team member of 26th IAE, a survey was carried out and the drilling site was finalised. Drilling was initiated on 18th November 2006 and 74.98 m of Ice core was raised till reports came last. The survey for new drilling site is in progress.

Expedition to Larsemann Hills



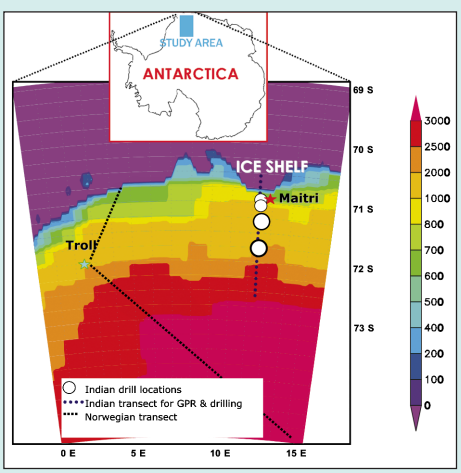
To coincide with the 25th year of Indian presence in Antarctica, a special expedition to the Southern Ocean and Larsemann Hills of East Antarctica was launched on board the Research Vessel Akademik Boris Petrov on 25th January 2006. The main objective of the expedition was to carry out Swath Bathymetric Surveys in the approach to the Larsemann Hills area where India has proposed its new station. Scientists from NCAOR, IMD, NHO, PRL, KBCAOS and Cochin and Goa Universities participated in the expedition to carry out various multi-disciplinary observations including biological, geological, physical, chemical, suspended particulates in oceans, aerosols, meteorology and atmospheric data and sampling.

Using vessel-mounted deep water multibeam system, bathymetry survey was carried out in an area of 55 km x 19 km in the Prydz Bay and 410 lines km data were collected.

Larsemann Hills Expedition Members

Ice Core Research

With the establishment of the India's first Ice Core Laboratory at NCAOR, ice core processing and analysis are systematically being carried out on the cores collected during the 15th and 22nd Indian Antarctic Expeditions. In order to conduct a long-term collaborative research programme on ice cores along a coastal to inland transect in Central Dronning Maud Land, East Antarctica, NCAOR has also entered into a MoU with Antarctica Division of Geological Survey of India.



Map showing the Ice Core locations along the proposed coastal to inland transect.

Ice core drilling near the Humboldt Glacier during 25th Indian Antarctic Expedition (IAE)

Drilling was carried out at 71° 20' 38" S and 11° 35' 38" E and successfully completed with output of 64.97 m ice core.

Ice Core drilling site and Ice Core

Volcanic Eruptions during the Past Five Centuries

The polar ice sheets provide one of the best possible archives of past volcanic events since they reliably record the stratospheric sulphate aerosols that have direct relevance to the climate. Systematic glacio-chemical analyses carried in a 62.2 m long ice core (IND-22/B4) recovered from the Central Dronning Maud Land, East Antarctica, revealed the dramatic occurrences of extreme natural events like volcanic eruptions during the past nearly five centuries.

Liquid Nitrogen Plant at NCAOR

International collaboration with ITASE (SCAR)

The sustained efforts by our scientists in the field and laboratory lead to the acceptance of India as an active member by international scientific bodies like International Trans-Antarctic Scientific Expedition (ITASE). ITASE has designated a scientist of NCAOR as the national representative of ITASE.

Physical Oceanographic Studies

During the special expedition to Larsemann Hills, various meteorological and physical oceanographic studies were carried out for a comprehensive understanding of the climatic variability of Southern Ocean on regional scale.

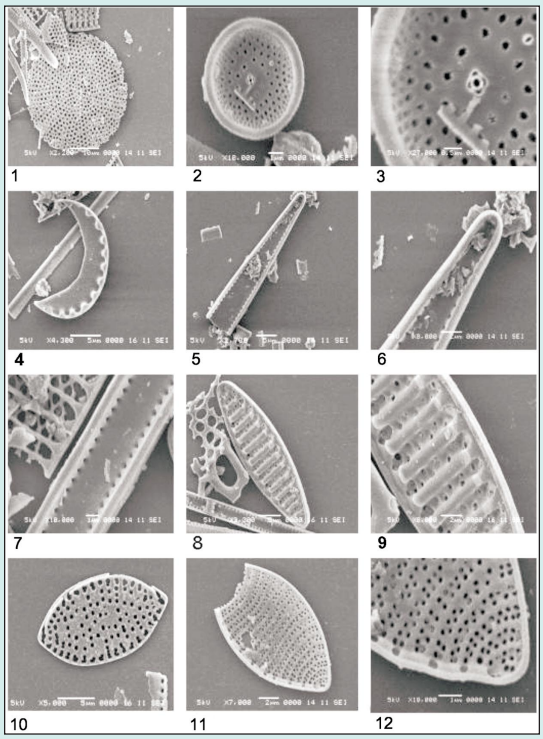
Temperature, Salinity and Oxygen Profiles in Prydz Bay Area

For the first time, a synoptic observation was carried out in the Antarctic waters (Prydz Bay area) at a regular interval of three hours for two days for a comprehensive understanding of the diurnal variations of the hydrographic parameters, circulation and rate of fresh water input into this region.

Diatoms in Surface Sediments of Southern Ocean

Studies have been carried out to identify the distribution patterns of fossil diatoms in surface sediments recovered from the Indian sector of Southern Ocean between 28ºS and 55ºS latitudes. The relative

abundance of seven relevant diatom species was studied to document the distribution patterns of diatoms with respect to various oceanic fronts prevalent in the Southern Ocean, its relation to the sea surface temperature, salinity, nutrients as well as the extent of the winter sea-ice and its utility in paleoceanographic reconstruction. In all, 24 diatom species were identified.



Diatom Plate-SEM Images: 1. Thalassiosira lentiginosa, 2. Thalassiosira gracilis, Internal valve view, 3. T.gracilis, enlarged view, 4. A part (girdle band) of the diatom Dactyliosolen antarcticus, 5. Thalassionema nitzschioides var. lanceolata, 6. T.nitzschioides-enlarged, 7. Thalassiothrix spp. (enlarged view), 8. Fragilariopsis kerguelensis, 9. F. kerguelensis enlarged view, 10. Fragilariopsis separanda, 11. Fragilariopsis rhombica. Internal valve view, 12. F. Rhombica enlarged showing two rows of poroides in between two transapical costae.

In Situ Chlorophyll Estimation and Determination of Algae

The Southern Ocean is known to be one of the High Nutrient Low Chlorophyll (HNLC) areas in the world oceans. Considering the paucity of real time data from the Indian ocean sector, study of the variation in chlorophyll concentration in these waters of the Indian sector was taken up. A Fluoroprobe was used for the chlorophyll estimation as well as determination of different algal

class and operated upto a water depth of 100 m during the Expedition to Larsemann Hills, Antarctica and Southern Ocean.

Environment and Ecology

Assessment of terrestrial and lake biodiversity in area of Larsemann Hills was conducted. The planktons diversity and distribution along the water column and the latitudes in Antarctic Sea were recorded. Lichens samples were collected from soils and rocks.

Microbes from an ice core

Microbes studies have been carried out in the ice core collected during the 22nd Indian Antarctic Expedition. Fifteen non-sea-salt-sulphate anomalies encountered were attributed to major volcanic events in Antarctica and elsewhere and examined the remnants (particles) of these eruptions buried in the ice core.

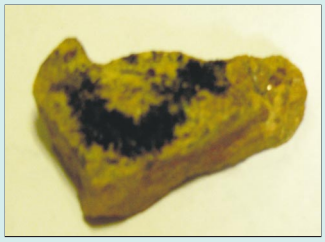
1. Lichen sampling.

2. Ice sampling.

3. Lake Sediment Coring.

4. Lake.

5. Sea Weed.



6. Lichen on rock.

7. Moss on soil.

8. Penguin rookery.

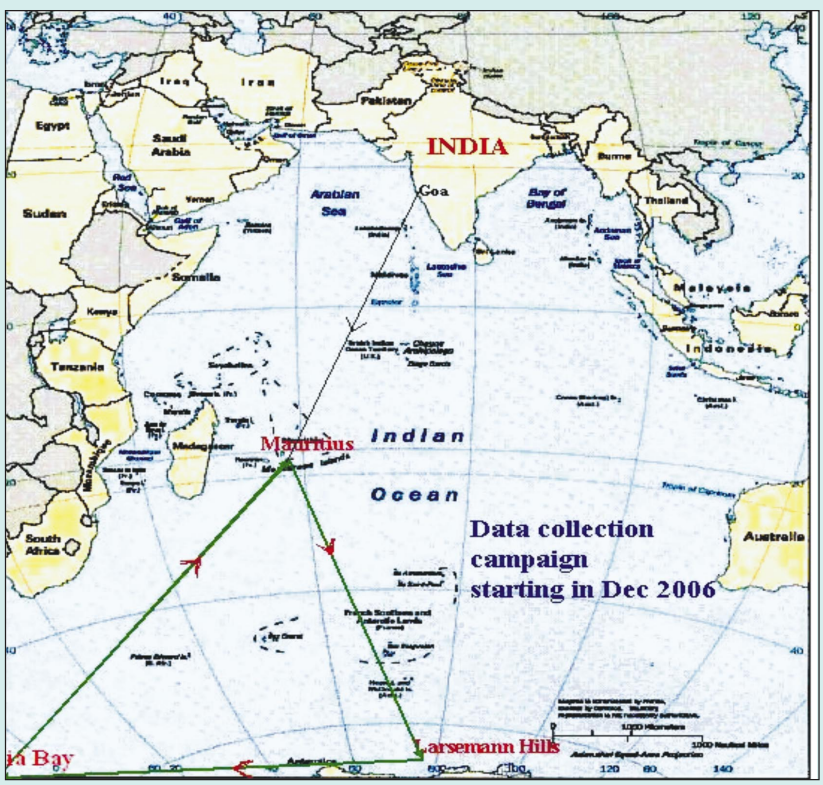
Polar Remote Sensing

Delineation of Sea Ice Margin using QuikScat Backscatter observations

Attempt has been made to analyse the backscatter observations from QuikScat to delineate the sea ice in the background of open sea.

Ocean- Atmosphere Interaction Studies in the Indian Sector of the Southern Ocean

The seasonal variability of heat fluxes with spatial resolution 0.5°×0.5° over the Indian sector of the Southern Ocean is being studied by using a combination of scatterometer measured winds and numerical weather forecasts (NWF) during 1999-2004.



Ship track of M.V. Emerald Sea during the 26th Indian Scientific Expedition to Antarctica during December 2006 to April 2007.

Oceanographic Survey and Service

ORV Sagar Kanya

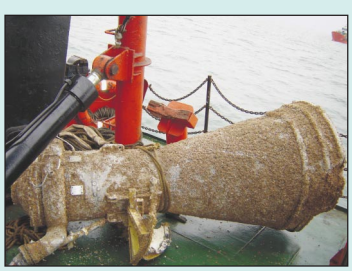
During the year 2006, the vessel has undertaken so far 20 cruises and has logged 239 days at sea. The newly installed Dynamic Positioning (DP) System and LARS (Launcher and Retrieval System for ROVs) are being utilised for the ongoing cruises. Vessel's capability was also improved by means of speed after the replacement of Generators and Power Management System on board and other repairs. NIO, ISRO and NIOT have utilised the vessel for programmes of Ministry of Earth Sciences and Department of Science and Technology.

New Facilities acquired

State-of-the-art Multibeam System, Dynamic Positioning System / HiPaP (High Precision Acoustic Positioning System) / Replacement of Bow Thruster / New Azimuth Thruster / DGPS / Gyros / Wind speed sensors, Deck Crane.

Location, Search & Recovery of GSLV Subsystems

NCAOR actively participated in the operation for the possible recovery of GSLV subsystems. About 77 sq km area were surveyed and diving operations were carried out for the possible targets. Various equipment such as Multibeam System, Side Scan Sonar, ROV were operated for the survey from different platforms. ORV Sagar Kanya, RV Akademik Boris Petrov, CRV Sagar Paschimi, CRV Sagar Purvi were the platforms used for the survey and recovery of the subsystems. The operations were jointly conducted with NIOT.



3. Polymetallic Nodules (PMN) Programme

The Polymetallic Nodules programme is oriented towards exploration and eventual exploitation of the nodules from the mine site allocated to India. India is the first country to have received the status of Pioneer Investor in 1987 and was allocated an area of 1,50,000 sq km in Central Indian Ocean Basin (CIOB) by UN. India is pursuing Polymetallic Nodules Programme for development of area retained by *India* with 75,000 sq km in Central Indian Ocean Basin (CIOB). The various components of the programme viz. Survey & Exploration Environmental Impact Assessment, Technology Development (Mining), Technology Development (Metallurgy), Unmanned submersible, are aimed at fulfilling this long-term objectives. The year has been eventful with successful demonstration of crawler, in-situ soil property measurement system and remotely operated submersible in deep sea.

3.1 Survey & Exploration

Retained Area comprising of consistently high grade and abundance for the possible location of the 1st generation mine site and approximately, 70% of the delineated area has been mapped using a multibeam system further, backscatter data has also been obtained for the area surveyed. Nodules from all the stations covered were analysed for the five critical elements viz. Ni, Co, Cu, Mn and Fe. Work is continuing for identification of the mine site.

3.2 Environmental Impact Assessment (EIA) Study

Mining of the deep-sea minerals is expected to alter the environmental conditions in the marine ecosystem. Environmental studies for mining of deep-sea polymetallic nodules were undertaken to evaluate the possible impacts of mining on deep-sea environment and develop protocols for environmental studies, to fulfill one of the obligations of the country as a Pioneer Investor under the UN Law of the Sea.

3.3 Technology for Deep Sea Mining

Considering that the technology to mine nodules at depths greater than 5000 m is highly challenging, this work has been taken up in phases. The first phase of development was through collaboration with University of Siegen in Germany, to validate the concept of flexible riser for slurry transport at a water depth of 400 to 500 m. As part of this programme, an underwater crawler was developed with a manipulator, cutter, slurry pump, instrumentation and control system. The crawler-based system was tested initially in the year 2001. In the second phase, in the year 2006 the system was tested successfully at a depth of 451m (where ambient pressure is 45 bar) along with the slurry pumping operation.

In-Situ Soil Property Measurement System

As part of the Manganese Nodule mining programme, the next phase is to design a crawler for 6000 m operation. The major challenges at 6000 m are high pressure of 600 bar, extremely soft sea bed and the varied topography of the ocean floor. In order to design a crawler capable of locomotion in the soft sea bed, it is essential that the sea bed property is measured in-situ which will provide undisturbed ground truth measurement. An instrument has been developed jointly with Sevmorgeo, Russia to measure the soil property in-situ, at a depth of 6000 m, and tested successfully at a water depth of 5200 meters.

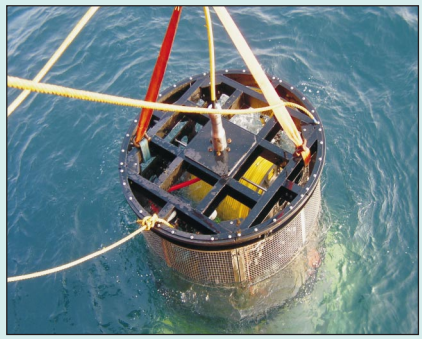
3.4 Extractive Metallurgy

Several campaigns have been carried out successfully at the demonstration pilot plant with a capacity to process 500 kg nodules per day for refining the process routes towards extraction of copper, nickel and cobalt at Hindustan Zinc Limited, Udaipur. In another significant development, a pilot plant was set up at National Metallurgical Laboratory (NML), Jamshedpur for producing ferro-silico manganese ores from residue generated from the pilot plant at Hindustal Zinc Limited.

3.5 Remotely Operable Vehicle (ROV)

In order to assist the mining system during its operation and also for other deep sea-related work, the Ministry also has taken up a project for development of a ROV jointly with Experimental Design Bureau of Oceanological Engineering (EDBOE), of the Russian Academy of Sciences, Russia. The scope of this project is to develop a work class ROV for operation at a depth of 6000 m. The system comprises of a ROV and Tether Management System (TMS) which is launched using a dedicated Launching and Recovery System (LARS). This is the first prototype developed and tested successfully for its functionality at a depth of 205 m off Mangalore during October 2006.

Launching of ROV & TMS



Deployment of ROV & TMS

4. Ocean Observation & Information Services (OOIS)

4.1 Indian National Centre for Ocean Information Services (INCOIS)

The INCOIS, an autonomous body set up under the Ministry of Earth Sciences in February 1999, started as a provider of operational data and services and swiftly transformed into a knowledge and information technology enterprise for the oceanic realm. The mission of INCOIS is to provide ocean information and advisory services to society, industry, government agencies and scientific community through sustained ocean observations, information management, modelling and constant improvements through systematic and focused research

4.2 Ocean Information Advisory Services

Potential Fishing Zone Advisory Service

The Ministry of Earth Sciences has formulated a programme to provide the fishing community with credible advisories on Potential Fishing Zones (PFZ). The concerted efforts of scientists from Earth Sciences, space and fishery science in collaboration with the coastal states have resulted in a timely and reliable service of Potential Fishing Zone (PFZ) advisories. This mission became part of the Common Minimum Programme (CMP) of the Government of India.

PFZ advisories are generated using both the Sea Surface Temperature (SST) and Chlorophyll based on the features such as oceanic fronts, meandering patterns, eddies, rings, up-welling areas that are proven to be prospective sites for fish accumulation. The integrated PFZ advisories prepared in local languages and local measurement units are disseminated thrice a week during non-ban and cloud free days, through innovative and novel initiatives such as Electronic Display Boards and Information Kiosks at the fishing harbors, radio, print media, emails and web sites supplementing fax and telephone. Frequent and intense interactions at the fishing harbors between scientists and fishing community ensure improved awareness and effective use of these advisories.

The significant achievements during the period under report are as follows:

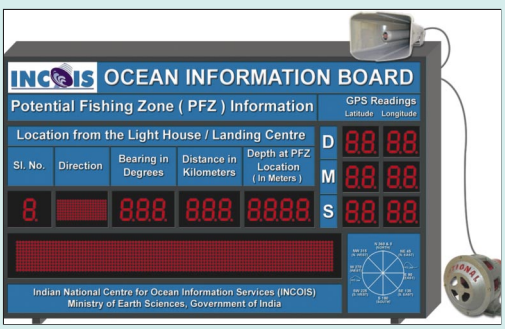
- 57 PFZ advisories were generated (till 30 December 2006) for entire coastal states of India including island territories and disseminated through about 3300 faxes/phones to the fishery community of the PFZ sectors of all coastal state including islands.

- PFZ data sets as well as no-data-messages were also transmitted through the Digital Display Boards at Veraval, Panjim, Vypeen, Veerampattinam, Thengaithittu, Nagapattinam, Thangachimadam and Visakhapatnam.

- SST and chlorophyll images, vector coverage's and text information pertaining to these advisories were simultaneously published on INCOIS web site.

- Text messages and map information also sent to the users through E-mails.

- A Prototype Electronic Display Board equipped with GSM Communication and capability of multi-lingual text messages display, voice messages and siren for disaster alerts was developed and successfully demonstrated.



- An Electronic Display Board was inaugurated at Srayikkad, Alappad Panchayat, Kerala on 20 December 2006 by Hon'ble President Dr. A.P.J. Abdul Kalam during his visit to the Amritapuri Ashram.

- Latest version of SeaDAS Software was installed on Linux platform for processing of MODIS Aqua data.

- A User Interaction Meeting on 'Potential Fishing Zone Advisory Services' was organised at the Fishing Harbour in Visakhapatnam on September 29, 2006 by INCOIS and Centre for Studies on Bay of Bengal, Andhra University.

PFZ User Interaction Meeting at Visakhapatnam.

- A workshop on 'Present Status and Improvements in the PFZ Mission' was organised on 18 August 2006. Scientists from Central Institute of Fishery Technology (CIFT), Central Institute of Fishery Education (CIFE), Mumbai, FSI, Gujarat State Fishery Department, Space Applications Centre, Ahmedabad, National Remote Sensing Agency (NRSA), Hyderabad etc. have participated in this workshop.

- A training programme on 'PFZ Methodologies' was organised for the officials from the Ministry of Fisheries, Agriculture and Marine Resources of the Government of Maldives during 3-13 October 2006 at INCOIS.

- INCOIS had undertaken PFZ Validation projects in Ratnagiri, Goa, Mangalore, Kerala, Machilipatnam and Gopalpur to validate the advisories and to assess the potential benefits to the fishermen.

4.3 Ocean State Forecast (OSF)

Reliable forecast of the ocean state is vital to the shipping sector, Fishery sector, Navy, Offshore industry, Port & harbors for the safe travel and operation in the sea. OSF developed out of a joint initiative taken by INCOIS and the Space Applications Centre (SAC). The Indian Institute of Technology (IIT-D), National Institute of Oceanography (NIO), Goa, National Institute of Ocean Technology (NIOT), Chennai and Integrated Coastal Marine Area Management (ICMAM), Chennai contributed to this endeavour.

INCOIS has been operationally providing forecast of wave, swell and wind parameters for tropical Indian Ocean for five days at six hourly intervals at 150 kms spatial resolution. Forecast of tidal currents is also being provided to Gujarat and Maharashtra coast (Ratnagiri to Porbandar) for five days at three hourly intervals (7 km × 7 km grid resolution).

Significant progress made during this year is as follows:

- More than 60 registered users from Navy, Coast Guard, Oil Industries, Offshore industry, academia and fishery availed the OSF products.

- OSF products were validated with the in-situ and satellite data. The results indicated that the forecast is reliable for two days.

- Commenced dissemination of coastal wave forecast on pilot basis through All India Radio and Pondicherry FM station for three districts Cuddalore, Pondicherry and Karaikal in

collaboration with Pondicherry Multi Purpose Social Service Society (PMSSS). The broadcast is given thrice a day in local units for different locations from the coast.

- The OSF information on wave height & direction, wind speed & direction is disseminated in local languages and units through public addressing system thrice a day at 20 Village Information Centres in Pondicherry.

- A user Interaction meeting on 'Ocean State Forecast and Ocean Observation Systems' was conducted with officers from different institutes of Indian Navy on 14 July 2006 at INCOIS. Nine officers from different institutes of Indian Navy attended the training programme.

- A user interaction workshop was conducted for the officers of Indian Coast Guard, East Coast regional Centers on 24 July 2006 at INCOIS. Participants were given hands on experience on retrieval and use of Ocean State Forecast data for the operational use of Indian Coast Guards. All regional offices of Coast Guard were registered to get the OSF Information.

- A training programme was conducted at INCOIS on 'Ocean Weather Forecast and Fishery Forecast' to 30 members of Pondicherry Multipurpose Social Service Society (PSMSS), a prominent at Pondicherry-based NGO during 26-27 October 2006. Lectures and practical sessions on Ocean State and Fisheries forecast were conducted.

- Recently, the Ministry of Earth Science (MoES) identified INCOIS as the nodal agency for the forecasting of Oil Spill Trajectory. The GENOME model developed by NOAA, USA was customised by ICMAM for the Indian coast and interfaced with a GIS data base of selected sensitive areas was setup at INCOIS. The model predicts oil spill trajectory, amount of oil beached and the sensitivity of the area affected based on the information of quantity and location of the oil spill received from Coast Guard Surveillance.

4.4 Ocean Information Bank and Web-based Services

Ocean Information Bank

Ocean Information Bank is the one stop shop for providing information on physical, chemical, biological and geological parameters of ocean and coasts on spatial and temporal domains that is

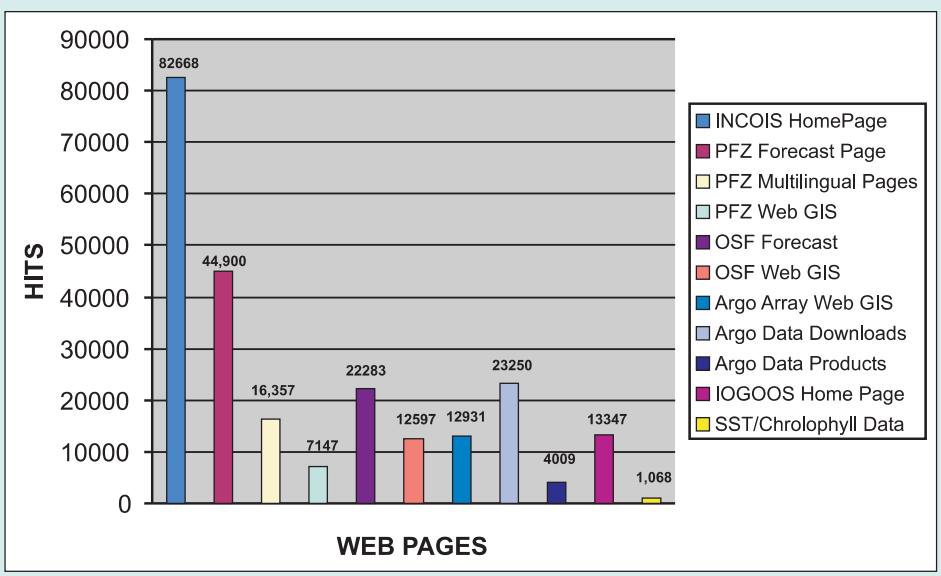
vital for both research and operational oceanography. The Ocean Information Bank is supported by the data retrieved from both the in-situ platforms and satellites as well as by a chain of Marine Data Centres. The Ocean Information Bank was updated regularly.

Apart from serving as a national repository of marine data, the INCOIS as the National Oceanographic Data Centre from India, also acts as national contact point for the International Oceanographic Data and Information Exchange (IODE), and Global Ocean Observing System (GOOS)-programmes of Intergovernmental Oceanographic Commission (IOC).

Web-based Services

INCOIS Website (www.incois.gov.in) matured as a prime vehicle for delivery of ocean data, information and ocean information and advisory services especially in the areas of (i) Potential Fishing Zone Mission, (ii) Indian Ocean Argo Project, (iii) Experimental Ocean State Forecast, (iv) IOGOOS besides facilitating users with Information Bank, various projects and programmes, Ocean Tutor, etc. The web-based multi-lingual on-line information delivery system with Web-GIS capability enables the users to query, analyse, visualise and download ocean data, information and advisories for their regions of interest. This has been widely used website among wide spectrum of users.

Statistics of INCOIS website usage during the period January November, 2006.



4.5 Indian Argo Project

Argo, an international programme designed to observe periodic profiles of temperature and salinity for better understanding of the structure of Upper Ocean and for enhancing climate predictability. International Argo Project endorsed by World Meteorological Organization (WMO) and International Oceanographic Commission (IOC) of UNESCO aims to deploy 3000 floats in the global ocean by the year 2006 to establish a global array at a spatial resolution of 300 km x 300km.

The Indian Argo Project envisages deployment of 150 Argo floats in the Tropical Indian Ocean, setting up and operation of Argo Data Reception and Processing System at National level, setting up a Regional Argo Data Centre, regional coordination for deployment in the Indian Ocean, development of Ocean Data Assimilation System, analysis and utilization of Argo data and capacity building at National level. INCOIS has a lead role in the project as (i) National Argo Data Centre (ii) the Regional Argo Data Centre for the region and (ii) the Regional Coordinator for implementation of Argo programme in the Indian Ocean.

Some of the studies carried out at INCOIS using Argo float data during the year are as follows:

- Eleven Argo floats including 2 Argo floats with Oxygen sensors were deployed in the Indian Ocean since April 2006.

- India deployed 122 Argo floats so far, in Indian Ocean out of which 78 are active. INCOIS as the National Argo Data Centre receives the data from Argo floats deployed by India real time and publish the data and data products after the quality control.

International Argo Project: International planning for Argo programme is coordinated by the International Argo Steering Team (IAST). Director, INCOIS is the Member of IAST and also the Regional Coordinator for the International Argo Programme in Indian Ocean.

4.6 Indian Ocean Modelling and Dynamics (INDOMOD) Project

INCOIS continued Ocean Modelling activities contributing to weather, monsoon, climate forecast by forcing functions for atmospheric models, to study the variability of ocean and marine environment and simulation experiments to optimize the observation system.

The project envisages focused research in the following 5 modules with active participation of several institutions, with a mission to enhance the basic understanding and knowledge base on

oceanic and atmospheric processes and catastrophic weather events and improve operation prediction by the respective agencies.

- Module-1: Ocean and Climate (IISc, IITM, NIO, C-MMACS)
- Module-2: Coastal Ocean (IIT-D)
- Module-3: Hazardous Events (IIT-D, NRSA)
- Module-4: Ocean Data Assimilation (IISc, C-MMACS, NCMRWF, IITM)
- Module-5: Validation with Observations (NIO)

A national team with a network of institutions viz. CAOS/IISc, CAS/IIT-D, Centre for Mathematical Modelling and Computer Simulation (C-MMACS), Indian Institute of Tropical Meteorology (IITM), IMD, NIO, NCMRWF, Naval Physical Oceanographic Laboratory (NPOL), NRSA, SAC and SOI played a key role in realising this mission.

4.7 Satellite Coastal and Oceanographic Research (SATCORE) Project

INCOIS, jointly with the Department of Space played a catalytic and facilitating role in building national capability for application of satellite remote sensing for oceans and coasts. SATCORE Project envisages development of various algorithms and models for retrieval of met-ocean parameters (e.g. sea surface temperature, winds, wave parameters, bathymetry, suspended matter, mixed layer depth, chlorophyll, aerosol, water vapour, clouds, currents and sea level) from the data from Indian and foreign satellite sensors including Oceansat-1 (IRS P4).

5. Marine Research & Technology Development

5.1 Centre for Marine Living Resources and Ecology (CMLRE)

Assessment of Marine Living Resources (MLRP)

This programme is designed to monitor the environment and productivity patterns, transfer of energy at each trophic level, and to explain the trophic structure including the role of marine benthos in the process of mineralization, the influence of deep scattering realm, algal blooms and migratory group like tunas and cetaceans in the energy budget of the ecosystem. The ultimate objective is to evolve management strategies for exploited resources through an ecosystem approach.

Fishery Oceanographic Research Vessel (FORV) Sagar Sampada

FORV Sagar Sampada was exclusively used to meet the requirements of the Marine Living Resources Programmes. The vessel undertook 14 cruises including 2 short calibration cruise, covering the Bay of Bengal (BOB), Arabian Sea and Andaman waters, sailing a total distance of 28,809 nm in 281 days of streaming and collecting data from 296 stations.

Scientific facilities on-board FORV Sagar Sampada were upgraded through the installation of a new deep-sea echo sounder and an integrated fish finding system.

To promote mass awareness of ocean related activities, exhibitions on-board the vessel, were arranged during the port-stay of the vessel at Vishakhapatnam, Kochi and Port Blair.

Students of Andhra University on a study visit onboard Sagar Sampada at Vizag.

Deep Sea and Distant Water Fishery

Trawl surveys were conducted in the depth range 200 - 1000 m of the shelf break and continental slope area at 41 stations covering the east and southwest coast of India.

Deep-sea fishes: Along the south west coast, a total of 77 species of deep-sea fishes belonging to 51 families were recorded.

Major Shrimp catches: At all stations off the west coast, Aristeus alcocki dominated the catch (85%) followed by other species like Heterocarpus woodmasoni, H. gibbosa, etc.

Deep-sea shrimp Oplophorus sp.

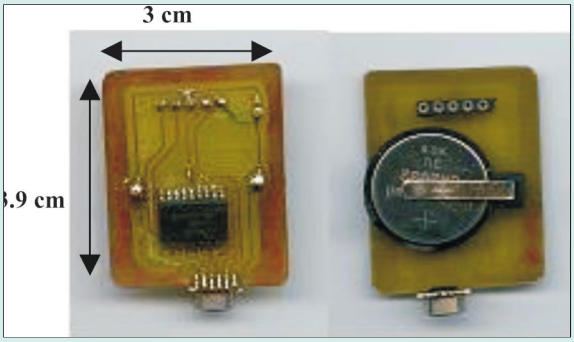
Deep-sea lobsters: The Indian Ocean lobster Nephropsis stewartii was recorded from 250 m depth off Mangalore. The total length range from 95 - 132 mm. Private trawlers based at Mangalore have already started exploiting these resources.

New fishing ground identified: A new fishing ground was located for deep-sea resources off the east coast along latitude 11°02'N, longitude 80°18'E at 637 m depths. A catch rate of 636 kg/hr was recorded.

Population parameters: For the first time, information on the population parameters of deep-sea fishes in the shelf break areas of Indian EEZ has been worked out.

Tuna resources: Exploited tuna fishery at Kochi in Kerala coast and Minicoy and Agatti in Lakshadweep islands were monitored for different craft-gear combinations. Methods for dissecting otoliths were standardised for Katsuwonus pelamis and Thunnus albacares. Protocol for isolation of DNA from tuna species was standardised and extraction of DNA was completed from K. pelamis and T. albacares. Cytochrome-b genes of mtDNA for both species were amplified with universal primers. Printing of the bibliography of tunas is in progress.

Tuna Tags: Towards the development of indigenous electronic tags for tracking tuna species, two tags with micro controller 16F88 containing special features such as low power consumption, built-in oscillator, low pin count, more programme memory, etc. have been developed. These tags were fitted with light and pressure sensors and were experimentally tested for its performance in air.

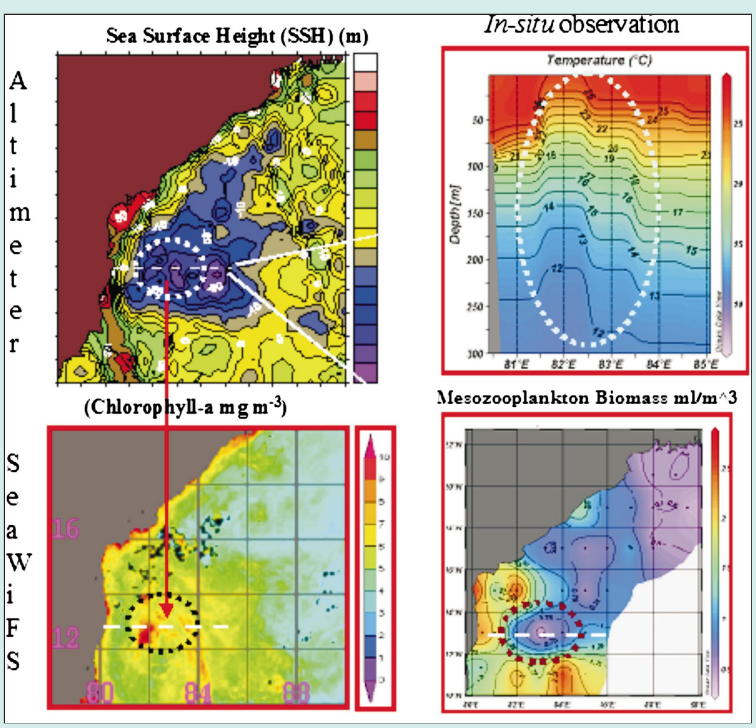


Prototype of pressure tag

Environment and Productivity Patterns in the Indian EEZ

Winter monsoon coverage of the BOB and spring inter monsoon coverage of the Andaman Sea were carried out. In the BOB, *in-situ* observations revealed the existence of a cold gyre in the central BOB, which coincided well with observations from altimeter and colour scanner from satellites.

Studies on the summer monsoon upwelling patterns off the southwest coast has shown that the process is highly localised and under the influence of different forcing mechanisms like wind stress, bottom topography etc.

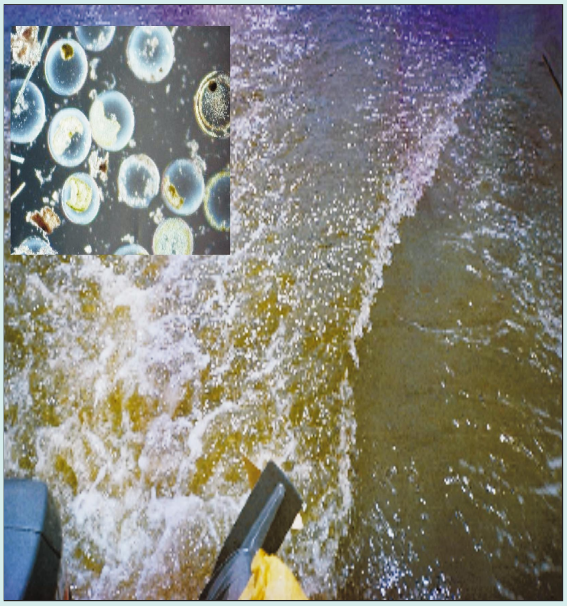


Existence of cold gyre in the Bay of Bengal during winter monsoon.

Monitoring and Surveillance of Harmful Algal Blooms

Several species of microscopic algae in the oceans can form blooms, some of which are harmful. Toxins released by them can accumulate in the tissue of finfish and shell fish and can find their way to humans to cause illness such as Paralytic Shell-fish Poisoning (PSP).

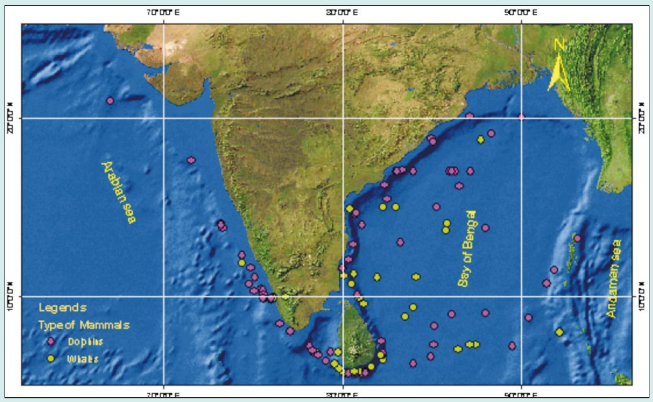
During the year, occurrences of algal blooms in the Indian EEZ, were monitored through FORV Sagar sampada cruises and locally along the Kerala and Tamil Nadu coasts, through hired boats. During the month of August, an intense bloom of the diatom, Coscinodiscus sp. was observed in the coastal waters north of Kochi (10° 11' N) and extending upto Mahe estuary (11° 51'N). Fish kill was observed at Mahe estuary possibly by the anoxic conditions due to the decaying bloom species. Along the Tamil Nadu coast, bloom of Skeletonema costatum were observed during April and May 2006 in the Coleroon estuary and a bloom of Odentella sinensis was recorded in the Vellar estuary in September 2006.



Bloom of Coscinodiscus sp. in the Mahe estuary .
Inset shows magnified view of Coscinodiscus sp.

Marine Biodiversity

Marine Mammals: Distribution of whales and dolphins in the Indian EEZ based mainly on sightings from FORV Sagar Sampada were recorded with a view to understand their diversity and migratory pattern during different seasons.



FORV-based sighting of mammals in Indian EEZ during 2006.

Molecular identification using mitochondria DNA cytochrome genes has been attempted to confirm the identity of the recorded species.

Plankton diversity: Biodiversity of phyto- and zooplankton around Andaman & Nicobar islands has been studied during the months of March - April 2006 and August - September 2006 covering 16 coastal stations and 16 off shore stations.

Benthic diversity: During the year, studies were carried out at 30 stations along 5 transects each in the continental slope of Bay of Bengal region and the Arabian sea. Seventy-eight species of nematodes including few new species have been identified.

Deep-sea Isopod Bathynomus giganteus: First record from Arabian sea.

Deep-sea glass sponge Monorhaphis chuni: First record from Indian EEZ

Farming and Pearl Production in the Blacklip Pearl Oyster Pinctada margaritifera in Andaman and Nicobar Islands

Black lip pearl oyster Pinctada margaritifera that produces superior quality pearls known as the "Queen of Pearls" is available in the Andaman & Nicobar Islands.

During this year more than 500 oysters were collected for broodstock development, nucleus implantation and studies on growth and fouling. Surgical implantation trials were carried out in more than 100 oysters. Presently 33 implanted oysters are in stock. Mabe pearl technology has been standardised in Pinctada margaritifera and Pteria penguin including the narcotisation and adhesion methodologies. New designs of images were made locally and a design for converting mabe-on-shell to a decorative table souvenir was finalised in consultation with local shell-craftsmen.

Mabe images produced in P. margaritifera.

FORV-Data Center

Aiming at advancements in research on marine living resources and environmental ecology, and in line with the specific tasks entrusted upon it by the Ministry, the CMLRE has set up a centralised FORV Data and Referral Centre in Kochi.

FORV - Referral Centre

Complementing the utility of data archived at the data centre, the objective of the Referral Center is to preserve and maintain representative sub samples of the marine living resources including plankton, fishery and benthic samples collected during FORV cruises for future studies and references by researchers and academicians. The Referral Centre thus aims at promoting research and development in marine living resources and ecology for several years ahead, making use of the adequately preserved specimens and samples.

Phytoplankton, zooplankton, benthic organisms and deep-sea fish samples collected during FORV cruises 165-243 sorted to genus level are preserved at the Centre in separate vials. Sub samples of organisms from the Deep Scattering Layers (DSL), collected through the above cruises, have also been preserved and maintained. The Referral Centre further also maintain echograms on acoustic back scattering recorded during cruises 165-200, beyond which acoustic recordings through the EK60 echo sounder are available in digital format. CMLRE took the initiative for preparing the first digitised inventory on marine bio-resources on the Indian EEZ. The inventory covers 4000 species recorded from Indian waters.

5.2 Ocean and Atmospheric Science and Technology Cell (OASTC)

The Ocean Policy statement enunciated by the Government of India during 1982 lays emphasis on training of skilled manpower in the ocean sector for creating self-reliant technological base and encouraging participation of scientists/technologists and engineers in the programmes of ocean development. The Ocean Policy further provides for appropriately strengthening the existing agencies to meet the demands of this growing challenge. The Ministry of Earth Sciences functions in conjunction with other concerned agencies through the medium of Ocean and Atmospheric Science & Technology Cells (OASTCs), as a focal point to promote institutional capabilities. In line with these provisions and understanding the implicit need for capacity building and creation of effective human resource base, the Ministry of Earth Sciences is promoting basic and applied research in the area of ocean science and technology, in academic institutions, national research institutes/ organisations, right from its inception in 1981.

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.

The research projects so far funded under this programme have provided useful results on the history of the sedimentation process; tectonic events before Miocene period including Himalayan drift; physical, chemical and biological oceanography of our seas; provided clues for development of potential drugs and chemicals from the marine organisms; etc.

Presently, 41 research and development projects are being supported in the interdisciplinary field of Marine Science & Technology. This includes 3 projects exclusively under Marine Manpower Development Programme and 38 projects being supported under the Ocean Science and Technology

Cells. Over 40 fellowships were awarded to the Universities and academic institutions, out of which 4 fellowships were given to women researchers.

One of the OSTCs at Annamalai University, Parangipettai was upgraded to a Centre of Excellence (CoE) in Marine Biology during 2005 and the other one at Goa University as the Centre of Excellence in Marine Microbiology during December 2006.

Based on the need of fine-tuning the programme and to give a major fillip to the science programmes in the field of Ocean Sciences, a new Policy was finalised and approved by the Ministry in April 2006. The New Policy on OSTCs & CoE has been framed, expands the role of OSTCs to take up and coordinate the Ocean and Atmospheric Science and Technology (OAST) activity in the region. The New Policy empowers the Research Coordinators of the OASTCs/ CoEs to play a lead role in the management and implementation of the Ministry's programmes by providing them physical, administrative and financial autonomy. The Centres of Excellence would play much deeper role into the designated activity providing world class research opportunities and capabilities.

Ornamental Fish Breeding and Rearing Facility has been established at Annamalai University, Parangipettai during the past year. All the necessary infrastructure facilities including the installation of HPLC for amino acid analysis and other organic compounds, besides, the breeding and rearing facility for ornamental fishes, have been created. The facility will cater to the breeding and rearing of marine ornamental fishes including sea horse, pipe fish, etc. A total of about 30 aquarium tanks have been set up in this modern facility with provision for regular exchange of sea water, maintenance of hygiene in the breeding and rearing facility, etc.

Reflecting the increasing importance of biotechnology to help the country gain the competitive edge, the Ministry of Earth Sciences has acted on the recommendations of the Expert Group on Antarctic and Marine Microbiology to establish a Centre of Excellence in "Marine Microbiology" at Goa University, Goa with an aim to provide novel microbes for agrochemical use, environmental monitoring & bioremediation, and nanotechnology. The focus areas would be:

- Phenotypic and genomic assessment of the organisms including extremophiles from oceans, coastal and extreme ecosystem (Antarctic, salt pan, hydro thermal vents)
- Biopotentials of microbes including extremophiles from these ecosystems
- Exploration of microbes as tools in nanotechnology.

Workshops / Seminars

- A workshop on "Technology needs of the Aquaculture Industry with special reference to Andhra Pradesh" was organised on 20th September 2006 by the Ocean and Atmospheric Science & Technology Cell, Andhra University at Kakinada that had participation of about 75 scientists and researchers, administrators and aquaculture industry professionals.
- Another workshop on "Impact of Bottom Trawling on Benthic Communities" was conducted on 11th January 2006 by the Ocean and Atmospheric Science & Technology Cell, Cochin University of Science and Technology at Kochi.
- A workshop on 'Seaweed Kappaphycus Culture' was organised on 26th August 2006 by the Centre of Excellence in Marine Biology at Annamalai University to help acquaint the local fisherfolk with the modern scientific techniques of algal culture.

5.3 Integrated Coastal and Marine Area Management (ICMAM)

ICMAM Project Directorate under the ICMAM Programme has been implementing following major projects during the Tenth Plan period.

- Marine Ecotoxicology
- Shoreline Management Programme along Ennore, Tamil Nadu; Munnambum to Kayamkulam, Kerala and Gahirmatha coast, Orissa
- Coastal Engineering Strategy for shore protection for Kerala

- Management of tidal inlets at Netravathi estuaries
- Ecosystem Modelling at Vedaranyam lagoon, Chilka lake and Kochi backwaters

Marine Ecotoxicology

The Marine Ecotoxicology Programme envisages development of seawater quality criteria for selected chemicals based on bioassay tests.

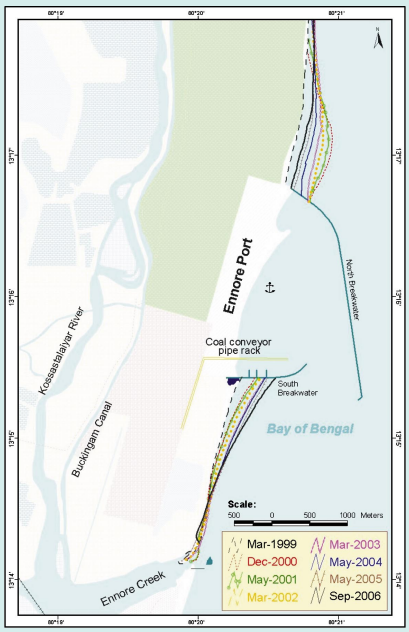
The ICMAM Project Directorate and the Institute for Ocean Management, Anna University have been continuing the bioassay tests under static renewal bioassay method to find out the range of concentrations for the toxicants tested, and then determine the 96 hrs LC50 under continuous flow through method. A modern automatic continuous flow through experimental system has been established at ICMAM-PD. The Sub lethal toxicity test was also conducted under continuous flow through method for a period of 14 to 21 days to obtain the concentration levels where no mortality of organisms occur and also to study the changes in enzyme activities and bio-accumulation in the exposed animals.

Shoreline Management Plan along Ennore Coast

The project was launched with objectives to develop hindcast, nowcast and forecast models on shoreline changes for identification of vulnerable areas of erosion/ accretion and to develop appropriate remedial measures for protection of coastline from natural and human perturbations.

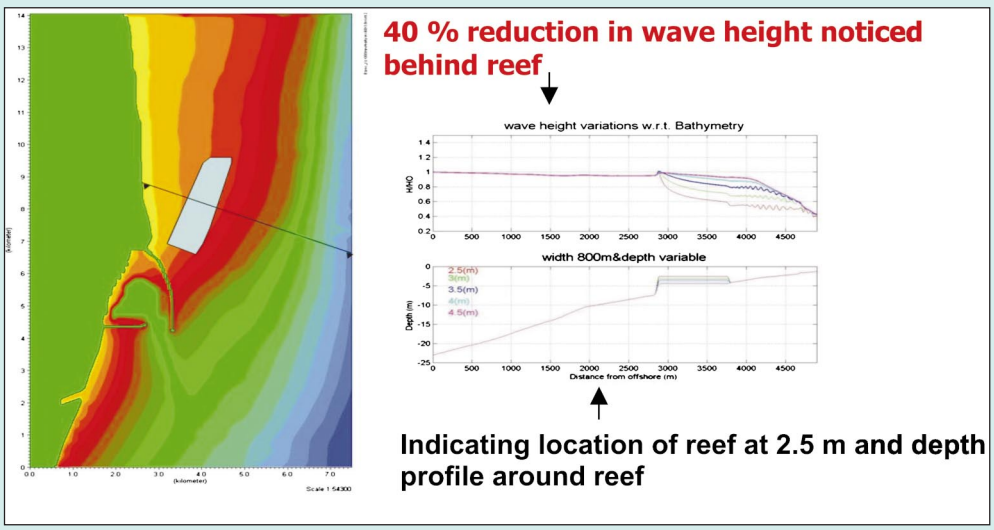
For validation of numerical models, field experiments were conducted in four phases, viz. November 2004, May 2005, January 2006 and August 2006. Tides, currents, waves, sediment characteristics and shoreline changes were monitored along the coastal stretch of 20 km from Ennore creek to Pulicat lake.

Shoreline changes were monitored from 1999 to 2006 between Ennore and Pulicat. The results indicate that the shoreline on north port has eroded to extent of 300 m, resulting removal beach material to extent of 2.5×106 m3 against 3.5×106 m3, which was placed to protect the northern coast from the likely erosion of port. The analysis and model studies indicate that entire beach fill will be lost by end of year 2007 and if no intervention is planned, coast north of port will be subjected erosion at rate of 30 m per year. It has been found through model studies that among the interventions



Ennore coast and observed shoreline at Ennore Port (1999 to 2006).

such as beach nourishment, groins and submerged reefs, the beach nourishment and submerged reefs are the most appropriate interventions useful to prevent the anticipated erosion. A shoreline management plan indicating the model outputs, recommended interventions etc. has been prepared.



Model output indicating appropriate location for deployment of submerged reef to prevent erosion along Ennore coast.

Shoreline Management Plan for Munnambum - Kayamkulam Sector, Kerala coast

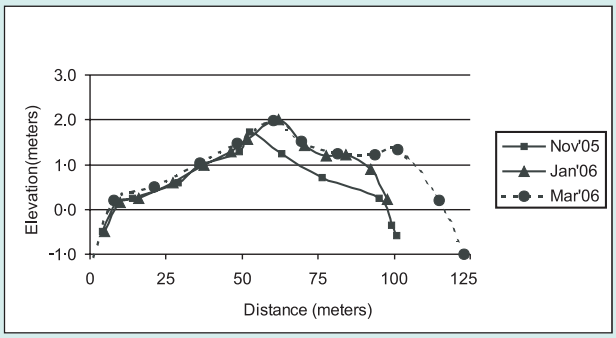
Similar to Ennore, the coastal erosion problem is significant in the coast between Munnambum and Kayamkulam in Kerala. Centre for Earth science Studies (CESS), Thiruvananthapuram in association with ICMAM-PD is investigating the problem.

Shoreline changes along Orissa Coast

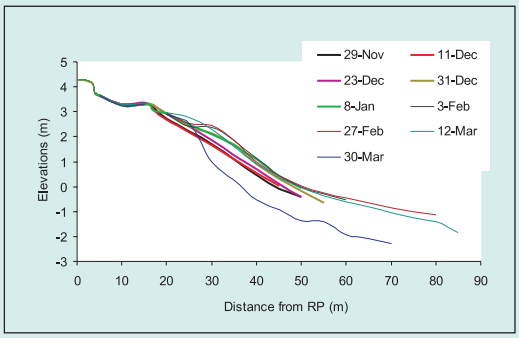
The Gahirmatha and Rushikulya beaches along Orissa coast are world's largest arribada i.e., *en masse* nesting aggregation of Olive Ridley turtles. Nearly 0.2 to 0.3 million Olive Ridley turtles visit these beaches every year during their winter migration for breeding and nesting activities. In the last two decades, natural coastal processes and man-made activities have caused major changes in beach geomorphology especially at Gahirmatha leading to loss of nesting habitat and/or shifting of turtle nesting grounds. Since 2004, the ICMAM Project Directorate with logistics help from NIOT, Chennai is studying the nesting habitats of Gahirmatha and Rushikulya to understand the importance of geomorphology and beach state in selecting a particular site by Olive Ridley turtles and also from future management and conservation point of view.

The turtle nesting beaches at Gahirmatha and Rushikulya were monitored during two nesting seasons of 2005 & 2006 using remote sensing data supported by field measurements. Data on beach profiles

were collected at Gahirmatha from November 2004 to April 2005 and January 2006 and at Rushikulya at bi-monthly intervals from April 2005 to November 2006. Shoreline mapping of the estuarine sand bar was done to understand the inlet dynamics.



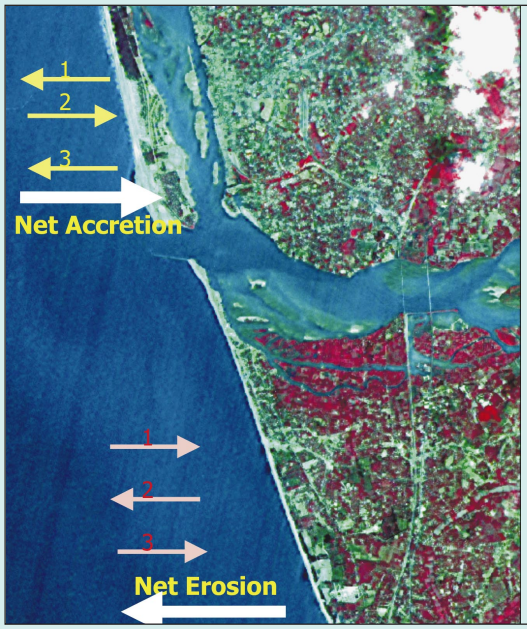
Profile of a mass mesting beach in Rushikulva



Beach Profile at Gahirmatha

Management of Tidal Inlet Management along West Coast

Construction of two training jetties at the mouth of Netravathi river, Mangalore in 1990 has caused problem of erosion of beaches in southern side at Ullal and accretion at Bangre. A comprehensive modelling approach to understand reasons for erosion and development of an appropriate remedial solution to solve the problem was necessary. Accordingly, a joint project between National Institute of Technology, Karnataka, Suratkal and ICMAM-PD was undertaken.



Year 2005-2006

1. Pre-monsoon	: Feb - May
2. Monsoon	: Jun - Sep
3. Post-monsoon	: Oct - Feb

Bengre (m^3/year/m)

1. Pre-Monsoon	-114.074
2. Monsoon	+264.826
3. Post-Monsoon	-83.919

Ullal (m^3/year/m)

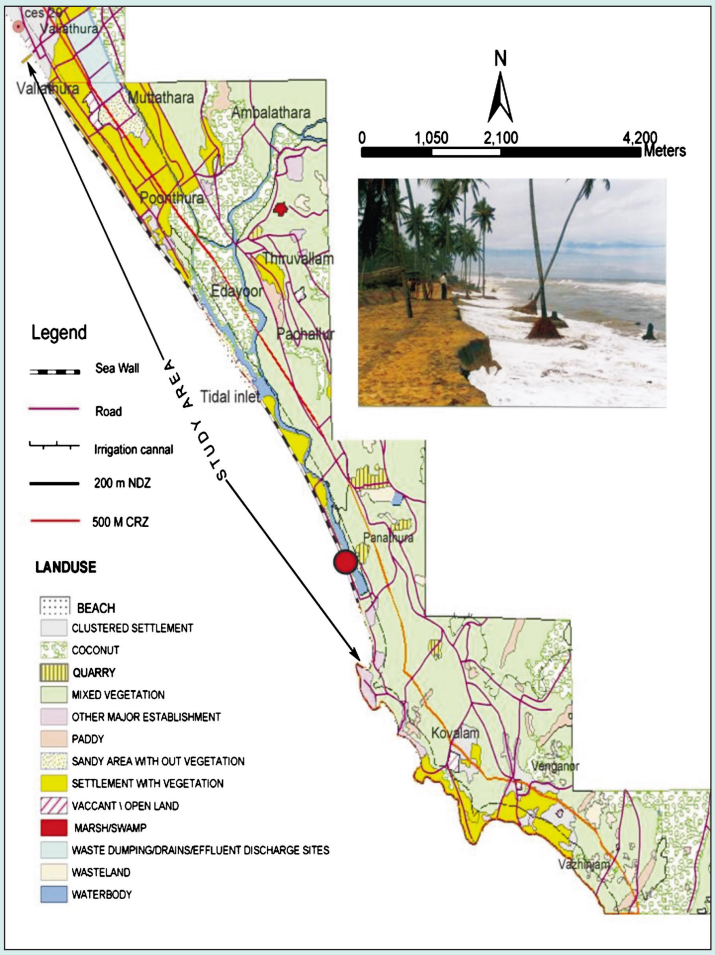
1. Pre-Monsoon	+475.7425
2. Monsoon	-1609.133
3. Post-Monsoon	+809.54

Ullal coast and estimation of erosion

Coastal Engineering Strategy for Shore Protection for Kerala - A Pilot Project

Different types of coastal protective measures have been implemented along the Kerala coast during the last 60 years. Of the various protective measures adopted so far, construction of seawalls is the most commonly used method and various types of seawall construction with different designs have been built along a large stretch of the coast. In spite of this, erosion is continuing at many locations. A pilot project is being undertaken at Panathura wherein construction of a series of groins has been suggested to mitigate the problem. The design of the groin has been provided to the Government of Kerala for implementation.

This project is being implemented through involvement of various state institutes such as Kerala State Council for Science and Technology (KSCST) and Centre for Earth Science Studies (CESS), Kerala State Irrigation Department and Indian Institute of Technology, Madras (IITM).



Location of site identified for demonstration of coastal protection strategy, Panathura

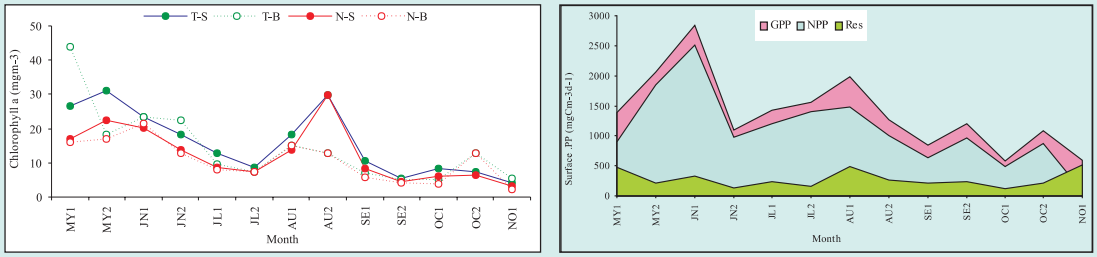
Ecosystem Modelling for Chilka Lake

Chilka Lake, Asia's largest brackish waterbody's ecosystem, is governed by tidal influx of seawater and riverine enrichment of nutrients. In order to understand interaction of these forces and consequent impact on biosystems, especially on its productivity, an ecosystem model is proposed to be developed. The chief objective of the study is to develop a biogeochemical model to understand the response of the Lake to changing salinity associated with biomass enrichment, catchments flow and load of nutrients, sediments and organic matter by explicitly considering the (coupled) cycles of inorganic sediment nitrogen, phosphorus and carbon within the lagoon system.

Ecosystem Modeling of Kochi Backwaters

The Kochi backwaters exhibit a complex pattern of biogeochemical cycles due to multiple source of input of natural and anthropogenic materials. An ecosystem model to understand the linear / non-linear relationships among physico, chemical and biological parameters has been proposed to be developed in a small area in estuary. The outcome will indicate the reasons for non-linearity especially between chemical and biological parameters.

The three-year study (2003-06) in the Kochi backwaters under the above programme was successful in highlighting the environmental condition of the estuary.



Variation of chlorophyll a (top) and goss production, Net production and Respiration (bottom) during May-November 2006 in the Cochin backwaters near Bolghatty Island.

5.4 Coastal Ocean Monitoring and Prediction System (COMAPS)

Maharashtra and Gujarat Coasts

Urbanisation of areas around Surat and industrialisation of the Hazira belt on the bank of the Tapi estuary since 1984 have considerably increased effluent/sewage load into this estuary. A marked decrease in dissolved oxygen (DO) in the middle and inner estuary from 7.7-8.1 mg/l during 1983-84 (considered as baseline) to 0.3-1.7 mg/l in December 2005 and May 2006 is eventually

due to oxidation of organic matter from constantly raising loads of domestic sewage as majority of industries in this region are not expected to produce large volumes of organic wastes. The trend of nitrogenous nutrients along the estuary suggests that the ammonia entering the inner estuary through sewage is not immediately oxidised to nitrite and then to nitrate but the process is delayed to their accumulation in the inner and middle estuary. This shows that the estuarine environment is under stress. Chlorophyll data also showed the stress conditions.

Goa coast

The coastal and hot spot (Mandovi and Zuari estuaries) areas were well oxygenated and all water quality parameters were within normal range. Bacterial count especially Faecal coliforms and other potentially pathogenic bacteria at Mandovi mouth, coastal waters off Candolim and Velsao showed an overall increase compared to previous years.

Kerala and Karnataka Coasts

Increasing anthropogenic activities (both domestic and industrial) has affected the phytoplankton standing crop and zooplankton density along southern Kerala coast. Bacterial count in the nearshore regions, especially Cochin, Neendakara and Nethravati estuarine regions, was high compared to offshore.

Andaman and Nicobar islands

The biological oxygen demand (BOD) and nitrate in the Bay and coastal waters envisaged the addition of increased anthropogenic wastes. Junglighat and Phoenix bay showed high population of pathogenic bacteria (total and faecal coliforms).

Tamilnadu, Pondicherry and Andhra Pradesh coasts

Pronounced variations were noticed in the total phosphorous level at harbour areas of the Visakhapatnam coast where a maximum of 59.7 µM was noticed during September 2006 and this may be due to the handling of fertilizers during transportation from the harbour area. Similarly, slightly elevated levels phosphorus and nitrogen were noticed in the Tuticorin harbour with the values of 4.43 µM and 13.45 µM, respectively.

The microbial populations were found to be in higher level in Navel channels, Bhuminipatnam and Pondicherry.

Orissa and West Bengal coasts

The coastal and estuarine regions of Hooghly are continued to experience high suspended matter (120-410 mg/l) due to river discharge. Inorganic and organic nutrients in the Hooghly and Mahanadi estuaries were recorded highest due to discharge of industrial effluents and organic debris (in Hooghly estuary).

Analysis of Pesticide Residues

Pesticides such as DDT, HCH, Endosulfan, Heptachlor, Aldrin and Dieldrin in edible fishes and bivalves collected from various coastal locations of the country were analysed. DDT was found to occur from 0.03 to 17 ng/g (wet). In case of HCH, the values ranged from 0.01 to 1.24 ng/g (wet). Higher values were found in fishes of Quilon and bivalves of Mumbai compared to Goa, Chennai and Andaman. In the case of Endosulfan, the values ranged from 0.1 to 9.5 ng/g (wet).

Inter-calibration Exercise

Three inter-calibration exercises each for nitrate, phosphate and total nitrogen have been conducted among the participating institutions by ICMAM Project Directorate, Chennai after it took over the charge from RRL, Thiruvananthapuram with effect from May 2006. These exercises ensured the quality of data collected by respective institutions.

GIS Database for Marine Pollution

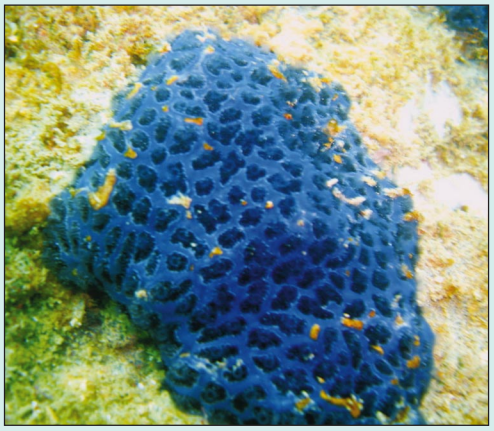
Under the COMAPS programme, 76 locations along Indian coast are being monitored at various frequencies to assess the health of the coastal environment. Data on various physical, chemical, biological and microbiological parameters are collected and archived in Oracle database. Development of Oracle database has been completed for 18 locations. These data are integrated in GIS along with other information such as coastal land use changes, locations of industrie, human settlements, etc. as possible sources of pollution.

5.5 Drugs From Sea

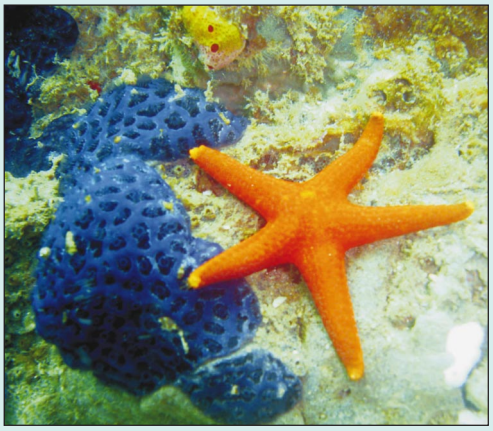
The National Project on **Development of Potential Drugs from Ocean** was taken up for implementation since 1990-91 with a view to harnessing the potential bioactive compounds from marine flora and fauna for human therapeutic purposes.

The nodal Institute, Central Drug Research Institute, Lucknow has been entrusted the responsibility of coordination and implementation; reconfirmation of bioactivity encountered by the other participating Institutions, elucidation of chemical structure by way of spectrometry and high throughput screening, testing in laboratory animal models, etc. so as to utilize their International standard infrastructure facilities and their expertise.

The Ministry has re-orientated this programme with the focus on exploratory and product development activities and initiated action to induct more institutional participation including pharmaceutical industry. Collection of wide range of marine organisms even from deep sea and islands was done and screened for 16 different bio-activities viz. (i) Anticancer; (ii) Immuno-modulatory; (iii) Anti-helminthic; (iv) Wound healing; (v) Antifungal; (vi) anti-protozoal; (vii) Anti-fungal; (viii) Antibacterial; (ix) Anti-inflammatory; (x) Anti-viral; (xi) Anti-fertility; (xii) Anti-hyperglycemic; (xiii) Anti-hyperlipidemic; (xiv) Spasmolytic; (xv) CNS; (xvi) Pesticidal and Anti-allergic. The routine experiments and defined protocols both for pre-clinical and clinical studies are



Marine Sponge



Star Fish

being carried out continuously. The assays for the drug/metabolite(s) concentrations in bio-samples are developed and validated as per the international guidelines.

Under this programme, more than 6,500 marine samples have been collected and screened. Two potential compounds are identified, and, in advanced stages of drug development. The Clinical Trial, Phase I of single dose has been completed successfully and the multi-dose trial of Phase I is in progress for anti-diabetic compound. In addition, nine more new leads viz (a) Anti-

hyperglycaemic; (b) Anti-hyperlipidaemic (c) Anti-fungal; and (d) Anti-viral are in pipeline for further optimisation of various pharmacological activities.

Considering the national importance of the programme, the Ministry is establishing Centre of Excellence at CDRI so as to engage a team of scientists exclusively to carry out these activities.

6. National Institute of Ocean Technology (NIOT)

6.1 Desalination

Low Temperature Thermal Desalination Plant at Kavaratti

The Low Temperature Thermal desalination plant at Kavaratti is functioning very well. Water generated is continuously being pumped to the local PWD tanks for supplying to the Islanders.

Formalities for handing over of the plant to Kavaratti Administration in the presence of Shri V.L.Chopra, Member, Planning Commission and Dr.P.K. Biswas, Advisor (S&T), Planning Commission was completed and accordingly the plant was handed over to them. Parallely, islanders have been trained to operate and maintain the plant.

UT Administration has sanctioned funds for putting up LTTD plants in seven more islands. They are also funding NIOT for the piping distribution network in Kavaratti.

MLD Barge Mounted Desalination Plant off Ennore

The complex task of towing, upending and connection of the cold water pipe to barge was accomplished successfully. The cold water was pumped from a depth of 700 m at a temperature of around 10^{o} C.

Towing of 1 m dia 700 m length HDPE pipe.

View of the barge "Sagar Sakthi" connected to the Single point mooring buoy at 1000 m water depth off Ennore port.

The desalination plant on the barge was commissioned on 14th April 2006 and it produced fresh water for more than two weeks. Fresh water with total dissolved solids (TDS) as low as 20 parts per million (ppm) was obtained using the indigenously designed and fabricated condensers.

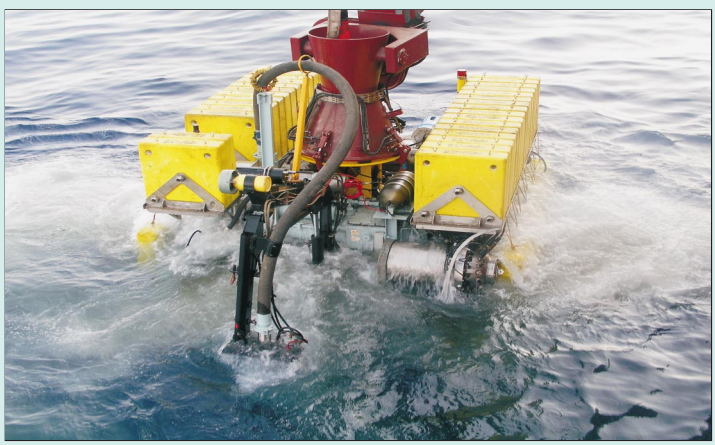
6.2 Deep Sea Technology and Ocean Mining

Developing technology for mining of manganese nodules from Central Indian Ocean Basin (CIOB) from a depth of 6000 m.

Development and test of the underwater mining system for long-term operation using Dynamic Positioning System.

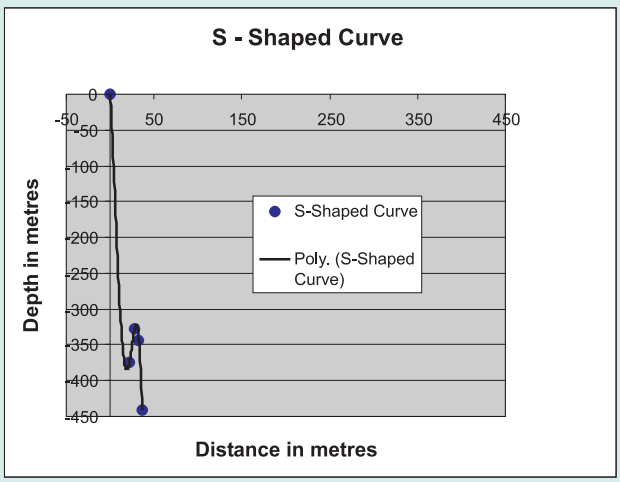
The underwater crawler was modified and refurbished with new pressure compensated hydraulic system, fins for system temperature stabilisation during underwater operations and new data acquisition and telemetry system. In order to qualify the LARS, a dummy weight of approximate size 3m×3m×3m was manufactured and filled with concrete to make its weight equivalent to that of the crawler and launched and retrieved using the LARS from ORV Sagar Kanya. The systems were initially qualified using a crawler dummy weight at a depth of 357 m off Chennai coast.

The dummy weight was launched successfully to a depth of 357 meters (lat13^0, 18.0N longitude.80^0, 39.5'E) using the new LARS, and an additional length of 120 meters of cable and hose was reeled out to obtain S-shape profile. The Vessel was maintained at an operational radius of 2 meters using DP and the performance of Field Installable Termination Assembly (FITA), Altimeter, Ambient pressure transducer and other instruments was satisfactory.



Underwater crawler being launched through LARS from ORV Sagar Kanya.

After completion of dummy trials and satisfactory performance of LARS and DP system, crawler trials was done near Angria Bank off Goa coast, to evaluate the performance of underwater Mining system for long-term operations at a depth of 451 meters.



S-Profile of the flexible riser system according to Pinger position.

Co-ordination between Crawler and Vessel was achieved during maneuvering, thereby avoiding crawler dragging and associated problems faced earlier. Station keeping of mother vessel with respect to crawler position was achieved within 2 meters radius for a seastate of 2.

The underwater mining system was augmented with oil-filled pressure compensated sub-sea power pack. Pre-deployment testing of underwater crawler in shallow depth was undertaken at Chennai port.

Development of Underwater Collection and Crushing System for Manganese Nodule Mining

Preliminary design of the crusher was completed and Scaled down model of crusher was realised and experiments were conducted using charcoal and polymetallic nodules.

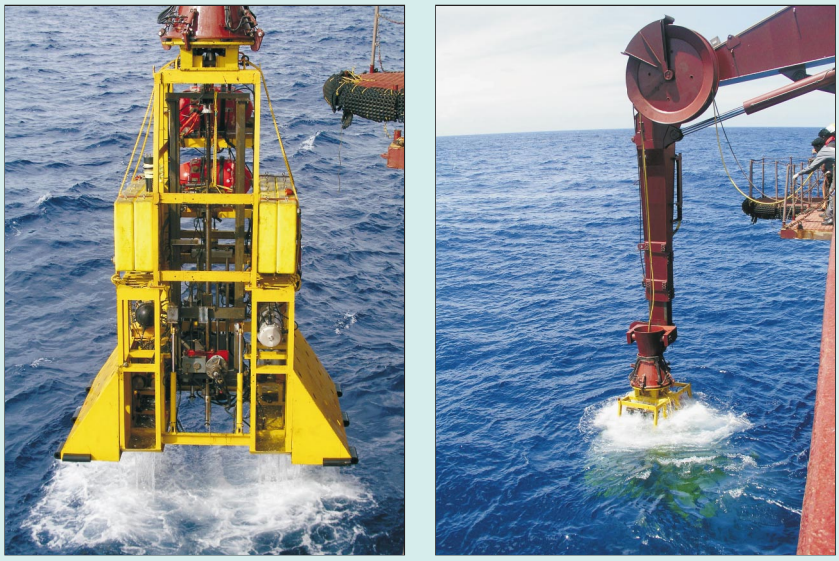
Development of Soil Tester for *in-situ* Measurement of Soil Properties in the Central Indian Ocean Basin

In-situ soil strength values are very useful inputs for design of underwater crawler for mining nodules from soft sea floor. An *In-situ* soil tester capable of operation in 6000 m depth has been developed jointly with SEVMORGEO, Russia to measure the *in-situ* soil properties in Central

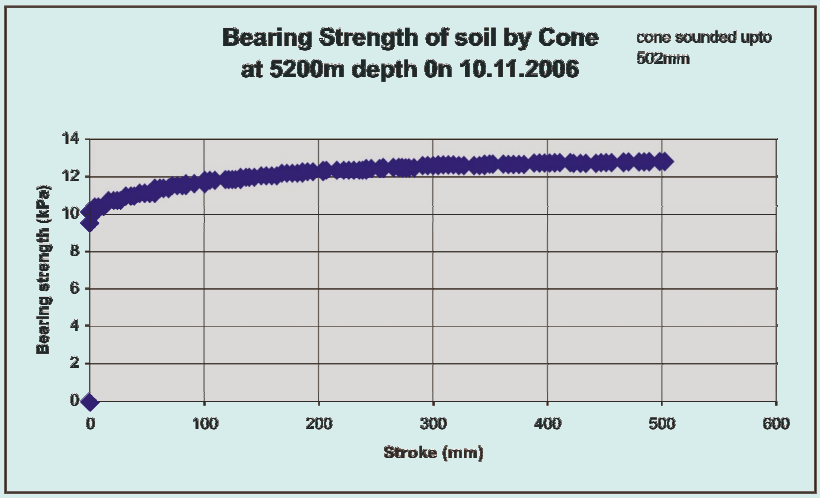
Indian Ocean Basin. The soil tester module was successfully pressure tested and calibrated at 600 bar pressure at Russia. A new Winch with drum and pedestal was fabricated to handle 7000 m length umbilical cable. The Winch was qualified by a load test for 15 tons.

Winch Load Test in progress.

As a part of development of *In-situ* soil tester for 6000 m water depth, Sea trials of the Soil tester were conducted.



Soil Tester entering splash zone.



Observation graph for soil tester cone operation at 5200 meters.

6.3 Coastal & Environmental Engineering

Shore Stabilization programmes - Uppada, Andhra Pradesh

The objective of these studies is to demonstrate the performance of cost effective environmentally acceptable solutions for coastal protection. Sites that are undergoing erosion have been identified at Uppada (Andhra Pradesh), Pondichery coast, Kumrakhethi - Port Blair (Andaman), INS-Kardip - Kamorta (Nicobar group) and Kulpi along the left banks of the Hoogli estuary. Site-specific coastal protection schemes have been worked out for these sites.

Adayar Creek, Tamil Nadu

The Adayar river that flows through Chennai is characterised by formation of bars at the confluence with the sea thereby resulting in negligible exchange. Studies are in progress for providing long-term solutions to keep the bar mouth open.

Risk Assessment Studies

Risk Assessment studies were carried out for the Gujarat Pipavav Port Limited (GPPL) for relocating the LPG jetty, using DNV Risk assessment model PHAST, which is a comprehensive hazard analysis package. It determines the consequence of an accidental release of hazardous material into the environment, by simulating toxic or flammable release.

Studies for Disposal of TBT from Shipyards

The objective of this project is to define strategies for safe disposal of TBT removed from shipyards following the International Maritime Organisation (IMO) ban on use of TBT paints on ships. Steps in the process were to (i) identify micro organisms that detoxify TBT, and (ii) evaluate the performance of various micro organisms in detoxifying the TBT.

Marine Archaeology

Offshore investigations in the Gulf of Cambay were carried out during the years 2003-05 and the data collected were undertaken for analysis by various associate institutes. Onshore investigations on the main landside are being carried out by the associate institutes (Deccan College, Pune, MS University, Baroda, etc.) and the analysis is in progress.

GSLV Search Survey

NIOT participated in the survey operations to recover GSLV subsystems.

Surface Current Observation by HF Radar

Observation of sea surface current and waves at Chennai Coast by HF Radar was operational during the year.

Wave Rider Buoy systems have been installed off Neelankarai, Chennai and the results have been compared with the HF Radar measurement and found to be satisfactory. Validation process is in progress.

Consultancy Projects

Consultancy projects to a tune of Rs.265.22 lakh have been carried out during the year. The survey project includes:

- Post dredge survey at Pipavav" for GPPL carried out.
- Bathymetric survey at Chennai Fishing Harbour has been completed

- Fixing of GPS points at Rameswaram - 4 nos. for comparison has been carried out for M/s Vax Consultants Pvt. Ltd, Chennai.

- Field Investigations for Dighi Port for WAPCOS, Pune has been carried out and the report preparation is in progress.

- Oceanographic survey at Jaitapur for NPCIL - part of investigations (Multibeam bathymetry, Shallow seismics, Coastline mapping, Discharge measurements) carried out during August 2006 and data processing in progress.

- Seabed and Oceanographic surveys at Cuddalore for M/s Nagarjuna Oil Corporation Ltd, Chennai, Phase II - Oceanographic observations off Jaigad for Chaowgule Shipping, etc.

EIA studies were carried out for the following.

- Road construction projects at Andaman Islands - Kamorta, Katchal, Chidiyatapu and Teressa Island

- Construction of Multi-Parametric Geophysical observatory at Shoal bay for IIG, Mumbai

- Proposed River Regulatory Measures (RRM) in the Hooghly estuary at Haldia, for Kandla Port expansion project.

- Construction of lighthouses at Cape Edinburg and Tries Islands

- Relocating the DG sets at the Kamorta and Katchal Islands

- Setting up a geochemical laboratory at Baratang

6.4 Marine Instrumentation

- Under the Tsunami Observation Network Programme, tide gauges installed and commissioned in different locations like Chennai, Tuticorin, Cochin, Port Blair, Mangalore, Vizhinjam, Nagapattinam Port, Kakinada and Kandla have been networked using GSM modems and the tidal data from these stations are available on the internet.

- This group has recently successfully commissioned and networked one Acoustic Tide Gauge (ATG) with INMARSAT communication link, another one ATG and Pressure Tide Gauge (PTG) with GSM communication link as standby at Minnie Bay in Andaman Island as a part of Early Tsunami Warning System Project.

- National Accreditation Board for Testing and Calibration Laboratories (NABL), Department of Science & Technology has accredited Acoustic Test Facility (ATF) in accordance with the standard ISO IEC 17025 : 1999 in the field of electrical testing and authorised to use NABL accreditation logo. The Surveillance Audit has been successfully completed 7th to 8th April 2006. Also, an impulse technique for extending the calibration range of acoustic tank to frequencies lower than 4 kHz has been successfully implemented in the Acoustic Test Facility of NIOT.

- More than 100 nos. of hydrophone and 120 staves of BEL were calibrated at ATF. Apart from the mentioned calibration, the facilities were used for in-house projects like ROSUB, NDBP of NIOT.

- A project on "Lighting System with Solar-Powered LED based Lamps for Remote and Rural Houses" has been sanctioned by Rural Technology Action Group (RuTAG) Cell, Indian Institute of Technology, Madras supported by the office of the Principal Scientific Advisor to the Government of India, to Instrumentation & Control group. The group has demonstrated successfully the reading, ceiling lamps and lantern for rural applications with solar power back-up with the bright light LEDs with a typical power consumption of 2-4 watts. The lamps were tested at a rural hospital in Sittilingi, Dharmapuri, Tamil Nadu.

- The new version of ATG system with low power consumption, simplified mechanical system and with two way GSM communication for tsunami monitoring application has been installed and commissioned at open pond in NIOT and it is successfully transmitting for continuous 4 months through GSM modem.

Marine Sensors And Electronics

As a part of the establishment of underwater electronic support facility EMI/EMC analyser has been procured to cater to the needs of NIOT in-house projects such as Remotely Operable Vehicle (RoV) and 6000 m deep-sea crawler. Helium Leak Detector to test the pressure casing of submersibles has been identified, and is being procured.

As a part of the programme, to develop underwater components the following components are being developed in-house with the Indian industry.

- A 250 kW underwater motor for submersibles is being jointly developed by NIOT and M/s PSG College of Technology, Coimbatore.

- As the Fibre Optic Connectors (FOCs) used for submersibles such as crawler and ROV are presently being imported at a very high cost, the development of Fibre Optic Connectors for 2000 m water depth in association with M/s FCI-OEN Connectors, Cochin has been taken up. The preliminary design has been finalised.

- Sub sea power converter used to supply power to the submersibles from the ship is being developed in-house by integrating the components available off-the-shelf.

As a part of sensor development programmes miniaturised flextensional transducers (CYMBAL) was taken up as a part of NSTL-sponsored project. These sensors were successfully developed and tested.

6.5 Ocean Science & Technology for Islands (OSTI)

Under this programme, technology dissemination to fishers on sea cage culture of lobster and mud crab was completed in many coastal villages in Tamilnadu, Orissa and A & N Islands. Further, GIS-based island resource data collection was initiated. Under marine antifouling studies, marine natural products were tested for antifouling property. In addition, the following projects were executed.

- Biofouling and its control on plate heat exchangers of prototype fast breeder reactor (Indira Gandhi Centre for Atomic Research)

- Performance of naval materials under immersed condition in sea environment (Naval Research Board)

- Marine organisms-mediated biodegradation of polymers (Naval Research Board)

- Prospects of mud crab and lobster farming and fattening in Orissa (UNDP - Orissa State Fisheries Department)

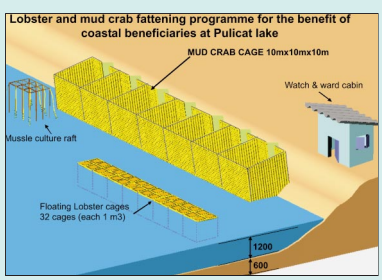
- Mud crab and lobster farming/fattening for additional income generation to fisher folk at Pulicat Lake (Department of Fisheries, Government of Tamilnadu)

- Biofouling in cooling tower fills of Talcher Super Thermal Power Station (NTPC Ltd.)

- Indo-Bulgarian project on Surface Modification Approach to control Biofouling (Department of Science and Technology).

Extension of Lobster and Mudcrab Fattening Technology for Societal Development

Demonstration and training of lobster fattening in seacages was extended in Kulasekharapatinam, near Tuticorin. Auto recruitment of large number of puerulii was also noticed in these cages. As a part of the tsunami rehabilitation programmes of the Govt. of Tamil Nadu, NIOT imparted training on lobster and mud crab fattening in seacages and pens to women Self-Help Groups at Parangipettai, Palaiyar, Thirumalaivasal, Madavaimedu and Kodiakarai.



Schematic view of crab pen.

FRP pen for crab fattening.

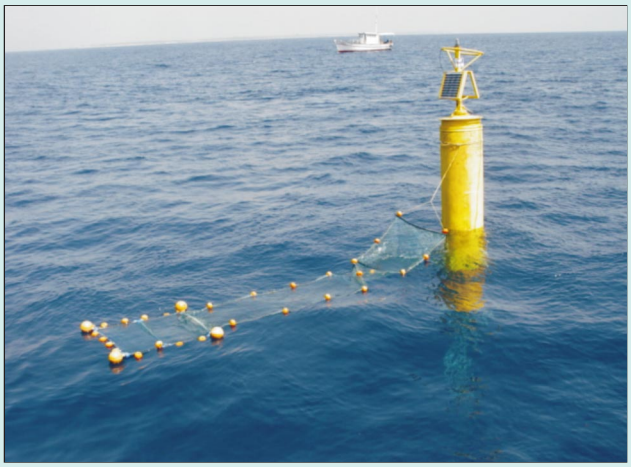
Cell type floating FRP cage.

Studies on Deep Ocean Water (DOW) Application for Mariculture

Experiments were conducted utilising DOW available through the one lakh litre Low Temperature Thermal Desalination plant at Kavaratti, Lakshadweep islands. Low temperature, nutrient-rich and pathogen-free nature of DOW makes it ideal for mariculture activities.

Oceanic Fish Aggregating Devices (Funded by Lakshadweep Administration)

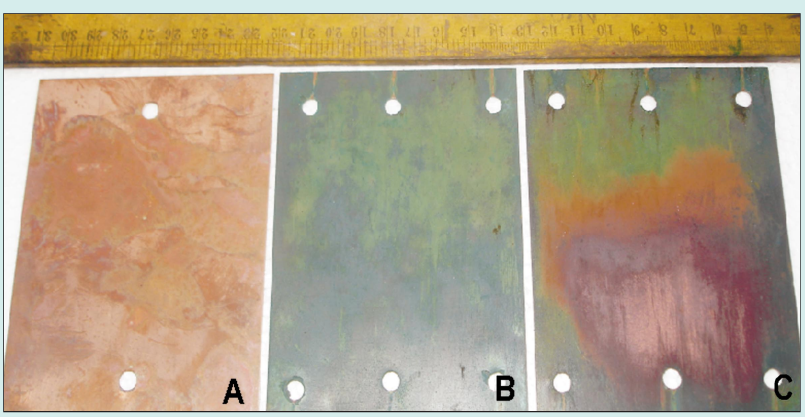
Under this project, 28 Fish Aggregation Devices (FAD) were successfully deployed around Lakshadweep. The complete design and fabrication of FAD was done by NIOT. The mooring analysis was carried out using ORCAFLEX software.



Deployed FAD with appendages.

Biofouling control Measures for Marine Sectors

As an in-house project, a non-invasive pilot study was conducted for controlling biofouling employing ultrasonic cleaning principle. A system, comprising of seawater in-take line, pumps, function generator, power amplifier, transducer (35 kHz) and copper coupons, was designed and examined by monitoring fouling rate for 3 weeks. While the control coupon was deposited with algae completely, the experimental coupon remained clean in the ultrasonic wave exposed area maintained under continuous seawater flow.



Ultrasonic wave- propagated biofouling control: A - Fresh coupon, B - Control coupon, C - Experimental coupon.

A & N Centre for Ocean Science and Technology, Port Blair

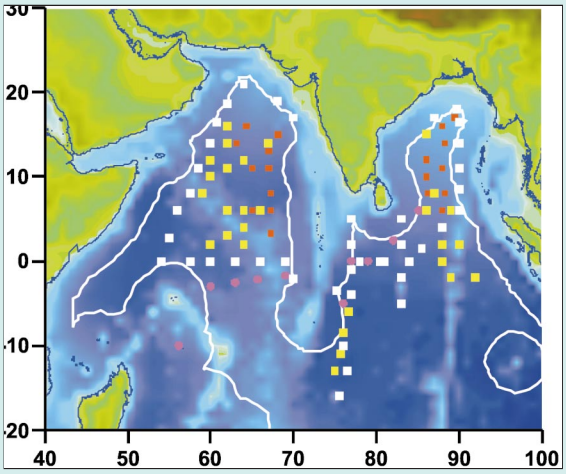
Suitable locations for resettlement of tsunami-affected populations of Nancowry group of Islands have been identified using GIS tools following all possible stringent criteria and as per the CRZ-IV regulations.

Marine Bioinformatics Centre (MBiC)

The main objective of the centre is to preserve data on marine species and to develop a better understating on marine ecosystem. Details of about 250 species are available online through this portal. In addition, phylogenetic studies have also been carried out employing bioinformatics tools. Three students were selected out of 150 applicants for online projects for taxonomic data collection of marine species.

6.6 Indian Argo Project

Indian ARGO programme is committed to deploy 150 Profiling drifters in the North Indian Ocean, Arabian Sea and Bay of Bengal. So far, NIOT has deployed 122 floats with 100% deployment success.



Deployment locations of Argo floats.

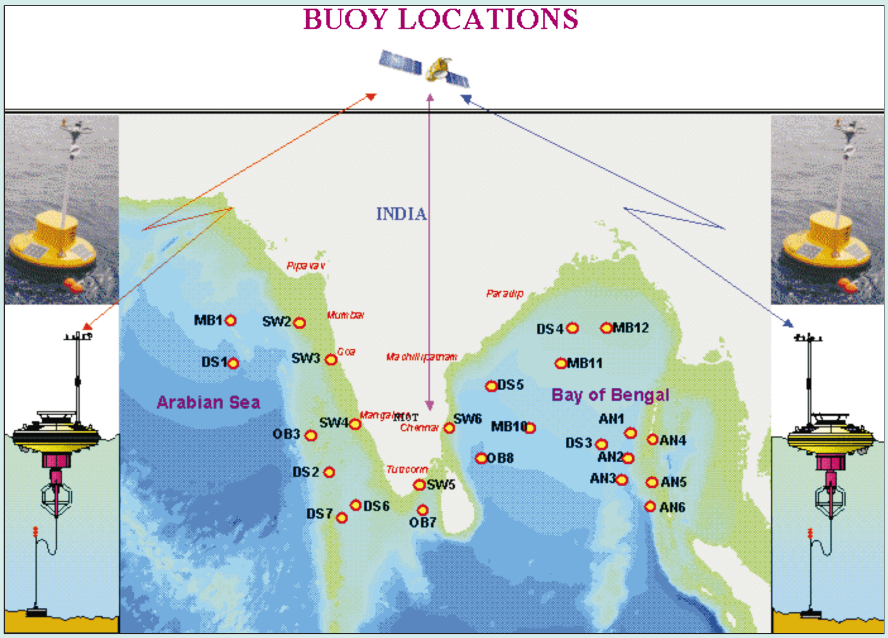
Indigenisation

The design and fabrication of Pressure enclosure (200 bar) for profiling drifter was completed.

6.7 National Data Buoy Programme (NDBP)

Moored Ocean Data Buoy Programme

The moored data buoys equipped with global positioning system, beacon light and satellite transceiver, collect all the significant met-ocean parameters. NDBP buoy data is available online since February 2006 to all the registered end users.



Convoy for cruise.

Buoy ready for deployment.

Maintenance activity.

7. Delineation of the Outer Limits of the Continental Shelf

The programme on delineation of continental shelf is a multi-institutional national endeavour that seeks to establish the outer limits of the country's legal continental shelf in accordance with the provisions of the 1982 United Nations Convention on the Law of the Sea (UNCLOS). India is a party to the UNCLOS and is entitled to the claim over her continental Shelf. The claim with supporting scientific and technical data is required to be submitted to the UN Commission on the Limits of the Continental Shelf (CLCS) by May 2009. The entire work *viz*. data acquisition, processing and interpretation of marine geophysical data consisting of more than 32000 line kilometer gravity, magnetic and seismic has been completed and the draft report is ready for submission before the commission.

8. Gas Hydrates Exploration and Technology Development

Gas hydrates with their abundant resource potential is emerging as a potential cleaner fuel resource. The preliminary assessment of geological condition and limited available seismic data suggests high possibility of occurrence of large quantity of gas hydrates within the EEZ of India. Gas hydrate exploration is a nascent science and a mission mode programme has been taken up to develop science and technology in India in respect of exploration of gas hydrate and to recommend suitable sites for drilling for ground truth validation and subsequent technology development for harvesting.

Gas Hydrate Exploration & Technology

Different modeling techniques (AVO response, VAMP, gravity response) were studied and tested to establish the occurrence of gas hydrates in Indian margins using existing seismic data sets. Gas hydrates were synthesized in laboratory scale to study the physical properties (thermal, electrics and acoustic) and structural characteristics of hydrates. Infrastructure development is in progress and all the necessary laboratory equipments for gas hydrates studies are procured and calibrated. Two sites have been identified in the Krishna Godawari basin off the east coast to take up further detail investigations.

Indo - Russian Centre for Gas hydrates

- Winter expedition to Lake Baikal was conducted for joint gas hydrate research with Limnological Institute, Irkutsk, Russia

- Gas hydrate sample were collected from the ice sheet cover using normal gravity core at a water depth of 1282 m.
- Three cores were recovered with gas hydrates in Malenki mud volcanic region
- Dissolved methane concentration anomaly of 25 nmol was observed near mud volcanic region lake bed surface at 1280 m

Deployment of Methane sensor

Recovered gas hydrates

Sampling during winter expedition

9. Swath Bathymetric Survey of entire Indian EEZ

The area of our Exclusive Economic Zone is over 2 million sq km abounds in various living and non-living resources. This new programme entails scientific mapping of this area to have an inventory

of potential resources and to identify the causes of hazards. Four successful cruises off Goa covering 1654 line km (397 sq km area) were carried out . An area of little more than 25,000 sq km around Andaman subduction trench and near about 2000 sq km around Great Nicobar Island was surveyed to obtain necessary data to produce swath bathymetry map of this area. The Andaman subduction trench, where the heavier oceanic Indian plate is shoving below the lighter continental Southeast Asian plate, is mapped successfully, along with several structural and geomorphic features .

10. Geophysical Study of Laxmi Basin

The main aim is to establish the nature of basement in the Laxmi Basin. The analysis and processing of marine geophysical data including seismic reflection and seismic refraction, gravity and magnetic data has been done followed by processing and interpretation of marine geophysical data gathered to arrive at a logical conclusion on the type and nature of the crust flooring the Laxmi Basin and Ridge and to facilitate an understanding of the Arabian Sea basin.

11. Acquisition of New Research Vessel

This new multipurpose vessel will serve as a platform for the programme envisaged in the 11th Plan and serve as a utility science vessel which will augment the capacity needs of the marine living and non-living resources programme of the Ministry. The vessel-Sagar Nidhi is being constructed in Italy.

12. Early Warning System for Tsunami and Storm Surges

The Project is envisaged with the following objectives:

- to realise an operational National Early Warning System for Tsunami and Storm Surges
- to set up the National Early Warning Centre in Hyderabad located at Indian National Centre for Ocean Information Services (INCOIS) for operation on a 24×7 basis
- to institute a mechanism to sustain the System to generate and issue 'warning' and 'watch' advisories, as the responsible national agency

The major participants in the Project are institutions under Ministry of Earth Sciences [Indian National Centre for Ocean Information Services (INCOIS), National Institute of Ocean Technology (NIOT), Project Directorate of Integrated Coastal and Marine Area Management (ICMAM), India Meteorology Department (IMD)], Department of Science and Technology [Survey of India (SOI)], Department of Space [Indian Space Research Organisation (ISRO) and National Remote Sensing Agency (NRSA)] and Council of Scientific and Industrial Research [National Institute of Oceanography (NIO) and National Geophysical Research Institute (NGRI)].

Developing Decision Support System and Setting up a dedicated Early Warning Centre for Tsunami and Strom Surge

An Interim Tsunami Warning Centre, following the Standard Operational Procedure, is operational at INCOIS on 24×7 basis, since July 2005. This centre receives earthquake and tsunami advisories from India Meteorological Department, Japan Meteorological Agency, Pacific Tsunami Warning Centre as well as Tide Gauge Data from SOI, NIOT and other International Stations.

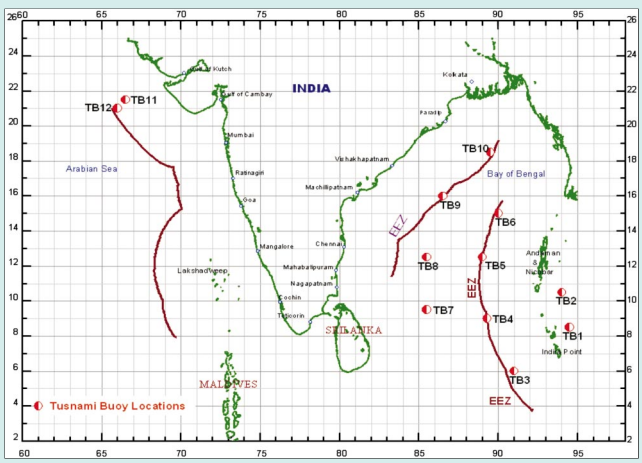
Communication of real-time data from Seismic Stations, Tide Gauges, BPR's to the early warning centre is very critical for generating timely tsunami warnings. An end to end communication plan has been worked out in collaboration with the Indian Space Research Organisation that envisages use of INSAT DRT for one way and INSAT MSS for two way communication from Tide Gauges and DART Buoys.

At present 15 nos. of tide gauges have been installed with GSM link and ISRO is working on two way communication. Two Coastal Radars have been installed off Chennai Four Bottom Pressure

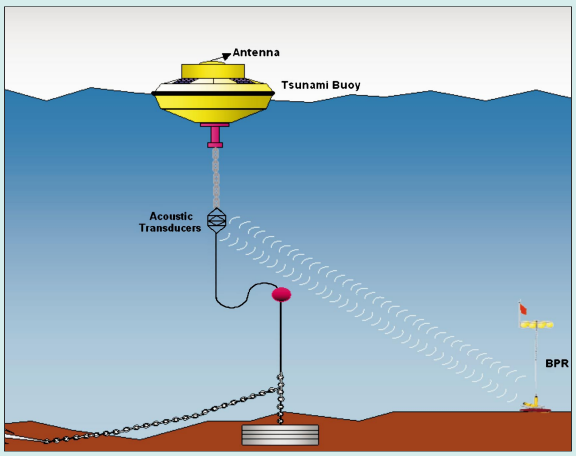
Recorders have been installed. Survey for Tamil Nadu completed for generating coastal bathymetry up to 20 M depth at transects of 250 M interval.

Deep ocean Tsunami Warning system

Presently the work is being carried out towards establishment of Deep Ocean Tsunami detection network in Indian EEZ waters by deployment of 12 data buoys equipped with ocean bottom pressure recording device.



Tsunami Buoy Locations.



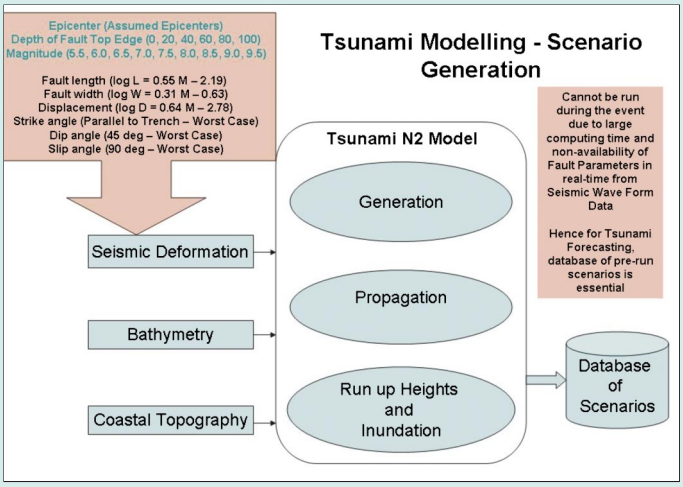
Tsunami Buoy System.

The Virtual Private Network for Disaster Management Support (VPNDMS) node has been set up at INCOIS that facilitates reliable connectivity to the Ministry of Home Affairs for dissemination of Warnings.

VSAT Terminal with 4.5 m Antenna established at INCOIS.

Data, Audio and Video Conferencing equipment for Disaster Management Support.

Tsunami N2 Model has been installed at INCOIS and number of scenarios have been worked by considering 9 cases of magnitudes ranging from 5.5 to 9.5 and 6 cases of depth ranges from 0 to 100 km and for 974 locations spacing with half degree. A small scale database of selective scenarios generation is under progress as a test case for operational purpose.



Coastal Vulnerability Modelling and Inundation Mapping

Standardised Tsunami N2 model by generating 3 scenarios of inundation for the Cuddalore to Parangipettai sector using high resolution bathymetry data.

Storm surge model for Nagapattinam was customised. The cyclone of 1977 was used to test the model especially to predict the surge height and the consequent inundation of seawater along the200 km long coast between Vedaranyam and Cuddalore (Tamil Nadu).

Capacity Building, Training and Education

- A work plan is also being made for organising periodic workshops for the user community to familiarise them with the use of tsunami and storm surge advisories as well as inundation maps. This is being taken up in collaboration with the State Disaster Management units, academia, local NGOs, etc.

- A dedicated multi-lingual web-site is also being developed to provide information on Tsunamis and Storm Surges.

Atmospheric Sciences

13. India Meteorological Department (IMD)

The India Meteorological Department (IMD) established in 1876 is the national meteorological service of the country and is responsible for monitoring and forecasting weather conditions in different scales of time. It has a network of observatories covering the landmass of the country and its surrounding sea areas from where ground-based, airborne and satellite observations are routinely taken. The services of IMD are utilised in almost all walks of national life and also provided to the international community under the charter of World Meteorological Organisation.

13.1 Meteorological Services

Weather Monitoring

Activities of Weather Forecasting

IMD issued weather forecasts and also precautionary warnings for hazardous weather like cyclonic storms, heavy rainfall, squalls etc. for the entire country so as to save human life, livelihood and property. Weather Central, Pune and Northern Hemispheric Analysis Centre, New Delhi are the two main forecasting Centres of the Department besides six Regional Meteorological Centres and Meteorological Centres at State headquarters. The weather reports were disseminated through media, passed on to all relevant Government agencies, hoisted on the Web and published in the Indian Daily Weather Report.

Experiencing the normal variability of weather the year 2006 did not witness any remarkable heat and cold wave, unexpectedly heavy rainfall or persistent and widespread fog, except for a few cases of extreme weather which were successfully foreshadowed.

Cyclone Monitoring

Three cyclonic storms formed over the Indian seas this year (somewhat lesser than the normal of five). Two out of these intensified into the ‘severe’ category which is a higher conversion rate than normal. A remarkable event was the storm of 29th October which was so compact and small that it could not be identified by satellites or on weather charts. Not surprisingly, no other centre engaged in tracking storms world over could detect its presence except the IMD which had the advantage of having two coastal Doppler Radars at Chennai and Machhilipatnam which could accurately gauge its severity from close range.

Very Severe Cyclonic Storm "MALA" over Bay of Bengal (25-29 April, 2006)

A very severe cyclonic storm named **"MALA"** developed over South East Bay of Bengal about 350 km South West of Port Blair as a low-pressure area and intensified into a depression in the morning of 25th April 2006. Moving initially in a westerly direction, it intensified into a deep depression in the afternoon, to a cyclonic storm in the evening of 25th April, to a severe cyclonic storm in the forenoon of 27th April and finally into a very severe cyclonic storm which turned northeastwards to cross Arakan coast in Myanmar at around noon of 29th April 2006. Heavy rainfall and strong winds were experienced over Andaman Islands. However, no damage occurred due to this system on the Indian coast.

Severe Cyclonic Storm "MUKDA" over Arabian Sea (21-24 Sept. 2006)

The severe cyclonic storm **"MUKDA"** developed over east central Arabian Sea as a depression and it lay centered about 450 kms southwest of Porbander, during the night of 21st September 2006. It intensified into a cyclonic storm when about 400 km southwest of Porbander. It remained practically stationary up to afternoon of 22nd. It moved slightly northeastwards and intensified into a severe cyclonic storm lying still about 350 km southwest of Porbandar. The system remained over the same area for more than 36 hours before dissipating around midnight of 24th September.

Cyclonic Storm "OGNI" over Bay of Bengal (28-30 October 2006)

The cyclonic storm **"OGNI"** developed over west central Bay of Bengal as a low pressure area off Andhra Pradesh coast in the evening of 28th October 2006. It intensified into a depression and lay centred about 50 km east of Nellore in the morning of 29th October. Moving slowly in a northerly direction it further intensified into a deep depression and then cyclonic storm in the evening of same day and lay centred about 50 km east of Kavali. The system moved very slowly till the morning of 30th October to about 30 km east of Kavali. Doppler Weather Radars at Visakhapatnam and Chennai showed band features with small core. Moving northwestwards it then crossed the coast near Bapatla around noon of 30th October 2006. The system had started to rapidly loose intensity just before landfall.

Project e-atlas (Electronic version of IMD's Cyclone Atlas)

The existing cyclone Atlas of IMD in print version presents tracks and statistics regarding Cyclonic Storms for the period 1891 to 1990. The e-Atlas data base has been updated to cover the entire

period, 1891 - present. The WMO/ESCAP Panel- 33rd session has appreciated the efforts made by India to digitise storm tracks of north Indian Ocean, which is of great use to all South Asian and Asia Pacific countries. The work was done by the Cyclone Warning Research Centre of IMD at Chennai.

Southwest Monsoon 2006

Monsoon Highlights

- The seasonal rainfall from 1st June to 30th September for the country as a whole was 99% of its long period average.

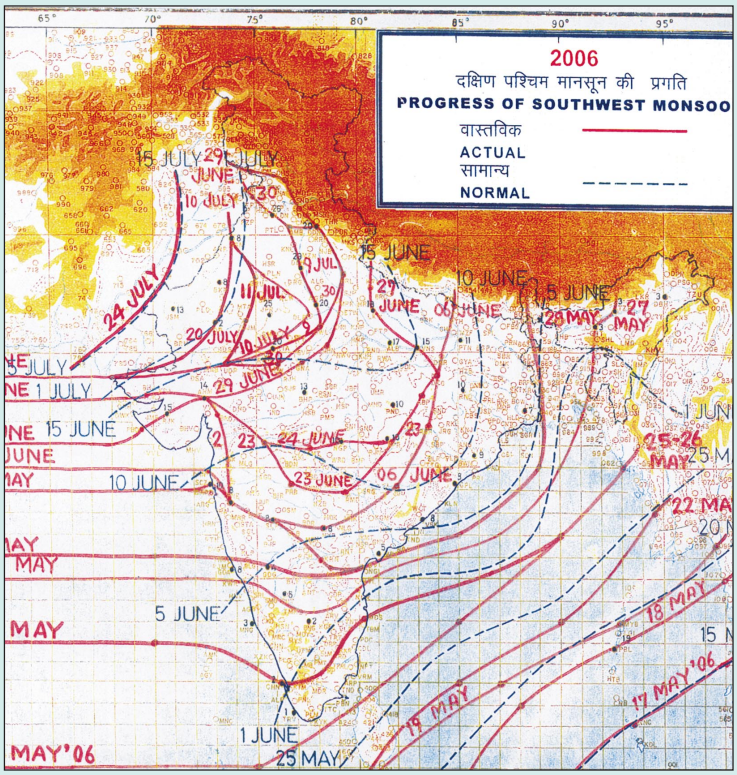
- Central India received more than the normal rains while Northeast India was deficient this year. Northwest India and Peninsula remained closer to normal.

- 60% of the meteorological districts received excess/normal rainfall and the remaining 40% received deficient/scanty rainfall during the season. 130 districts (25%) experienced moderate drought and 30 districts (6%) experienced severe drought conditions at the end of the season.

- IMD's long range forecasts for July rainfall over the country as a whole and the 2006 seasonal rainfall over Northwest India and South Peninsula were proved to be accurate. However, the 2006 monsoon seasonal rainfall over the country as a whole was slightly more than the predicted value.

In the year 2006 the southwest monsoon advanced into Andaman Sea on 17 May and arrived over Kerala on 26 May, almost a week prior to the normal date. After an initial burst of rapid movement there was a prolonged hiatus from 7-22 June when it remained stranded over Gujarat, Central India and Bihar. Thereafter, it moved further into North and Northwest India as a weak current before going into a second hiatus between 1-8 July. It finally advanced into west Rajasthan on 20 July.

The season as a whole had been quite active in terms of the number of low pressure systems. In all, 16 systems -1 severe cyclonic storm, 8 depressions/ deep depressions and 7 low pressure/ well marked low pressure areas formed during the season. All the systems formed over the Bay of Bengal except one depression which formed over land and one severe cyclonic storm which formed over Arabian Sea.



Progress of Southwest Monsoon 2006

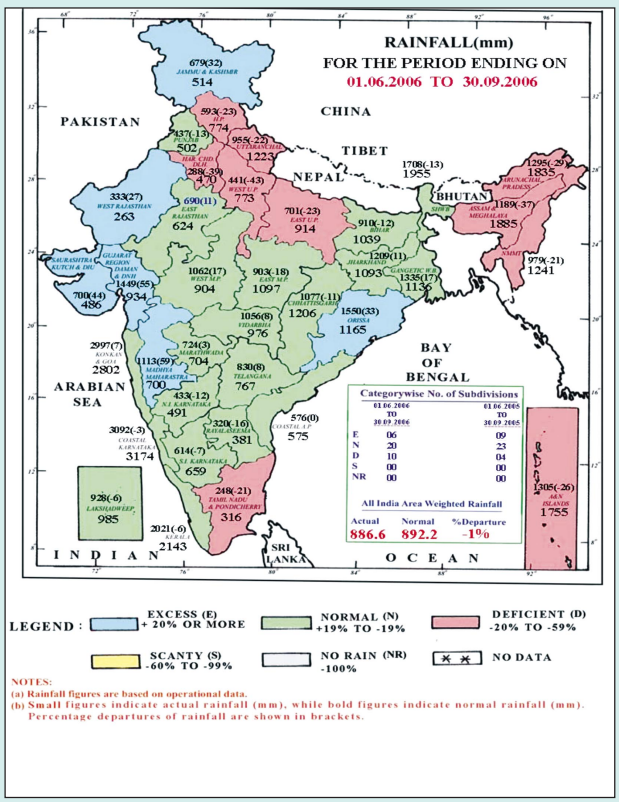
Rainfall Distribution during Monsoon Season

The southwest monsoon rainfall (June to September) for the period 1 June to 30 September 2006 for the country as a whole and the four broad homogeneous regions are as follows.

Region	Actual (mm)	Normal (mm)	Percentage Departure
All-India	886.6	892.2	-1%
Northwest India	573.7	611.6	-6%
Central India	1152.2	993.9	16%
South peninsula	684.6	722.6	-5%
North east India	1177.6	1427.3	-17%

Even though the season was active in terms of number of low pressure systems, their movement was more or less confined to the central parts of the country resulting in an inequitable distribution

of rainfall. The seasonal rainfall (1 Jun to 30 Sep) was excess in 6, normal in 20 and deficient in 10 meteorological sub-divisions. Five sub-divisions (Andaman & Nicobar Islands, Arunachal Pradesh, Assam and Meghalaya, West Uttar Pradesh and Haryana experienced moderate drought conditions (rainfall deficiency of 26% to 50%).



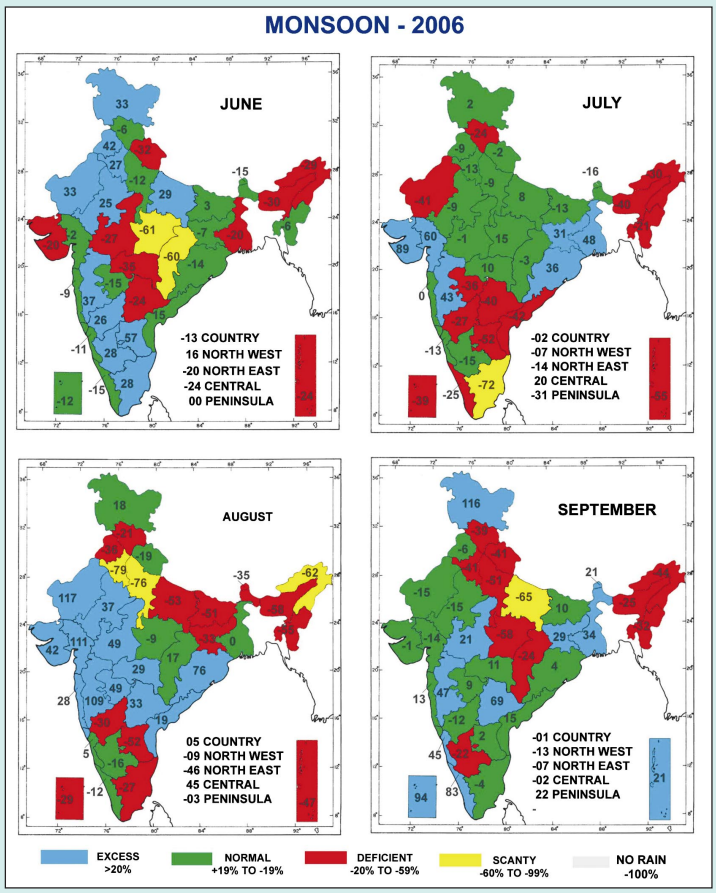
Sub-divisional rainfall distribution over India during southwest monsoon season-2006

Out of 533 districts, 209 (40%) districts received deficient rainfall (rainfall deficiency more than 19%) during the season, out of which 130 (25%) districts experienced moderate drought conditions (rainfall deficiency 26% to 50%) and 30 districts (6%) experienced severe drought conditions (rainfall deficiency 51% and more).

Month-wise distribution of rainfall departure from Long Period Average (LPA), over the country as a whole, is given below:

June:	13% below LPA	July:	2% below LPA
August:	5% above LPA	September:	1% below LPA

The spatial distribution of month wise rainfall departures is given in figure below.



Spatial Distribution of Monthly Rainfall Departure (%) over India during southwest Monsoon season 2006

Long Range Forecast of Monsoon Rainfall

- IMD issued the prediction for monsoon onset over Kerala on 30 May, using an indigenously developed statistical model with a model error of ±3 days. The actual occurrence though was on 26 May, which was six days earlier than normal date.

- Forecasts for northeast monsoon rainfall and northwest India winter precipitation were issued for the first time this year, using indigenously developed statistical models.

Details of long range forecasts of SW Monsoon and actual rainfall

Region	Period	Issued on	Forecast	Actual
All India	June to September	24th April, 2006 30th June, 2006	93% of LPA ± 5% 92% of LPA ± 4%	99% of LPA
All India	July	30th June, 2006	97% of LPA ± 9%	98% of LPA
Northwest India	June to September	30th June, 2006	91% of LPA ± 8%	94% of LPA
Northeast India	June to September	30th June, 2006	94% of LPA ± 8%	83% of LPA
Central India	June to September	30th June, 2006	90% of LPA ± 8%	116% of LPA
South Peninsula	June to September	30th June, 2006	97% of LPA ± 8%	95% of LPA

Meteorological services to Aviation

Meteorological safety has assumed prime importance for Aviation services in the country owing to massive expansion in air traffic. IMD prioritized its modernization programme to meet the immediate demands of the Aviation Sector.

- A Dual baseline transmissometer was installed at the airport at Kolkata for measuring visibility making it CAT II compliant.

- An integrated current weather instrument system was installed at Juhu airport, Mumbai and newly designed Distant Indicating Wind Equipments were installed at six airports namely: Jamshedpur, Bairagarh, Coimbatore, Barapani, Mangalore and Hyderabad.

- International Civil Aviation Organisation (ICAO)s Universal Safety Oversight Audit of the meteorological facilities at airports was conducted for the first time in India during 10 -19 October 2006. The audit showed that services provided by IMD adequately comply with Standard and Recommended Practices (SARPs) of ICAO.

- A *Manual on Meteorological services of Aviation in India*, 3rd edition-2006 was prepared and supplied to all departmental and extra departmental offices.

- Ministry of Earth Sciences constituted a Committee for "Augmentation of Meteorological Services at Airports" which submitted its report during the year.

Flood Meteorological Services

IMD has 10 Flood Met. Offices, located at Ahmedabad, Asansol, Agra, Bhubaneswar, Guwahati, Hyderabad, Jalpaiguri, Lucknow, New Delhi and Patna in the flood-prone areas. These offices issued warnings and provided data services to Central Water Commission for flood forecasting purposes for river catchments of Yamuna, Chambal, Betwa, Narmada, Tapi, Mahi, Sabarmati, Banas, Deman Ganga, Ajoy, Mayuraksi and Kangsabati, Mahanadi Brahmani, Baiterini, Bruhabalang, Subernarekha, Rushkulya, Vansdhara, Brahmaputra, Barak, Godawar, Krishna, Teesta, Sahibi, Kosi, Mahananda, Baghmati, Kamla, Gandak, Buri Gandak, Northkoel, Kanhar, Pun Pun, Sone, Ganga, Ramganga, Gomti Sai, Tapti, Ghagra, Sarada. During the flood season each FMO provided hydromet bulletins on a daily basis containing the following information:

- Prevailing Synoptic situation.
- Heavy Rainfall Warning.
- Quantitative Precipitation Forecast (QPE) catchment-wise /sub-catchment-wise.

World Bank-Funded Hydrology Project

Cabinet Committee on Economic Affairs approved the Hydrology Project Phase II for extending the infrastructure created in Phase I for Peninsular States to the northern states of India. The project commenced on 5th April 2006. It is planned to be implemented over a period of six years and the target date of completion is 2011. Under this programme IMD will set up networking and data processing facilities to compile the entire data from rain guages under State Government and produce near real time reports of rainfall anomalies.

13.2 Specialized Services

Earthquake Monitoring

- India Meteorological Department (IMD), as per its mandate, maintained the National Seismological Network for keeping a round-the-clock vigil on seismic activity occurring in

and around the country. Information pertaining to significant earthquake activity was disseminated to various agencies including Ministry of Home Affairs for initiating necessary disaster management-related actions.

- The great Pakistan earthquake of 8th October 2005 and its aftershock activity were monitored on a continuous basis by IMD. The aftershock activity of the great Sumatra earthquake of 26th December 2004, which led to the Tsunamis on the Indian coasts are being monitored by India Meteorological Department (IMD) on a continual basis. Information related to aftershock activity of magnitude of 5.0 or higher is transmitted to Ministry of Home Affairs (MHA) and other Government agencies related with disaster management.

- IMD has set up a network of five temporary seismological observatories for precise monitoring of aftershock activity in the Andaman & Nicobar island region.

- As part of the Early Warning System for Tsunamis and Storm Surges in the Indian Ocean region being set up by Government of India, IMD is setting up a Real Time Seismic Monitoring Network consisting of 17 stations.

- A joint proposal for bilateral collaboration with Iceland on "Earthquake Prediction Research" has been prepared by IMD, which is under consideration.

- IMD is in the process of working out a mechanism for archival and vector digitisation of all its analog seismograms.

- IMD has initiated actions for upgradation of 20 existing seismological observatories and establishing 20 new seismological observatories as part of a project for strengthening and upgrading the national seismological network. Site preparation work is in progress.

Environmental Monitoring

Air Pollution

- IMD set up a Background Air Pollution Monitoring Network (BAPMoN) programme in 1972 with the objective of documenting the long-term changes in composition of trace species

of the atmosphere. The activity was brought under the Global Atmosphere Watch Programme of WMO in 1989. The monitoring stations located at Allahabad, Jodhpur, Kodaikanal, Minicoy, Mohanbari, Nagpur, Port Blair, Pune, Srinagar and Vishakhapatnam continued to collect rain samples for chemical analyses and measurement of atmospheric turbidity. The data has been useful in delineating trends of rainwater acidification over the country.

- The modernisation of Air Pollution Laboratory was completed in 2006 to enable it to extend and improve its analytical capabilities.

Environmental Monitoring Unit

Environmental Management is the key to sustainable development. Estimation of pollutant dispersal in the atmosphere is important for air shed management of large industrial areas. The Environmental Meteorology Unit (EMU) has evaluated 644 major projects covering Industrial, Thermal Power and Mining activity during this year to advise the Ministry of Environment and Forests on grant of clearance for the respective projects.

Industrial Projects

1.	Metallurgical	-	40
2.	Agro chemicals	-	7
3.	Pharmaceuticals	-	70
4.	Petroleum	-	50
5.	Cements Plants	-	8
6.	Distillery	-	20
7.	Miscellaneous	-	20

Thermal Power Projects:

1.	Coal-based	-	62
2.	Naphtha based	-	30
3.	Diesel-based plant	-	20
4.	Natural gas	-	40

Mining Projects

1.	Lime stone	-	75
2.	Chromite	-	15

3.	China clay & Quartz	-	15
4.	Iron Ore	-	80
5.	Aluminums Laterite mineral	-	07
6.	Bauxite	-	37
7.	Gypsum	-	20
8.	Silica sand	-	28

Meteorological Monitoring at Taj Mahal

Regular monitoring of micro-meteorological parameters has been carried out at Meteorological observatory, Taj Mahal, Agra (U.P.) and the Annual Reports entitled "Meteorological Conditions at Taj Mahal, Agra" for the years 2005 and 2006 have been prepared and sent to Central Pollution Control Board (CPCB) and Ministry of Environment & Forests, New Delhi for appraisal of pollution status around the Taj.

Climate-Related Environment Monitoring (CREM)

IMD has initiated implementation of CREM, a multi-agency project for monitoring the Green House Gases (GHGs) and aerosols on a long-term basis. Such data are of vital interest to our country with regard to climate change policy formulation.

Initially, a Pilot Project CREM is being implemented. A device called Sky radiometer for monitoring of aerosols has already been installed at Delhi and the observatory at Hill Campus, G.B. Pant University of Agriculture & Technology at Ranichauri, in Uttaranchal has been built this year. The sky radiometer is the first operational system of its kind in India with capability of computing aerosol radiative forcing. It has yielded useful insights into the Brown Cloud phenomenon of the region.

Sky radiometer installed to monitor the impact of atmospheric aerosol on Radiation balance.

Ozone Monitoring

The importance of Ozone as an environmental parameter stems from the fact that several industrial substances are considered to be destroyers of the natural ozone layer in the stratosphere thus enabling

higher dosages of Ultra violet radiation penetrating to the ground to the serious detriment of health factors. The global network of Total column ozone measurements has come up since late 1950s and India has been a pioneering country in this regard.

- Total ozone – the integrated amount of ozone over any vertical column and UV irradiation were regularly monitored using Dobson Spectrophotometer and Brewer Ozone Spectrophotometers at Delhi, Varanasi, Pune, Kodaikanal and Maitri (Antarctica)

- The Dobson Spectrophotometer no.112 has been converted to the NATIONAL STANDARD and was globally intercompared in Japan in 2006 (accuracy ±0.1%). The past intercomparisons were done in 1996, 1984, 1977 and 1974.

- Vertical distribution of ozone in the atmosphere continued to be regularly measured by ozone sondes once every fortnight from Delhi, Pune, Thiruvananthapuram and Maitri (Antarctica). The data is used for studying mechanisms of vertical movement of stratospheric ozone.

- Surface Ozone, which is an air pollutant, was measured continuously from Srinagar, Delhi, Nagpur, Kodaikanal, Thiruvananthapuram, Port Blair and Maitri (Antarctica).

Climate Change Impacts

A significant contribution in the area of climate change impact assessments was made by IMD by focusing for the first time on the future status of monsoon circulation caused by a credible climate change scenario for the country. The model results for the Hadley Centre Regional Model 2 are widely accepted as the best results, as yet, in simulating conditions over the Indian region. These results were probed to reveal the identifiable features of the monsoon circulation which are currently associated with rainfall activity over India. The findings indicate minor but perceptible shifts in monsoon trough positions and strength of monsoon flow. The findings have to be corroborated against newer models seeking to include effects of aerosols in addition to Greenhouse Gases.

Meteorological support to Agriculture

- IMD continued to render Agromet Advisory Services to the State Governments and farmers by issuing Weekly / biweekly bulletins prepared jointly with State Agricultural Departments. These advisories were tailored to meet the requirements of farmers based on past and anticipated weather conditions and were broadcast by AIR stations in the respective regions

in regional languages and also telecast through DD wherever the facilities exist. Significant agronomic and logistic interventions intended for crop protection and growth are based on these advisories.

- Consolidated All India Agromet Advisory Bulletins were prepared by Indian Agromet Advisory Service Centre (IAASC), Pune and issued to Ministry of Agriculture and other users in the country to help policy decisions.

- The Agricultural Meteorology Division of IMD maintains a network of Agrometeorological Observatories across the country in collaboration with the Agricultural Universities and Research Institutions. The Division provided comprehensive technical assistance to its own observatory units and those of cooperating institutions by way of training, calibration and maintenance of instruments, scrutiny and archival of data etc.

- Processed agro-climatic data were supplied to end users like Ministry of Agriculture, State Departments of Agriculture, Scientists of Agricultural Universities / Institutes for planning agricultural strategy and research work.

- As a part of ongoing activity Crop Weather Calendars for crops in the state of Madhya Pradesh were prepared this year. These calendars depict the state and stage of crop under normal weather conditions and warnings that should be issued under specific situations. They also identify crop vulnerabilities at various growth stages.

- Special forecast of rainfall and upper wind are given for Rajasthan and adjoining areas during swarm incidence for anti-locust operations to be adopted by the Directorate of Plant Protection, Quarantine and Storage, Ministry of Agriculture, Govternment. of India. For this purpose a special observatory network of 7 pilot balloon and micro-met stations continued to function in West Rajasthan.

- Analysis of heavy rainfall over the dry farming tract of the country was done for proper selection of crops and strategic planning of agricultural operations.

- Soil moisture data were recorded at the Departmental evapotranspiration stations and soil moisture recording stations for the benefit of research workers in various fields of agriculture, irrigation management etc.

- Inter-relation between crop pests and diseases and concurrent weather parameters was studied in collaboration with 14 Agricultural Universities / Research Institutes for forewarning their outbreaks / spread on the basis of forecast weather parameters on operational mode continued.

- Likely places for onset of epidemics of different major crop pests and diseases were delineated so that warning against their outbreak and also subsequent control measure could be adopted on time.

- Comprehensive All India Agromet Advisory Service Bulletin - Weekly comprehensive All India Agromet Advisory Service Bulletins were prepared and issued to the Director of Agriculture of 23 states of the country. All India Agromet Advisory Service Bulletins were also issued to all Government functionaries and Ministries.

13.3 Deployment of State of The Art Technology

Meteorological observations have undergone profound changes in terms of sensitivity and data handling with new electronic sensors and devices coming of age. There has been a paradigm shift in sampling the atmospheric space time continuum from ground - and space-based remote sensors. Thus, infrastructural modernisation in IMD has largely been that of observational systems. A major process has been initiated this year to continue in a phased manner by integrating every new acquisition with the overall forecast delivery system.

Automatic Weather Stations

The need to supplement manned weather observatories with automated devices has been felt acutely for some time now, because of pressing demands from high resolution numerical models used in forecasting. IMD took up a major project to replace its first generation of automatic data collection platforms and to extend the network further. It has procured 125 new state-of-the-art Automatic Weather Stations (AWS) during 2006-07 out of which 48 AWS systems have been installed till December 2006. The data from AWS are transmitted to the Receiving Earth Station at Pune *via* satellite. Arrangements have been made to upload the data to the Global Telecommunication System of World Meteorological Organization so as to reach all national and global users. Quality of AWS data is presently under evaluation before it is rendered open for operational use.

Weather Radars

Doppler Radars have an advantage over the conventional ones in that they give additional information on winds. This helps to gauge the intensity of the weather system and its damage potential. Moreover

the data being of digital type can be directly accessed and assimilated in Forecast models thereby enhancing their accuracies. Doppler Weather Radars in IMD have already demonstrated their usefulness in predicting storms.

One S-Band Doppler Weather Radar (Meteor 1500S) imported from Germany was commissioned at Visakhapatnam adding on to the already existing network of Radars at Chennai, Kolkata and Machilipatnam. Web-based dissemination of Doppler Weather Radar products from all four stations has been started.

Satellite Application

The IMD continued to process data from INSAT and Kalpana satellites for improving early warning of Cyclonic storms that originate over sea areas and derive products that are usable in Flood Warning and monitoring of high impact weather events. Such data is regularly put up on the IMD Website. IMD has now put new thrust in using space platforms for metrological communication and in the upcoming INSAT 3D satellite for deriving a large number of new parameters.

- IMD has signed an MOU with ISRO, Antrix Corporation Bangalore, for the establishment of new ground segment facilities to receive and process data from INSAT-3D. This will consist of establishment of an Earth Station & Data Reception and processing computer systems through M/s Antrix Corporation and ISRO, Bangalore.

- Satellite Meteorology Division is in the process of installing 5 GPS receivers for the measurement of Total Precipitable Water Vapour (TPWV) at 5 locations (Delhi, Kolkata, Chennai, Mumbai and Guwahati). The installation and commissioning is expected to be completed soon.

- A new scheme called Digital Met Data Dissemination (DMDD) is in the process of implementation by the Satellite Meteorology Division under which an uplink station at Delhi and about 40 DMDD Receivers shall be deployed all over India and in SAARC countries for the dissemination of cloud imageries and meteorological data in LRIT/HRIT formats. It will replace the Analog MDD with Digital satellite data broadcast using C x S band transponders of INSAT-3C. The system is expected to be commissioned by middle of 2007.

- A scheme for 500 Automatic Rain gauge Stations (ARS) relaying data through INSAT DRT is in an advanced stage of implementation. The data flow will be managed in the same way as the AWS from the Earth Station at Pune.

Radiation Measurements

Solar radiation is a source of non conventional energy. It is the prime driver of atmospheric motions. It is also the source of harmful radiation like the ultraviolet. A major initiative has been taken in IMD to strengthen and diversify its existing Radiation Network.

- State-of-the-art instruments have been procured to augment existing Radiation and Aerosol Monitoring Networks and improve their performance.

- Ultraviolet Radiation reaching the ground which is known to cause skin cancer is likely to increase if there is further stratospheric ozone depletion. Monitoring of such radiation has now been taken up across the country from a large number of stations.

- A project on "Revision of Handbook of Solar Radiation data for India" is now in its final stage of completion.

Telecommunication Support

Telecommunication has played a vital role in delivering services to both end users as well as service producers requiring observational inputs. The following systems are being commissioned to provide better integrated services:

- Interactive Voice Response System is being set up at 26 locations, where users can get weather information through telephone.

- High Speed (64 Kbps) data terminals and VSAT stations are being installed at 27 stations, and also for the benefit of Indian Air Force.

- Upgradation of Regional Telecommunication Hub at New Delhi is being carried out to handle higher data loads and better data processing.

- Replacement of Automatic Message Switching System (AMSS) at Guwahati and new AMSS at Nagpur have been taken up to enhance capacity of data exchange between various forecasting stations.

13.4 New Technology Development

Radio sonde Sensors

The radio sonde is a balloon payload capable of observing meteorological parameters in the upper air and transmitting them to ground. The existing analogue radio sonde which has a mechanical pressure sensor has been replaced by an imported solid state pressure sensor in a successfully tried prototype model in 2006. The new equipment is currently under field trials. The performance of upper air sounding equipment is significantly improved as a result of this.

IMD is engaged in development of new digital Radio sonde having indigenously manufactured sensors for self sufficiency in this area of critical technology. IMD finally wants to induct the indigenous digital sonde into its operational network.

Satellite Data assimilation

Normally, Satellite data is used in the form of images to identify weather systems. But, this data can also be used in digital form and assimilated into numerical weather prediction models. After the Kalpana satellite was launched in September 2002 its data was used to derive winds in the upper air. In 2006 operational forecasting models were modified to assimilate these winds and issue forecasts on a regular basis. The performance of these models have considerably improved as a result of this. (*Roybhowmic. et.al., 2006, MAUSAM 57,3, 419-430).*

Multi ensemble modeling

Shortcomings of individual numerical weather prediction models can be overcome by clubbing together outputs from a family of models thereby improving the overall accuracy. A 4 member multi model ensemble technique has been developed and tested in the year 2006 for rainfall prediction in the short range time scale (1-3 days). This method will be operationally inducted during monsoon 2007.

A new value added dynamical system for District level Rain fall forecast in short range time scale has been developed. Further work is in progress to refine the value addition techniques. (*Lal et. al. 2006, MAUSAM, 57,2, 209-220 & Singh et.al 2007, MAUSAM, 58,1,1-8)*

Numerical Weather Prediction

The operational Limited Area Model of IMD covering the Region of its forecast domain was improved in terms of spatial resolution from 75 km to 50 km. The model was delinked from the T80 Model of NCMRWF and linked to the NCEP GFS - available freely on the internet at higher resolution. The trial runs conducted during monsoon 2006 have demonstrated mark able improvement in the forecasts. It will be implemented on routine basis from monsoon 2007. In similar manner the Cyclone track prediction model of IMD was also delinked from T 80 and run with the inputs from NCEP. The track prediction was demonstratably improved by this.

13.5 Other Activities

Antarctic Scientific Programme

- IMD is maintaing a Metrological Observatory at Matri, Antarctica. Automatic Weather Station has been sent to Antarctica with the 26th Indian Antarctic expedition.

- Short period climatology of Maitri has been published (Lal, 2006 MAUSAM, 57, 4, 684-688).

- Two IMD team members of 24th Indian Antarctic Expedition to Antarctica have returned to India on 18th March 2006 after successful completion of the meteorological work at Maitri (Antarctica). Two IMD team members for 25th IAE are working at Maitri (Antarctica) and will stay there up to March 2007.

- A two-member IMD team is participating in the 26th Antarctic Expedition.

- One IMD scientist deputed to participate in Special Expedition to Southern Ocean to Larsemann Hills, Antarctica (Third site station) has returned to India in April 2006 after successful completion of the meteorological proramme.

Ocean Research Cruise

IMD participated in 2 ORV Sagar Kanya Cruises under Integrated Campaign For Aerosols, Gases And Radiation Budget (ICARB). The ICARB programme was conducted by ISRO in two spells.

The first spell of ORV Sagar Kanya Cruise No. SK223A was launched during March April 2006 and second spell of ORV Sagar Kanya cruise No. SK223B took place during April May 2006. The area of operation is Arabian Sea and Bay of Bengal.

Marine Meteorology

Marine Section of IMD Pune coordinates data collection from Voluntary Observing Fleet, through its six Port Meteorological Offices at Kolkata, Visakhapatnam, Chennai, Kochi, Goa and Mumbai. Ships of Merchant Navy, Indian Navy and Foreign Navy are recruited in IVOF. Meteorological Observations from ocean area are collected on real time basis for operational forecasting and the scrutinised data is archived for climatological purpose.

- Under VOSCLIM Project of WMO, Marine Section has recruited the services from 20 ships of Indian origin to participate in the above Programme to collect quality data on High Seas and transmit them on real time basis.

- Excellent Awards in the form of books and Certificate of Merit were given to ships' officers, for their meritorious meteorological work, who were involved in collecting routine and other valuable Meteorological information from High Seas.

- For providing Met. Services and safeguard shipping industries on high seas, IMD has recruited over 185 Voluntary Observing Ships (VOS), which take meteorological observations and transmit to IMD and the coastal radio stations on real time basis as well as in delayed mode.

- TURBOWIN software have been installed at many ships (25 Nos.) for automation of synoptic observation and reporting.

Positional Astronomy Centre

The objective of the centre is to generate accurate data on positional astronomy of celestial bodies i.e. positions of the Sun, Moon, Planets, Bright Stars etc and to provide a unified National calendar, both for civil as well as religious purposes in order to unify various divergent practices of Calendar making.

In order to meet the above objectives, the centre published the following.

- *Indian Astronomical Ephemeris* which provides authentic data on celestial objects for academicians, research scholars and scientists in the filed of astronomy and astrophysics.
- *Rashtriya Panchang* in 14 languages which also provides authentic data of Panchang elements, calculated on the basis of science of astronomy.
- *Tables of Sunrise-Sunset and Moonrise-Moonset*.

The Centre also supplied lunar data for prediction of tides for Survey of India, Sun-Moon rise/set data for a large number of places for newspapers, judiciary, religious bodies, defence and scientific bodies, eclipse phenomena for scientific researchers and general public etc. The centre also acted as national agency for determination of dates of festivals of all communities in India, sufficiently in advance, for declaration of official holidays.

The centre also contributed in popularising astronomy by displaying Star-Charts, Astronomical Bulletins, information on panchang matters and current astronomical events etc. on website. The centre also organised sky viewing programme through telescopes, delivered popular lectures in astronomy in different institutions and published popular articles on astronomy.

A few significant tasks have been recently accomplished.

- **Implementation of Nirayana calendar in Rashtriya Panchang**

  As per recommendation in the final report of Peer Review Committee, a separate all India Nirayana Calendar based on Kali Era has been compiled and recently introduced in Rashtriya Panchang.

- **Indigenization in computation of planetary positions for Indian Astronomical Ephemeris:**

  Most of the data for the publication are being generated indigenously and relevant computer programmes have been developed accordingly.

National Data Centre

As a custodian of all meteorological data collected at different stations of the country, National Data Centre (NDC) processes and archives data in standard format. The total holding of metrological data in the archives as of date is 100.5 million records.

NDC received a large number of queries and requests for data supply from numerous parties that included Government, private institutions, industries, research and operational users. On receipt of

requests, the required data were retrieved from the computer archives, within a short time and supplied to the users on floppies, cartridges, CDs, magnetic tapes or in printout forms in the desired formats. During the year 2006, 268 million records were retrieved and supplied till date to more than 700 users as shown below in the tabular form.

Collection of revenue from data sales proceeds amounted to Rs.1.17 crores.

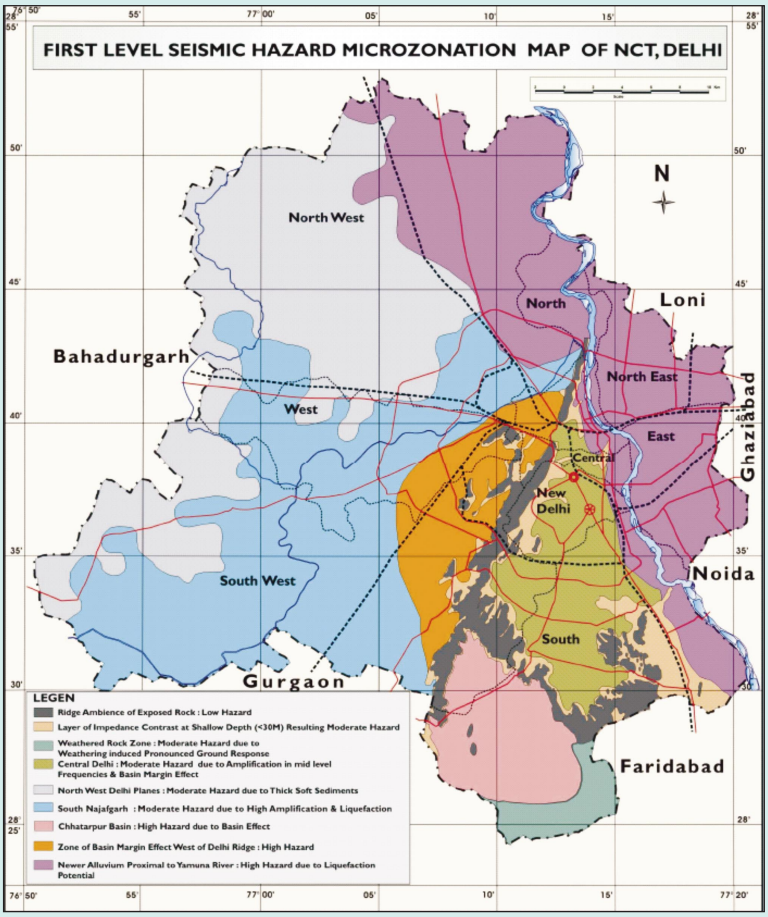
13.6 Application of Technology to Socio-economic Development

Earthquake Risk Evaluation

Earthquake Risk Evaluation Center (EREC), India Meteorological Department (IMD), has been setup with the objective of Earthquake Risk Evaluation in national perspective to generate, archive and disseminate input data to user agencies for disaster mitigation planning. In this context, EREC has drawn proposal for multi-disciplinary studies on seismic microzonation of cities of the country having more than half million population and falling in seismic zones III, IV and V identified by Ministry of Home Affairs. EREC has also taken up initiative to closely monitor seismic activity by deploying short aperture telemetry network. The VSAT-based seismic telemetry in and around Delhi is being augmented and another is being established in northeast India. Also, Micro Earthquake Surveys by deploying local temporary field stations are being undertaken for the study of local seismicity during sudden rise in seismic activity as and when required.

Seismic Microzonation of NCT Delhi

Fifteen multi-thematic maps pertaining to 'Geoscientific', 'Geotechnical' and 'Site-Response' characterisations have been generated and integrated into first level seismic microzonation map of NCT Delhi on 1:50,000 scale categorising by three levels of hazard (Low, Moderate and High). These three hazard zones of NCT Delhi have further been sub-divided into nine units *viz.* (i) Ridge ambience of exposed rock: low hazard, (ii) Layer of impedance contrast at shallow depth (<30 m): moderate hazard, (iii) Weathered rock zone: moderate hazard, (iv) Chhattarpur Basin area: high hazard due to anticipated Basin effect, (v) Central Delhi area: moderate hazard due to site amplification in mid frequency level and Basin margin effect, (vi) Northwest Delhi plains (Bangar): moderate hazard due to thick soft soil strata, (vii) South Najafgarh sedimentary fill area (Dabar): moderate hazard due to high ground amplification and liquefaction, (viii) Zone of Basin margin effect in the western part of Delhi ridge: high hazard, (ix) Newer alluvium proximal to Yamuna river: high hazard due to liquefaction potential.



First level Seismic Hazard Map of Delhi

Seismic Microzonation studies of NCT Delhi with higher precision on 1:10,000 scales have now been initiated for actual societal use. This would provide attributes of hazard for all microzones with site-specific details. The 'Hazard' would be integrated with results of collateral studies on 'Vulnerability Analysis' for final risk evaluation. In this regard several meetings, interactions, discussions and field survey have been undertaken with collaborative agencies such as SOI, GSI, CGWB, CSMRA etc. and following products have been generated and initiated, which are in progress.

- A base map of NCT Delhi that consists of 75 Nos. Toposheets on 1:10,000 scale, have been generated by Survey Of India and provided to EREC and GSI.

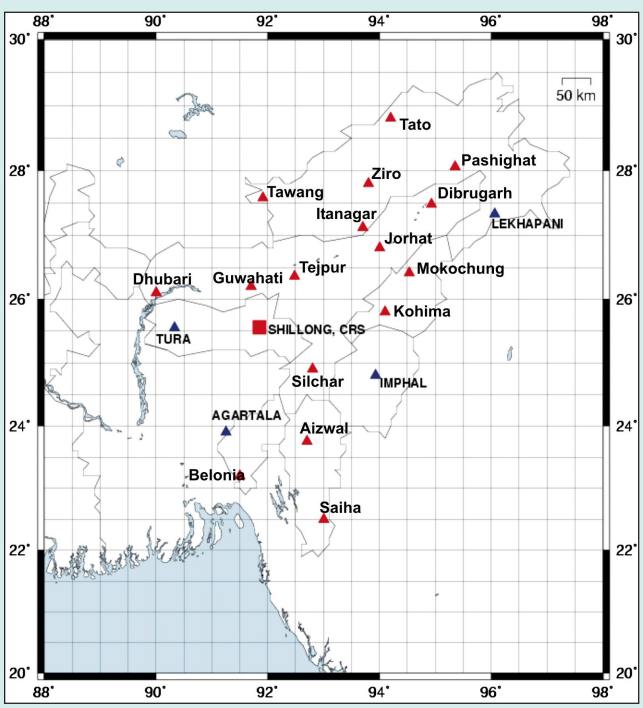
- A pilot project in collaboration with GSI was undertaken to develop a 1:10,000 scale geological map of North Delhi encompassing 360 sqkm areas, which is almost at the completion stage. To generate this map Quickbird satellite imageries procured through

National Remote Sensing Agency (NRSA) were used initially for developing photo interpretative geological map. Further, these maps are used for field checks and finalisation of Geological Map.

- During the process of field survey by GSI and EREC officials for preparation of geological map, several soil samples at different geological domain have been collected and are in process of Laboratory Testing in collaboration with CSMRS.
- Quickbird satellite imageries for the rest of NCT Delhi are being procured through NRSA, Hyderabad for generating photo interpretative geological map for further validation with field survey in collaboration with GSI.
- Geo-technical investigations at about 550 sites in NCT Delhi are in process. A pilot project in this regard for exploratory drilling of boreholes at 10 different sites in north Delhi to investigate the sub-surface geotechnical and geological parameters is expected to start shortly.
- Study on bedrock level Peak Ground Acceleration (PGA) for NCT Delhi at 10% and 20% exceedence for 50 years has been completed. Another study on Basin effect and Basin Margin effect in Chhatarpur Basin, Delhi is in the process.

VSAT-based Seismic Telemetry Network in North East India

A project of establishment of a VSAT-based seismic telemetry network of 20 field stations is under process. The four existing IMD observatories at Agartala, Imphal, Lekhapani and Tura will also be upgraded and form a part of the proposed network. A Central Receiving Station will be established at Shillong to receive and process the data from these observatories in near real time. The data generated by this network will improve our knowledge about seismicity of northeast India. It will be useful for precursory studies of earthquakes, seismic site response studies, attenuation characteristics, engineering practices and risk evaluation and hazard mapping-related issues. Site identification, site selection and preparation are in progress with



Proposed NE Telemetry Network

close interaction with respective State Government officials. The project is expected to be completed by June 2007.

Augmentation of VSAT-based Seismic Telemetry Network in and around Delhi

A 16 element-VSAT-based seismic telemetry network was installed in and around Delhi in 2000-01 for monitoring seismic activity in the region. This network has proved to be very useful in monitoring the local seismic activity of the region as well as augmenting seismic monitoring of the country. The data generated by this network are also being used in updation of seismotectonics map pertaining to the seismic microzonation study of NCT Delhi. The analysis of the data acquired reveals that focal depth of the earthquakes are of the order of 10-25 km. However, for accurate delineation of hypocentral parameters, augmentation of this network has been undertaken by establishment of nine more stations in this network. The new sites have been identified in coordination with state and central government agencies.

Seismic Micro Earthquake Survey in Andaman & Nicobar Region

After occurrence of Great Sumatra earthquake on 26 December 2004, a temporary field observatory network of five digital seismographs has been deployed at Polytechnic College, Port Blair, Baratang, Havelock, Hutbay and Campbell Bay in the Andaman Nicobar region. This network is still in the operation and generating useful seismic data. The data generated by the network is being analysed to understand rupture processes and seismicity of the region.

Human Resource Development

Meteorological services being of specialised nature, proper training of officers and staff of India Meteorological Department and human recourses development is very essential. The general requirement of training is being met by the department itself. The Central Training Institute, Pune provides training facilities in General Meteorology, Meteorological Instruments, Meteorological Telecommunications and Agricultural Meteorology. These are open not only to department personnel but also to the officers of other departments, Defense services, and to the candidates from foreign countries. The training facilities of India Meteorological Department in Pune and New Delhi is designated as WMO Regional Meteorological Training Center (RMTC) for Regional Association II.

Under the joint Government of India - US AID collaborative project on Climate Forecasting System 11 young Scientists of IMD have been trained in USA in different component areas of numerical

weather prediction. A total of 15 scientists would be covered in this programme. The collaboration includes transfer of technology related to advanced modeling and data assimilation.

Scientific Publications and Research support

- A high resolution gridded daily rainfall data set for the Indian region for the period 1901-2003 was developed by the National Climate Centre which evoked a good response from the scientific community because of its immense value in model validation and planning and policy matters. Many institutes (more than 60) in India and abroad have obtained the data set from IMD for their research work.

- A Report entitled ‘ Probable maximum Storm Surge Heights for the Maritime Districts of Inda” has been published as a Met Monograph (*Kalsi et al 2007, Met Monograph, IMD*)

- Publication of monthly and seasonal *Climate Diagnostics Bulletins* was continued. As in the previous years, *Annual Climate Summary for 2006* was published.

- The International Quarterly Research Journal of IMD named Mausam continued to be published from New Delhi.

- IMD prepares climatological summaries for specific users requirements and issues them in the form of publications. It caters to the needs of various projects undertaken by agriculture, aviation, energy, industry and other sectors, both Governmental and Non-Governmental organisations. It also prepares/updates and supplies the district climatological summaries of the states as and when required by State Editor, District Gazetteers Unit and also supplies to the parties on demand, on payment basis. Such activity was continued in 2006.

- Work on the content of *Disastrous Weather Events 2004* has been completed and the publication is ready for public issue.

- Research projects covering various areas of activity were awarded to different Regional Centres and Meteorological Centres. Eithteen such projects were completed last year.

- New major project proposals received from other scientific agencies such as DST, CSIR,

IITs etc. in the area of atmospheric sciences have been evaluated and accordingly recommended to the concerned authorities.

- More than 70 Research Papers were published by IMD scientists in National and International Journals.

13.7 Infrastructure Development

- Relocation of Pusad observatory to an alternative site at Washim and started functioning from 12th January 2006.

- Establishment of Meteorological Centre at Itanagar and started functioning from January 2006.

- Upgradation of Part Time Observetory Gulbarga into a class I observatory with effect from 1st Sept 2006.

- Construction of PAC building at Saltlake, Kolkata is in steady progress and expected to be completed next year.

- Additional 2.0 acres of Revenue land at the total cost of Rs.44.00 lakh at Mangalore was procured on 16 May 2006 for relocation/construction of RS/RW building and staff quarters at new site at Sakthi Nagar Mangalore.

- 2.0 acres of land at M.O. Honavar at the cost of Rs.7.04 lakh towards net present value was procured on 18 May 2006 on lease basis from forest department for construction of observatory buildings and staff quarters.

13.8 Important Events Held During The Year

- An International workshop on "Agrometeorological Risk Management- Challenges & Opportunities" was organised by IMD and World Meteorological Organisation from 25th to 27th Oct 2006 at Vigyan Bhavan, New Delhi.

- 14th Session of WMO Commission for Agricultural Meteorology from 28th Oct to 3rd Nov 2006 was held at Vigyan Bhavan, New Delhi.

- A two-day Workshop-cum-Seminar on "Communicating Meteorology" was conducted jointly by IMD and the Centre for Environmental Education (CEE) at the Central Training Institute, Pashan and Pune.

- IMD organised a workshop on "Improving Agro Advisory Services" during 19th - 20th June 2006, at Pune.

- IMD organised a National Seminar on "Agrometeorological Services for Crop and Location-Specific Advisories" during 21st - 22nd June 2006 at Pune.

- As part of the activities of the Indo-Russian Centre for Earthquake Research (IRCER), a joint Indo-Russian workshop was organised by DST at Moscow October 2006, where in the progress of the ongoing projects reviewed and several new projects formulated for implementation by the Centre. The joint workshop was attended by four officers from IMD.

14. National Centre for Medium Range Weather Forecasting

Numerical, weather forecast models of high resolution have proved to be viable tools for the production of weather forecasts in the medium range time scale (3-10 days in advance). Since inception, NCMRWF has been working on development of such models and data assimilation techniques to provide meteorological forecasts for agro-advisory purposes and other applications.

14.1 Research and Development

- The Weather Research & Forecast Model (WRF) with 3DVAR assimilation system had been ported and operationally implemented on C-DAC PARAM PADMA System at NCMRWF. A report on the operational implementation of this mesoscale model on the PARAM PADMA super computer is prepared and submitted. The report also gives the details on the current status and suitability of the current set up for operational and research activities.

- Post-processing package for WRF model has been developed and ported to PARAM PADMA, CRAYX1E and Linux computer systems. Documented the "RIX (Read, Interpolate and eXtract) User Guide - A utility program to create geolocated WRF model output on isobaric surfaces.

- Using Reynold's observed SST, 45-day forecast runs for the years 2004 and 2005 were completed to update the predicted rainfall climatology of T80 GCM from 5 years to 7 years for the months of June and July.

- Extended Range Monsoon Predictions were made on monthly basis during monsoon 2006 using 16-member ensemble and forecasts were sent to IMD Delhi, IMD Pune and SAC, Ahmedabad.

- Downloading of QSCAT wind data from KNMI site has started operations since March 2006, and implemented in operational suite on examining the feasibility of its utilisation in operational mode.

- A study was carried out using the latest version of NCEP Regional Spectral Model (RSM97) nested to operational T80L18 global spectral model during Monsoon 2005. Spatial distribution of monthly rainfall especially associated with the orography was resolved better in RSM compared to T80 global model.

- A statistical analysis of the daily rainfall data for the 10 stations for the whole monsoon period was carried out to get about 10 Yes/No (dichotomous) verification scores to summarise into single figures. These statistically significant numbers showed better skill for RSM in comparison to the direct model output from T80 global model throughout the medium range.

- Fortran code is developed for running the NCEP community Noah Land Surface Model (LSM) on 1×1 global scale in standalone mode and tested successfully on Cray SV1. The model had been physically initialized for 1×1 deg global grid and run experimentally daily for May and June 2006.

- The T80L18 and T170L28 model have been ported on Cray X1E system.

- The regional spectral model (RSM97) model and postprocessors have been ported on CRAY X1E system.

- The analysis-forecast datasets have been prepared for the compilation of 'Monsoon-2006 report on performance of NCMRWF global analysis-forecasts system'. The Report will be brought out by December 2006 in printed form.

- Currently the 3-D and 4-D variational analysis schemes at many operational centres work in the spectral space. At NCEP, a global 3DVAR analysis scheme has been constructed in model grid space that is as effective as 3DVAR in spectral space. This formulation allows greater flexibility for background error statistics. Work has been initiated on the implementation of the NCEP's Grid Point Statistical Interpolation (GSI) code at NCMRWF.

- Quantitative precipitation estimate from KALPANA-1 satellite has been compared with METEOSAT-5 product. Rainfall analysis algorithm for "large scale observed rain data preparation" has been tested by merging gauge and KALPANA-1 satellite estimates.

- Data packing and preprocessor for T170L42 were developed and implemented on CRAYX1E. Post-processing for the same was ported on PARAM PADMA. The test runs for the complete suite were started since 18 September 2006.

- Developed and installed the post-processor and operational plotting packages in PARAM PADMA system for T170L42 benchmark version.

- Workshops / Brainstorming sessions organised.

- A national seminar on "Agromet Advisory service to ensure food security in the NE Region" was organised by ICAR Research Centre, Tripura in association with NCMRWF during 7-8 February 2006.

- Sponsored a short course on the "Role of Weatherbased Agro-Advisories in minimising Climate risk in Rainfed Agriculture" organised by Department of Physics and Agro-meteorology, College of Agricultural Engineering JNKVV, Jabalpur (M.P).

14.2 Scientific Services

Issue of weather forecast to Agromet Advisory Service (AAS) Units

Daily forecasts with a temporal range of 4 days were issued for weather parameters such as cloud cover, maximum and minimum temperatures, wind speed and direction and rainfall to 107 Agromet Advisory Units twice a week. In addition, weekly cumulative rainfall forecast were also supplied to crop weather watch groups.

Feed to the Ministry of Agriculture

All India weekly weather forecasts were supplied to crop weather watch group, Department of Agriculture and Co-operation, Ministry of Agriculture on every Monday. Review of weather vis-à-vis different crop situations all over country during the previous week and fore-view of weather sensitive crop scenario for the forthcoming week were facilitated by the participation in the group discussions every Monday at the Ministry of Agriculture.

Extensive Agro-advisory

An extensive agro-advisory covering all the agrometeorological zones of the country was prepared for the use of all the functional Agrometeorological Forecasting Units (AMFU) and all other user agencies. The agro-advisory explicitly included regional weather forecast in relation to all possible cropping patterns over different regions of the country. The bulletins were circulated to all the users during monsoon season.

Daily Weather Forecast

Daily weather forecast products from operational T80 global data assimilation and forecast system were provided to IMD, Indian Air Force, Directorate of Oceanography and Meteorology, Indian Navy, Indian Army and Snow and Avalanche Study Establishment of DRDO. Besides, daily forecast for strategic locations were also issued to Indian Army.

Feed for KISAN channel

The KISAN channel launched by Ministry of Agriculture and coordinated by IGNOU were provided with weeklong scenario on current weather situation, agro-climatic zone specific synoptic weather bulletin and all India consolidated agro-advisory. These weeklong forecasts were issued 4 times a week starting from Monday through Thursday.

Web Based Services

- The district level forecast system developed for about 440 stations over India has been linked to NCMRWF web page.

- Deterministic weather forecast for all district headquarters of India and implemented on operational basis. This service is not available for all stations currently.

- Information on detailed weather systems likely to prevail during the next 5 days including temperature and rainfall forecast for metropolitan cities has been started

Weather Forecast for Special Events

NCMRWF had received numerous requests for issue of weather forecast for special events of scientific and national importance. The highlights of weather forecast issued for such events include:

Mountain Expeditions

Weather guidance was provided on hourly winds, temperature and cloudiness at various levels of atmosphere for day and night ballooning expedition undertaken by Indian Army in March 2003. A

new record was achieved for longest duration low-level flight of balloon with an unpressurized enclosure. The balloon completed total flight duration of 17 and half hour and landed safely near Shivpuri in MP starting from Jaipur.

14.3 National Collaborations

- One-day meeting on review of existing/past collaborations and deciding the priorities of joint work with SAC/ISRO was organised at NCMRWF. Scientists from SAC/ISRO. Dr Navalgund, Head, SAC/ISRO, Ahmedabad attended the meeting.

- Various parameters required for global OSF are being generated operationally from T80 and T170 analysis and forecast system, and are being provided to A-OSF partners.

- NCMRWF T80 global model has been transferred and ported on CDAC's machine at Bangalore as a part of DST-sponsored project 'SPIM' intended to compare performance of different global models in assessing the Indian summer monsoon on a seasonal scale. Coordination work with CAOS, IISc Bangalore is continued on other aspects of the project. Under NCMRWF-IISc project SPIM A 156 days run (initial condition 26 April 2003) of T80/L18 model was completed for monsoon 2003 season, and the output rainfall data was transferred to IISc, Bangalore.

14.4 Training

Training Imparted

A 5-day course on the familiarisation of NWP products for IAF officers was organised from 11th to 15th September 2006 at NCMWRF.

Trainings Attended

Dr. Raghavendra Ashrit participated in the 8th International Winds Workshop at National Satellite Meteorological Centre (NSMC) of China Meteorological Administration (CMA), Beijing, China, during 24-28th April 2006. Also presented a paper entitled "Impact of Satellite winds on simulation of Tropical Cyclone over Indian Seas".

Smt. Munmun Dasgupta attended meteorological training Course on “Data Assimilation and Use of Satellite Data” at ECMWF, Reading (UK) during 22-31 March 2006.

During deputation to NCEP, USA for attending a Short-term Training on GFS (14 Aug-6 Oct), all components of GFS were tested and transferred to NCMRWF. Efforts are now going on to install the same GFS at NCMRWF.

15. Indian Institute of Tropical Meteorology (IITM), Pune

The Indian Institute of Tropical Meteorology (IITM) was separated from the India Meteorological Department in 1962 and established as a Centre for Research. It now functions as a National Centre for basic and applied research in Tropical Meteorology. Its primary functions are to promote, guide and conduct research in the field of Meteorology and Atmospheric Sciences, in all its aspects, with special reference to the tropics and sub-tropics.

Awards/Honours

The Shanti Swarup Bhatnagar (SSB) Award, the nation's most prestigious award of the Council of Scientific and Industrial Research (CSIR) for young scientists for the year 2006 has been conferred upon Dr. G. Beig of the Institute for his outstanding scientific contribution in the field of Earth, Atmosphere, Ocean and Planetary Sciences.

15.1 Ongoing Research Programmes

Predictability of Summer Monsoon

Monsoon predictability studies

The El Niño events with the warmest sea surface temperature (SST) anomalies in the central equatorial Pacific are more effective in focusing drought producing subsidence over India than events with the warmest SST in the eastern equatorial Pacific. The physical basis for such different impacts has been established using atmospheric general circulation model experiments forced with idealized tropical Pacific warming. These findings have significant implications for Indian monsoon forecasting (Krishna Kumar K. et al, Unraveling the mystery of Indian monsoon failure during El Niño, Science, 2006).

Prediction of duration of the Indian summer monsoon breaks

Prediction of duration of Indian summer monsoon breaks is highly desirable. It is required for planning water resource management, sowing and harvesting. Applicability of the recently discovered regime transition rules for the Lorenz model in predicting the duration of monsoon breaks has been explored. Using several indices of the observed summer monsoon intraseasonal oscillation (ISO), it has been shown that the peak anomaly in an active regime can be used as a predictor for the

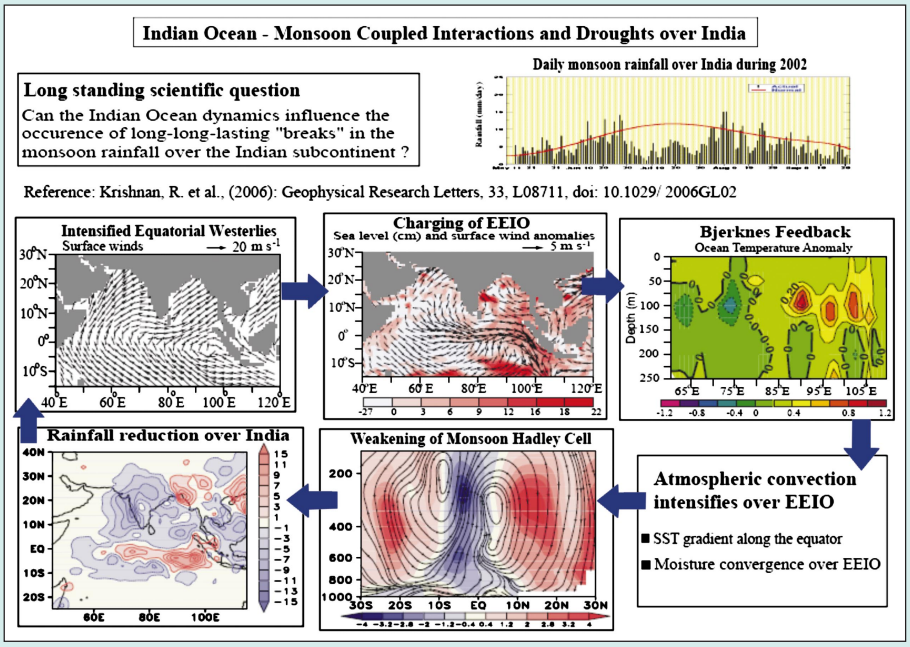
duration of the subsequent break spell. It has also been found that the average growth rate around the threshold to an active condition can be used as a predictor of the peak anomaly in the active spell. Average growth around the threshold to an active condition can give useful prediction of the duration of the following break, on an average, about 23 days in advance of its commencement (Dwivedi, Suneet; Mittal, Ashok Kumar; Goswami, B. N., An empirical rule for extended range prediction of duration of Indian summer monsoon breaks, Geophy. Res. Lett., 2006).

Seasonal predictability of the Asian summer monsoon

Factors responsible for limited predictability of the Asian summer monsoon have been investigated. Predictability of the seasonal mean depends on the interannual variability (IAV) of the monsoon annual cycle (MAC) and is determined by relative contribution of the predictable "external" component of IAV compared to the unpredictable "internal" IAV. Contribution from the external IAV over the region is relatively weak compared to that from internal IAV thus limiting the predictability of the Asian summer monsoon. In contrast the summer climate in other areas of the Tropics is more predictable because internal variability is much smaller than the external one there. (Goswami B. N. et.al , The Annual Cycle, Intraseasonal Oscillations, and Roadblock to Seasonal Predictability of the Asian Summer Monsoon, J. Climate, 2006).

Droughts over India - coupled interactions between Indian Ocean and monsoon

Monsoon droughts over the Indian subcontinent produce calamitous impacts on agriculture and industry that cut across all sectors of society. Rainfall deficiencies largely result from prolonged breaks in the summer monsoon rainfall, which occur on sub-seasonal/intra-seasonal time-scales, the underlying causes for which are poorly understood. Recent advances in sustained ocean-observations, new data from satellites and model simulations have indicated the existence of a coupled feedback between the tropical Indian Ocean circulation and the southwest monsoon winds on intra-seasonal time-scales which is pivotal in forcing long-lasting monsoon breaks over the subcontinent. This coupling involves a dynamical feedback between the monsoonal flow and the thermocline depth in the Equatorial Eastern Indian Ocean (EEIO), in which an anomaly of the summer monsoon circulation induces downwelling and maintains a higher-than-normal heat content. The near-equatorial anomalies induce strong and sustained suppression of monsoon rainfall over the subcontinent. This new understanding should foster major advances in ability to predict the evolution of the monsoon rains on time-scales of days to weeks. (Krishnan R., et. al, Indian Ocean-monsoon coupled interactions and impending monsoon droughts, Geophy. Res. Lett., 2006).



Indian Ocean Monsoon coupled interactions and droughts over India.

Seasonal Prediction of the Indian Monsoon (SPIM) using Numerical Models

An attempt was made to estimate the skill of different atmospheric general circulation models (AGCMs) in generating monthly/seasonal predictions of the Indian summer monsoon rainfall. Numerical models from various modeling groups in the country were ported on the C-DAC Param Padma computer and the models were integrated for 25 years (1985-2004) by forcing the model with observed sea surface temperature (SST). Each of the 25-year simulation consisted of 5-member realisations which were initiated from 26-30 April of a particular year. Two AGCMs from IITM (*viz*., PUM 4.5 model and COLA GCM) participated in SPIM. Among the models that participated in SPIM, the PUM 4.5 GCM showed a more realistic simulation of the mean monsoon precipitation; however, the inter-annual variability of the monsoon rainfall was not as well simulated in all models.

Projections of monsoon variability over South and East Asia

The summer monsoon variability over South (India) and East (China, Korea, Japan) Asia has been investigated from the outputs of the 23 coupled climate models made available under the Intergovernmental Panel on Climate Change Fourth Assessment Report. Projections under the radiative forcing of doubled CO2 scenario are examined. Projections reveal a significant increase in mean monsoon precipitation of 8% and a possible extension of the summer monsoon period

over South Asia (Kripalani R.H., et. al, South Asian summer monsoon precipitation variability: coupled climate model simulations and projections under the IPCC AR4, Theo. and Appl. Clim. (in press).

Over East Asia, the projected increase in summer monsoon precipitation could be attributed to the projected intensification of the frontal zone, the north Pacific subtropical high and the influx of moist air from the Pacific inland. A possible increase in the length of the summer monsoon precipitation period from late spring through early autumn over East Asia is also projected (Kripalani R.H. et. al Response of the East Asian summer monsoon to doubled atmospheric CO2: coupled climate model simulations and projections under IPCC AR4, Theo. and Appl. 2007).

Air Sea Interactions in Tropical Monsoons

The analysis of the vertical profiles of radiosonde data from 4 to 8 June ARMEX-2003 (just 2 to 3 days prior to the onset of monsoon over Kerala) has shown that top of the marine atmospheric boundary layer (MABL) depth has increased to 630 hPa (4060 m) on 6 June, i.e. two days prior to the onset. The MABL is humid and cloudy from the LCL to 1500 m and dry between 1500 and 4000 m. The depth and intensity of southwesterlies have shown an increase from 6 June 1100 UTC onwards with the onset process on 8 June. The large scale evolution of the monsoon is reflected in sharp fall in SST over the SEAS with a reduction in diurnal oscillations, strengthening of the zonal winds at the ship's location as well as over the coastal stations along Kerala, change of fair weather cumulus clouds to rain producing stratocumulus, nimbostrarus and altostratus and the northward movement of the mid-tropospheric shear line at 700 hPa (Nagar S. G., et. al, Evolutionary Features of Marine Atmospheric Boundary Layer MABL over the Arabian Sea and the Onset of Monsoon over Kerala during ARMEX-2003, PAGEOPH (in press).

Tropical Indian Ocean SST during La Niña years

The tropical Indian Ocean (TIO) was characterised by anomalous sea surface cooling during the La Niña years (winter season) before 1976. Analysis of Hadley Centre Ice Sea Surface Temperature (HadISST) showed that the cooling (SST anomalies < -0.1ºC) started during the boreal summer over most of the TIO (69% area) in the La Niña composites of 1958-1976 and enhanced by the following winter, resulting in basin-wide cooling (98%).

Dynamical modeling studies using MOM4

The Modular Ocean Model Version 4 (MOM4p0c) was used to study the oceanic processes associated with the Indian Ocean dipole (IOD) mode events in the tropical Indian Ocean. The model successfully simulated the cooling/warming trend observed in the region during dipole mode years. The heat budget analysis of the model simulated fields revealed that the positive surface heat flux and vertical advection terminated IOD co-occurring with El Nino, whereas horizontal and vertical advections were found to be responsible for IOD termination during the non El Nino years.

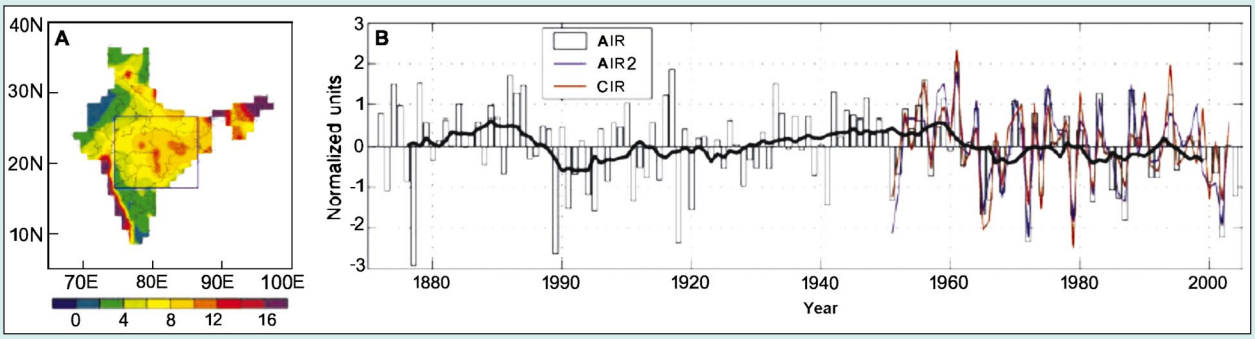
Impact of Climate Change on rainfall

Impact of climate change on active/break spells of Indian summer monsoon

The influence of climate change on active/break spells of Indian summer monsoon simulated by ten coupled models, under the Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR4), was investigated by comparing their number, duration and the spatial pattern of composite rainfall anomaly with control simulation. The impact of climate change was assessed from two experiments *viz*., 1% per year CO_2 increase to doubling and 1% per year CO_2 increase to quadrupling. The simulations suggested that the rainfall reduction over India during monsoon breaks is larger in the global warming scenarios as compared to the control experiment.

Trend of extreme rain events over India

The global mean surface temperature has risen over the past century, with rapid warming in the last few decades. However, the seasonal mean Indian summer monsoon rainfall has remained stable. The puzzle of lack of a trend in seasonal mean monsoon in the background of global warming has been studied. Using a new quality controlled daily rainfall data set; the first evidence of a significant rising trend in the frequency and intensity of heavy rain events; and decreasing trend in the frequency of light to moderate rain events over central India in the monsoon season during 1951-2000 has been produced. It has been observed that the mean rainfall does not show any significant trend because contribution from the increasing heavy events is offset by that from the decreasing light events. The study suggested a substantial increase in severe rain events and associated hazards over India in the coming years. (Goswami B. N. et.al, Increasing Trend of Extreme Rain Events over India in a Warming Environment, Science, 2006).



(A) Climatological mean summer monsoon rainfall (mm/day). The box indicates the CI region used in the analysis. (B) Normalized (by the interannual standard deviation) JJAS AIR based on 306 stations (26) from 1871 to 2003 (bars). The mean is 84.9 cm, and the standard deviation is 8.4 cm. The solid blackline represents an 11-year running mean indicating interdecadal variability but no trend. The AIR2 (blue) is the normalized seasonal mean AIR on the basis of the new gridded rainfall data (24). The seasonal mean and standard deviation are 94.0 cm and 9.1 cm, respectively. The CIR (red) is the normalized seasonal mean over CI on the basis of the gridded rainfall data set, the mean and the standard deviation of which are 69.5 cm and 11.2 cm, respectively.

Study of the heavy rainfall over Santacruz

Weather Research and Forecasting (WRF) model developed by NCAR, USA was tested for a case of heavy precipitation that occurred on 30 May 2006 over Ratnagiri (16.98oN; 73.33oE) in west coast of India. The 24-hour accumulation ending 0300 UTC of 31 May 2006 reported by the India Meteorological Department (IMD) was as high as 640 mm. WRF successfully simulated this heavy rainfall event, with the high resolution 10 km model producing 963 mm for the same period. The model revealed that the sequence of events started with the presence of a strong low-level moisture convergence in the vicinity of Ratnagiri associated with a north-eastward travelling non-deepening mesoscale low (Sanjay J. et al., TROPMET-2006).

Simulation of extreme heavy precipitation in Mumbai has also been attempted using Advanced Regional prediction systems model (ARPS) with 40 km of grid resolution (Vaidya S. S. and. Kulkarni J.R., Simulation of heavy precipitation over Santacruz, Mumbai on 26 July 2005, using Mesoscale model, Meteorology and Atmospheric Physics) and in another study based on Satellite Observations.

Paleoclimatology

Dendroclimatic analysis of Himalayan conifers from high altitude near glacier sites

Analyses of recently collected conifer tree-ring data from high-altitude, near-glacier sites from Gangotri (Uttarakhand) and Kinnor (Himachal Pradesh) gave long tree-ring chronologies

(A.D. 1458-2003; 546 years). These chronologies indicated positive relationship with temperature during winter months. General pattern of relationship between glacial mass balance and tree-ring variation is inversely correlated.

Hydrometeorological studies for applications in hydrology and power generation

Extreme Rainfall, Estimates of PMP, Design Storm, Return Periods for Extreme Events have been estimated and tailor made hydro-climatic products have been developed for various hydrological projects, on request from various national agencies, for which 18 major river basins have been studied, *viz*., (1) Yamuna up to Tajewala Dam Site, (2) Beas up to Pong Dam Site, (3) Betwa up to Rajghat Dam Site, (4) Mahi up to Kadana Dam Site, (5) Baitarni up to Bhimkund Dam Site, (6) Mahanadi up to Tikkarpara Dam Site, (7) Narmada up to Narmada Sagar and Sardar Sarovar Dam Sites, (8) Godavari up to Paithan Dam Site, (9) Bhima up to Ujjani Dam Site, (10) Koyna up to Koyna Dam Site, (11) Krishna up to Almatti, Narayanpur, Srisailam and Nagarjunasagar Dam Sites, (12) Tungabhadra up to Tungabhadra Dam Site, (13) Malprabha up to Malprabha Dam Site, (14) Subansiri up to Gerukamukh Dam Site, (15) Bhagirathi up to Vishnugad, (16) Dhauliganga up to Tapovan, (17) Siang up to Passighat Dam Site, (18) Upper Siang Basin (Tsangpo).

Super cyclone in the Bay of Bengal

Sensitivity experiments were carried out to see the impact of domain size (in terms of grid points in X and Y direction: Large- 150 × 150 grid points, Medium - 100 × 100 and Small- 50 × 50) with five different cumulus parameterization schemes (AK, BM, Grell, KF and KF2) on a single domain simulation of Bay of Bengal super cyclone. European Centre for Medium Range Weather Forecasts (ECMWF) 40-year Reanalysis dataset (ERA-40) with $2.5^{o} \times 2.5^{o}$ horizontal resolution interpolated to model grid was used as initial and boundary conditions for model integration of five days (26 - 31 October 1999) and a horizontal resolution of 50 km. The model was found to be sensitive to domain size.

Applications of Physical Meteorology

Effect of electric field on the deformation of raindrops

The results of a laboratory simulation experiment conducted with vertical wind tunnel effectively demonstrate the stretching and elongation of the oblate-shaped drops in the direction of electric field [Bhalwankar R.V. and Kamra A.K., A wind tunnel investigation of the deformation of water drops in the vertical and horizontal electric fields, Jr. Geophys. Res. (Under Revision)].

Novel observation of the inverted End-of-Storm Oscillation

Thunderstorms occurring over Pune region frequently exhibit `End-of-Storm-Oscillation' (EOSO). A novel case of an `inverted EOSO' is observed in a thundercloud with the inverted dipole structure in which the surface electric field had an excursion from the fair-weather to foul weather polarity and then back to fair-weather polarity before attaining the normal fair-weather field values. The phenomena of `inverted EOSO' has been explained on the basis of the 'inverted convective charging mechanism in the thundercloud. To our knowledge, this is the first time that such an `inverted EOSO' has been observed [(Pawar S. D. and Kamra A. K., The end-of-storm-oscillation in tropical air-mass thunderstorms, Jr. Geophys. Res. (in press)].

Marine aerosols during a cyclonic storm

The marine aerosols observations made during a cyclonic storm over the southern Indian Ocean show that the concentration of aerosols particles generated by the wave-breaking process increases as the wind speeds increase up to 11-13 m/s and then decreases with further increase in wind speed. The decrease in aerosols concentrations when wind speed exceeds 11-13 m/s has been explained as due to the effect of scavenging of aerosols by the water drops generated by the sea spray (Pant V., Deshpande C.G. and Kamra A.K., On the aerosol concentration-wind speed relationship during a severe cyclonic storm over South Indian Ocean, Jr. Geophys. Res./Under Revision)].

Variations in lightning activity over the Indian region

Spatio-temporal variability of lightning activity over the Indian land-mass region (8^o-33^o N, 73^o - 86^o E) was studied using monthly satellite-based lightning flash grid ($5^o \times 5^o$) data for 5-year (1998-2002) period. These data were examined for depicting the annual, seasonal and spatial distribution of the lightning activity. The study revealed a non-linear relationship between lightning flash density and latitude on the annual time scale and it is linked with the convective activity, large-scale circulations, land-mass gradient and orography of the region under study.

Remote sensing of the atmosphere using LIDAR, radiometric and other ground-based techniques

Multi-channel radiometric measurements of aerosol, ozone and precipitable water have been made as part of ARMEX Phase-II at a coastal station (Kochi), an island station

(Minicoy, Lakshadweep) and also over the SE Arabian Sea (on-board a passenger ship) during the premonsoon period of 2003. Results showed that the mean AOD are smaller over the sea region (Raj P.E., Devara P.C.S. and Dani K.K., DST Group Monitoring Committee Workshop, New Delhi, 11-12 Jan. 2006).

An ultraviolet (UV) Excimer-Raman laser-based ozone lidar system operating in the DIfferential-Absorption-Lidar (DIAL) mode has been developed for the first time in the country. The lidar system has been operated during 2003 and 2004 to obtain vertical distributions of ozone number density. The retrieved ozone concentrations are found to vary between 1011 and 1013 molecules c/m3 (Devara P.C.S. et al., Measurement Science and Technology, U.K. (in press).

Extensive data on the ship, aircraft, over land and at Antarctica on various atmospheric electrical parameters and aerosols were collected during the expeditions *viz*., Pilot Expedition to the Southern Oceans (PESO), 24th Indian Scientific Expedition to Antarctica, Severe Thunderstorm Observations and Regional Modeling (STORM), Integrated Campaign for Aerosol and Radiation Budget (ICARB). Antarctic environment at Maitri was found to provide good conditions for generation of intermediate ions by the ion-mediated nucleation process. The intermediate ion concentrations were observed to increase with the increase in solar radiation. However, the process of their generation was found to operate more efficiently when temperatures are below freezing point.

A simple line-of-sight Raman LIDAR system has been developed for detection and path-averaged concentration determination of various atmospheric constituents using a multi-wavelength Argon-ion laser as transmitter, and a dual holographic grating-based high spectral resolution spectrometer along with a detector connected to a 25 cm diameter Newtonian telescope through a fibre optical cable as receiver. Prominent Raman-shifted peaks were identified to be due to the presence of nitrogen dioxide, carbon dioxide, ethylene and methane respectively (Devara P.C.S., Laser Probing of the atmospheric pollutants-recent trends, in Power Beams for Clean Environment and Processes, Ed. N.K. Joshi et al, Allied Publishers, 2006).

Dual Polarization Micro Pulse LIDAR study of boundary layer aerosols

Using aerosol inhomogeneities as traces, the structure and stratification of nocturnal boundary layer were investigated utilising the recently installed dual polarization micro pulse LIDAR (DPMPL).

The high space and time resolution (one-min interval vertical profiles with 30 cm altitude resolution) observations carried out during December 2005 - April 2006 were analysed.

Dual Polarization Micro Pulse LIDAR.

Impact of Indian chemical emissions on the level of tropospheric ozone in the south Asian region

Results of the Chemistry-Transport Model (MOZART) forced with dynamical fields provided by meteorological analyses and new emission inventories for 2001 indicated that the influence of Indian emissions in the boundary layer ozone for the south Asian region is almost negligible but it is strong in the free troposphere for the monsoon month of July because the vertical gradient is much stronger and the high concentration values over the Indian region are immediately transported upwards and spread horizontally (Beig, Gufran and G. P. Brasseur, Influence of anthropogenic emissions on tropospheric ozone and its precursors over the Indian tropical region during a Monsoon, Geophy. Res. Lett., 2006).

Environmental Information System (ENVIS) - Center, SDNP (Sustainable Development Network Partner): Acid Rain and Atmospheric Pollution Modelling

Database development: Development of primary as well as secondary data base for all atmospheric pollutants *viz*. O_3, NO_x, CO, CH_4, VOCs, PMx, SO_2, SPM, etc.

Online Graphic Visualization: Hourly /daily /monthly variations for the past 3 years.

Model Data Archive: Geographical map of the concentration of pollutants for Indian subcontinent (resolution of $1^o \times 1^o$ in latitude and longitude using chemical model).

- Emissions Inventory database: For major pollutants and GHGs.
- Dissemination: Current knowledge through periodic newsletter, abstracting service, publications, bibliography.

Miscellaneous

Institute scientists participated in the ISRO-GBP Programme of Integrated Campaign for Aerosols, Gases and Radiation Budget (ICARB) organised for two months from 18 March 2006 to understand the role of aerosols in cloud formation and radiation balance. Vertical distribution, mass size distribution and optical depths of aerosols, total column ozone and water vapour, net radiation and down-welling SW radiative flux, total suspended particulates and mass size distribution were measured during the programme.

The Department of Science and Technology (DST), Government. of India plans to conduct an intensive experiment, viz., Severe Thunderstorm Observations and Regional Modelling (STORM) in northeast India to understand the interactions between dynamics, microphysics and electrification of severe thunderstorms during 2007-2009. The Pilot phase of this experiment was conducted at Indian Institute of Technology, Kharagpur during April - May 2006 in which the institute scientists participated.

15.2 Research Highlights

- Unraveling the mystery of Indian monsoon failure during El Niño by Krishna Kumar K., Rajagopalan Balaji, Hoerling Martin, Bates Gary and Cane Mark, No. 5796, 6 October 2006. El Niño events with the warmest sea surface temperature (SST) anomalies in the central equatorial Pacific are more effective in focusing drought producing subsidence over India than events in the eastern equatorial Pacific.

- Global change in the upper atmosphere by Lastovicka J., Akmaev R.A., Beig G., Bremer J. and Emmert J.T., No. 5803, 24 November 2006, Science. The anthropogenic emissions of greenhouse gases influence the atmosphere at nearly all altitudes between ground and space, affecting not only life on the surface but also the propagation of radio waves.

- Increasing trend of extreme rain events over India in a warming environment by Goswami B.N., Venugopal V., Sengupta D. Madhusudanan M.S., and Xavier Prince K., No. 5804, 1 December 2006, Science. Evidence of a significant rising trend in the frequency and intensity of heavy rain events and decreasing trend in the frequency of light to moderate rain events over central India in the monsoon season during 1951-2000 has been found.

Other Publications/Papers

"Seasonal variability in the stratospheric aerosol layer in the current volcanically-quiescent period over two tropical stations in India using the twilight sounding method" by B.Padma Kumari, et. al., Geophysical Research Letters, 33, 28 June 2006, L12807 has been selected by the Geophysical Union as "AGU Journal Highlights". Study of the variability of stratospheric aerosol layer over the tropical Indian inland stations, Pune indicates that injection mechanism for background aerosol appears to be the tropics through strong monsoon convection and the Inter-tropical Convergence Zone (ITCZ).

"Effect of the onset of southwest monsoon on the atmospheric electric conductivity over the Arabian Sea" by S.D. Pawar, Devendraa Singh, V. Gopalkrishnan and A.K. Kamra, Journal of Geophysical Research, 2005, has been selected by the American Geophysical Union for its publication in the online version of a virtual journal, Editor's choice: Atmospheric and Space Electricity.

"Long lead predictions of Indian summer monsoon rainfall from global SST evolution" by A.K. Sahai, A.M.Grimm, V.Satyan and G.B.Pant published in Climate Dynamics, 2003 received the 16th IITM Silver Jubilee Award for the year 2003.

"Atmospheric electric conductivity and aerosol measurements during fog over the Indian Ocean" by C.G. Deshpande and A.K. Kamra published in Atmospheric Research, 2004 received the 17th IITM Annual Silver Jubilee Award for the year 2004.

A total of 87 Papers have been published

15.3 Workshop and Seminars

- UK - India Workshop on Regional Climate Change, Variability and Impacts: Scientific Perspectives was organized at the Institute during 23 - 27 January 2006 in collaboration with Department of Science and Technology, Govt. of India, British High Commission, British Council and Royal Society, U.K. About 88 eminent experts from U.K. and India participated in this workshop.

- First Meeting of the Scientific Steering Committee for Continental Tropical Convergence Zone (CTCZ), sponsored by the Department of Science and Technology, Government of India was held at the Institute during 20 - 21 January 2006.

- International Geosphere Biosphere Programme (IGBP) Workshop on Global Change on 3 March 2006. The Workshop was attended by about 95 delegates from India and abroad

- Scientific Steering Committee (SC) Meeting of IGBP during 4 -7 March 2006

- A Session of Joint Meeting of SC-IGBP and Joint Scientific Committee - World Climate Research Programme (JSC - WCRP) Meeting during 6-7 March 2006. The Session was inaugurated by Dr. P.S. Goel, Secretary, Department of Ocean Development, Government of India.

- JSC-WCRP Meeting during 6 - 11 March 2006
  About 100 scientists from various organizations all over the world participated in the IGBP Workshop and the Meetings of the IGBP and JSC-WCRP.

- Second Meeting of the Operations, Airworthiness and Human Engineering Panel (OA & HEP-2) of the Defence Research and Development Organisation (DRDO) Head Quarter, New Delhi was organised at the Institute on 8 May 2006.

- A Meeting for Evaluation of the Glacier Atlas of India of the Department of Science and Technology, New Delhi was organised at the Institute on 27 May 2006.

- 10th Meeting of the Programme Advisory and Monitoring Committee (PAMC) on Weather and Climate Research Programme (WCRP) of the Department of Science and Technology was held at the Institute during 1-16 June 2006.

- Indo-US Workshop on Integrating Weather and Climate information for Water Management was held at the Institute during 5-7 July 2006. It was sponsored by INDO-US Science and Technology Forum, New Delhi.

- Fifth Programme Advisory Committee - Atmospheric Sciences (PAC-AS) Meeting was organised at the Institute during 13-14 November 2006.

- TROPMET-2006: National Symposium on Role of Meteorology in National Development was organized at the Institute, jointly with India Meteorological Department during 21-23 November 2006 to commemorate the Golden Jubilee of the Indian Meteorological Society (IMS).

- The Annual Monsoon-2006 Workshop was held on 22 November 2006 by the Pune Chapter of IMS.

UK - India Workshop on Regional Climate Change, Variability and Impacts: Scientific Perspectives.

International Geosphere Biosphere Programme (IGBP) Workshop on Global Change.

Joint Meeting of SC-IGBP and Joint Scientific Committee - World Climate Research Programme (JSC - WCRP) Meeting.

Members and Chairperson of JSC-WCRP at the Annual Meeting.

16. International Cooperation

India played a global leadership role in all the key international forums pertaining to ocean affairs. India's elected members on the bodies established under United Nations Convention on Law of the Sea *viz*. Council, Legal and Technical Commission, Finance Committee of International Seabed Authority (ISBA), and Commission on the Limits of Continental Shelf (CLCS) participated in their respective sessions and contributed actively on all fronts. Subsequent to India's re-election as a member of Council of International Seabed Authority in Group B category of largest investors in June 2004, India's Member was re-elected to the Legal and Technical Commission of the Authority in 2006. India's elected Member is represented on International Tribunal on Law of the Sea, another body established under UNCLOS. India took leadership in implementing Indian Ocean Component of Global Ocean Observing Systems (IOGOOS) set up under Intergovernmental Oceanographic Commission of UNESCO. The IOGOOS secretariat is set up in Hyderabad. India is also the chairman of International Coordination Group of Indian Ocean Tsunami Warning System of the Intergovernmental Oceanographic Commission of UNESCO. India as a Consultative Member to Antarctic Treaty System is playing a key role in Antarctica and all the associated forums *viz*. Antarctic Treaty Consultative Meeting (ATCM), Commission for Conservation of Antarctic Marine Living Resources (CCAMLR), Scientific Committee on Antarctic Research (SCAR), Council of Managers of National Antarctic Programmes (COMNAP), and Standing Committee of Antarctic Logistics and Operations (SCALOP). India is hosting the XXX ATCM in International Polar Year 2007.

Regional Cooperation

India is assisting Sri Lanka and Myanmar in the exercise of delineation of their continental shelf. Upon conducting the workshop in Goa for Sri Lankan scientists, India conducted meeting of experts with Sri Lanka and offered help in processing the geophysical data. India also offered two births for Sri Lankan geologists. India would also cover Sri Lanka in developing the Tsunami Early Warning System. India carried out the desk top studies for the Myanmar's continental shelf delineation at National Centre for Antarctic and Ocean Research (NCAOR) from the 12th to 19th June 2006. Around 11 Myanmar scientists/ officials participated in the studies.

International Cooperation in Meteorology

- IMD continued to provide data services to the international community through the Regional Telecommunication Hub of the World Meteorological Organization located at New Delhi.

The Regional Specialized Meteorological Centre for Tropical Storms documented and issued warnings for all Tropical Storms formed in the north Indian Ocean. The Regional Meteorological Training Centre of IMD at Pune, provided training to the countries of the region RA II of WMO.

- **INDO-USAID on Climate Forecasting System:**

Under this collaboration programme, five sub-projects for improving Hydro Meteorological forecasting and Early Warning System in India were identified/ approved for scientific studies.

Tropical cyclone forecast & warning
Local severe storms (including flash floods)
Extreme temperatures
Flood forecasting
Forecast communications

- **Indo-Russian Cooperation Programme**

A joint Seismology Programme is currently underway dealing in Testing and Calibration of measurement systems, design of portable equipment, design of expert systems for event recognition and GIS applications in impact prognostication.

- **Cooperation with neighboring countries- Nepal, Sri Lanka and Maldives**

The IMD continued to provide support in terms of hardware and warning services for the benefit of these countries.

- **Indo-Australian Cooperation Programme**

The areas of cooperation include Numerical Weather Prediction (NWP), Tropical Meteorology, Satellite Meteorology and GTS links. IMD received a software programme on CD-ROM of Australia Tropical Cyclone Workstation (ATCW) from Bureau of Meteorology (BoM), Australia. Short term visits (10 Nos.) of working scientists from both sides took place.

- **Indo-China Cooperation Programme**

  Following areas were identified for research collaboration.

  Asian Monsoon Studies
  Climate Variability and Change
  Tropical Cyclones
  Ground Based Observation Systems including Radars
  Data exchange communication Links
  Satellite Meteorology
  Numerical Weather Predication
  Environmental Meteorology and Atmospheric Chemistry

- **WMO Commission for Agricultural Meteorology** held its 14 th session at New Delhi hosted by the IMD. The Commission elected Dr. Jim Salinger (New Zealand) as its new President and Dr. L.S. Rathore (India) as Vice President for a new 4 year term. Three experts from India – Dr. G. Srinivasan, Dr. N. Chattopadhyay (IMD) and Dr. V.S. Murthy (Agri Univ Andhra) were selected as Members for the RA II Region to coordinate international activities in different Open Programmes of the Commission.

Intergovernmental Oceanographic Commission (IOC): India is the founder member of IOC and also a Member of the Executive Council. Director, INCOIS participated in the 39th IOC Executive Council Meeting held during June 20-29, 2006 held at Paris, France.

Regional Alliance in Indian Ocean for GOOS (IOGOOS): INCOIS, as the Secretariat for IOGOOS till 2008, has been effectively leading IOGOOS that has taken a place of pride among such GOOS Regional Alliances. Since its formal launch at the First Indian Ocean Conference held at Mauritius on November 05, 2002, IOGOOS membership has grown from 19 to 25 institutions from 15 countries. Some of the major initiatives of IOGOOS are (i) the setting up of Indian Ocean Panel working towards a strategy and implementation plan for Indian Ocean Observations for Climate, (ii) Data & Information management, (iii) Remote Sensing Capacity Building Strategy, (iv) Prawn Pilot Project, (v) Keystone Ecosystems Project, (vi) Shoreline change monitoring project, etc. IOGOOS members have played a key role in Argo deployments and enhancing the tropical moored buoy array.

Major accomplishments of IOGOOS during the year are as follows:

- IOGOOS Secretariat coordinated and arranged the IOGOOS Workshop & 4th Annual Meeting (IOGOOS-IV) at Zanzibar, Tanzania during October 10 - 12, 2006. Thirty participants from 11 countries as well as IOC participated in the Annual Meeting.

- A science workshop was organised as part of the meeting with scientific talks by eminent Scientists. The work plan to be pursued by IOGOOS for the next couple of years for each of its activities was evolved during the meeting

- Dr. Shailesh Nayak, Director, INCOIS was elected as the new Chairman of IOGOOS.

Participants of IOGOOS-IV Meeting at Zanzibar, Tanzania

Partnership for Observation of Global Ocean (POGO): Partnership for Observation of Global Ocean (POGO) is an international network of major oceanographic institutions in the world and established to promote and enhance the implementation and integration of global oceanographic activities. As of now, POGO has 26 institutional members from 16 countries. INCOIS is the Member of POGO since 2004 and Director, INCOIS is the Executive Committee Member of POGO from 2006 onwards.

Commission for the Conservation Antarctic Marine Living Resources (CCAMLR)

25th Meeting of CCAMLR were held in HOBART from 23.10.2006 to 03.11.2006. Dr. V.N. Sanjeevan, Scientist 'E', Shri P. Madeswaran, Scientist 'E' and Shri Dinesh Kumar, Director (Finance), MoES attended the meeting.

17. Awareness Programme

17.1 Exhibitions & Fairs

With a view to promote awareness among public and school children, Ministry participated in major National and International Exhibitions in India and abroad by showcasing the objectives and achievements of Ministry and by distributing publications like Annual Reports, Newsletters, Brochures and Mementos to the visitors.

Awards

Prof. B.L.K. Somayajulu was given the National Award for Ocean Science & Technology 2006.

List of the Exhibitions & Fairs participated by the Ministry during 2006-07

Exhibitions in India

- "4th Infra Educa 2006" held from 16th-18th June 2006 at Pragati Maidan, New Delhi
- "10th National Expo" organised by Central Calcutta Science & Culture Organisation for Youth from 1-8 September 2006 at Netaji Colony Maidan, Baranagar, Kolkata.
- "Exhibition cum Fairs on Rural Technologies" from 27th -31st October, 2006 at Deoghar, Jharkhand organised by CSIR, New Delhi
- "IITF 2006" held at Pragati Maidan, 2006 during 14-27 Nov, 2006.
- "2nd Infra Medica 2006" from 8-10 December 2006 at NSIC Exhibition Centre, New Delhi

- " Pride of India" Science Expo ISC 2006 during 94th Session of Indian Science Congress from 3-7 January 2007 at Chidambaram, Tamil Nadu

- "Satyendranath Bose Smarak Bijnan O Projukti Mela" organised by Pachim Banga Bijnan Mancha North East Committee at Hedua on Bidhan Sarni, Kolkata from 17-21 January 2006

- "Bharat Kranti Utsav" at Rabindra Sarovar Stadium, Kolkata from 19-28 January 2007

Exhibitions abroad

- "Hannover Fair" at Hannover, Germany held from 24-28th April 2006

- "INDIA TECH" at Beijing, China held from 8-11th September 2006

17.2 Seminar/Symposia/Conferences Workshop

In order to exchange information and views among the scientists, user community and general public and also to support the scientific and technological activities in the ocean sector, Ministry of Earth Sciences sponsor 29 numbers of International and National Seminar/Symposia/Workshop/ Conferences etc. on Ocean, climate and other related topics during financial year.

Visit to FORV Sagar Sampada

FORV Sagar Sampada was opened for school and college students at Visakhapatnam, Kochi and Andaman & Nicobar Islands in August 2006

18. Use of Hindi

The Ministry is constantly working for promotion and propagation of Official Language. During 2006-07 also efforts were made to promote the progressive use of Hindi in the Ministry. Meetings of Official Language Implementation Committee were held regularly under the chairmanship of the Joint Secretary.

The Annual Report, Performance budget, Demand for grants, all Cabinet notes, reports, monthly summary to Cabinet and documents relating to Consultative and Standing Committees, parliamentary papers, etc were prepared bilingually. Important materials like quarterly newsletters of Ministry were published in Hindi also. Ministry organised a three day Hindi workshop from 22 May to 24 May 2006 for officers and a five-day workshop i.e. from 22 May to 26 May 2006 for staff to help officers and staff of the Ministry to overcome their difficulties in the official work in Hindi. In all 11 officers and 17 staff members took part in the workshop.

The Ministry organized a Hindi fortnight from 1 to 15 September 2006. In this period, various competitions including Hindi essay writing, noting, drafting, debate and poetry were held. A Hindi quiz programme was also organised to test the knowledge of staff about Ministerial activities and official language policy of the Government. About 60 staff members participated in these programmes. Secretary gave away the prizes and certificates to winning officials during a ceremony. This was followed by a Kavi Goshthi, wherein six reputed poets enthralled the audience.

Indian National Centre for Ocean Information Service, Hyderabad and Centre for Marine Living Resources and Ecology, Kochi were inspected by an Inspection Committee of the Ministry during 2006 with a view to ascertain the progress of implementation of official language policy. Several important suggestions were made to encourage the use of Hindi.

The Ministry organized 15th National Scientific Hindi Seminar on the topic “Antarctic Abhiyan ke 25 varsh”. It was held on 22 October 2006 at New Delhi. Dr. S.Z.Qasim, renowned Scientist and First Secretary of the Department of Ocean Development inaugurated the seminar. Seventeen scientists from various institutions related to the subject presented their papers in the Seminar. On this occasion, a Hindi book titled “Desalination”, a compilation of proceedings of seminar held in 2005, was also released.

Under the Mahasagar Vikas Mantralaya Puraskar Yojna 2006, the Ministry awarded first, second and third prizes to the books titled (i) *Rochak aur Romanchak Antarktica* by Shri Arun Chaturvedi (ii) *Lehron ka Kahar* by Smt. Vineeta Singhal (iii) Samudra Vigyan by Ms. Anjali.

19. Parliament Work

The Parliament Standing Committee on Science and Technology, Environment and Forests met on 5th April 2006 at New Delhi to Consider the Detailed Demand for Grants in respect of the Ministry for 2006-07.

Between April to December 2006, Ministry replied questions as below in the Parliament.

1	Lok Sabha Starred Questions	3
2	Lok Sabha Unstarred Questions	10
3	Rajya Sabha Starred Questions	3
4	Rajya Sabha Unstarred Questions	25

20. Administrative Support

The sanctioned strength of the Ministry of Earth Sciences including attached offices is 280 during the year 2006-2007. The detailed break up is given below:-

	Scientific/ Technical Posts	Non-Technical Posts	Grand Total
Ministry Headquarters	25	118	143
National Centre for Medium Range Weather Forecasting (NCMRWF), Noida	48	41	89
Centre for Marine Living Resources & Ecology (CMLRE) Kochi.	17	8	25
Integrated Coastal and Marine Area Management, (ICMAM) Chennai	15	8	23
Total	**105**	**175**	**280**

Implementation of the 15-Point Programme on Minority Welfare

The activities of the Ministry do not have a direct bearing on the development of minority communities, Scheduled Castes, Scheduled Tribes, Other Backward Classes etc. The Ministry, however, has been taking due care to ensure adequate representation of minority communities while making recruitment to the posts. Adequate representation to the officers belonging to the minority communities is invariably given on the Selection Committee set up for filling up vacancies in Groups A, B, C, and D.

Grievances of Public and staff and their Redressal

The Ministry of Earth Sciences is a scientific Ministry and has no direct public dealings. However, the Ministry has taken steps to ensure that due attention is paid to the public/staff grievances. Staff Grievances Redressal Officer and Public Grievances Officer have been nominated. Details are given on website of the Ministry. To address the grievances of female employee, a lady officer has been nominated as per the guidelines issued by the Ministry of Human Resource Development (Department of Women & Child Development).

So far no grievance from the general public has appeared in the grievances column of any newspapers.

Department is implementing 3% reservation in Government job for handicapped and disabled persons.

Gender Budget

Most of the activities undertaken by the Ministry in 'Ocean Science' are in the nature of research and technology development and demostration projects. However, the Ministry through its autonomous institute, NIOT, Chennai has taken up certain programmes on mari-culture to improve the livelihood of fishers where the women folk also participate wherein NIOT also imparts training to the fishermen/women. While the successful implementation of such programmes are entirely within the purview of the State Government of Tamil Nadu and the A&N Island Administration, the NIOT shall continue to provide the technology and the training as and when required.

Right to Information Act

Right to Information Act, 2005 was circulated to all Officers/staff members of the Ministry including attached offices and autonomous bodies. Information about the activities of the Ministry and staff have been put on website. Central Public Information Officer and Assistant Public Information Officer have been nominated in respect of the Ministry proper and its attached /Subordinate offices and autonomous institutes. During the period April to December 2006, 29 request under the Right to Information Act, 2005 ware been received and replies were sent to applicants.

Vigilance activities and achievements

Shri Ajai Saxena, Director has been declared as Chief Vigilance Officer in consultation with the Central Vigilance Commission. Vigilance Officers have been appointed in attached / subordinate offices and autonomous bodies of the Ministry. The Vigilance Awareness week was observed from 06-10 November 2006 with the taking of pledge by the officers and staff members and organising competitions like Slogan and Essay writing and Short Lecture during the awareness week

Training for the Human Resource Development

During the year, the following Officers/Staff of the Ministry were sent for different training/workshop/ seminar programmes to update their knowledge and skill.

Sl. No.	Designation	Subject	Place	Duration
1.	Joint Secretary	Workshop on 'Coastal Ocean Monitoring and Prediction system (COMAPS)'	Chennai	1 Day
2	Director	Training Programme for Non-IAS Officers posted in Government of India under Central Staffing Scheme	Administrative Staff College of India, Hyderabad	5 Days
3	Scientist D	Advanced Techno-Management Programme for Scientists and Technologists	ASCI, Hyderabad	40 Days
4	APS to Hon'ble Minister of S&T and ES	Training Programme on 'Inter Personnel Relation and Effective Communication for Office/ Organisation Growth'	Goa	5 Days
5	Section Officer	Workshop on 'Fixation of Pay'	Institute of Secretariat Training and Management, New Delhi	3 days

21. Finance

The total budget allocation for the Ministry of Ocean Development for the year 2006-07 was Rs. 475.75 crore, which includes Rs. 438.00 crore for the Plan Schemes, and Rs. 37.75 crore for the Non-Plan Schemes. However, Vide Presidential Notification No. Doc CD-384/2006, dated 12th July, 2006 the new Ministry i.e. Ministry of Earth Sciences came into existence from July 2006 merging the erstwhile Department/Ministry of Ocean Development with India Meteorological Department(IMD), National Centre for Medium Range Weather Forecasting (NCMRWF), Indian Institute of Tropical Meteorology (IITM) and the Revised Estimate for the Ministry of Earth Sciences have been fixed at Rs. 589.95 crore (Rs.400 crore for Plan and Rs.189.95 crore for Non-Plan activities) for the year 2006-07. The Budget allocation in respect of Meteorology component (IMD, NCMRWF and IITM) was merged through Final Batch of Supplementary Demand for Grants. The budget estimates for Non-Plan schemes for 2007-08 are Rs 197.00 crore. The details of BE and RE 2006-07 are given in the following table.

	Major Head	2006-2007 Budget Plan	Non-Plan	Total	2006-2007 Revised Plan	Non-Plan	Total
1. Secretariat - Economic Services	3451	0.00	7.90	7.90	0.00	7.90	7.90
2. Oceanographic Research							
2.1 Oceanographic Survey(ORV and FORV) and Marine Living Resources(MLR)	3403	8.00	29.85	37.85	6.00	29.85	35.85
2.2. Antarctic Research / Polar Science	3403	41.00	0.00	41.00	41.00	0.00	41.00
	5403	0.00	0.00	0.00	0.00	0.00	0.00
	Total	**41.00**	**0.00**	**41.00**	**41.00**	**0.00**	**41.00**
2.3. Coastal Research Vessel	3403	5.00	0.00	5.00	5.00	0.00	5.00
2.4. Drugs from Sea	3403	5.50	0.00	5.50	5.50	0.00	5.50
2.5. Polymetallic Nodules Programme	3403	19.00	0.00	19.00	14.85	0.00	14.85
2.6. Other Programmes							
2.6.1 Assistance for Research Project	3403	4.00	0.00	4.00	4.00	0.00	4.00
2.6.2 Coastal Ocean Monitoring & Prediction System	3403	2.20	0.00	2.20	2.20	0.00	2.20
2.6.3 Exhibition and Fairs	3403	0.60	0.00	0.60	1.00	0.00	1.00
2.6.4 Assistance for Seminar, Symposia	3403	0.40	0.00	0.40	0.40	0.00	0.40
2.6.5 Manpower Training	3403	0.30	0.00	0.30	0.30	0.00	0.30
2.6.6 Marine Non-Living Resources Programme (MNLR)	3403	3.00	0.00	3.00	2.00	0.00	2.00
2.6.7 Integrated Coastal & Marine Area Management (ICMAM)	3403	5.00	0.00	5.00	5.00	0.00	5.00
2.6.8 Information Technology & Computers	3403	3.00	0.00	3.00	1.75	0.00	1.75
2.6.9 Ocean Observation & Information Service.	3403	25.00	0.00	25.00	19.00	0.00	19.00
2.6.10 Ocean Data Buoy Programme	3403	25.00	0.00	25.00	18.00	0.00	18.00
2.6.11 National Institute of Ocean Technology.	3403	87.00	0.00	87.00	47.00	0.00	47.00
2.6.12 Continental Shelf	3403	0.00	0.00	0.00	0.00	0.00	0.00
2.6.13 Comprehansive Swath Bathymetric Survey	3403	9.00	0.00	9.00	4.00	0.00	4.00
2.6.14 Gas Hydrates	3403	30.00	0.00	30.00	12.00	0.00	12.00
2.6.15 New Research Vessel	3403	70.00	0.00	70.00	55.00	0.00	55.00
2.6.16 Geophysical Study of Laxmi Basin	3403	0.00	0.00	0.00	0.00	0.00	0.00
2.6.17 Tsunami and Storm Surge Warning System	3403	95.00	0.00	95.00	56.00	0.00	56.00
	Total	**359.50**	**0.00**	**359.50**	**227.65**	**0.00**	**227.65**
Total Oceanographic Research		**438.00**	**29.85**	**467.85**	**300.00**	**29.85**	**329.85**
3. Meteorology							
3.1 Direction & Administration	3455	0.00	13.33	13.33	0.00	13.43	13.43
3.2 Training	3455	0.58	1.95	2.53	0.54	1.95	2.49
3.3 Research & Development Programme	3455	1.18	12.74	13.92	0.88	12.65	13.53

3.4	Satellite Services	3455	4.89	6.83	11.72	5.36	6.85	12.21
		5455	22.50	0.00	22.50	18.06	0.00	18.06
		Total	**27.39**	**6.83**	**34.22**	**23.42**	**6.85**	**30.27**
3.5	Observatory and Weather Stations	3455	10.65	73.97	84.62	11.25	73.99	85.24
		5455	20.30	0.50	20.80	16.89	0.50	17.39
		Total	**30.95**	**74.47**	**105.42**	**28.14**	**74.49**	**102.63**
3.6	Other Meteorological Services	3455	5.20	36.71	41.91	5.25	36.65	41.90
		5455	9.50	0.10	9.60	4.20	0.10	4.30
		Total	**14.70**	**36.81**	**51.51**	**9.45**	**36.75**	**46.20**
3.7	Other Programmes	3455	2.50	1.62	4.12	1.72	1.63	3.35
		5455	5.70	0.00	5.70	1.85	0.00	1.85
		Total	**8.20**	**1.62**	**9.82**	**3.57**	**1.63**	**5.20**
	Total Meteorology		**83.00**	**147.75**	**230.75**	**66.00**	**147.75**	**213.75**
4.	Other Scientific Research							
4.1	National Centre for Medium Range Weather	3425	7.50	2.25	9.75	7.50	2.25	9.75
	Forecasting	5425	15.50	0.00	15.50	17.50	0.00	17.50
		Total	**23.00**	**2.25**	**25.25**	**25.00**	**2.25**	**27.25**
4.2	Indian Institute of Tropical Meteorology, Pune	3425	9.00	2.20	11.20	9.00	2.20	11.20
	Total Other Scientific Research		**32.00**	**4.45**	**36.45**	**34.00**	**4.45**	**38.45**
	Grand Total		**553.00**	**189.95**	**742.95**	**400.00**	**189.95**	**589.95**

Note : The Figures shown in blue indicate the items budgetted under Demand for grants of Deaprtmednt of Science & Technology

ABBREVIATIONS

AGCM	Atmospheric General Circulation Model
AIR	All India Radio
ARMEX	Arabian Sea Monsoon Experiment
AVHRR	Advanced Very High Resolution Radiometer
BoB	Bay of Bengal
BSIP	Birbal Sahani Institute of Palaeobotany, Lucknow
CAS	Centre for Atmospheric Sciences
CGWB	Central Ground Water Board
CMAP	CPC (Climate Prediction Centre) Merged Analysis of Precipitation
C-MMACS	Centre for Mathematical Modelling and Computer Simulation
COMNAP	Council of Managers of National Antarctic Programs
CRS	Central Receiving Station
CSMRS	Centre of Soil and Material Research Station
CSIR	Council of Scientific and Industrial Research
DD	Door Darshan
DIPR	Defence Institute of Physiological Research
DOS	Department of Space
DST	Department of Science and Technology
ECMRWF	European Centre for Medium Range Weather Forecast
EDB	Electronic Display Board
EEZ	Exclusive Economic Zone
EEIO	Eastern Equatorial Indian Ocean
E-OSF	Experimental Ocean State Forecast

ESCAP	Economic and Social Commission for Asia and Pacific
QFDL	Geophysical Fluid Dynamics Laboratory
GIF	Graphic Interchange Format
GOOS	Global Ocean Observing System
GRAND	GOOS Regional Alliances Networking Development
GSI	Geological Survey of India
GTS	Global Telecommunication System
HC	Heat Content
HLL	Hindustan Lever Limited
IAE	Indian Antarctic Expedition
IAST	International Argo Steering Team
ICG/IOTWS	International Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
IIG	Indian Institute of Geomagnetism, Mumbai
IIT	Indian Institute of Technology
IITM	Indian Institute of Tropical Meteorology
IMD	India Meteorological Department
INDOMOD	Indian Ocean Modelling and Dynamics
IO	Indian Ocean
IOC	Intergovernmental Oceanographic Commission
IQD	Indian Ocean Dipole
IODE	International Oceanographic Data Exchange
IOGOOS	Indian Ocean Global Ocean Observing System
IOM	Indian Ocean Model

IOP	Indian Ocean Panel
IRS	Indian Remote Sensing Satellite
ISRO	Indian Space Research Organization
ITWC	Interim Tsunami Warning Centre
KPP	K-Erofile Parameterization
MDT	Mean Dynamic Topography
MLD	Mixed Layer Depth
M.O.	Meteorological Office
MODIS	Moderate-resolution Imaging Spectroradiometer
MOM	Modular Ocean Model
NCEP	National Centre for Environmental Prediction
NCMRWF	National Centre for Medium Range Weather Forecast
NCT	National Capital Territory
NGRI	National Geophysical Research Institute, Hyderabad
NHO	Naval Hydrographic Office, Dehradun
NIO	North Indian Ocean
NIO, Goa	National Institute of Oceanography, Goa
NIOT	National Institute of Ocean Technology
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Centre
NPL	National Physical Laboratory, New Delhi
NPOL	Naval Physical Oceanographic Laboratory
NRSA	National Remote Sensing Agency
NW	North West
OCM	Ocean Color Monitor

OGCM	Oceanographic General Circulation Model
ORV	Oceanographic Research Vessel
PBL	Planetary Boundary Layer
PRL	Physical Research Laboratory
PFZ	Potential Fishing Zone
PO	Pacific Ocean
POGO	Partnership for Observation of Global Ocean
POM	Princeton Ocean Model
RDBMS	Relational Data Base Management System
ROMS	Regional Ocean Model
RRSSC	Regional Remote Sensing Service Centre
SAARC	South Asian Association for Regional Cooperation
SAC	Space Applications Centre
SASE	Snow & Avalanche Studies Establishment, Chandigarh,
SATCORE	Satellite Coastal and Oceanographic Research
SCALOP	Standing Committee on Antarctic Logistics and Operations
SCAR	Scientific Committee on Antarctic Research
SDAPS	Satellite Data Acquisition and Processing System
SLD	Sonic Layer Depth
SODA	Simple Ocean Data Assimilation
SOI	Survey of India
SSH	Sea Surface Height
SSHA	Sea Surface Height Anomaly
SST	Sea Surface Temperature
SWAN	Simulating Waves Near shore

T/P	Topex/Poseidon
TRMM	Tropical Rainfall Measuring Mission
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WEB-GIS	Web based Geographical Information System
WMO	World Meteorological Organisation
XBT	Expendable Bathy Thermograph

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