

Annual Report 2007-2008



सत्यमेव जयते

Ministry of Earth Sciences

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Introduction

Recognizing the importance of coupled ocean atmosphere processes for understanding the variability of earth, the Government of India established MoES by bringing the meteorological agencies and ocean development department under one umbrella. The creation of MoES aims at looking at the planet in a holistic way in as much as understanding of interplay of earth dynamics and systems phenomenon. It also strives to provide applications such as forecasting weather / ocean state, future climate scenarios, natural hazards (earthquakes, tsunami, coastal erosion, landslides), assessment of macro resource provinces both on land and in ocean, macro assessment of ground water potential, interplay of weather elements in evolution of continental morphology etc. This planet offers immense opportunities and challenges through its varying nature manifested through weather and more evidently in the ever-dynamic oceanic and atmospheric conditions. While, common human perception distinguishes the terra firma, the oceans and the atmosphere from each other, we are slowly learning to look at these three systems as a part of a bigger earth-system entity.

Ministry of Earth Sciences is working towards unraveling the interlinking forces playing within, and influencing the environment around us. India has a coastline of about 7500 kilometers, and the seas around India influence the life of large coastal population including about 7 million coastal fishing community. Understanding our ocean and weather is therefore vital to their livelihood. Gathering adequate knowledge of the potential of ocean especially within our Exclusive Economic Zone (EEZ) of about 2.02 million sq km (our landmass area being about 3.27 million sq km) forms a key multidisciplinary research which is again closely linked to weather and atmosphere.

The schemes of the Ministry relating to ocean development are directed towards achieving sustainable development and use of Science & Technology for the exploration and exploitation of vast marine resources for the socio-economic benefit of the society and these take into account global developments in the field of marine environment.

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

Ocean Science & Technology

2. Polar Science & Ocean Research

2.1 National Centre for Antarctic & Ocean Research (NCAOR)

2.1.1 Launching of 27th Indian Scientific Expedition to Antarctica (ISEA)

Coordination and launching of scientific expedition to Antarctica are among the major tasks of NCAOR. During the current financial year, the 27th ISEA was launched with 66 members comprising of scientists, engineers, doctors and logistic support personnel. Based on operational requirements, the team left for Antarctica by different modes - by air and by ships. The first three groups flew to the Antarctica via Mumbai, Johannesburg and Cape Town in South Africa. Their passage from Goa to Mumbai was by Air India; Mumbai to Cape Town by South African Airways and from Cape Town to Maitri, Antarctica, by a chartered flight operated under Dronning Maud Land Air Network (DROMLAN) agreement.

The first contingent of the 27th Indian Scientific Expedition, comprising two geologists from the Geological Survey of India and four logistic support personnel of NCAOR departed from Goa on 30 October, 2007 and reached Maitri, Antarctica, in the early hours of 3 November, 2007.

The second contingent of the 27th Indian Scientific Expedition, comprising logistic support personnel, three from Border Roads Organization and one from NCAOR left Goa on 4 November, 2007 and reached Antarctica in the afternoon on 8 November, 2007.

The third contingent of 16 members reached Antarctica on 15 November, 2007, early in the morning.

The fourth and final contingent, comprising 38 members (scientists, doctors, engineers and helicopter pilots) led by Shri Arun Chaturvedi, the leader of the Expedition from the Geological Survey of India, sailed onboard MV Emerald Sea from Goa on 6 December, 2007 at 13:45 hrs.

2.2 Scientific Achievements at Antarctica

2.2.1 Earth Sciences and Glaciology

The National Geophysical Research Institute (NGRI) collected the Geotech Broad Band Seismic three - component digital data. Using Seisan 8.0 software, this data was regularly processed to identify the possibility of earthquake that might have been recorded and to identify their first arrival time at Maitri. The number of earthquakes (some 300 to 400) being very clearly recorded with well - developed phases each year, is itself an indicator of the quality of the observatory.

The Snow & Avalanche Studies Establishment (SASE) observed hourly snow-meteorological parameters over the continental ice sheet and measured air temperature, relative humidity, speed and direction of wind, incoming and reflected solar radiations, pressure and snow temperature. Wide temporal variability was observed in different estimated energy fluxes during the whole year. Short Wave (SW) radiation flux was observed maximum for the months of November, December,



Sampling of lake water at Larsemann Hills, Antarctica

January and February and the monthly average values varied from 60W/m^2 to 100W/m^2 . Net energy balance of the Antarctic ice sheet was found negative throughout the year, indicating a continuous ablation of energy from the ice sheet in the form of long wave radiation and turbulent flux of latent heat.

The Geological Survey of India (GSI) carried out monitoring of Dakshin Gangotri (DG) snout and the western polar front of the Schirmacher oasis. The data recorded indicated that during the year 2007-2008, the average retreat of the DG polar ice front was 0.6 m and that from the western margin of Schirmacher Oasis was around 1.4 m. The accumulation/ablation of snow over the shelf in the DG station was also monitored. The collected data showed an average accumulation of 65.5 cm during the year 2007-08. Permafrost data were collected on regular basis from sensors placed near the Maitri Station.

2.2.2 Meteorology and Atmospheric Sciences

Indian Institute of Geomagnetism (IIG) recorded different types of oscillations in the positive conductivity and negative conductivity observed calm wind condition in April, 2007. Such a large variation in the amplitude during the quiet condition could be due to a sudden enhancement in the ionization rate at the surface level due to radioactive sources or cosmic ray intensity. The long - term monitoring of the geomagnetic field variation and GEC parameters and inter - comparison of data between various stations in Antarctica and global thunderstorm activity is expected to further strengthen the possible electro - dynamic coupling between the upper and lower atmosphere.

India Meteorological Department (IMD) carried out ozone sonde observations which indicated that the ozone depletion was recovering.

2.2.3 Polar Biology

As a part of Environmental Impact Assessment, various physiological groups of bacteria (retrievable fraction) from lake water samples at the Larsemann hills were enumerated. Community level physiological profiling was carried out for the lakes in the Larsemann hills region.

Sediment cores from different physical regimes were studied for their relations between pore water geochemistry, organic carbon and the living biomass. Preliminary results have shown that there is a considerable deviation in the use of redox couples in the sediments from hitherto known utilization profiles.

During the 27th ISEA, several samples (water, sediment, soil and ice) were collected from various locations at the Schrimacher oasis and Larsemann hills area.

The project "Biogeochemistry and hydrodynamics of the tropical Indian Ocean during the southwest and northeast monsoons (10°N to 18°S along 65°E)" has been initiated. The biology component of this project will strive to address the variations in fundamental bacterial food web dynamics in the scenario of changing circulation patterns in the equatorial Indian Ocean.

2.2.4 Medical Sciences

- A prospective study on heart rate variabilities under cold climate and prolonged isolation is being carried out on all wintering members to reveal the physiological changes in the heart due to exposure to cold climate.
- Haemoglobin levels of all wintering members were measured once in two months to monitor the changes in haemoglobin level.
- Lung volume and lung capacity of all wintering members are being recorded to reveal the vital lung ratio changes in them.
- Serum samples of all wintering members were collected for immunological studies to reveal variations in different immunoglobulins (IgG, IgM, IgA, IgD, and IgE).
- WHO approved tests have been carried out on all wintering members to know alterations in their psychology.
- Vital body parameters like blood pressure, pulse rate and sleep duration of all wintering members are being recorded regularly to derive mean arterial pressure. Apart from this, body weight, Mid Arm Circumference (MAC), and Skin Fold Thickness (SFT) are recorded every third week to know changes in metabolism, Body Mass Index (BMI) and to prevent life - style

diseases like obesity, hypertension, diabetes, cardiac abnormalities, etc. in lengthy expeditions.

2.3 Arctic Expedition

India has a strong presence in the Antarctica for the past 27 years. However, a wide gap exists in our knowledge about the Arctic. This is infact, hindering a much-needed bi-hemispherical approach to polar sciences. The Arctic Ocean and the surrounding regions are one of the most important areas that not only govern the earth's climate but have also faithfully recorded the past climatic history. The region is also an excellent harbinger of future changes, as the signals or clues that signify climate change are much stronger in the Arctic region than anywhere on the planet. This region has always been significant to the Indian subcontinent due to the probable tele-connection between the northern polar region and Indian monsoon intensity, which is critical for our agricultural output and economy. However, the exact mechanism by which this tele-connection exists is still open to debate and is a topic of the ongoing research. India embarked upon Arctic research by launching her first scientific expedition to this region under the leadership of Shri Rasik Ravindra, Director, NCAOR, Goa, in the first week of August, 2007 using the international research facility at Ny-Alesund in Spitsbergen island of Norway. This first Indian Arctic expedition has marked a beginning of long-term scientific research by Indian scientists in yet another arena of global scientific collaborative research in the difficult Polar Regions. The five - member interdisciplinary and inter-institutional team of scientists of the first Arctic Expedition, drawn from NCAOR, Goa; CCMB, Hyderabad; IITM, Pune; and Lucknow University, has initiated three projects on Atmospheric Studies, Arctic Microbes and Earth Sciences. In the second phase, four more projects will be initiated in the next early spring in February, 2008.



Launching of first Indian Arctic Expedition by Hon'ble Minister of Earth Sciences

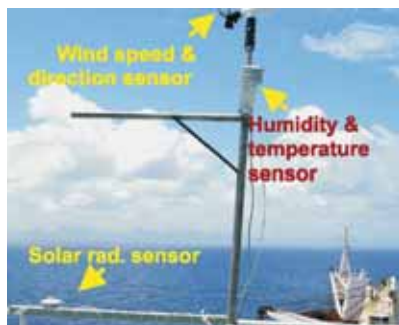
Trainings Organized

- A week-long training workshop on “Introduction to ArcGIS 9” was organized by ESRI, Bangalore at NCAOR during 4 - 8 December, 2006. In addition to NCAOR officials, personnel from NIO, GSI and ICAR, Goa, also participated in it.
- An online training from Norway on the GEOCAP software was organized at NCAOR, from 21st to 25th May, 2007.
- NCAOR organized a 3 - day training workshop for six scientists from Myanmar on marine geophysical data acquisition, processing and interpretation during 18 - 20 December, 2007.

2.4 Polar Remote Sensing

Satellite Data Validation under International Polar Year Project

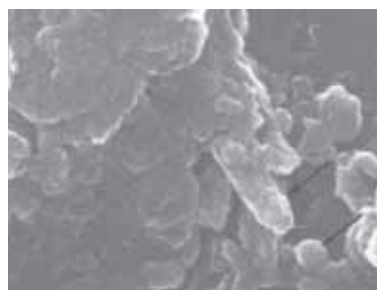
India is involved in a major way in the International Polar Year (IPY) 2007-2008 through scientific as well as outreach activities. As a part of scientific component, a project entitled “Monitoring of the upper ocean circulation, transport and water masses between Africa and Antarctica” has been initiated, which was endorsed by the IPY Secretariat. Under this project, data collection campaign was launched during the 26th Indian Scientific Expedition to Antarctica on board ice-class vessel, Emerald Sea. Meteorological data such as wind speed and direction, atmospheric pressure, humidity, air temperature and downward solar radiation in the marine atmospheric boundary were recorded.



2.5 Ice Core Research

The ice core team retrieved two shallow ice cores during the 26th ISEA summer season (2006-07). The total lengths of the retrieved cores were 130 m. We carried out the analysis for major, trace and isotopic studies from large number of ice core samples from 22nd and 25th ISEA cores using ion chromatograph, ICP-MS and IR-MS. These studies provided better insights into the paleoclimatic stories during the past 500 years. In addition, scanning electron microscopic analysis of the micro particles enclosed within the 22nd ice core revealed the presence of volcanic ash particles. These particles, trapped in ice, showed that they had harboured a plethora of cells with

different shapes (cocci and rods) and sizes (micron and sub - micron). The presence of nano-bacteria in conjunction with microbes could indicate that the former may not be a fossilized form of the latter; rather it is a specialized group with morphologies to withstand extreme environments. With regards to the ice core drilling technology, a major effort is being made to improvise and indigenize this technology by interacting with the Indian manufacturing/ engineering firms.



2.6 Southern Ocean Studies

The annual variations in the hydrodynamics of the Indian sector of Southern Ocean were studied based on the data collected during 2004 and 2006. A sudden drop in heat content from subtropical to polar region has been identified. This can affect the meridional heat transfer, which is crucial to the studies related to regional climatic variability.

2.7 ORV Sagar Kanya

During the year 2007-08, the vessel Sagar Kanya has undertaken 14 cruises and has logged 192 days at sea till 23.11.2007. During this period, four cruises were taken up for Tsunami Buoys deployment in the Bay of Bengal and the Arabian Sea. Cruises for 'River Channel' studies, 'Artificial Nodule Laying', HANS Testing were taken up.



Core collected from the central part of the palaeo river channel

Sediment cores were collected from different locations in the palaeo river channel of the Bay of Bengal region. The locations were chosen in such a way as to understand variations in the texture, length and characteristics of the sediment deposits formed in the river channel.

Long Sediment Cores Collection in KG/Mahanadi Basins and Central Bay of Bengal.

NIO-NCAOR in collaboration with NIOT undertook a cruise onboard chartered research vessel Marion Dufresne to acquire sediment core length of 60m.

NCAOR Sampling Onboard

NCAOR participated in the KG-Mahanadi Basin, Central Bay of Bengal cruise and collected 31 cores (half portion shared with NIO) for paleoclimatic studies.

Marine Magnetotelluric Studies

A 19-day cruise onboard RV-AB Petrov was undertaken jointly with NGRI and USA for marine Magnetotelluric (MMT) studies in the Gulf of Kachchh for offshore and underway geophysical data collection. This first time endeavour in marine environment in India has been a great success.



Briefing function for marine magnetotelluric (MMT) cruise at NCAOR

2.8 IPY and Outreach Articles

A big scientific programme with focus on the Arctic and the Antarctic has been planned during the International Polar Year (IPY) with stress on international collaborations comprising coordinated interdisciplinary observations and research. Organized through the International

Council for Scientific Unions (ICSU) and the World Meteorological Organization (WMO), it is actually the fourth polar year, following those in 1882-83, 1932-33, and 1957-58 (it started as a Polar Year, but was subsequently re-named as “International Geophysical Year”). The official period of the current IPY will be from 1 March 2007 to 1 March 2008 in order to allow observations during all seasons, and the possibility of two summer field seasons in each polar region. The aims of IPY programme are:

- To explore new scientific frontiers,
- To deepen our understanding of the polar processes and their global linkages, to increase our ability to detect environmental and societal changes,
- To further involve the Arctic residents with research activities, and
- To attract and develop the next generation of polar scientists, engineers and logistics experts.

India is actively involved with IPY 2007-08, and has constituted a national committee chaired by Dr P. S. Goel (Ministry of Earth Sciences, New Delhi) with Shri Rasik Ravindra (National Centre for Antarctic & Ocean Research, Goa) as secretary and contact person.

The launching of the Indian chapter of the International Polar Year (IPY) 2007-2008 took place at National Centre for Antarctic and Ocean Research (NCAOR), Vasco-de-Gama, India on 1 March, 2007. A special function was organized at NCAOR to mark this occasion. An overview of IPY and its significance was presented by Sri Rasik Ravindra, Director, National Centre for Antarctic & Ocean Research, Goa. He informed about the need, goals and scope of IPY (2007-2008). The inaugural lecture was delivered by Prof. U. R. Rao, former Chairman, Indian Space Research Organization, who elucidated various positive and negative feedbacks affecting the global warming and provided insights about the latest developments in this field. Subsequently, another lecture was delivered by Dr S. R. Shetye, Director, National Institute of Oceanography, Goa on the need to manage our environment. It illustrated how different systems through various feedbacks will mitigate the effect of global warming. Later, during the function, the “Calendar of Events” be undertaken throughout 2007-2008 was released by Prof. U.R. Rao.



IPY was also launched in J.N.U, New Delhi in coordination with WWF-India (World Wildlife Fund for Nature). Dr S.L. Jain, Emeritus Scientist, National Physical Laboratory, New Delhi, delivered a lecture on the 'Effect of global warming and its impact on earth's climate'.

An important aspect of IPY is its outreach to the general public with special emphasis on school children. In this regard, brochures have been downloaded from the IPY website that would be translated into Hindi and distributed in schools and colleges to generate public interest in IPY. Apart from this, various outreach activities/competitions have been planned in association with WWF-India for school children, scientists, academicians, and policymakers that will be started from March, 2007 and will go up to December, 2008.

The prize-winning students of the competition organized in 2007 were invited to Goa to attend the launching of 27th Indian Antarctic Expedition, where they received prizes from the Secretary, MoES. They visited the ship MV Emerald Sea and were shown various laboratories at NCAOR.

Further, under the aegis of IPY 2007-2008, a 14-year old Indian student, Mirza Omar Beg, from Father Agnel School, New Delhi, was selected by the Canadian organization, *Student On Ice*, for their annual Arctic Expedition which was held from 2 August to 17 August, 2007. The participants were accompanied by an international team of polar scientists, experts and educators. The ice-strengthened ship-based expedition provided a unique platform for polar and environmental education.

Under the "Popular Book Series" initiative of the Ministry of Earth Sciences, a book entitled "*Story of Antarctica*" is under publication NCAOR. Similar books on "Story of the Oceans" and "Glaciers - The Rivers of Ice" have already been published and distributed to students in different states of India.

Exhibitions

NCAOR participated in a Science Exhibition at Mumbai University, as part of 150th Year Celebrations of Mumbai University during 22-24 Januray, 2007. The theme of the exhibition was 'Science &



NCAOR stall at science exhibition held at Mumbai

Society' under which the activities of NCAOR in Antarctica and results of Indian scientific research undertaken in Antarctica during the past 25 years were highlighted. It also contributed to the Exhibitions on Poles at Nehru Science Museum, Mumbai.

2.9 Meetings and Conferences

XXX ATCM and X CEP at New Delhi

The Antarctic Treaty Consultative Meeting (ATCM) is the highest administrative forum for governing the activities at Antarctica under the unique and one of the most successful treaties, the Antarctic Treaty of 1959. Critical issues concerning Antarctica are discussed in ATCMs and management decisions are taken by consensus by the 28 Consultative Parties of the Treaty. There are 18 non-consultative parties to the Treaty. Observers, experts and international organizations assist in the Treaty matters. The ATCM provides a platform for the exchange of information among the members in formulating and recommending measures to facilitate scientific research in Antarctica; and preservation and conservation of fragile Antarctic ecosystems

Government of India hosted the 30th Antarctic Treaty Consultative Meeting (ATCM) at New Delhi. The meeting was inaugurated by Shri Kapil Sibal, Hon'ble Minister for Science & Technology and Earth Sciences on 30 April, 2007. This meeting continued at Vigyan Bhavan, New Delhi from 30 April to 11 May 2007.

India is privileged to host the Antarctic Treaty Consultative Meeting (ATCM) for the first time ever since India joined the Antarctic Treaty in 1983 and was granted the consultative status. It coincided with the Silver Jubilee Year of signing of the Treaty by India. The year is also being celebrated as the International Polar Year, to commemorate the International Geophysical Year 1957-58, which led to the framing of the Antarctic Treaty in 1959.



Prof. U.R. Rao, an eminent space scientist and the former Chairman, Space Commission and Secretary, Department of Space, Government of India, was elected Chairman of the XXX ATCM.

India introduced Information Paper (IP) *Studies in the Indian Sector of the Southern Ocean: India's initiative and future Plans*, providing details on the objectives of Indian expeditions to that region, covering hydrodynamics.

India also introduced IP, the *Proposed New Polar Research Vessel (PRV) of India for Bi-Polar Expeditions and Southern Ocean Research*, and provided general information about the vessel. The vessel would be registered in India and would comply with all statutory and regulatory national and international requirements applicable at the time of construction and delivery. The designing, construction and delivery of this vessel have been scheduled within the XI -Plan period of India (by end of March 2012) or before. A total of 45 WP's, 143 IP's and 13 Secretariat Papers (SP) were presented by various participating countries and organizations.

The Meeting was closed on 11 May, 2007, after the special address by the Hono'erable Minister of External Affairs of India, Shri Pranab Mukherjee.

2.10 Awards and Honours

1. Dr Rahul Mohan was awarded Certificate of Merit on the Foundation Day of Ministry of Earth Sciences on 27 July, 2007 for his outstanding contributions to the ocean science and technology.
2. Shri Rasik Ravindra was invited to deliver the 37th Birbal Sahni Memorial Lecture at BSIP, Lucknow on 14 November, 2007.
3. Shri Rasik Ravindra, Director, NCOAR, was elected to the Executive Committee of COMNAP (Committee of Manager of National Antarctic Program) for a period of three years from 2007.
4. Shri Rasik Ravindra, Director, NCAOR was also elected as the Council Member of the Geological Society of India in the AGM of Society held in Nov. 2007.
5. Dr. M. Sudhakar Scientist G was elected as a Member of the Legal and Technical Commission of the International Seabed Authority for the period 2007 – 2011.
6. Dr. S. Rajan, Scientist F, was elected as India's representative to the United Nations



Commission on the Limits of the Continental Shelf (CLCS) for a five-year period beginning 15 June 2007.

7. Dr. N. Khare Scientist E, NCAOR was awarded Krishnan Gold Metal- 2006 by IGU.
8. Dr. Manish Tiwari, Scientist 'B' at NCAOR was selected for the Young Scientist Award Award from the Hon'ble President of India on 5 January, 2007 at the 94th Indian of Indian Science Congress for his studies on variations in the intensity of Indian monsoon on millennial timescale.

2.11 Training

1. Dr. Rahul Mohan and Dr. Manish Tiwari undertook Training on JEOL Scanning Electron Microscope at Tokyo, Japan during 27-31 August, 2007.

3. Polymetallic Nodules (PMN) Programme

India is the first country to have received the status of 'Pioneer Investor' since August, 1987. An area of 1,50,000 sq. km was allocated to India in August, 1987 by the UN on the basis of extensive work carried out at Central Indian Ocean Basin (CIOB). It may be mentioned here that exhaustive survey work was carried out by the Ministry of Earth Sciences, formerly Department of Ocean Development (DOD) in the Central Indian Ocean Basin. In order to fulfill the obligation as a Pioneer Investor, 50 % of the area has been relinquished on the basis of detailed survey work. In 2002, India (DOD) had signed a 15-year contract with International Seabed Authority (ISBA) for carrying out various developmental works in the area with the approval of the union Cabinet.

3.1 Survey and Exploration

The present objective of survey is to identify the most potential area in the Retained Area which would form the nucleus of the First Generation Mine – Site (FGM) for nodules in the Central Indian Basin on the basis of close grid survey results.

India is pursuing several activities relevant to the development of mine site at Central Indian Ocean Basin (CIOB). As a part of initial exercise, an area of about 13,965 sq. km has been identified as the First Generation Mine – Site, based on grade, abundance, and topography data during the earlier surveys.

Various activities in relation to the processing and analysis of data were carried out by National Institute of Oceanography (NIO), Goa. M/s Engineers India Limited (EIL) is providing technical guidance to this programme.

3.2 Environmental Impact Assessment (EIA)

The objectives of the proposed ongoing EIA activity are:

- Validation of Plume Dispersion Model
- Impact of Mining Plume on Seawater Characteristics
- Monitoring of Dispersion of Plume and its Impacts
- Preparation of Environmental Management Plan
- Creation of Environmental Database

After its inception, three of the activities (viz. environment of baseline condition, assessment of benthic impact and monitoring of restoration) have been completed successfully. These studies have resulted in generation of significant results, development of an environmental database, as well as assessing the potential impacts of deep seabed mining.

In order to study effects of sediment re-suspension and resettlement, monitoring of the environmental parameters have been carried out during 10th plan by collection of samples at the test and reference areas for the benthic disturbance experiment periodically. Results of the monitoring cruises have indicated that some of the sediment characteristics appear to have regained the conditions similar to that of pre-disturbance stage, the numbers and diversity of benthic organisms showed only marginal restoration. The parameters indicate that the benthic conditions are steadily moving towards restoration and the effect of disturbance is waning off.

Regarding environmental variability data in Central Indian Ocean Basin (CIOB), the results of one degree spacing sampling showed distinct difference in distribution patterns of sediment characteristics, faunal assemblages and seafloor morphology which are critical for mining activity. More data was collected in the likely first generation mine site for knowing the spatial variation in distribution patterns and the data are being processed. This work was entrusted to National Institute of Oceanography (NIO), Goa.

3.3 Technology Development (Mining):

The National Institute of Ocean Technology has been actively involved in the development of technology for Polymetallic nodule mining from 6000m water depth. The various components of the project are:

3.3.1 Development of underwater mining system for long term operation:

The mining trials were conducted using Research Vessel ORV Sagar Kanya and the underwater crawler was successfully tested during year 2000 off Tuticorin coast at 410 m depth for short period.

In order to qualify the LARS, a dummy weight of approximate size 3mx3mx3m was manufactured. The systems were initially qualified using a crawler dummy weight at a depth of 357 meters off Chennai coast.

After completion of dummy trials and satisfactory performance of LARS and DP system, crawler trials were carried out near Angria Bank off Goa coast. The launching operation went in two phases. In the first phase, it was launched to a depth of 20m and all the operations including slurry pumping was done at 45 m³/h.



Crawler dummy weight launched through LARS from ORV Sagar Kanya

Deep sea testing of underwater mining system for long term operation at a depth of 515 m off Chennai Coast with new isolated oil filled pressure compensated sub-sea power pack was completed off Chennai Coast during mid July 2006 to study the behavior of various subsystems with the new configuration, without the crawler sitting on sea floor.

3.3.2 Development of underwater collection and crushing system for Manganese Nodule Mining.

The second phase of development is the development of collection and crushing systems for manganese nodule mining. The system is being designed for mining rate of 8 tons/hour of wet nodules with nodule abundance of 5 to 10 kg/m³ in sea floor. The manipulator in sand mining crawler will be removed and replaced with collector & crusher. The Crawler will be made to collect artificially laid nodules at 500m depth for qualifying system. The two phases of the project are:

- a) Development of Artificial Nodule Laying System.
- b) Underwater Collection and Crushing System for Manganese Nodule Mining.

A Remotely Operated Subsea Artificial Nodule Laying System has been developed for creating a small mine site similar to that of the one in CIOB. Artificial nodules have been prepared with properties close to that of manganese nodules. The system was tested successfully off Chennai coast at a depth of 518 m during the third week of June, 2007.



Subsea Artificial Nodule Laying System being launched



Underwater crawler entering the splash zone in sea

3.3.3 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 6000m depth has been developed jointly with SEVMORGEO, Russia to measure the in-situ soil properties in Central Indian Ocean Basin.

The sea trials were conducted in two phases one at around 1000m depth for initial qualification of the system and the other at full ocean depth for final qualification of the system to the final requirements. The first test was done off Mangalore coast in October, 2006 at a depth of 1272m to qualify the soil tester system for its operation. Two experiments were conducted at this position by shifting the soil tester and landing it in other location. The second test of the soil tester was done in the Central Indian Ocean Basin at 5200m depth in November, 2006.



Soil tester entering splash zone

3.3.4 Technology Development (Extractive Metallurgy)

The present objective is to develop technology for efficient metal recovery from the polymetallic nodules. Various developmental works have been undertaken by India as a part of the obligation as Pioneer Investor, which include development of process technology for extraction of available metals from ocean. This work has been carried out in association with various research laboratories/ organizations. Initially, 15 process routes were taken up for further studies. After detailed investigations during the 10th Plan period, following three processes were identified studied in a major way by three research laboratories:

- Roast reduction ammoniacal leach by National Metallurgical Laboratory, Jamshedpur [NML (J)];
- Ammoniacal Sulphurdioxide leach by Regional Research Laboratory, Bhubaneswar [RRL (B)]; and
- Starch-sulphuric acid leach by Central Research & Development Laboratory (CRDL), Hindustan Zinc Ltds., Udaipur [HZL (U)].

A semi-continuous pilot plant of 500 kg/ day was commissioned at Hindustan Zinc Limited, Debari, Udaipur to validate the Ammoniacal Sulfur-di-oxide leach process package developed by Regional

Research Laboratory, Bhubaneswar [RRL (B)] & BARC, Trombay. After a large number of campaigns, RRL(B), in consultation with M/s. Engineers India Ltd. [EIL] has modified the process for downstream section of the pilot plant for extraction of Cu, Ni and Co from leach solution. The joint campaigns were carried out and the results are encouraging. The pilot plant has exceeded the overall metal extraction efficiency higher than the achieved efficiency at laboratory scale. National Metallurgical Laboratory [NML] has already commissioned a pilot plant for extraction of Ferro-Silico-Manganese from the residue generated at pilot plant located at Jamshedpur.

The activities related to the performance improvement in various sections of the pilot plant have also taken up by RRL (B) simultaneously and the results were continuously been used for improvement in the recovery efficiency of the pilot plant at HZL (U).

In addition, NML (J) were pursuing following R&D activities in respect of their Roast Reduction Ammoniacal leach.

- Studies on the absorption behaviour and catalytic activity of manganese nodules leached residue.
- Improvement of cobalt extraction from roast reduction polymetallic sea nodules in ammoniacal solution.
- Separation and recovery of Cu, Ni and Co from leach liquor of sea nodules bulk sulphide precipitation – Chloride leaching SX-EW route.
- Recovery of manganese from leached sea nodules residue and toxicological studies of the wastes.

HZL (U) has been pursuing the starch – sulphuric acid leach process development efforts. A number of bench scale campaigns were carried out by HZL (U).

4. Ocean Observation & Information Services (OOIS)

4.1 Indian National Centre for Ocean Information Services (INCOIS)

The mission of INCOIS is to provide ocean data, information and advisory services to society, industry, government and scientific community through sustained ocean observations and constant improvements through systematic and focused research, data and information management and ocean modelling.

The main goal of INCOIS is to develop capability to forecast key ocean parameters and processes such as availability of fish stocks, ocean state, tsunami, etc. for societal and economic benefits. In order to support these activities, an ocean observation system alongwith data management system has been designed. The feedback on advisory services of potential fishing zone and ocean wave forecast has been very encouraging and efforts are on to further improve the generation and dissemination of these services. Significant progress achieved to realize the above-mentioned goals has been summarized below:

- (i) **Increasing Resilience to Oceanic Hazards:** An early warning centre for tsunami has been established at INCOIS.
- (ii) **Identifying Status and Trends of Fishery Resources:** Potential Fishing Zone (PFZ) advisories are issued regularly during non-ban and cloud-free days. The forecast is proving beneficial to fishermen in saving time and fuel and thus increasing their profit. About 27,000 fishermen (boat owners) are availing these forecasts.
- (iii) **Enabling Safe Marine Operations:** Open ocean state forecasts for waves, swell and wind are issued daily. It is being increasingly used by fishery, offshore, shipping, Coast-Guards and Indian Navy. The number of users has grown considerably. Coastal ocean forecasts have been provided to Cuddalore, Puducherry and Karaikal areas on experimental basis and it is planned to for extending this service to other coastal states.
- (iv) **Ocean's Role in Climate Studies:** Ocean modelling activities have been initiated to provide description of past, present and future state of ocean at appropriate time and spatial scales. One of the important requirements is to understand heat budget of Upper Ocean. INCOIS is actively participating in deploying Argo floats to understand variability in sub-surface temperature and dynamic height of sea.

- (v) **Ocean Information and Web-based Services:** INCOIS has huge in-situ data, remote sensing data and model-derived data of the Indian Ocean. These data are being organized for easy retrieval, query and analysis. INCOIS Website has emerged as a prime vehicle for delivery of ocean data, information and services. More than 10,000 users avail this facility. Web-GIS is being used increasingly.

INCOIS continued to play a lead role in the Indian Ocean region and was associated with a number of international initiatives, such as Indian Ocean Global Ocean Observing System (IOGOOS), Regional Co-ordination of Argo Programme, and Partnership for Observation of Global Ocean (POGO).

4.2 Coastal and Ocean Advisory Services

4.2.1 Potential Fishing Zone Advisory Service

Through this Programme, credible advisories on Potential Fishing Zones (PFZ) are provided to the fishing community. This mission is a part of the “Common Minimum Programme (CMP)” of the Government of India. These advisories are generated by using satellite data of the entire coastline of the country in a mission mode with active participation of all stakeholders.

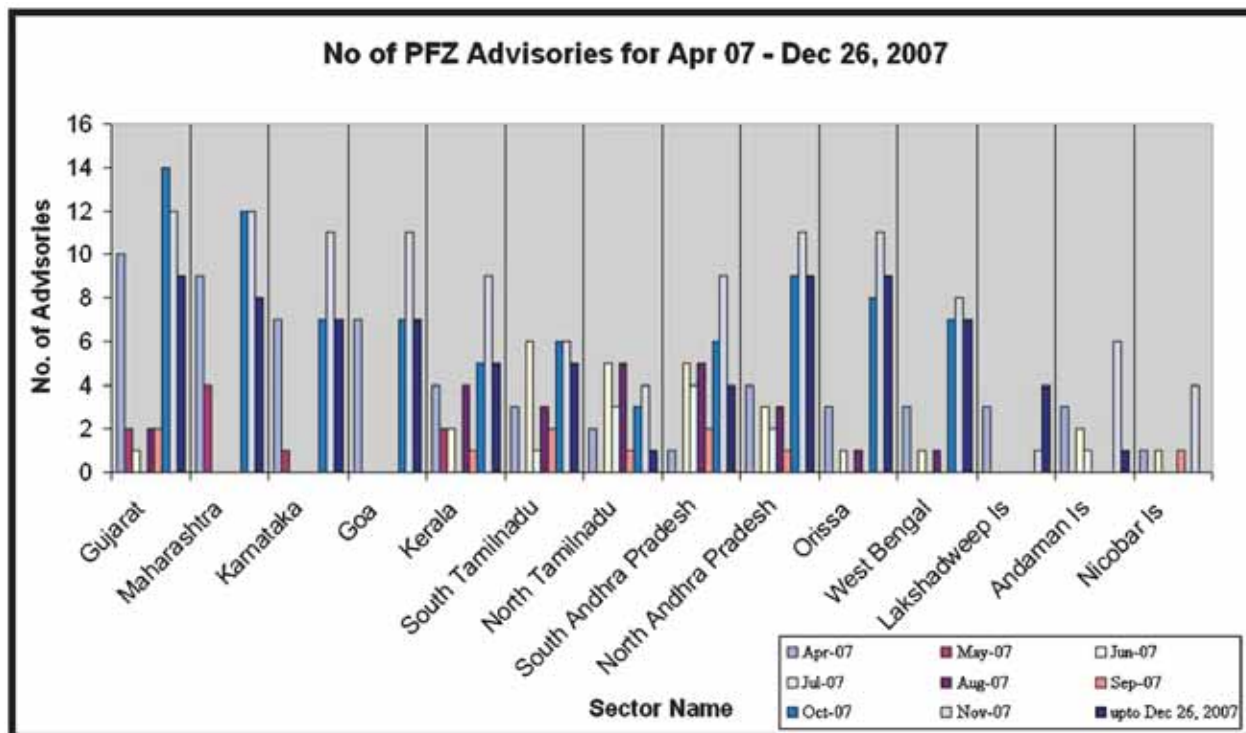
PFZ advisories are generated based on the features such as oceanic fronts, meandering patterns, eddies, rings, up-welling areas as seen on sea surface temperature (SST) and chlorophyll images. The integrated PFZ advisories prepared in the local languages and local measurement units are disseminated thrice a week during non-ban (15 April –31 May on the East Coast; 15 June– 10 August on West Coast) and cloud-free days, through innovative and novel initiatives such as electronic display boards and information kiosks at the fishing harbours, Doordarshan, print media, e-mails and through INCOIS website supplemented with fax and telephone. This is the only short-term forecast available to the fishing community of the country. These advisories are issued on every Monday, Wednesday and Friday.

It has been observed that the PFZ advisories are more beneficial to artisanal, motorised and small mechanised sector fishermen engaged in pelagic fishing activities such as ring seining, gill netting, etc., thereby reducing the searching time, which in turn, results in the saving of valuable fuel, oil and human effort. The reduction in searching time was found to be 30-70%.

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

Generation and Dissemination of PFZ Advisories

384 PFZ advisories were generated and disseminated to thirteen sectors of the country, viz., Gujarat, Maharashtra, Karnataka, Goa, Kerala, South Tamilnadu, North Tamilnadu, South Andhra



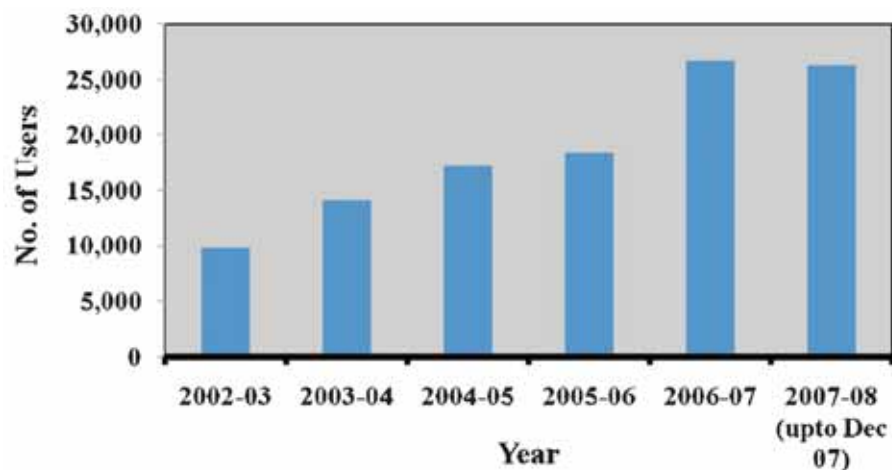
Pradesh, North Andhra Pradesh, Orissa, West Bengal Andaman & Nicobar and Lakshadweep Islands on every Monday, Wednesday and Friday during April 01, 2007 to December 27, 2007.

Improvements in Generation and Dissemination PFZ Advisory Service

The following activities were initiated for improvements in generation and dissemination of PFZ advisory service:

- Experimental PFZ forecast with wind parameter
- Experimental forecast for Tuna Fishery using SST, Chl, Kd-490, MLD, etc.
- Generation of mosaic/ binned products of Sea Surface Temperature (AVHRR), Suspended Sediment Concentration (OCM) and Yellow Substance (OCM)
- New generation of Electronic Display Boards
- 32 Industrial LCD Display Panel and small LED panel
- Two communication channels for redundancy
- Built-in Single Board Computer (SBC)

- Online broadcast of voice messages and playback of recorded messages
- Secured siren system with audibility up to 1 km
- Intelligent power Management System to automatically switch off the LCD Display in case of Mains Power Failure and operate only LED Display, Voice & Siren System
- One hour power backup facility
- Solar Panels for charging the battery bank
- Web-based dissemination of information
- Health Monitoring System and automatic report generation
- One-click addressability to all the boards and individual addressability to each board
- Pilot Project on Integrated GPS & Radio Information System for providing location-based services



Improvement in the total number of users of PFZ Advisories by all modes of dissemination (Web Text, Web GIS, E-mail and Electronic Display Boards)

Electronic Display Boards

Ten Modified Electronic Display Boards with voice, siren and alert system to cater to the dissemination of disaster information, in addition to the PFZ information were installed at Paradeep, Penthakothe, Astaranga, Arjipalli, Bahabalpur, Chudamani, Talachuan, Kharanasi in the Orissa State, and Harne Paj and Deogad in the Maharashtra.

Validation Projects

- A review meeting of the projects on validation of Potential Fishing Zone Advisories was organized on April 13, 2007 at INCOIS. Experts from Space Application Centre (SAC), Fishery Survey of India (FSI) and other research institutes and academia participated in the meeting.

The meeting discussed the benefits of PFZ Advisories in terms of reduction in search time and Catch Per Unit Effort (CPUE). In Kerala, reduction in searching time was found as 60-70 % for oil sardine and 30 - 40 % For mackerel. The result of validation experiments indicated that the catches in the PFZ area gave more CPUE and net profit compared to the results of operations in the non - PFZ areas. In the presence of PFZ Advisories, the fishermen are willing to travel longer distances to get catch. The experts also suggested for providing PFZ information, as per the specific requirement of the user, at a cost as an additional value-added service.

- Two new PFZ Validation Projects (in addition to the existing 7 projects) have been sanctioned to (i) School of Oceanographic Studies, Jadavpur University for carrying out the validation experiments off West Bengal and (ii) Central Institute of Fishery Technology, Kochi for carrying out the validation experiments off Gujarat Coast. CIFT, Veraval Regional Centre will coordinate the project at Gujarat

Awareness Workshops and Field Campaigns

INCOIS organised field awareness campaigns at various fishing harbours with active participation of fishermen for providing information on PFZ Advisory Service and the benefits of the PFZ to the fishing community.

The field awareness campaigns on the dissemination of PFZ Advisories were organised at (i) Ennore Kuppam Fish Landing Centre, Tamilnadu on 05 August,2007 with the active participation of 40 fishermen and (ii) Kovalam Fish Landing Centre, Tamilnadu on 26 August, 2007 with the active participation of about 60 fishermen.



User-Interaction Workshop on the dissemination of PFZ Advisories held at Kovalam Kuppam, Tamilnadu on 26 July, 2007



Fishermen community participated in the Awareness Campaign on the dissemination of PFZ Advisories held at Kovalam Kuppam, Tamilnadu on 25 August, 2007



Awareness Campaign on usefulness of PFZ to Purse Seine Boat Owners/ Boat Operators at Purse Seine Boat Owners Co-operative Federation, Cutbona, Goa in June 2007



Lecture on PFZ at Regional Workshop organized by FSI at Agathi, Lakshadweep Islands in May 2007

4.2.2 Ocean State Forecast (OSF)

Reliable forecast of the ocean state is vital to the shipping, fishery, offshore industries, ports and harbours as well as to navy and coast guards for safe travel and carrying operations in the sea.

Open Ocean Forecast

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

Experimentation is underway for providing fine resolution open ocean forecast (25 km) for 10 days at three - hourly interval for the Arabian Sea, Bay of Bengal and the southern Indian Ocean (up to 60° S).

Coastal Ocean Forecast

- Coastal Ocean Forecast Data were generated for Puducherry, Karaikal and Cuddalore and were disseminated to the users by radio, TV and Village Information Centres.
- Model using ECMWF forecast data for 10-days is being run regularly. Setting up of model for other coastal regions of Tamilnadu is under progress.
- Validation of model output for July 2007 was carried out. The model was forced with forecast winds of ECMWF. Simulation of waves during extreme weather events was also carried out for the cyclone conditions and the validation has shown a good agreement with observations.

Dissemination of Coastal Forecast

Forecast and nowcast of wave, wind and swell parameters were disseminated to the users through the following modes:

- All India radio and FM Radio - thrice a day in local language
- Six TV channels twice a day in local language
- 20 Village Information Centres thrice a day in local language
- Websites of NGOs in English
- Digital Display Boards in local language

It has been estimated that the forecast is reaching to about 25000 people in the districts of Puducherry, Cuddalore and Karaikkal.



Inauguration of Ocean Information Board at Thengaitittu, Puducherry

Efforts for Nowcast and Validation

In collaboration with National Institute of Oceanography (NIO), Goa, INCOIS has deployed a wave rider buoy and a current meter in the Bay of Bengal, about 4 km off the coast of Puducherry. The data obtained from the wave rider buoy and the current meter would provide vital information required for the validation of various Ocean State Forecast products generated and disseminated by INCOIS and thereby would improve the services from the INCOIS. The data from the wave rider buoy is transmitted via Argos (received at NIO) and VHF set at Puducherry. Multipurpose Social Service Society (PMSSS) building. It has been proposed that the awareness among the local community on the protection of these instruments will be created through local church and fisherman Panchayath. The President of the Fishermen Panchayath participated in the deployment exercise. The significant wave height and average wave period from the shallow water buoy SW7 was



Wave rider buoy and current meter deployed in the Bay of Bengal

validated with the data from the wave rider buoy data deployed by NIO for the period from 5 September, 2007 to 29 September, 2007. Significant wave heights matched very well whereas the average wave period from the NIOT buoy was underestimated.

4.2.3 Value - Added Services

During the year, INCOIS took up the following need - based user projects for coastal and offshore applications:

- Interpretation of satellite data for the presence of the pipelines prior to 1990 and the dispersal of the flux from the industry for Tata Chemicals Limited.
- Landuse classification for the Paradeep area in Mahanadi Deltaic Environs, Orissa coast for Essar Steel Orissa Limited.
- Long-term and short-term shoreline changes around Kandaleru Creek, Krishnapatnam, AP coast for Krishnapatnam Port Authority.
- Ocean State Forecast for 10 ports on daily basis and setting up of display board in the GMB control room to provide information and forecast of wave, wind and swell conditions for each port, especially during cyclonic conditions for Gujarat Maritime Board.

4.3 Observation Networks (Argo, XBT, Drifters, Gliders, Current Meter Arrays and Reference System)

4.3.1 Indian Argo Project

Indian National Centre for Ocean Information Services (INCOIS), acts as Argo Regional Data Centre (ARC) for the Indian Ocean region. The Indian Argo Project has been implemented by (INCOIS), jointly with the National Institute of Ocean Technology (NIOT), Chennai, and Centre for

Atmospheric and Ocean Sciences (CAOS) of Indian Institute of Science, Bangalore.

Several R&D institutions, operational agencies including the National Institute of Oceanography, Goa; Space Applications Centre, Ahmedabad; National Remote Sensing Agency, Hyderabad; Indian Institute of Tropical Meteorology, Pune; National Centre for Medium Range Weather Forecasting, New Delhi; Centre for Mathematical Modelling and Computer Simulation, Bangalore participate in the utilization of Argo data. Efforts are underway to encourage and enable academic institutions in this endeavour.

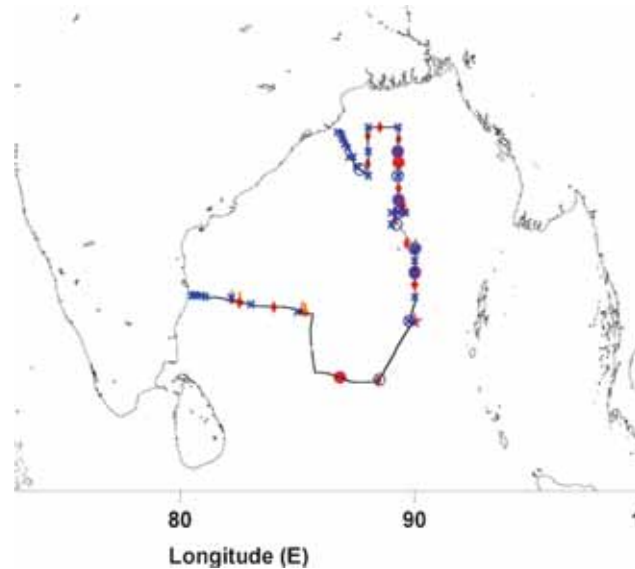
Argo

- Twenty - four Argo floats (including 10 floats with oxygen sensors) were deployed in the Indian Ocean by India.
- A total of 85 out of 153 floats deployed by India are actively providing subsurface temperature and salinity data. From all the active floats, data are received through INCOIS Satellite Data Acquisition and Processing System, processed and disseminated to the user agencies after real time quality control. 517 floats are actively giving data in the entire Indian Ocean.
- Updated the value - added products, viz., float - wise (waterfall plots for temperature and salinity, time series plots for temperature, salinity, surface pressure and bottom pressure, temperature vs. salinity, float trajectories) and objectively analysed monthly data products (temperature, surface salinity, geostrophic currents at various levels, mixed layer depth, depth of 20° C and 26° C isotherms, Isothermal layer depth, heat content up to 300m, dynamic height, sea surface height anomaly) till April 2007 and published them on INCOIS website.
- Delayed mode quality control was applied for 34 floats and these data have been uploaded to GDAC.
- The upper ocean thermohaline structure is observed before and during the passage of cyclone using Argo Float temperature and salinity profiles. Satellite - derived surface parameters like Sea Surface Temperature (SST), Precipitation and OLR data were used to compliment the study. Surface parameters were observed for a total of forty - five cyclones that were formed in the Indian Ocean during 2003-2004 out of which Argo data is available for thirty cases.
- Sensitivity studies related to the validation of AMSRE and TMI SST data were carried out. The diurnal variability of SST along with the precipitation data was studied. .
- The trajectory data derived from 112 Argo floats were generated in netCDF format and uploaded to the DAC.
- Grided data set of Argo T/S profiles using objective analysis was updated. Grided Sea Surface Height Anomaly data was updated and these grided products were made available on INCOIS live access server (LAS).

- Temperature and Salinity Climatology for 19 levels was developed using Argo data and it is available in netCDF format for publishing it on Web.
- Sea Surface Temperature from Argo float data along with the moored buoy were utilised to validate the AMSRE and TMI SST data. Results of this study were communicated as a research paper on “Comparison of AMSR-E and TMI sea surface temperature with Argo near surface temperature over the Indian Ocean” for publication.
- Relationship between Indian Ocean surface oceanographic parameters and Indian summer monsoon rainfall was studied using satellite derived sea surface temperature and sea surface height anomaly.
- Argo/Altimeter based currents were integrated with Ekman currents derived from Qscat winds for getting total currents. Information on the available current meter data is being pooled for validation of the derived currents from Argo Altimeter and Qscat.
- Heat content in Indian Ocean was analysed starting from 1990 to 2006. The temperature at (0 m, 100 m, 500 m, 2000 m) and heat contents (integrated up to 300 m, 500 m, 1000 m) were analysed with Sea Surface Height Anomaly. Trends and relation between temperature, heat content and SSHA are being analysed.
- Float - to - float data and float - to - CTD data comparisons were carried out to check the consistency of the Argo float data.
- Heat content anomalies with respect to World Ocean Atlas 2005 in the Indian Ocean are being analysed for the periods 1990-2006. The temperature anomaly trends at (0 m, 100 m, 500 m, 2000 m) and heat content anomaly (integrated up to 300 m, 500 m, 1000 m) are being analysed in this study.
- Diurnal to inter-annual rainfall variability over Indian Ocean is being studied.
- Studied the Mixed Layer Depth (MLD) variability in the Northern Arabian Sea, based on the daily data obtained from float (WMO 2900211) and the manuscript has been accepted for publication in Ocean Science Journal.
- Sonic Layer Depth (SLD) variability in the central Arabian Sea monthly mean SLD was obtained from temperature and salinity data from 2002 to 2006 and the manuscript is under review for publication in Ocean Science Journal.

Ocean Observations

- Bay of Bengal Cruise was organised to understand the upper ocean heat budget by conducting observations with CTD, hyper-spectral radiometer and other surface met flux measurements onboard ORV Sagar Kanya during 10-23 November, 2007. Scientists from INCOIS, NIO, IISc, PMEL/NOAA, SAC and NCAOR participated in this cruise.



Track of the Bay of Bengal cruise onboard ORV Sagar Kanya (SK 242-A)

- During the cruise10, Argo floats, 10 drifters, 2 PMLE moored buoys and 22 XBTs were deployed.
- The cruise was utilized to study upper ocean behaviour of cyclone “Sidr”.

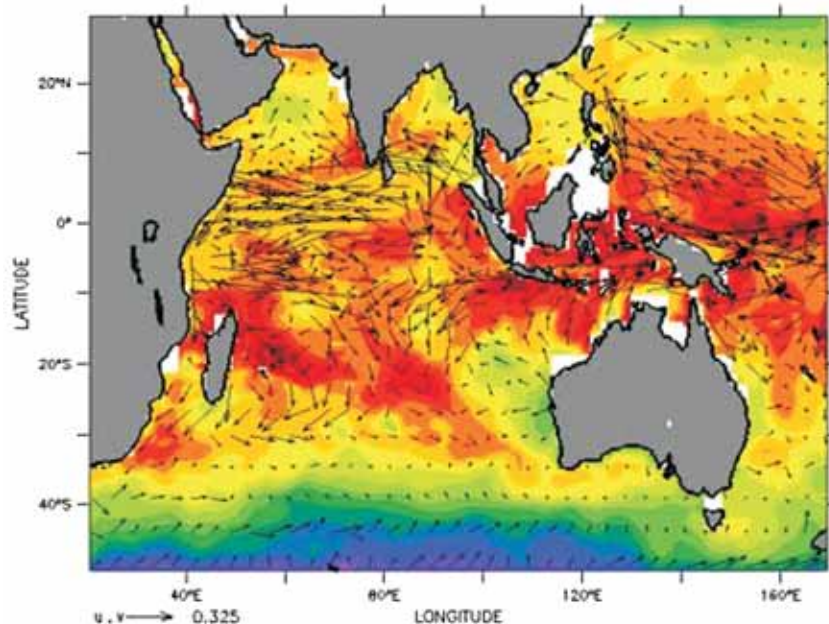
4.3.2 Ocean Modelling

The prime objective of the ocean modelling activities at INCOIS is to contribute to weather, monsoon, climate forecast by forcing functions for atmospheric models, study the variability of ocean and marine environment and simulation experiments to optimize the observation system. The deliverables of the ocean modelling activities at INCOIS are:

- Descriptions of past, present and future states of ocean at appropriate time and spatial scales.
- Contributions to weather/monsoon/climate forecast by providing forcing for atmospheric models.
- Understanding the variability of ocean and marine environment by publishing in a peer reviewed journal.
- Optimization of the marine observation system.

Modular Ocean Model (MOM) of GFDL was customised for the Indian Ocean domain with higher vertical (40 layers) and spatial resolutions (0.25 degree X 0.25 degree) on SGI Machine with 6 processors. The following experiments and studies were carried out with MOM:

- Control experiments - A set of idealized conditions (5, 10, 15 years)
- Studies on vertical mixing schemes (PP, KPP)
- Studies on the influence of viscosity (1/2, 1, 2)
- With Just Horizontal Diffusion and No Neutral Physics
- Studies on various 'Advection Schemes'
- Tidal forcing - (a). just M2 tide, and (b). 8 main constituents)
- No Heat and fresh water fluxes
- Indonesian Through Flow (open & close)
- Real time wind forcing, heat flux and fresh water flux for the years 1990 to 2000, and
- Forced with Quikscat winds and heat flux for the years 2002 to 2005.



Experimentation with MOM

The Regional Ocean Model (ROMS) is being fine tuned for realistic simulations by introducing 32 vertical levels and MY2 mixing scheme in the model. The present set up was spin up for 9 years. The model simulations with realistic forcing are being carried out. Various experiments based on Regional Ocean Modelling System (ROMS) to understand the sensitivity of the model to different parameterizations/options have been conducted and considerable progress in understanding the

problems in simulating the sea surface temperature has been obtained.

Further, fine tuning of Regional Ocean Model for realistic simulation is underway. Simulation for 1998 – 2006 was carried out and compared with available observational data sets. Model simulated the observed interannual and intraseasonal variations in the Indian Ocean realistically.

- Studies on relationship between surface oceanographic parameters over Indian Ocean and Indian summer monsoon rainfall are under progress.
- Various experiments were conducted to understand the influence of forcing fields in the model simulations and it was concluded that the simulations using forcing from OMIP (Ocean Model Inter-comparison Project) was giving best results.
- A comparison of model simulated currents with SODA has been shown in It is clearly seen from the figure that the model could simulate currents reasonably well in the Arabian Sea.

Model - simulated annual mean climatology of surface temperature was validated with NOAA-AVHRR satellite observations. The model could simulate the SST reasonably well, except the eastern equatorial Indian Ocean. Efforts are underway to simulate the temperature in inter-annual scale with higher temporal and spatial resolutions.

4.3.3 Indian Ocean Modelling and Dynamics (INDOMOD) Project

INDOMOD project focuses on the end goal of achieving ocean predictability and enabling climate predictability in a mission-mode with concomitant efforts in modelling, data assimilation and validation. The project envisages 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 operational predictions.

Twenty - five proposals were received from Indian Institute of Science (IISc), Bangalore; Indian Institute of Technology (IIT-D), Delhi; Indian Institute of Technology (IIT-Kgp), Kharagpur; National Institute of Oceanography (NIO), Goa, Centre for Mathematical Modelling and Computer Simulation (C-MMACS), Bangalore; Andhra University (AU), Visakhapatnam; Hyderabad University, Hyderabad; Cochin University of Science and Technology (CUSAT), Kochi; Annamalai University, Chennai; Jadavpur University, Jadavpur; and Allahabad University, Allahabad. These proposals have been categorised under the following modules

- Ocean and Climate (8)
- Coastal Oceanography (6)
- Bio-Geo-Chemistry (3)
- Ocean Observation (5), and

- Hazardous Weather Events, Atlas and Computational (3)

4.3.4 Satellite Coastal and Oceanographic Research (SATCORE)

The integrated information on Chlorophyll and Sea Surface Temperature (SST) is used for locating the fish stock all over the world. Both chlorophyll and SST are the important indicators of the state of the ecosystem. Presently, there are several international missions that have been established to retrieve chlorophyll and SST from the space globally. In the recent IOGOOS IV Meeting, the remote sensing activities of IOGOOS were identified as IOGOOS contributions to the coastal ocean and were given the prime role for the Indian Ocean elements of ChlorOGIN Project. ChlorOGIN aims at networking of distribution of the chlorophyll and SST maps and the in-situ measurements.

India has also ventured into the Satellite Oceanography since the launch of the IRS-P4 Oceansat-1 Satellite. The various organisations and universities are working on the applications of chlorophyll and SST. Oceansat-1 data has been used to give operational Potential Fishing Zone (PFZ) forecast, in addition to SST data derived from NOAA AVHRR for the Indian coast. INCOIS is the organization responsible for providing operational PFZ forecast and maintaining the data archives. In - situ time series measurements of these parameters are necessary to support the satellite - derived parameters.

INCOIS joined this programme to provide chlorophyll, SST maps and time-series measurements. The scope of the study includes (i) processing of satellite data in real time to support operational users and generation of products such as chlorophyll, SST, K490 and TSM, (ii) establishment of time-series stations off Goa, Mangalore, Kochi, Pondichery, Paranginettai, Nagapattinam, Machlipatnam, Visakhapatnam coasts for measuring chlorophyll, TSM, CDOM, SST, kd490 by involving the universities / research institutes / agencies to maintaining time-series locations: and (iii) procurement of necessary instruments such as Continuous Plankton Recorder, HPCL, Fluorometer, Profiling Radiometer etc. for analyzing the in-situ parameters. The data generated under the project will be used to validate the satellite - derived products.

The status of the study is given below:

- Workshop was organized at INCOIS for finalizing the In-situ Time Series Projects
- Time-Series Measurements has been planned off Goa, Mangalore, Kochi, TN & Vizag
- Research projects were allocated to NIO – Goa, Goa University, IITM – Pune, Mangalore University, CIFT – Kochi, CASMB – Annamalai University and Andhra University after reviewing by the INDOMOD-SATCORE Steering Committee
- Initiated procurement of hyperspectral radiometers
- Initiated processing and web dissemination of TSM, Kd490, and SST, and daily and monthly

composite products of Chlorophyll, TSM, k_d 490 and SST from MODIS data were processed and published on INCOIS website.

4.3.5 Eco-morphological Zonation of Coral Reef Health Monitoring

Remote sensing (RS) data has been used for inventorying, mapping, monitoring and recently for the management and planning of the optimum sustainable utilization of natural resources. Due to its repetitive, multi-spectral and synoptic nature, RS data has proved to be useful in providing information on various components of the coastal environment, viz., coastal wetland conditions, mangrove degradation, coastal landforms and shoreline changes, tidal boundaries, brackish water areas, suspended sediment dynamics, coastal currents, air pollution, etc. Using multispectral satellite data, the coastal habitats of the entire Indian coast were mapped on 1:250,000/1:50,000 scale for creating baseline information. Similarly, RS data has been successfully used to map the Indian coastal region for Regulation of the Coastal Zone at 1:25,000 scales. Usefulness of RS data has also been demonstrated for mapping the mangroves at the community level and for mapping the live and dead corals.

The responsibilities of INCOIS under the project are (i) Monitoring Reef Health (RH) Indicators using satellite data, (ii) Finalization of RH criteria, (ii) Generation of composite map, (iii) Validation of RH model, (iv) Bringing out Health bulletins, and (v) Documentation.

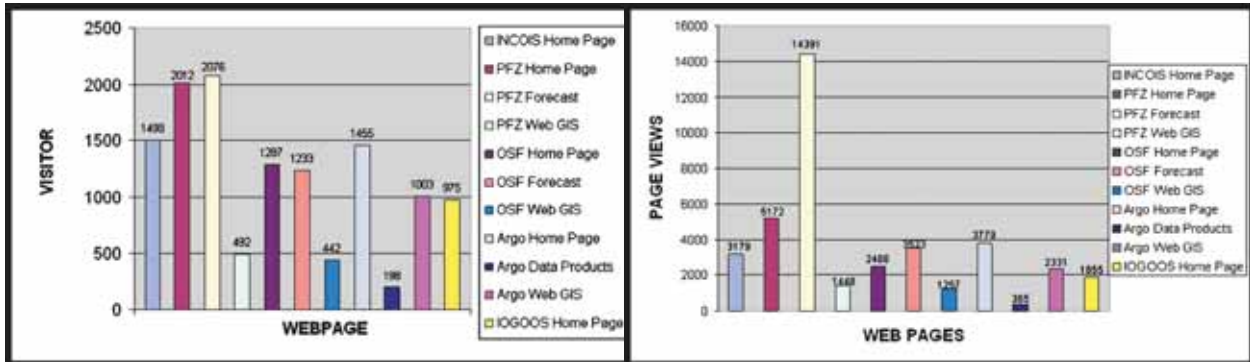
4.3.6 Web-based services

INCOIS Website (www.incois.gov.in) matured as a prime vehicle for the delivery of ocean data, information and advisory services, especially in the areas of (i) Potential Fishing Zone, (ii) Indian Ocean Argo Project, (iii) Experimental Ocean State Forecast, and (iv) IOGOOS. 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 a widely used website by a wide spectrum of users. The content updation of INCOIS Website was carried out and several new web pages were developed. INCOIS has initiated the development of data warehouse and data mining facility to improve the functionality of the website and to maintain a centralised repository of enterprise data. A database was designed using Oracle data warehousing tools for managing in-situ as well as remote sensing data. A GIS-based interface for selection and retrieval of data from various observing platforms in the Indian Ocean was developed.

The statistic of INCOIS Website usage during the period 01 April, 2007 –26 December, 2007 have been given below:

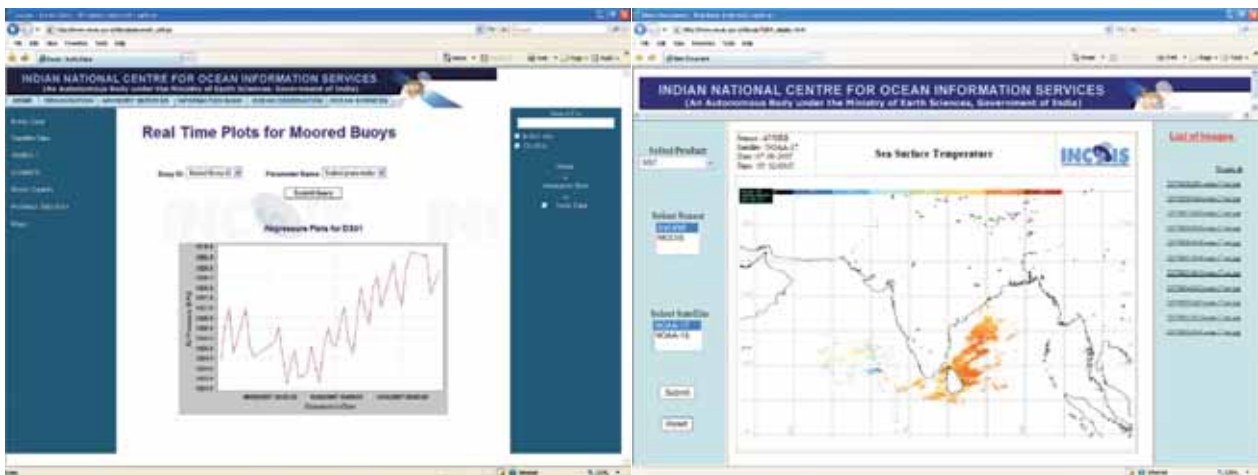
4.3.7 Ocean Information Bank

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

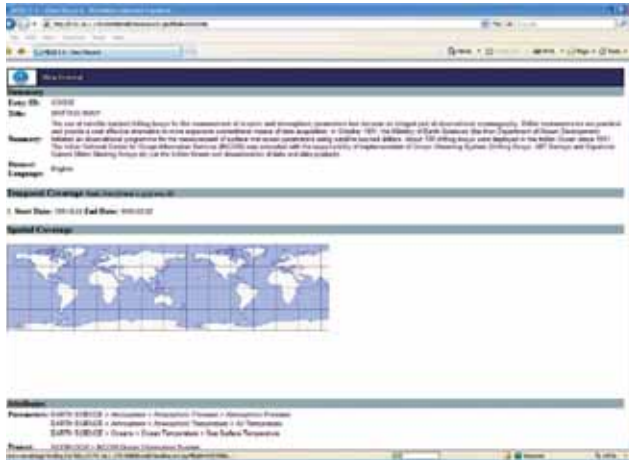


from both the in-situ platforms and satellites as well as by a chain of Marine Data Centres.

- Ocean Information Bank is being updated with the data from moored buoys in real time and remote sensing data from AVHRR (NOAA-17,18) and MODIS (Aqua and Terra) are being received in real time. Data products, viz., SST, Chlorophyll, Aerosol Optical Depth, Clouds, etc. are being generated in real time and published on INCOIS Website.
- Global Telecommunication System (GTS) connectivity has been established for acquiring the met-ocean data, and sea level data in real time. Developed software application data extraction from GTS, loading into database and an web-interface for data delivery.
- Automated the data extraction and storing into database for the data received from drifting buoys (deployed by INCOIS in Nov, 2007) through e-mail.
- Metadata base was generated for moored buoys, drifting buoys and XBT data sets.
- Application software was developed for (i) real-time quality control check of the moored buoy data and storing the data into data base and (ii) quality control of the current meter data and storing the data into database.



Display of moored buoy data and remote sensing data in real-time on INCOIS Website



Metadatabase



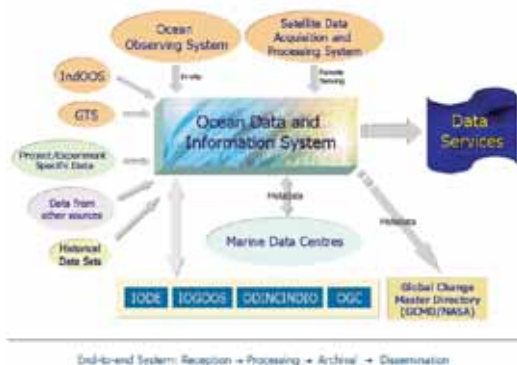
Web-interface for the COMAPS datasets

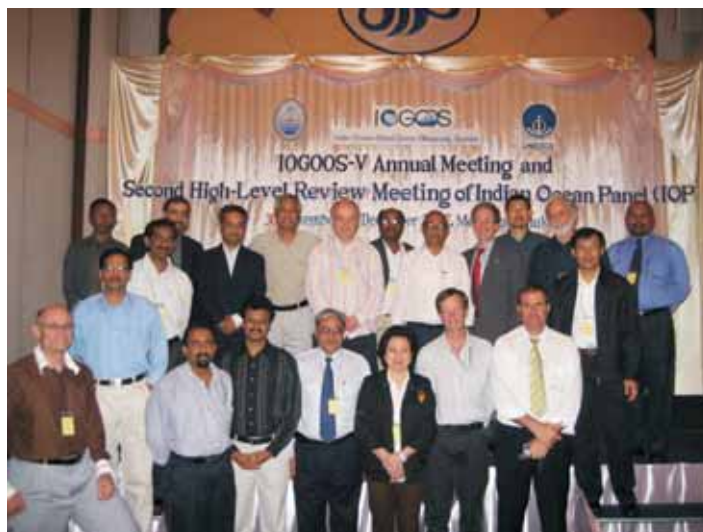
- Database has been generated for the data received from moored buoys, drifting buoys, XBT and current meter mooring array.
- Real time data display system was developed for the moored buoy data, remote sensing data and also a web-interface for COMAPS data query and display system

Ocean Data and Information System (ODIS), an end-to-end database management system is being developed for providing web-based data services. The ODIS is supported by the data received from both the in-situ platforms and satellites, Global Telecommunication System (GTS), Project/Experiments funded by the Ministry of Earth Sciences, data from the other sources (web) and the historical data exclusively retrieved for the Indian Ocean from historical data sets, viz., World Ocean Database 2005 (WODB), World Ocean Circulation Experiment, etc.

INCOIS plans to strengthen the Ocean Information Bank with the data generated from the chain of marine data centres, MoES institutions, academia, etc. by networking of these centres and enabling them on the INCOIS Web-site with appropriate access privileges.

Apart from serving as a national repository of marine data, the INCOIS as the National Oceanographic Data Centre from India, also acts as a national contact point for the International





IOGOOS-V Meeting and Second High-Level Review Meeting of Indian Ocean Panel held at Phuket, Thailand

Oceanographic Data and Information Exchange (IODE), and Global Ocean Observing System (GOOS)-programmes of Intergovernmental Oceanographic Commission (IOC).

4.4 INCOIS in International Scene

Intergovernmental Oceanographic Commission (IOC): India is the Founder Member of IOC and also a Member of its Executive Council. Director, INCOIS participated in the 24th Session IOC Assembly at Paris, France during 19-28 June, 2007.

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 05 November, 2002, IOGOOS membership has grown from 19 to 25 institutions from 15 countries. Some of the major initiatives of IOGOOS are: (i) setting up of Indian Ocean Panel working towards a strategy and implementation plan for Indian Ocean Observations for Climate, (ii) Data and 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 were:

- IOGOOS Secretariat coordinated and arranged the IOGOOS Workshop, 5th Annual Meeting (IOGOOS-V) and the High Level Meeting of the representatives of countries putting observation systems in the region at Phuket, Thailand during 30, November–3 December, 2007.

International Argo Project: International planning for Argo programme is being 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. INCOIS has been identified as the Regional Argo Data Centre for the Indian Ocean region. Regional Argo Data Centre has been set up at INCOIS and Basin-level Coordination is being implemented by INCOIS.

Partnership for Observation of Global Ocean:

Partnership for Observation of Global Ocean (POGO) is an international network of major oceanographic institutions in the world and was 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 the Director, INCOIS is the member of its Executive Committee Member of POGO from 2006 onwards.

5. Marine Research & Technology Development

5.1 Centre for Marine Living Resources and Ecology(CMLRE)

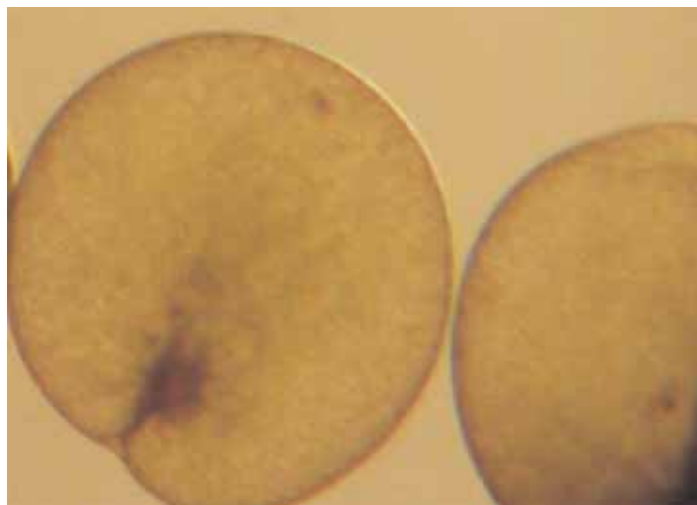
The CMLRE, an attached office of MoES at Kochi is entrusted with the mandate of implementing the Marine Living Resources Programme of the Ministry and management of the Fishery Oceanographic Research Vessel, FORV Sagar Sampada.

5.1.1 Marine Living Resources Programme (MLRP)

Major activities under this programme are charting of exploitable resources of the deep sea, promoting operational fishery oceanographic services, ecosystem monitoring & modelling, promoting basic R&D on MLR and transfer of technology for societal development. The research vessel, FORV Sagar Sampada, forms the backbone of MLR research surveys.

5.1.2 Harmful Algal Bloom

Occurrence of Harmful Algal Bloom (HAB) in brackishwater farms, estuaries, territorial waters and contiguous sea were monitored on a regular basis. Dense *Noctiluca* blooms were noticed in the northern Arabian Sea during March, 2007 by FORV Sagar Sampada cruise 253. The blooms were observed as patches and turned the water colour greenish. Cell counts of the *Noctiluca* sp. were about 4×10^6 cells m^{-3} , while the pigment concentration was high at about 21.9 $mg\ m^{-3}$ in the bloom samples.



Bloom of Noctiluca sp. in the Northern Arabian Sea – March 2007.

Validation of HAB retrieval algorithms being developed at Space Application Centre, Ahmedabad, was carried out on-board FORV Sagar Sampada during the late winter monsoon 2007. Absorption coefficient for particulate and soluble matters in water samples were measured following the ocean optics protocol for satellite ocean colour sensors validation.

5.1.3 Deep Sea Demersal Fishery Resources Assessment and Biology

Assessments were made on the basis of surveys of the continental slope area using expo model and high speed demersal trawl (crustacean version) operations. As many as 222 fishing hauls have been carried-out to delineate fishing grounds suitable for bottom trawling and to assess the fishery resources thereof. Major deep-sea fishing grounds along the continental slope areas off the west, east and Andaman coasts have been identified. As many as 13 new record of deep-sea fish species have been reported through these surveys. Most of these fishes were previously reported only from African waters and it seems to be a case of extended distribution of African fish



Ratfish

fauna to the Indian waters. Demersal trawl surveys conducted at 8 pre-determined grounds in Andaman sea during winter monsoon 2007 indicated that during this season the fishery was dominated by *Priacanthus hamrur* (22.26 %), followed by *Chlorophthalmus punctatus* (18.26%).

5.1.4 Plankton Diversity in Andaman Waters

Andaman waters have been data poor area despite their significant fishery production which depends on plankton and productivity. For the first time, a comprehensive survey of phyto - and zooplankton at spatial and temporal scales have been carried out. The presence of diatom-dominated phytoplankton community during South West Monsoon (SWM), followed by dinoflagellate - dominated community in the inter-monsoon is an interesting observation which would help in corroborating fishery resources in this region. Similarly, zooplankton biomass was recorded to be very high (110 mL/1000 m³) during the intermonsoon period, which indicated low predation of zooplankton by fishes. An atlas on the zooplankton in the Indian waters has been generated under the project.

5.1.5 Environment and Productivity Patterns

The mechanisms underlying the spatial variations in biological production of the Arabian Sea as a consequence of the intensity of upwelling and related process and theoretical formulation explaining

microscale variations in the upwelling patterns along the south-west coast are the major accomplishments of the project during the year under of report. Further, elucidation of mechanisms of formation of cold gyre in the Bay of Bengal and its implication in the net primary and secondary productions was also carried out under this project.

5.1.6 Benthic Fauna of Continental Slope

Sorting, group level identification and estimation of biomass of the macrofauna, meiofauna and microfauna in the sediment samples collected from 200 m, 500 m and 1000 m stations along the continental slope areas were undertaken. Highest biomass of macrofauna (3.23 gram wet wt/m²) was recorded at 500 m depth stations and the lowest (1.59 gram wet wt/m²) at the 200 m depth



Berried ghost shrimp *Callianassa* sp



Berried ghost shrimp *Callianassa* sp



Desmoscolex sp

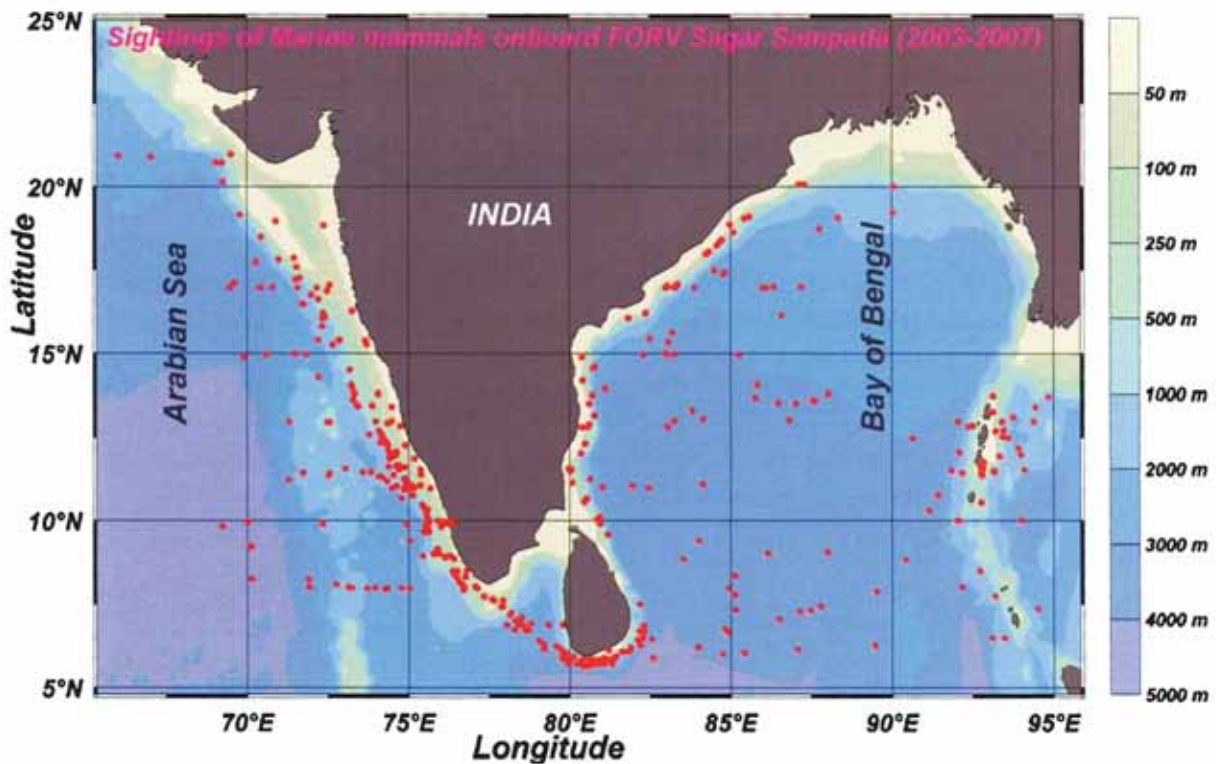


Pselionema sp

station. Polychaetes were found to be the most abundant group (67 %), followed by crustaceans and molluscs. The meiofauna was dominated by nematodes (56 %), followed by foraminiferans (24.6 %), crustaceans, nemertines, etc. The top layer (4 cm) of the sea bottom contributed about 85 % of the meiofauna.

5.1.7 Marine Mammals

Data on marine mammals gathered through 657 days on board observations involving 473 sightings and 5865 individuals were analysed and interpreted. The highest number of sightings and individuals per hour of observation were recorded from the Southern SriLankan Sea. In all, fourteen species of cetaceans were identified, of which six species were whales and 8 species were dolphins. Among large whales, *Physeter macrocephalus* was the most abundant species. The baleen whales, *Balaenoptera musculus*, and *B. borealis* were found more in the SriLankan Sea. Observations on the incidental catches of marine mammals in fishing gears have shown that the gillnets accounted for 68.9 % of the 44 cetaceans landings. *Stenella longirostris* (spinner dolphin) was the most



Sightings of marine mammals (2003 – 07)



Stranded *Balaenoptera* sp.- Karnataka coast



Stenella longirostris - Chennai coast

frequently caught species at Chennai and Kakinada in gillnet fishery. In Mangalore, a large number of finless porpoise were incidentally caught. A national workshop on marine mammals was held at CMFRI, Kochi on 25 July, 2007. An atlas and a CD-ROM on the distribution of marine mammals in the Indian EEZ was released during the workshop.

5.1.8 Archival Tag for Tuna Migration Studies

Two prototype external archival tags have been developed for light and depth measurements. The prototype light tag has a built-in light sensor (ISC 29001), real time clock and micro-controller. The light tag with its accurate real-time clock calculates the day-length for computing the geo-location at a given point of time. From the experimental results, it was observed that the computed values of longitude and latitude from the tag were satisfactory and close to the accurate location measured by GPS.



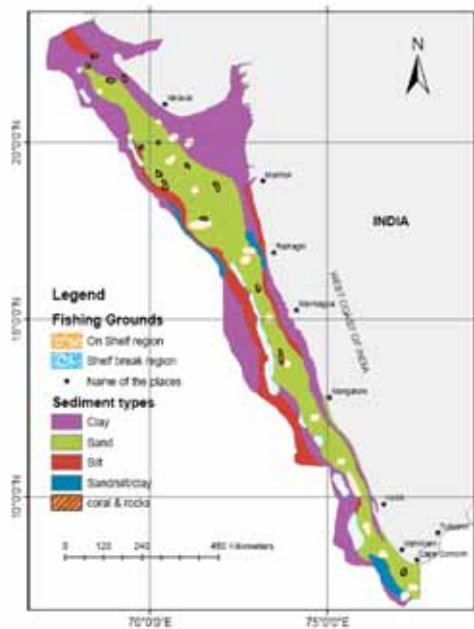
CD-ROM of atlas of marine mammals in Indian EEZ

5.1.9 Bioactive Antifouling Compounds from Selected Marine Organisms

Crude extracts of about 36 sponges, 29 softcorals, 5 mangrooves and 5 terrestrial medicinal plants were tested for antifouling properties. The extract from sponge, *Haliclona exigua*, showed antifouling property and when characterized later, was found to have an alkaloid Araguspongiine belonging to Bi-1-oxaquinolizidine. Similarly, extracts of soft corals, *Sinularia kavarattiensis* and *Cladiella* sp have shown antifouling properties and found to have compounds like seaquiterpene-furoic acid and a novel tetracyclic diterpenoid, 6- Hydroxy polyanthellin, respectively.

5.1.10 FORV Data and Referral Centre

While continuing to archive the data of FORV Sagar Sampada, a GIS database on the bottom topographic features of the west coast (200 – 100 m depth) was created and grounds suitable for



Demersal fishing grounds along the shelf and slope regions off the West coast of India.



Samples inventory software and budget monitoring modules



New records of glass sponges from off North Andaman – February 2007

demersal fish trawl operations were delineated. Further, a software module for retrieval of digital inventory of marine bio-resources covering 4000 species has been developed and is being constantly updated with new species collected through FORV Sagar Sampada. New records of a deep sea polychaete collected from off Mangalore and a glass sponge from off North Andamans are new additions of the digital inventory maintained in the Referral Centre.

5.1.11 Hindi implementation – related Activities

The CMLRE's representative participated in the XII All India Rajabhasha Conference convened by the Bharatiya Bhasha & Samskruti Kendra, Delhi at Thiruvananthapuram during 2 - 4 October, 2007.



New records of deep sea polychaetes from off Mangalore – January 2007



Visit of Parliamentary Standing Committee for Science and Technology & Environment Onboard FORV Sagar Sampada

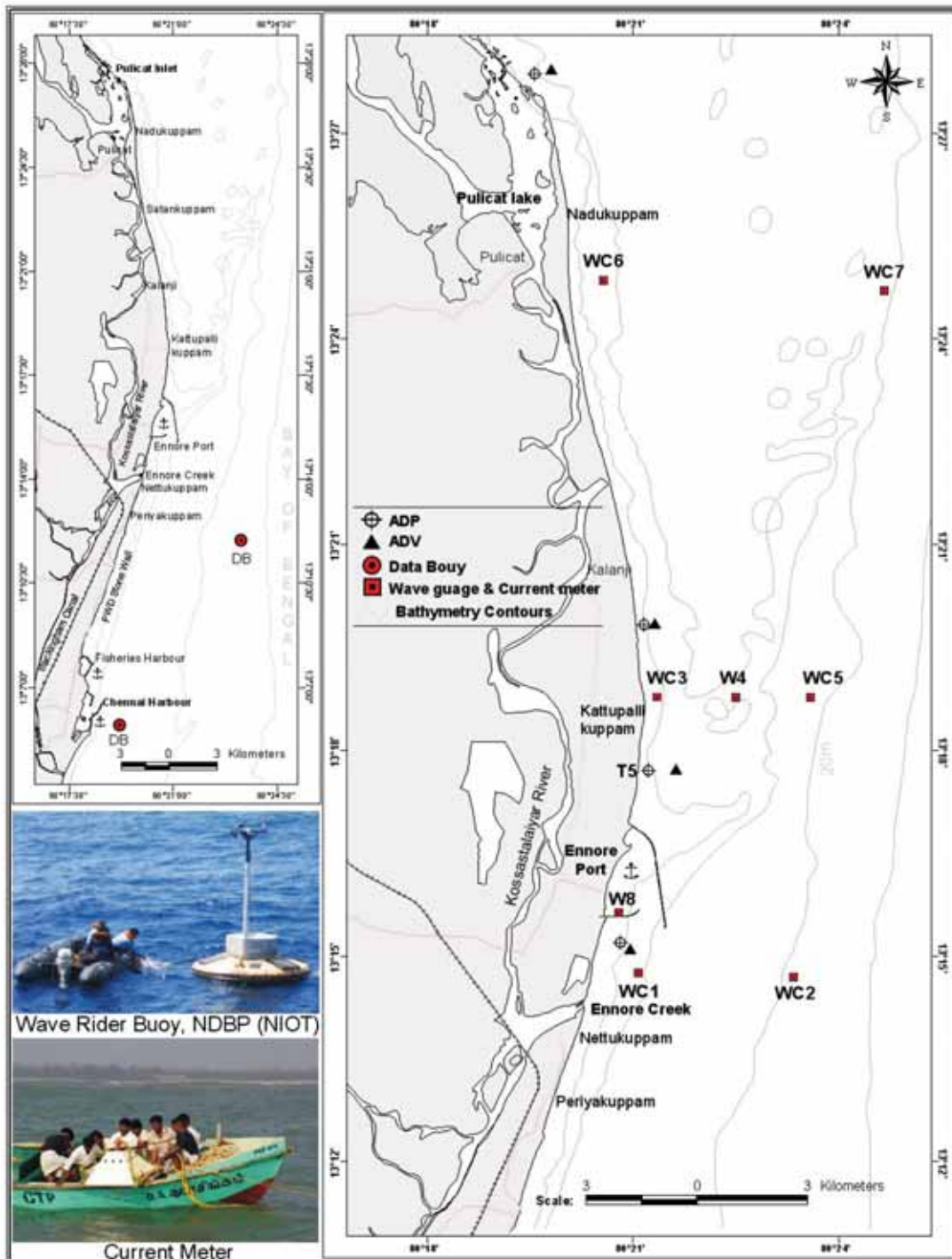
5.2 Integrated Coastal and Marine Area Management (ICMAM) Programme

Under the Integrated Coastal and Marine Area Management (ICMAM) Programme, several projects related to integrated coastal zone management were initiated during the 10th Plan period. The major projects include: (i) Preparation of shoreline management plans for Ennore, Ullal, Munambam to Kayankulam and Panathura, (ii) Management of plan for tidal inlet at Vellar, Tamilnadu, (iii) Shoreline characteristics of Gahirmatha/ Rushikulya coast, (iv) Marine ecotoxicological studies, (v) Ecosystem modelling and (vi) Tsunami modelling and mapping. While the projects relating to Shoreline management have been completed at specified locations, other projects are being continued during the 11th Plan period also. The progress made under the above projects during the year 2007-08 is given below:

5.2.1 Shoreline Management Plan along Ennore Coast

Creation of Ennore port in a region which is highly sensitive to sediment transport is bound to lead to further complexities in terms of coastal erosion and/or accretion. Port constructed in the year 2000, was made operational from 2001 with coal as a major cargo. It has a water-spread area of 240 ha with southeastern entrance, sheltered by breakwaters of 1.1 km long on its south and 3.2 km long on north. It is located 17 km north of Chennai port, between two tidal inlets, viz., Pulicat on north and Ennore creek on south, has distinct morphological characteristics such as narrow barrier spit, shoals and coastal orientation forms a complex near shore system. At present, the southern coast of Ennore is witnessing accretion (attributable to breakwater) and, a tidal creek some 2.6 km away is silting up rapidly, causing concern to nearby power plants drawing cooling water from it. Artificial beach nourishment (to prevent down drift erosion) was therefore taken up in the year 2000 by placing 3.5×10^6 m³ of sand dredged from the harbour basin and the approach channel through capital dredging. Under these circumstances, a careful assessment of shore protection measures for optimum performance and likely cross impacts on adjacent coast would appear essential for any judicious implementation of coastal zone management practices.

A project on Shoreline Management was initiated, with the objective to develop hindcast, nowcast and forecast models on shoreline changes for identification of vulnerable areas of erosion/ accretion to develop appropriate remedial measures for protection of coastline from natural and human perturbations. For validation of numerical models, field experiments were conducted for one year 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. The data was used in setting up of numerical models



Location of Chennai and Ennore port and location of observations for tides, currents and waves

required for the preparation of Shoreline Management Plan for protection of coast from erosion.

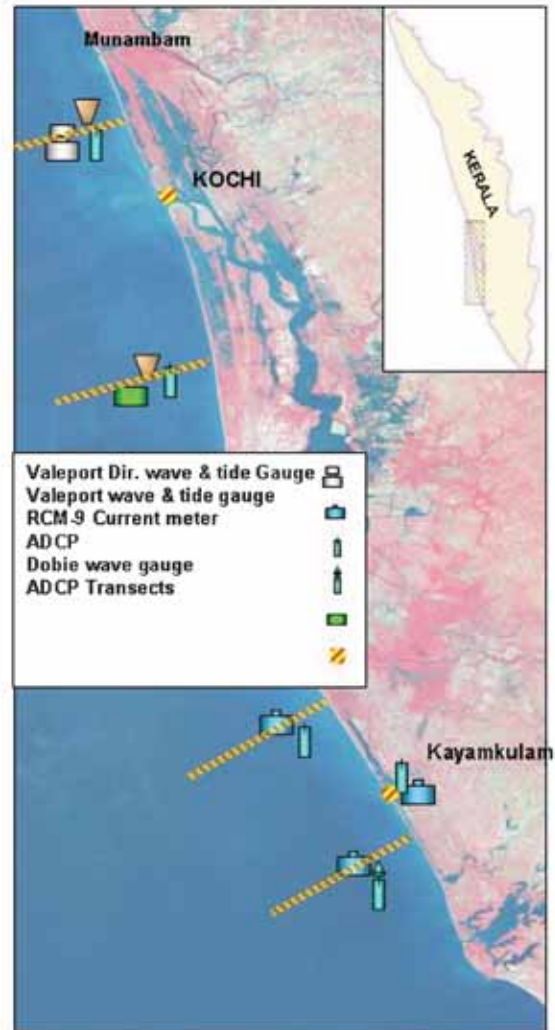
The Shoreline Management Plan was prepared with remedial options such as beach nourishment, groins and offshore geotubes to prevent erosion of north Ennore coast. The plan was submitted to the user namely Ennore Port Limited, for implementation of remedial measures. Ennore port authorities have taken up action for its implementation.

5.2.2 Shoreline Management Plan along Kerala Coast (Munambam to Kayamkulam)

The Kerala coast experiences severe erosion and accretion, which has led to the loss of several acres of coastal land. This phenomenon is more pronounced between Munambam and Kayamkulam stretch in the Kerala coast. Most of the coastline along the Kerala coast was protected by stone wall, which could not give fruitful solution, due to lack of understanding of the coastal processes and sediment pathways. This project aims at studying the physical and geological processes that are responsible for causing erosion/accretion and providing appropriate remedial solution for protection of coast. The project was implemented by the Centre for Earth Science Studies, Trivandrum. The project has determined the extent of erosion and accretion along the stretch and also the areas more vulnerable for such damages.

The project has three major components, viz., collation of secondary information on a variety of issues related to shoreline management, field experiments to understand the coastal processes and numerical modelling to evaluate the coastal processes and develop shore protection strategies.

Data on tides, waves, currents and sediment characteristics were collected from 4 offshore stations, viz., Thrikunnapuzha, Mararikulam, Andhakaranazhi and Njarakkal for three seasons, each seasonal measurement extending for a duration of 20-30 days. For calibration of hydrodynamic model, additional deployments were undertaken during November-December, 2005 in addition to the



Location of coastal stretch considered for Shoreline Management and location of observations for tides, currents and waves

regular measurements. Numerical models (MIKE 21 and LITPACK) were constructed to simulate circulation, wave transformation and sediment transport. Impact analysis was carried out for the Thrikunnappuzha-Kayamkulam inlet sector where coastal engineering interventions have caused substantial erosion.

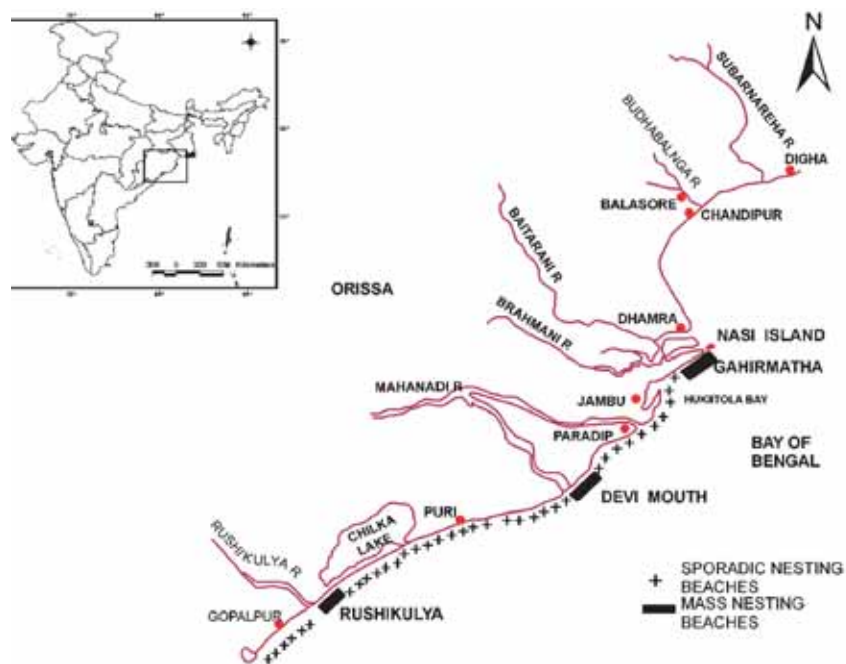
A Shoreline Management Plan has been prepared for the Kayamkulam–Thottappally coast which encompasses the most critically eroding sector of the coastline. The Irrigation Department, Govt. of Kerala, has already expressed their interest in taking up implementation of the coastal protection measure proposed under the project.

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

Different designs of seawalls/rock walls have been constructed along the Kerala coast for coastal protection during the past sixty years. In spite of this, erosion is continuing at many locations and even the seawall gets damaged within one year of its construction at many places. The seawalls are being maintained incurring huge expenditure every year. The Government of Kerala is in need of alternate strategies for protecting the coast. A project on 'Coastal Engineering Strategy for Shore Protection for Kerala' has been taken up by Kerala State Council for Science and Technology in association with Centre for Earth Sciences, Trivandrum.

5.2.4 Shoreline Characteristics of Gahirmatha/ Rushikulya Coast

The beaches along Orissa coast (viz., Gahirmatha and Rushikulya) support world's largest nesting aggregation of Olive Ridley turtles. Nearly 0.2 to 0.3 million Olive Ridley turtles visit every year during winter for breeding and nesting activities. The ICMAM Project Directorate studied the nesting habitats at Gahirmatha and Rushikulya to understand the importance of geomorphology and beach



Map showing the locations of mass nesting along Orissa coasts

state in selecting a particular site by Olive Ridleys.

The studies indicated that at both the sites - the most preferred nesting beach was formed on the northern unstable sand bars at the river inlets. At Gahirmatha, the major nesting activities have been shifted to 2-3 km long sand bar islands beaches on the northern side of River Dhamara, which is a part of 5 km long spit of the original nesting beach because of erosion of the main nesting beaches.

5.2.5 Management of Tidal Inlets along Mangalore Coast

Tidal inlets provide a conduit for water exchange between the ocean and coastal seas. The most of tidal inlets along the Indian coastline are facing problems of siltation, migrations, etc. due to coastal processes and change in the estuarine inputs. Therefore, a scientific understanding of the local coastal process around inlet is very vital to investigate the cause of problem and to provide the technical solution for safe navigation route for fishing vessels, maintaining the productivity in nearby coastal region as well as to minimize adverse impact on the adjacent coast. ICMAM-PD has implemented a R&D project on Tidal Inlet Management along Mangalore Coast involving National Institute of Technology, Karnataka (NITK), Surathakal and has investigated the root cause of the problem and has provided an eco-friendly Tidal Inlet Management Plan for Netravathi (Mangalore) inlet to provide technical inputs for the Karnataka State Government to maintain the coast.

5.2.6 Marine Ecotoxicology

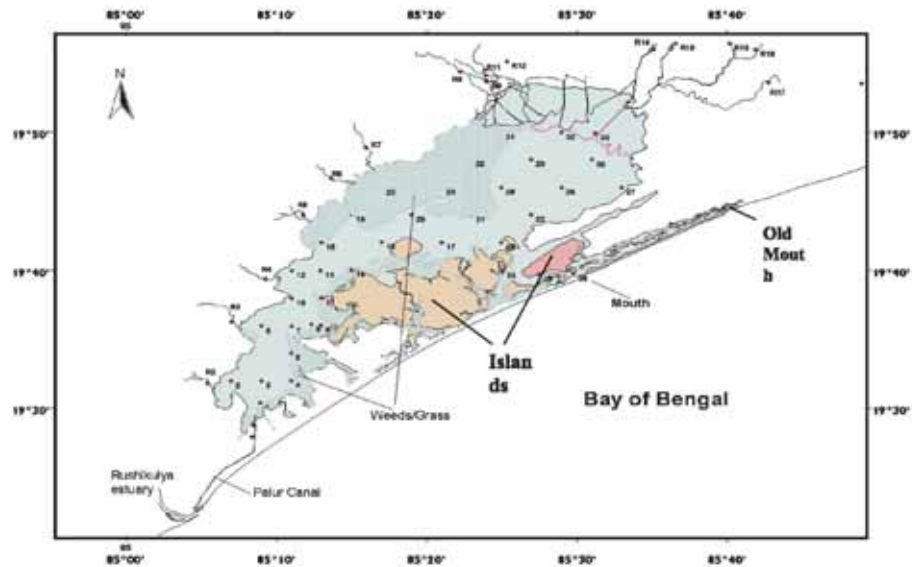
The coastal waters form the habitat for ecologically sensitive and commercially important marine organisms. The coastal waters are recipient of land-based wastes from sewage, industrial and agricultural sources. The sea-based activities like navigation by ships and near shore oil exploration also cause pollution of the coastal areas. In order to maintain water quality in coastal waters to sustain productivity, land-based discharges like sewage, especially from municipalities; effluents from a variety of industries and also from ships need to be regulated. However, while determining the concentration of chemical and physical constituents of these waste waters, especially the aggregated quantities of wastes arising from a group of industries and the impact of discharge of these aggregated quantities on water quality of the coast are not realized often. It is mainly because lack of target water quality which would not cause any harmful effect to the marine organisms. In other words, the total waste load to be discharged derived from discharged standards are not being worked out to meet the water quality criteria for coastal waters. In the absence of the water quality criteria for chemical parameters, there would be a situation where the levels of certain chemical parameters will exceed the tolerance limit of marine organisms. Such occasions would lead to deterioration of water quality and finally, would result in decrease in productivity, affecting the fisheries.

In order to develop scientific-based water quality criteria using the widely accepted concept of bioassay techniques, ICMAM Project Directorate has started implementing a long-term project on Marine Eco-toxicology, in association with Institute for Ocean Management, Anna University

(Chennai), Madurai, Kamaraj University, Madurai and University of Madras (Chennai). The main objective of the project is to determine Seawater Quality Criteria for heavy metals, pesticides, oil residues for coastal waters, estuaries and coral reef ecosystems to facilitate better management of seawater quality in these areas by State Pollution Control Boards.

5.2.7 Ecosystem Modelling for Chilka Lake

Chilka Lake, Asia's largest brackish water lagoon, represents a unique ecosystem considering that it is a Ramsar site serving both commercial fishing sector and local tourism. Catchments modification together with the opening of a new mouth in September 2000 substantially altered the Lake's environment, resulting in what has been apparently a gross shift from limnetic oligotrophy to mesotrophic conditions.



Chilka Lake Sampling locations (1-36)

On the basis of water quality (periodic monthly) monitoring (at 36 stations,) involving a suite of environmental variables together with (hydrodynamic) investigations on alterations to the flushing and salinity regimes associated with engineering interventions (mentioned above) as well as addressing a set of scenarios such as river discharge, estimating nutrient loads and exchange between the Lake and the Seas (fractionated) phytoplankton productivity and zooplankton biomass, seagrass, (micro) phyto and zoobenthos densities, it was possible to examine system behaviour during the past three years.

Biota

Chilka Lake is a shallow and generally well-mixed water body with continuous but slow exchange with the Sea, thereby offering adequate time for the nutrients to be converted into phytoplankton or other autotrophic biomass. All other biological and biogeochemical processes in the Lagoon are dependent on photosynthetic process. From the (integrated) works held so far, it was possible to identify five functional groups, (smaller and larger) phytoplankton, microphytobenthos, seagrass, macroalgae and aquatic weeds, which seem to play a crucial role in regulating the nutrient dynamics within the Lagoon.

5.3 Coastal Ocean Monitoring and Prediction System (COMAPS)

Coastal environment of India is under immense stress due to discharge / disposal of domestic wastes and industrial effluents from point and nonpoint sources as a result of rapid growth of population and economic activities. Further, lack of proper sewer systems and discharge of untreated/semi-treated sewage and effluents from coastal towns/cities are causing degradation of coastal environment. Monitoring the health of coastal seas is highly essential by assessing the status of pollution, detecting the radical changes of pollutants and alerting the government and public institutions, about the implications. In view of this, the programme on Coastal Ocean Monitoring and Prediction System (COMAPS) is being operated along the Indian coastal areas since 1991. Data on nearly 25 environmental parameters including physical, chemical and biological including microbiological characteristics of water and sediments at about 76 locations are being collected with the participation of R&D institutions and academia, within the 10 km sector of the coastline of the country, covering the maritime states and UTs. During the current XI Plan period, in addition to the existing tasks, the Ministry has expanded the COMAPS activities by taking-up oil spill modelling, reading pollution history and chemical transformation of mercury in the Vembanad Lake. The results obtained on the status of pollutants along the coastal waters of the country during the year 2007-08 indicate that :

Goa

Pollution in coastal waters of Goa is likely to arise from the mining of iron ores in the Western Ghats, beach tourism, and industries like fertilizer, pharmaceuticals, etc. Effluents from industries reach the coastal waters through backwaters. During the year, monitoring was carried out at Mandovi (Apr, May, Jul, and Sep' 07), Zuari (Apr, Jul, '07) and beaches of Candolim, Mobor, Benaulim and Velsao (Apr, '07).

Karnataka

Along the coast of Karnataka, the major source of pollution is sewage generated in cities/towns such as Honavar, Karwar, Chitrapura and Mangalore. There are a few industries located along the coast. The industrial sources at Mangalore include one major industry of chemicals and fertilizers besides iron ore handling and a refinery. Few small scale industries also discharge effluents into municipal drains. Intensive fishing activities and a large number of fishing vessels berthing in fishing ports also affect the coastal water quality. During the year, monitoring was carried out at Mangalore (May, Jun, Aug, '07).

Kerala

In Kerala, about 300 medium and large scale and about 2000 small scale industries are discharging effluents directly into saline or fresh water bodies. About 104536 m³ of treated effluents per day

are being discharged into the backwaters or sea. Further, out of estimated sewage of 243 MLD generated from coastal towns, about 166 MLD is collected through sewers and disposed mostly in the untreated form into backwaters, which ultimately reach the sea.

During the year, monitoring has been carried out at Kochi (May, Jun, Nov, '07) and Veli (Nov, 07). Here, suspended solids concentration was slightly high (up to 33 mg/L) in monsoon season. Dissolved oxygen level was low (4-5 mg/L) in all seasons. Slightly high levels of nutrients (nitrate, total nitrogen and phosphate) were observed in pre-monsoon and monsoon.

Andaman

In view of a steady increase in the shipping activities and growing urbanization, monitoring was carried out at 7 places in and around Port Blair (May, Aug, Nov' 07). The results indicated that suspended solids were more in pre-monsoon at all locations, but were in the range of 25-80 mg/l, highest being at Junglighat. Dissolved oxygen levels were high during monsoon in all locations, highest being at Junglighat (8.9 mg/L).

Tamil Nadu and Puducherry

Chennai harbour handles 40 million tonnes of cargo a year and it mainly include coal, fertilizers, chemicals, oils, acids, cement, etc. Textile, chemical and distillery industries are located at Puducherry, while a SIPCOT industrial complex, comprising pesticides, pharmaceuticals, etc. is located at Cuddalore. Harbour, industries like petrochemicals, fertilizers, salt pans, etc. are located at Tuticorin. Besides thermal power plants are also located at Chennai and Tuticorin.

Along Tamil Nadu coast, coastal waters of Chennai, Muthukadu, Puducherry, Cuddalore, Karaikal, Nagapattinam and Tuticorin were monitored (May, Jul, Dec' 07). The results indicated that a slightly high suspended solids concentration at Chennai and Nagapattinam (up to 110 mg/L). Dissolved oxygen was in the range of 4-5mg/l at all locations and was less during premonsoon, especially at Cooum (1-4 mg/L).

Andhra Pradesh

Along Andhra Pradesh coast, a variety of industries ranging from steel, engineering, chemicals, fertilizers, petroleum and thermal power plant are located in Visakhapatnam, while a steel and thermal power plants are located at Gangavaram. Kakinada is a port town having a few industries of fertilizers, petrochemicals, etc. coupled with fishing, agriculture and aquaculture as other major sectors. Kakinada canal, through which the town's sewage enters the Bay is the major source of organic pollution. Discharges from aquaculture farms, agriculture and industries cause pollution in the vicinity of Bhimavaram. As a result of multiple industrial discharges, which are mostly treated, the coastal waters of Andhra Pradesh receive a combination of untreated sewage and treated industrial waste.

During the year, monitoring was carried out at Visakhapatnam, Gangavaram, Kakinada and Bhimavaram (Jun, Sep, '07). The results revealed occasional high suspended solid concentration (up to 140 mg/L) at Bhimavaram, especially during summer. Dissolved oxygen was observed to be low (<5 mg/L) in all areas except Bhimavaram (4-6 mg/L).

Orissa

Along the Orissa coast, there are seven major industries, of which four significant ones are in Paradip. Untreated wastes from several hatcheries and agricultural wastes reach the coastal waters. Mining of chromium and iron ores affect the coastal waters. Domestic sewage, especially from non-point sources like 6 major rivers is another minor source of pollution. None of the coastal urban local bodies, including Paradip port township and municipalities have any proper collection, treatment and disposal facility for the domestic sewage and hence dispose untreated effluents into the coastal waters.

During the year, coastal waters of Mahanadi, Paradip and Puri were monitored (May, '07). Coastal waters of Orissa were characterized by high dissolved oxygen levels (6-7 mg/L), low suspended solids concentration (<18 mg/L) and low biochemical oxygen demand (<2 mg/L).

West Bengal

Along the West Bengal coast, many of the major industrial and urban establishments are located around the Hoogly river. More than 100 industries such as paper and pulp, distillery, textile, paint, metal, chemical, thermal power plant, etc. discharge about 4.3×10^8 m³/d of effluents into the tidal stretch of Hoogly. Most of the pollutants enter the coastal waters through river discharges, agricultural runoff and port activities.

Coastal waters of Sandheads, Hoogly estuary and Haldia port were monitored (Jun, '07). Low suspended solid concentration (15-31 mg/L), high dissolved oxygen levels (6.4-7 mg/L), low biochemical oxygen demand (0.8-2.1 mg/L) indicated good water quality.

Inter-calibration Exercise

The Ministry of Earth Sciences continuously monitors the water quality of Indian coasts through various institutes/universities under the COMAPS programme. More than decadal data has been generated under this programme. A quality check of this collected data for different parameters is highly essential before using the data for various purposes. The quality check process is highly complicated as the errors in the results could be due to variations in conditions, viz., sampling, preservation, timely analysis, methodology adopted for analysis, environmental conditions for analysis, apparatus used, quality of chemicals, configuration of the instrument, etc. Apart from these, the analytical skill of the chemist is very important. In view of this, MoES has started the

“Inter-calibration Exercise (ICE)”, to periodically check the accuracy of data submitted. It can be interpreted that the accuracies reflected in these exercises reflect the accuracies of the data reported by these institutions for the corresponding period.

ICMAM-PD conducted four ICEs : Nitrate (NO₃) (in June, 2007), Sediment Lead (Pb) (in June-July, 2007), Inorganic Phosphorus (PO₄) (in September, 2007) and Total Nitrogen (TN) (in January, 2008).

The national and state R&D laboratories and coastal universities, which are executing the monitoring activities under COMAPS programme have participated in all these ICEs. The results reported by the laboratories mostly varied within $\pm 10\%$ with a few laboratories showing deviated results in one or two exercises. The erring laboratories were provided adequate guidance and they showed improvement in subsequent exercises. The New centres inducted for the first time under COMAPS programme are : (i) Goa University, Goa and Mahatma Gandhi University, Kerala.

GIS Database for Marine Pollution

Along Indian coast, 76 locations 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 14 locations, namely Okha, Porbandar, Hazira, Daman, Mahim, Koodankulam, Puducherry, Ennore, Nizampatnam, Gopalpur, Rushikulya, Puri, Konark and Matla. These data are integrated in GIS along with other information such as coastal land use changes, locations of industries, human settlements, etc. as possible sources of pollution.

5.4 Drugs from Sea

The Ministry of Earth Sciences has been implementing a National Coordinated Research Programme on ‘Development of Potential Drugs from the Ocean (Drugs from Sea)’ to harness bioactive compounds from the marine organisms for human therapeutic purposes since 1990. This programme is being carried out successfully under the leadership of Central Drug Research Institute (CDRI), Lucknow and with the participation of 13 other national and state R&D laboratories, including universities. The drugs are being explored for various priority diseases like cancer, HIV, etc. The centralized compounds basedata is being continuously updated and the *Ocean Drug Alert Bulletin* is published periodically.

In addition to regular exploration of new chemical entities under the programme, the following compounds are in advanced stages of product development:

- | | | |
|----|------------------|---------------------|
| 1. | CDR-245, 258 | Antifungal |
| 2. | CDR-134-D-212 | Antihyperlipidaemic |
| 3. | CDR-131, NIO-492 | Antihyperglycaemic |

During 2007-08, some new activities have been initiated under this programme, they are

1. Receptor binding studies to participate quick screening and evaluate the possible mechanism of action,
2. Development of facilities for test systems for aquatic animals,
3. Incorporation of new test systems for evaluation of marine samples/active molecules on cardiovascular and central nervous systems and wound healing,
4. Synthesis of active compounds based on new leads, and
5. Analysis of neurotoxic potential of marine organism as a novel chemical entity for drug development.

So far, 31 samples with significant activities has been discovered.

1.	Antihyperglycaemic (Anti-diabetic)	07
2.	Antihyperlipidaemic (Lipid-lowering)	06
3.	Anti-fungal	14
4.	Spermicidal	02
5.	Anti-tubercular	01
6.	Anti-viral	01
	Total	31

Activity	Code
Antihyperglycaemic	NIO-492;CSM-436-A001
Antihyperlipidaemic	CDR-269;CDR-333
Antifungal	NIT-204
Antifilarial	AU2-357-A001

After confirmation of activities, the following leads have been selected for detailed pharmacological evaluations:

5.4.1 Product Development

Among active samples following samples have been identified for product development:

Product	Activity	Lab.	Status
CDR-134-D-123	Antihyperglycaemic	CDRI	Clinical Trials Phase I Multiple dose
CU1-002/004	Antihyperlipidaemic	CDRI&BCR-PGI	IND filed
CDR-134-F-194	Antihyperglycaemic & Antihyperlipidaemic	CDRI	IND being filed

5.4.1.1 Potential Antidiabetic Product from Marine Samples

One crude extract, CDR-134-D123, and two marine fractions, CDR-134 F194 and CDR-267 F018, have shown antihyperglycaemic effect in sucrose-challenged streptozotocin-induced diabetic rats and db/db mice. These fractions also prevented the rise in postprandial hyperglycaemia in both normal rats and hyperglycaemic db/db mice post-glucose load. Both CDR-134 F194 and CDR-267 F 018 have an additional advantage as these agents have also shown antidyslipidaemic activity in both hyperlipidaemic golden hamsters and db/db mice. CDR-267-F018 has pronounced lipid lowering activity with significant antihyperglycaemic activity.

1. CDR-134 (D123)

Phase I Clinical Trial (Single dose study)

Phase I single oral dose clinical trial studies are being conducted at Clinical Pharmacology Unit, Department of Medicine, King George's Medical University, Lucknow.

These studies have been completed in a total of 31 volunteers receiving drug /placebo. All the volunteers have tolerated the drug very well and no minor or major side effects have been observed. Investigations were done before giving the drug (zero hour) and at 24 hours after the drug (+ 24 hour) and at +7 days post-medication. The careful recording of all the haematological, biochemical investigations and ECG data in individual case record forms was done. After completion of the single dose studies, the codes were opened and the data was compiled and analysed, and conclusions were drawn.

Phase I Clinical Trial (Multiple doses study)

The ethical clearance has been obtained and trial will be initiated soon at KEM Hospital, Seth G.S. Medical College, Mumbai.

2. CDR-134 F194 (Antihyperglycaemic and antihyperlipidaemic):

The fruit were extracted and fractionated and out of many fractions only F194 fraction was found to be the most active fraction. This fraction was further purified and 14 markers were identified, 8 markers were isolated, identified and bioassayed and rest 6 markers were identified by LCMS. All markers are the known markers. Out of these 8 markers tested, only one major marker (K211) showed promising activities.

Regulatory Toxicity and Safety Pharmacology

Acute and sub-acute toxicity studies of CDR-134-F194 were completed on rats as well as mice. The regulatory pharmacology in rats and mice has also been completed and the preparation has been found to be devoid of any undesirable pharmacological effects.

3. CDR-267-F018 (Antihyperglycaemic and antihyperlipidaemic)

The active crude extract of the fruits of the mangrove was fractionated and out of four fractions , fraction-F018 was the most active fraction. The fraction F018 was further purified and 8 markers were isolated and identified. Out of these 8 markers, 7 are the known markers and one of them is a new structure and is a mixture of two isomers. Out of all the markers and fractions bioassayed, the fraction F018 was found to be the most active fraction in both the activities.

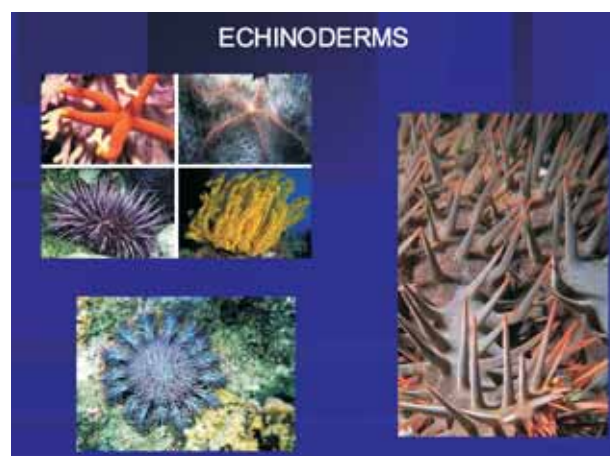
Regulatory Toxicity and Safety Pharmacology

Single dose toxicity study of CDR-267 -F018 has been completed in both rats and mice and sub-acute toxicity study is under progress. The regulatory pharmacology in rats and mice has also been completed and the preparation has been found to be devoid of any undesirable pharmacological effects.

5.4.1.2 Potential Antihyperlipidaemic Product from Puffer Fish

PFO (Puffer fish oil)-CU1-002

Anti-dyslipidaemic product was evaluated in Triton hyperlipidaemic model in rats. Safety pharmacology and chronic toxicological studies in rats and Rhesus monkeys have been found safe. No significant changes in the studies on stability and pharmacokinetics have been found. IND was filed in March 2007 and the approval is awaited for initiation of Clinical Trials- Phase-I. Thus, an extensive work has been done on marine samples under the project, which has resulted in the identification of active samples having immense potential for treatment of diseases like diabetes and lipid disorders, affecting a large number of population in our country.



5.5 Marine and Atmospheric Science Research and Capacity Development

The Ministry of Earth Sciences provides supports to basic and applied research in ocean and atmospheric science & technology in the universities/institutes for promotion of front-ranking research in the specialized areas of Earth Sciences, Atmospheric sciences and related subjects. The programme has following objectives:

- To create adequate expertise in various disciplines of ocean and atmospheric science & technology for the benefit of the society.
- To maximize the benefits that our country could realize from her vast ocean regime.
- To promote scientific temper and awareness among the public and school children about ocean and its resources, usefulness, management and development.

Following nine Ocean and Atmospheric Science and Technology Cells (OASTC) have been established in various universities for conducting research in different specialized areas of marine

and atmospheric sciences.

1. Marine Microbiology at Goa University,
2. Marine Biology at Annamalai University,
3. Marine Geology & Geophysics at Mangalore University,
4. Coastal Marine Culture Systems at Andhra University,
5. Marine Coastal Ecology of West Coast at Bhavnager University,
6. Marine Coastal Ecology of East Coast at Berhampur University,
7. Beach Placers at Tamil University,
8. Marine Benthos at Cochin University of S&T and
9. Ocean Engineering & Underwater Robotics at IIT, Kharagpur.

The Ocean and Atmospheric Science and Technology Cells (OASTCs) regularly organize advanced training programmes and workshops to generate skilled manpower in the identified areas of ocean sciences. The cells at Goa University and Annamalai University are functioning as Centers of Excellence (CoE) in Marine Microbiology and Marine Biology. Besides these, Principal Investigators can also submit their project proposals directly to the Ministry for funding. It is further planned to augment this programme by providing assistance to the retired scientists for conducting research. The programme also provides assistance to Indian Scientists for participation in workshops, seminars, symposiums, trainings, etc. abroad.

The ongoing projects and achievements of the OASTCs during past one year are as follows:

- Evolving an X-Ray diffraction method for quantification of clay minerals in sediments and its applications for the study of coastal and continental margin sediments of western India
- Surf zone dynamics and foreshore sedimentation process along the coast between Bhatkal and Baindur, Karnataka
- Nitrous oxide and methane in coastal ocean and estuaries.
- Sea level changes and neotectonic evolution of south Andaman Coast, Andaman Sea
- Training programme on production of disease free shrimp seed in the hatcheries
- Hands on Training programme on production of disease - free shrimp seed in the hatcheries- Andhra University
- Molecular taxonomy, reproductive biology and juvenile distribution of groupers (pisces: serranidae) off east coast of India
- Biodiversity of plankton in the coastal waters of Alang, Gujarat
- Studies on bioaccumulation/biosorption of heavy metals by marine algae of Gujrat coast

- Halophilic Archaea and Halotolerant Bacteria in remediation of petroleum Hydrocarbon contaminant saline sites.
- Biodiversity of halophytes along Gujarat coast and preparation of a monograph on halophytes
- An assessment of pollution status in relation to biodiversity of Narmada and Tapi estuaries of Gujarat, India
- Studies on benthic and planktonic biodiversity of Kachchh coast-Gujarat
- Molecular characterization and biochemical evaluation for bio-prospecting marine algae in Chilka lake
- Anoxic phototropic bacteria of Chilka lagoon
- Phytodiversity and ecology of sandy coastal ecosystem of Orissa
- Population study of mud crab in the Chilka lagoon, East Coast of India
- Biogeochemical control and feedback on primary production of Mahanadi Estuary of North - East coast of Bay of Bengal
- Publication of a monograph on "Coastal Non Living Resources of Tamil Nadu."
- Investigations on the effect of bottom trawling on the benthic fauna off - Saurashtra coast
- Bioactive compounds from benthic microbes
- Ecology of marine microbenthos, physicochemical processes and microfaunal communities with special reference to ciliated protozoans and flagellates.
- Assessing coastal and marine biodiversity for south Andhra Pradesh: Macro and Meiobenthic communities of Nizampatanam Bay
- Trophic relationship of polychaetes with microorganisms along Trivandrum coast
- Role of benthic vibrios in the mineralization process in the Marine environments.
- Development of an autonomous underwater vehicle capable of operation in shallow water with operation up to 150 m depth IIT Kharagpur and Central Mechanical Engineering Research Institute, Durgapur,

Achievement

- During last one year the findings of the research projects were published in 10 national and international journals.
- Two Monographs on Indian Barnacles and Taxonomy of Bryozoa from the Indian EEZ were published.

- After extensive collection and selection of brooders from the Coramandel coast, two species – *Pereneries cultrifera* and *Nephtys polybranchia* were identified as potential species for live feed for aquaculture industry. The *Pereneries* sp was found to be responsible to enhance the colour quality of the ornamental fishes and accelerate the spawning periodicity especially in clown fishes.
- Collection, documentation and evaluation of Streptomyces belonging to mangrove ecosystem of Bhitarkaniaka, Orissa were completed.
- Anoxygenic phototrophic bacterial diversity of marine ecosystems and their capability to degrade aromatic compounds were examined.



Captive culture of Perineries sp

6 National Institute of Ocean Technology (NIOT)

6.1 Commissioning and Testing of Hyperbaric Test Facility

Hyperbaric test facility is used to simulate the pressure in ocean environment inside a high pressure vessel. It has been designed to test a pressure up to 90 MPa (900 bar) max., approximately equal to 9000 m of water depth. A high pressure test facility to test up 900 bar was commissioned at NIOT Campus in August, 2007.



Hyperbaric Test Facility



Testing of Argo Float Main components of Hyperbaric Test Facility

It consists of a steel cylindrical vessel with lids at the top and bottom. Test component is placed inside the pressure vessel as shown in the picture. The top lid is handled by hydraulic hoist system. Intensifier type high pressure pump is used to pressurize the vessel up to 900 bar. Various manual and automatic valves are used to control the pressure in the vessel. And the pressurization medium is a mixture of water and anti-corrosive additive.

System can be operated in two modes-manual and automatic. In the manual mode, control is done through the push-button on the touch screen. In the automatic mode, pressure cycle is performed automatically from the filling to the draining. Programmable Logic Controller (PLC) controls various functions of the Hyperbaric Test Facility.

Various underwater components like crawler parts, high pressure pump and motor, buoyancy package, hydraulic circuits, flotation for Tsunami buoy, Argo float, etc. were tested successfully up to the working pressure.

6.2 Marine Sensors and Electronics

NIOT, with a mandate to develop and demonstrate technologies for oceans, has many electronics-based underwater projects. The design, development and integration of electronic systems for underwater applications pose many insurmountable problems. Facilities to qualify electronics under the conditions of underwater operation like, EMI/EMC, Leak Testing, Environment Testing and Shock & Vibration Testing are being set up.

6.2.1 Underwater Electronics Support Facility

It is necessary that all the sub-systems should be tested for EMI and EMC individually and also after the integration. Hence, as first step towards the establishment of the underwater electronic support facility, an EMC/EMI analyzer with broad frequency range alongwith the current probe, data logger and necessary software was procured and commissioned. EMI/EMC analysis of the noise generated by the thrusters of remotely operable vehicle ROSUB 6000 has been successfully carried out using this facility. In addition to this, helium leak detector facilities such as global test, spraying test and sniffing test, etc. have been initiated.

6.2.2 Underwater Component Development

Components such as cables, connectors, transformers, slip rings, underwater cameras, power converters form a major part of systems such as Data Buoys, Deep Sea Mining Crawler, ROV for 6000 m, Argo, etc. These components are not always available off-the-shelf, even in the international market. Many a time procuring these equipment and getting them serviced, when required, interfered with the project schedules and involved costs.

M/s FCI, OEN, Kochi, was identified as the industry partner for the development of Fiber Optic Connector. The design experience of the OEN connectors and the experience of NIOT scientists in underwater design were integrated for the manufacturing of these connectors. A mock-up connector with aluminium was fabricated and tested up to 200 bars at NIOT laboratory facility. The prototype connector was later made and fibre optic characteristics were tested at the Bangalore manufacturing unit of M/s FCI,OEN, Kochi. It was found that attenuation in the connector is as per requirements.

The development of underwater motor was taken up in collaboration with M/s PSG Industrial Institute, Coimbatore. The design of a 250 kw motor was completed and major vendors for the sub-systems of the motor were also identified.

A low cost fully integrated echo sounder GPS interface and RF telemetry was designed, developed and tested up to 80 m water depth off-Chennai with indigenously made transducer.

MS&E group had taken-up the task of developing semiconductor devices that are used in the underwater power supplies. As a first step, MS&E started testing commercially available diodes, transformers and other devices at high pressure to understand their behaviour at higher hydrostatic pressures.

With the available pressure chamber at NIOT, the V-I characteristics of a commercially available diode were studied at 50 bar pressure for one month. A change in temperature and

pressure inside the pressure case was noticed during the study and it was correlated with the power and the properties of the oil used. These studies provided a valuable input for designing the underwater pressure cases and pressure compensators.



200 kHz integrated Echo-Sounder developed and successfully tested

6.2.3 Marine Sensors and Technology Development

The development of underwater acoustic sensors for oceanographic applications like Echo Sounders, Sub-bottom Profilers and Long-range Underwater Communications was taken up and successfully developed and tested. Interaction between some public sector organizations for the development of underwater acoustic sensors of mutual interest was also initiated by the group. The cymbal transducer technology for M/s NSTL, Visakhapatnam, was successfully developed, tested and handed over to them for their use under a sponsored project. An MoU was signed between NIOT and BEL, Bangalore for transducer development of mutual interest. The Transfer of Technology (ToT) to BEL, for the first project (LF Stave development) is under progress.

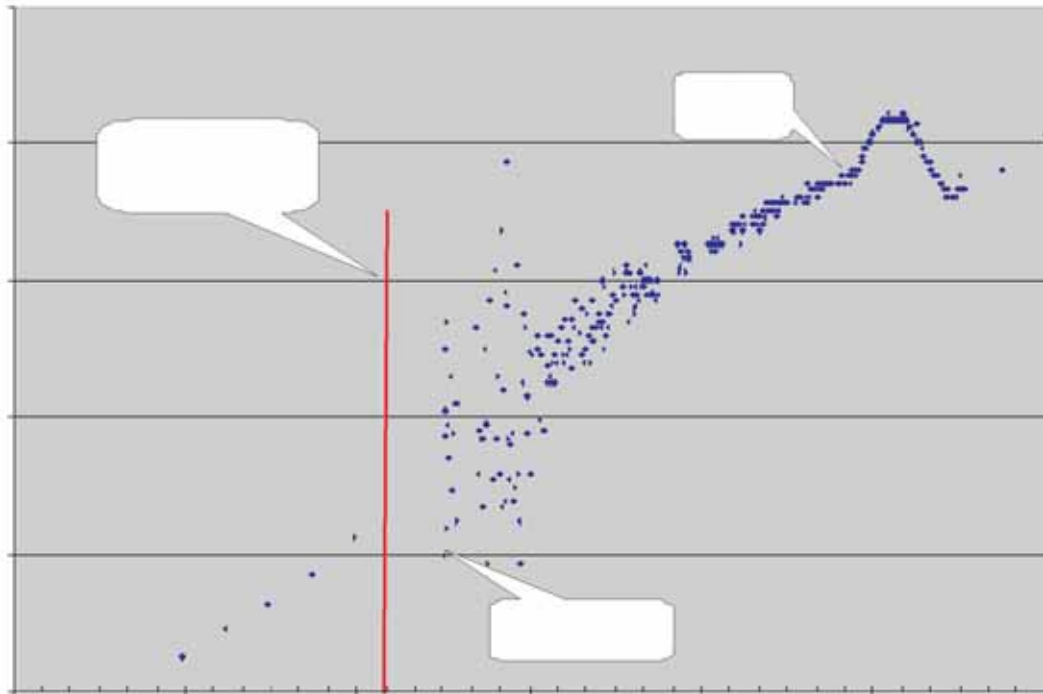
6.3 Ocean Observation Systems

6.3.1 Moored Data Buoys

Under ocean observation system, 28 buoy networks have been established and efforts are underway to make it as a 40 buoy network.

6.3.2 Tsunami Warning System

Towards setting up the Tsunami Buoy Network in Indian seas, 8 Tsunami buoys in the Bay of Bengal and 2 Tsunami buoys in the Arabian Sea have been established and the Tsunami systems captured the earthquake event on 12 September, 2007 off-Sumathra



Seismic / Tsunami event captured on 12 Sep, 2007, by TB 10A

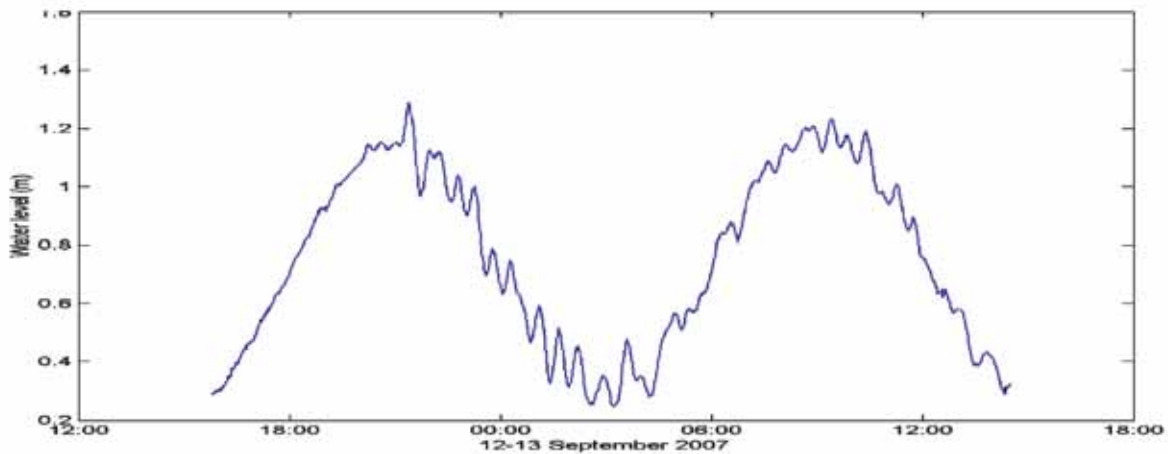
6.3.3 Tide Gauges Networking

The tide gauges have been installed and commissioned in different locations like Kakinada, Chennai, Tuticorin, Vizhinjam, Cochin, Mangalore, Kandla, Pippav, Simhadri-NTPC terminal - Andra Pradesh, Gopal Puri, DIU Port, Gujarat and networked using GSM modems. In Minnie Bay and Rangat Bay tide gauges have been networked with INMARSAT modem and the tidal data from all these stations are available on the internet.

As mutually agreed by NIOT-SOI, the installation, commissioning and networking of NIOT tide gauges utilizing infrastructure of SOI like jetties, stilling wells and VSAT connectivity at Main Land like Ennore, Chennai, Cochin and Machilipatnam and Island like Port Blair and Nancowry in Andaman islands have been successfully completed.

INSAT communication link has been installed and interfaced with tide gauge at the Ennore port and data is being transmitted to SAC, ISRO and INCOIS.

The Ennore ATG & PTG have captured the water level rise at Chennai coast caused by the 12 September, 2007 Earthquake event.



Water level rise due to earthquake event (Ennore ATG)

6.4 Coastal Environmental Engineering and Survey Group

6.4.1 Environmental Engineering and Modelling

NIOT is one of the seven partners for a European Commission project on “Assessment of impacts of tributyltin (TBT) on multiple coastal uses”, alongwith, TERI-India, NIO-Goa, ENEA-Italy, University of Goteborg-Sweden, Stichting Katholieke Universiteit-Netherlands and NSRDC-India. For this project, NIOT’s role is to (i) evaluate TBT degradation mechanism using microorganisms and (ii) identify waste disposal strategies for safe disposal of TBT paints removed from ships.

As part of this project, a ‘Workshop on Antifouling Paint Effects on Fisheries’(WAPEF) 2007 was conducted by NIOT in Chennai on during 26-27 September, 2007.

The objective of the workshop was to disseminate knowledge of TBT impacts and safe fishing grounds to the fisher folk and boat manufacturers. Other participants were fisheries stakeholders like Department of Fisheries, Govt. of Tamilnadu, fisheries research organizations, boat manufacturers, fishermen societies and self-help group representatives.

The representatives of fishermen community belonging to all the 13 coastal districts of Tamil Nadu, attended the two-day workshop packed with lectures by eminent scientists, interactive questionnaire and poster sessions.



In addition to impacts of TBT, pollution issues of the fisheries harbours such as discharge of industrial and municipal wastewaters, discharges from fishing boats, disposal of used nets, batteries in fisheries harbours and their impacts were discussed.

The entire workshop was conducted in non-technical local language (Tamil) and was widely appreciated by the fishing community.

A souvenir with bilingual (English and Tamil) abstracts of the lectures presented during the workshop, was released.



Section of audience



Poster Session

6.4.2 Water Quality Monitoring and Environmental Impact Assessment (EIA)

- Rapid EIA studies were undertaken for the following infrastructure development projects in the Andaman and Nicobar Islands
- Construction of road at Katchal, East Bay Jetty to Kapanga, infrastructure development at Katchal for Andaman Police, construction of rural road from Chidiyatapu to Bada Nalah, Bada Balu, construction of a helipad to Indira Point, Great Nicobar



Soveiner Realse

- Conveyance of freshwater from the perennial streams at Rutland Island to Port Blair through pipelines with the objective of augmenting the acute drinking water shortage
- Creation of shelters for tribals at 10 sites in Great Nicobar and Little Nicobar

6.4.3 Monitoring of Environmental Quality for Cairn Energy Offshore Platforms off-Gulf of Khambat

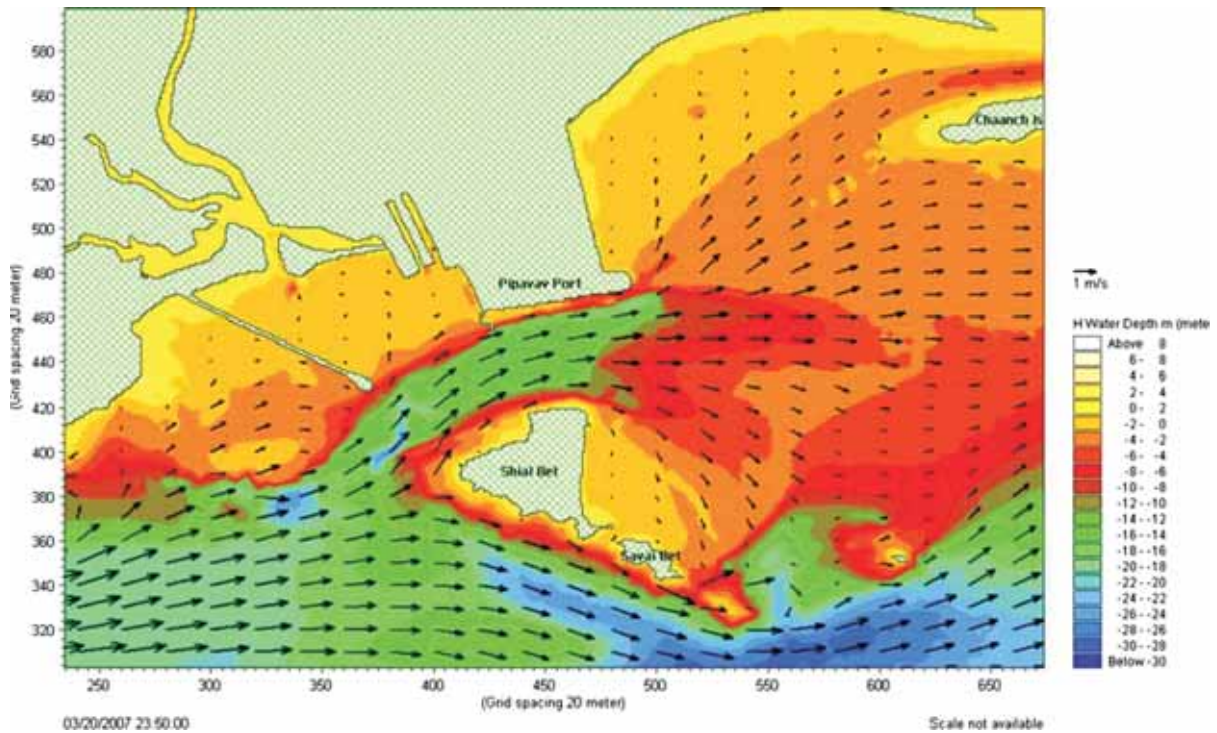
Numerical Modelling Studies for Port Expansion

NIOT has undertaken a numerical modelling study in 2007 to arrive at a feasible layout for expansion of Pipavav port, Gujarat, considering the effect of hydrodynamics and sediment transport. The proposed expansion plans are vital for setting up thermal power plants at Pipavav. Extensive data collection in the area has been carried out during March-April and September-October, 2007, representing non-monsoon and monsoon seasons. It includes bathymetry survey, geotechnical sampling, geophysical survey, surface elevation measurements, current observations, profiling current meter observations, float tracking and water quality analysis. Data collected has been analyzed and a report has been submitted. Hydrodynamic and sediment model calibration is under progress. The calibrated models will be used to simulate various scenarios of port expansion.

Numerical modelling studies for Thermal Power Plant Expansion

NIOT carried out numerical model studies to evaluate the impact of the future expansion of 1950 MW NTPC power plant at Kayamkulam, Kerala. The hydrodynamic, advection and dispersion

studies were required in order to estimate the maximum rise in temperature and salinity in kayal due to excess discharge of cooling tower. Water level variations and current velocity measurements were carried out at two different locations along the kayal for a period of 15 days each for monsoon and non-monsoon seasons. ADCP survey has been conducted at six locations to estimate the current profile and discharge across the kayal. Salinity and temperature data were collected at 5 different locations for a period of 15 days. Bathymetric survey has been carried out for the entire kayal, which is about 12 km long, with 100 m interval lines. The model covers an area up to 15.5



Result from HD simulation showing current vectors

km from the channel mouth towards NTPC plant with an average width of 400 m. MIKE 21HD is used to simulate the hydrodynamics, advection and dispersion. The model was successfully calibrated against actual water level, current, temperature and salinity data by using MIKE 21. Calibrated model was used to study the effects of intake and outfall discharges.

6.4.4 Coastal Engineering Survey

Development of Sub-bottom (Shallow Seismic) Data Processing and Visualisation Utility

The in-house development of sub-bottom data processing and visualisation utility, using Matlab is being continued and has been named as NiotSeis.

Objectives

- (1) To visualise the recorded sub-bottom data in the form of numbers and to present them as per the user's choice, which is not applicable with any of the presently available softwares at NIOT.
- (2) To find the possibilities of applying more rigorous processing techniques.

The most important feature so far has been the spectral analysis tool. None of the commercially available sub-bottom data processing software at NIOT has got this feature. Utilizing this tool, the dependence of frequency with time for a given trace can be observed.

Multiple Suppression

As mentioned earlier, this topic has great significance in view of the difficulties faced while processing and interpreting the sub-bottom data acquired in coastal waters and none of the existing softwares provides a solution for this common problem. Several processing routines were written in matlab to pre-process the data before applying Predictive Deconvolution, viz., selection of data samples and traces, frequency filtering, muting water-column, TVG correction, etc. The fine-tuning of the tool and testing of its reliability are currently in progress.

6.4.5 Deep-Sea Cruise aboard Marion Dufresne

Two NIOT officials have participated in an ocean cruise on board the French vessel Marion Dufresne (MD-161) from 10 - 29, May, 2007. This cruise was organized by NIO as a part of Gas Hydrate project. Marion Dufresne is well known for collecting long core samples (about 60 m) using a giant corer (10 tons) Calypso. On an average, about 30 m long cores were collected during this cruise in Krishna-Godavari and Mahanadi basins.

6.4.6 Marine Archaeology

Indian coastline with a length of 7517 km is dotted with a number of ports that were actively involved in maritime activities for nearly 3000 years. Literary references to such activities indicate the presence of foreign vessels in the Indian waters and the sinking of some of them in the course of their voyage. The study of shipwreck will reveal various aspects like the type of ship, nature of the cargo, and weapons carried at the time of sinking, etc. The public letters written to the Secretary of the Admiralty of the East India Company in the year AD 1805 contain references to the ships lost in the Indian waters until the time of the letter.

In this context, a preliminary survey-using sub-scan was planned to identify a wreck site near Chennai. The side scan data indicated the probable orientation of the wreck in the east-west direction. Since the wreck is lying at a depth of 60 m, 'ground truth verification' could not be carried out to extract other relevant data about the ship or the causes, which led to the sinking of the

ship. The Admiralty Records and the Memoirs of the Travellers mention a number of wrecks in the Madras Road. Further geophysical study on the offshore of is likely to throw light on the shipwrecks, including those from the English East India Company.

6.5 Marine Instrumentation and Ocean Acoustics

Ocean acoustic research comprises components such as measurement, analysis and interpretation. The group is focusing its activities towards the following:

- To undertake a wide spectrum of research activities that will lead to a better understanding of underwater acoustic signatures of various nature, the mechanism of sound propagation in the oceans, how acoustic transmissions can be employed to measure the physical properties of the ocean and its boundaries, acoustics scattering and bioacoustics.
- To design and develop marine systems which include underwater acoustic systems/devices, oceanographic systems and implementation of advanced methods of data acquisition for carrying out the above emphasized research.
- To perform data processing and analysis and interpretation using approaches drawn from theory, numerical modelling and observations, for precise judgment. Understanding the theory, the measurement tools and the numerical tools within the same context will be required.
- To establish two fully instrumented pontoons, followed by assembly, integration and deployment, which can serve as platforms to conduct open sea experiments like acoustic scattering studies, calibration of low frequency acoustic devices / instruments, etc. The acoustic test facility will continue to be maintained and used for calibration and other work.
- To create a unified platform to work under the broad area of 'Ocean Acoustics and Marine Systems', giving emphasis to scientific research and technology development.

Studies have been initiated for the design and development of automated systems for underwater noise measurements which are vital for ocean acoustics.

Collaborative projects with institutes like NPL, IIT (Delhi), NIO and IISc, are being taken up to achieve the above objectives.

6.6 Ocean Science and Technology for Islands (OSTI)

Under this programme, continuous technical support for lobster, crab fattening and farming is being extended to the island and coastal fishers in Tamil Nadu, Puducherry, Orissa and Andman & Nicobar. Training programmes on mud crab fattening and farming in FRP cages and in pen in backwaters were conducted in the coastal village Killai, Cuddalore District, based on the request from the Directorate of Town Panchayats, Chennai. District Collector, inaugurated the training programme and distributed NIOT-FRP cages to Women Self Help Group. Training programme on

mud crab fattening and farming in bamboo cages and in pen for Women Self Help Group was conducted in Mirzapur and Mahisa, Chilika Lake, Orrisa.



District Collector distributing FRP cages at Killai, Tamil Nadu



Floated FRP cages inside of pen at Killai, Tamil Nadu



Bamboo cages floated inside of pen at Mahisa, Orissa

6.6.1 Breeding and Larval Rearing of Mud Crabs

Life cycle of the mud crab, *Scylla serrata*, was successfully completed in Neelankarai Seafront Laboratory. The zoea had five stages, followed by a megalopa stage that moulted into crab let within 30 days. The crab lets (male & female) reared in seafront laboratory moulted 13 times and reached 112.5 g weight in a span of six months. The growth rate, specifically the increment per moult, was slower in the male, then female crab.



Mud crab brooder



Mud crab crablet

6.6.2 Stock Identification & DNA Taxonomy of Lobsters and Crabs

Intra-and inter-specific differentiation of Indian spiny lobster of the genus *Panulirus* were studied employing Restriction Fragment Length Polymorphism (RFLP) analysis of the mitochondrial (mtDNA) gene cytochrome oxidase 1 (COI). PCR-RFLP analysis is being applied to determine the intra-specific population structure and patterns of differentiation to delineate reproductively isolated stocks of genus *Panulirus* from different regions of Indian coast.

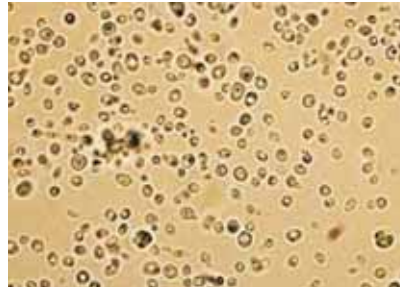
6.6.3 Marine Micro Algal Biotechnology

Development and commissioning of outdoor tubular photobioreactor for a consultancy project entitled "Studies on the mass culture of selected marine micro algae for cell growth in

photobioreactor” is in progress. Five strains of marine *Chlorella* sp. have been isolated from Chennai coast and experiment of the growth performance and biomass production is in progress. Heterotrophic production of *Chlorella vulgaris* using different sources of carbon yielded a maximum biomass of 10 g/L dry weight with glucose as the source of carbon. Harvesting of micro-algae culture by microbial-based bioflocculation method has proven to be 90 % efficient using bacteria isolated from Minnie Bay.



Isolation and culture of micro-algae in agar slant



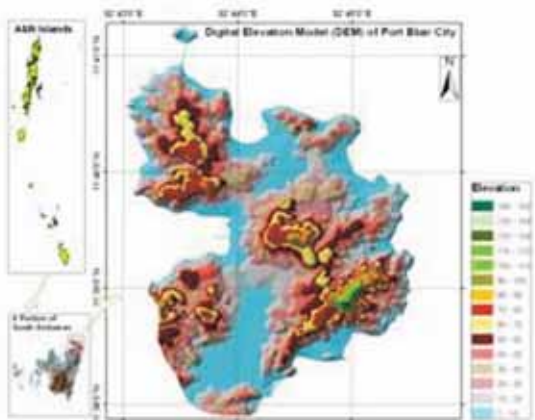
Chlorella vulgaris grown under heterotrophic condition



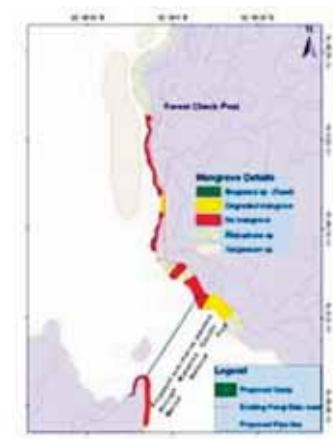
Algal harvest using bioflocculants

6.6.4 Island Resource Information System (IRIS)

Digital Elevation Model (DEM) for Port Blair and Rutland has been developed. Mangrove and seaweed areas were demarked by GPS survey and GIS classification map is being prepared for Pongi Balu and Manjery.



Digital Elevation Model (DEM) of Port Blair city prepared using 1:25,000 scale toposheets (Survey of India) having 10 m contour interval



Mangrove classification at Pongi Balu and Manjery using GIS tools

Under 'Drugs from Sea' project, a total of 98 samples were collected from Andaman and Nicobar Islands and 33 were identified. Four samples showed antibacterial activity and two samples were reported to have anti-osteoporotic activity and one sample was reported have anti-filarial activity during a preliminary investigation. The changes in the physio-chemical and biological parameters of Port Blair Bay stations were periodically monitored under the Coastal Ocean Monitoring and Prediction System programme.

6.6.5 Marine Bioinformatics

The species information collected mainly from Andaman and Nicobar Islands is maintained under the Island Database. A new website for user-friendly access of information on our activities has been developed. Phylogeny studies on few selected molecules like *Wnt*, Vitellogenin yolk protein and GnRH were carried out to find its evolutionary significance.

6.6.6 Materials for Marine Applications

National Institute of Ocean Technology (NIOT), Chennai and University of Chemical Technology & Metallurgy (UCTM), Sofia, Bulgaria are working together on the development of silicon-based coatings to prevent marine biofouling.



European Patent on New Foul release formulation developed jointly by NIOT (India) & UCTM (Bulgaria) being handed over to Dr. S. Kathirolu, Director, NIOT, by the Bulgarian Investigators in the presence of Dr. P. S. Goel, Secretary, MoES



Barnacle adhesion tester jointly developed by UCTM (Bulgaria) and NIOT (India)

NIOT and UCTM are working together to develop a new paint system to prevent corrosion. A patent was filed for the new foul release coating system developed under this joint project. Barnacle Adhesion Tester, an equipment to measure the shear force required to detach the barnacle attached

to different experimental coupons was designed and constructed according to ASTM standards.

Under the project on Performance of Naval Materials under Immersed Condition in Seawater funded by Naval Research Board, the behaviour of different materials under immersed conditions in seawater was evaluated. As part of the project on Biofouling Studies in Plate Heat Exchangers at Madras Atomic Power Station funded by IGCAR, Kalpakkam, the long-term effects of operation of plate heat exchangers in seawater environment were examined to determine the optimum levels of biocidal dosage required for controlling biofouling on plate heat exchangers for the 500 MW PFBR brought to BARC.

As part of the programme on Marine Natural Products, marine organisms like sponges, seaweeds, echinoderms are being screened for identification of potential antifouling compounds. Out of these 25 extracts, two extracts obtained from *Caulerpa taxifolia* and *Padina gymnospora* showed antibacterial activity against one biofilm forming marine bacterial strain each. The extracts of *Padina gymnospora* exhibited significant activity (9–11 mm zone of inhibition at 200 µg per 6-mm disc) against strain BF-3 and extracts of *Caulerpa taxifolia* exhibited significant activity (9-11 mm zone of inhibition at 200 µg per 6-mm disc) against strain BF-10. The crude organic extracts were also evaluated for antifouling properties through field experiments.

7. Delineation of the outer limits of continental shelf

Coastal states having continental shelves that exceed 200 nautical miles (M) from their territorial sea baselines are required to submit claims to determine the outer limits of their continental shelves to an international commission by May 2009. The Commission on the Limits of the Continental Shelf (CLCS), in turn will consider the data and other material submitted by the Coastal States and make recommendations in accordance with the provisions of the UNCLOS.

The delineation of continental shelf claims beyond 200 M has important implications for offshore development and the legal issues pertaining to such development. The continental shelf is rich in non-living resources and minerals, including hydrocarbon resources. These resources, if found within the continental shelf, after proper delineation, as stipulated in the Convention, would be the inherent resources of the coastal States, with no obligation to give any access for the surplus.

A comprehensive desktop study on various scientific and technical issues was carried out. It was followed by an elaborate work programme comprising multichannel seismic reflection, refraction, gravity and magnetic data acquisition, processing, interpretation and synthesis, these were implemented in three of the leading national institutes, viz., NCAOR, NGRI and NIO. Synthesis of the result and documentation were carried out by NCAOR, as per the provisions of UNCLOS.

While the submission is ready, the Indian claim needs to be presented and defended till it gets recommended by the Commission on the Limits of Continental Shelf. For this purpose, all necessary activities, including handling the acquired data, preparation of more documents, maps, undertaking additional studies, if any, would have to be carried out till our claims are finally accepted in the UN. Considering the extensive workload of the Commission, the consideration of Indian claim is likely to continue during XI Plan period.

8. Gas Hydrate Exploration and Technology Development

Gas hydrates with their abundant resource potential are emerging as a potential cleaner fuel resource of tomorrow. The preliminary assessment of geological condition and the limited available seismic data have suggested high possibility of occurrence of quantity of gas hydrates in large quantities within the EEZ of India. The scheme has broadly been divided into science component and technology component.

Science Component

The data acquired under the Continental Shelf Programme was examined, reprocessed and

analysed for identification of Bottom Simulating Reflectors, indicating the presence of gas hydrates. Based on this data, two promising sites of 100 km x 100 km were identified in Krishna- Godavari (KG) and Mahanadi basins for detailed survey. Deep sea core sampling were carried out onboard a French vessel in the KG basin and Mahanadi Basin in May 2007. The data processing and analysis are under progress at the National Institute of Oceanography, Goa. Various modelling studies were continued at the National Geophysical Research Institute (NGRI) to understand composition of gas hydrates.

Technology Component

A remotely operated submersible system capable of operating at water depth of 2500 m was designed, developed and is presently undergoing trial. National Institute of Ocean Technology is in the process of designing and developing an Autonomous Coring System. The detailed design review is being carried out presently.

9. Comprehensive Topography Survey of the Exclusive Economic Zone (EEZ)

The main objective of the project is to prepare a comprehensive seabed topographic map for the entire EEZ of the country using the state-of-the art technologies of multibeam swath bathymetric systems. These data collected in Arabian Sea, Bay of Bengal and Indian Ocean would be useful to identify the major topographic features in the EEZ.

The project is a continuation from X plan, being implemented by three national institutions, viz., National Centre for Antarctic & Ocean Research (NCAOR, Goa), National Institute of Ocean Technology (NIOT, Chennai) and National Institute of Oceanography (NIO, Goa). It is proposed to continue the topographic surveys in deep waters of EEZ (> 500 m) with the help of Sagar Kanya as well with the new vessel Sagar Nidhi based on the availability considering the implementation of other national programmes.

The total EEZ area was divided into blocks both in shallow water (10 to 500 m depth) and deep water (> 500 m depth). The total area surveyed in deep sea waters during the X plan is 0.25 million sq km, of which NCAOR covered 0.22 million sq km and NCAOR/NIO jointly covered 0.03 sq km. The total shallow water area surveyed during the X plan is about 1600 sq km by NIOT and NIO covered on the East and West coasts, respectively.

10. Acquisition of Technology Demonstration Vessel “Sagar Nidhi”

The Ministry of Earth Sciences undertook the programme of acquisition of Research vessel with a view to provide a platform for the programme envisaged in the XI Plan, to serve as a utility science vessel and to augment the capacity needs of the marine living and non-living resources programmes. The National Institute of Ocean Technology (NIOT) is the nodal agency to implement this programme and to operate and maintain the vessel.

The construction of the vessel was completed in Italy and has been acquired by the Ministry in February, 2008. The technology demonstration vessel (Sagar Nidhi) with state-of-the art navigational facilities will be a first of its kind to be used for demonstration of under water technology like Remotely Operated Vehicle (ROV), Autonomous Underwater Vehicle (AUV), Gas Hydrates, Deep Sea mining and Manned Submersibles.



Technology demonstration vessel Sagar Nidhi

11. Early Warning System for Tsunami and Storm Surges

Early Warning System for Tsunami has been established by MoES, as the nodal ministry, at a cost of Rs125 crore in collaboration with Department of Science and Technology (DST), Department of Space (DOS) and the Council of Scientific and Industrial Research (CSIR). The National Tsunami Early Warning Centre has been set up at INCOIS, Hyderabad.

The Hon'ble Minister for Science & Technology and Earth Sciences, Shri Kapil Sibal inaugurated the National Tsunami Early Warning System that has been set up at the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad on 15 October, 2007. Hon'ble Chief Minister of Andhra Pradesh, Dr. Y. S. Raja Sekhar Reddy graced this occasion. Dr. P.S Goel, Secretary, Ministry of Earth Sciences delivered the welcome address and explained the Tsunami Early Warning System at INCOIS.



Hon'ble Minister Shri Kapil Sibal giving the introductory talk at the inauguration of Tsunami Early Warning Centre at INCOIS

Tsunami Early Warning Centre at INCOIS

Early Warning System for Tsunami and Storm Surges comprises of :

- Installation of tsunami warning sensors close to the ocean bottom at appropriate locations in the Indian Ocean, with real time connectivity;
- Tide gauge and data buoys networking to validate arrival of tsunami waves at the coast;
- Strengthening of the existing seismological network to indicate, near real time occurrence of tsunamigenic earthquakes;
- Modeling of the inundation scenarios for the entire coast and mapping of potential risk areas;
- Collection of information, analysis and generating status advisories.

The Early Warning Centre receives real-time seismic data from the national seismic network of the India Meteorological Department (IMD) and other international seismic networks. The system detects

all earthquake events of more than 6 magnitude occurring in the Indian Ocean in less than 20 minutes of occurrence. Bottom Pressure Recorders (BPRs) installed in deep ocean are the key sensors to confirm the triggering of a Tsunami. The National Institute of Ocean Technology (NIOT) has installed 4 BPRs in the Bay of Bengal and the 2 BPRs in the Arabian Sea. In addition, NIOT and Survey of India (SOI) have installed 30 Tide Gauges to monitor the progress of tsunami waves. Integrated Coastal and Marine Area Management (ICMAM) has customised and ran the Tsunami Model for 5 historical earthquakes and predicted the inundation areas. The inundated areas are being overlaid on cadastral level maps of 1:5000 scale. These community-level inundation maps are extremely useful for assessing the population and infrastructure at risk. High-resolution Coastal Topography data required for modelling is generated by the National Remote Sensing Agency (NRSA) using ALTM and Cartosat Data. INCOIS has also generated a large database of model scenarios for different earthquakes and these are being used for operational tsunami early warning.

Communication of real-time data from seismic stations, tide gauges and BPRs to the early warning centre is very critical for generating timely tsunami warnings. A host of communication methods are employed for timely reception of data from the sensors as well as for dissemination of alerts. Indian Space Research Organisation (ISRO) has made an end-to-end communication plan using INSAT. A high level of redundancy is being built into the communication system to avoid single point failures.



Communication facilities to receive data from seismic stations, tide gauges and BPRs in real-time

The National Early Warning Centre generates and disseminate timely advisories to the Control Room of the Ministry of Home Affairs for further dissemination to the public. For the dissemination of alerts to MHA, a satellite-based Virtual Private Network for Disaster Management Support (VPN DMS) has been established. This network enables the Early Warning Centre to disseminate warnings to MHA, as well as State Emergency Operation Centres. In addition, messages will also be sent by phone, fax, SMS and e-mails to the authorised officials. In case of confirmed warnings, the National Early Warning Centre is being equipped with necessary facilities to disseminate the advisories directly to the administrators, media and public through SMS, e-mail, fax, etc. The cyclone warning network of IMD and electronic ocean information boards of INCOIS could be effectively used for dissemination of warnings directly to the public.

12. India Meteorological Department (IMD)

The India Meteorological Department (IMD) established in 1876, provides the national meteorological service to 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 are also provided to the international community under the charter of World Meteorological Organisation.

12.1 Meteorological Services

Weather Monitoring

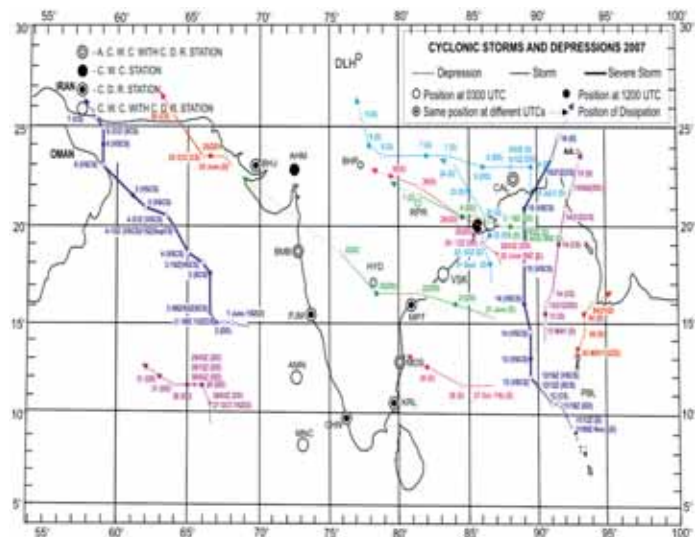
Activities of Weather Forecasting

IMD issues weather forecasts and also precautionary warnings for hazardous weathers like cyclonic storms, heavy rainfall, squalls, etc. for the entire country so as to save human life, livelihood and property. Weather Centre, 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 and passed on to all relevant government agencies, hoisted on the Web and also published in the Indian Daily Weather Report.

Experiencing the normal variability of weather, the year 2007 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

The year 2007 was a year of near normal cyclonic activity over the north Indian Ocean. The basin witnessed the formation of twelve cyclonic disturbances (Depression and above intensity) against a normal of fifteen. Out of twelve disturbances, five intensified into deep depression, two into cyclonic storms and

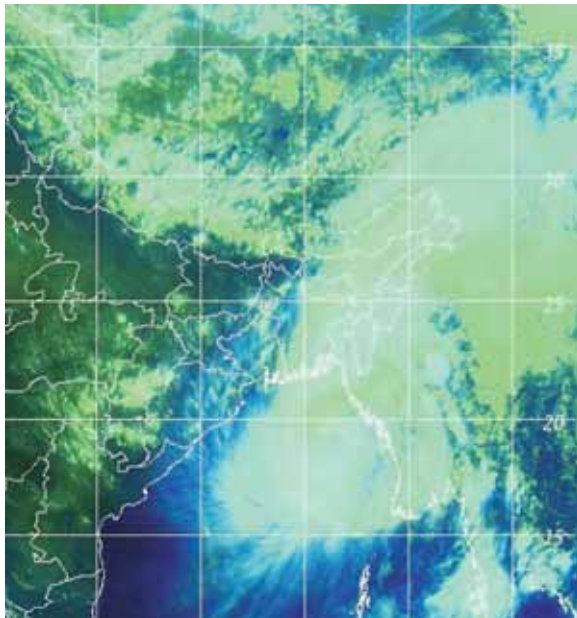


Cyclonic disturbances during 2007 over North Indian Ocean

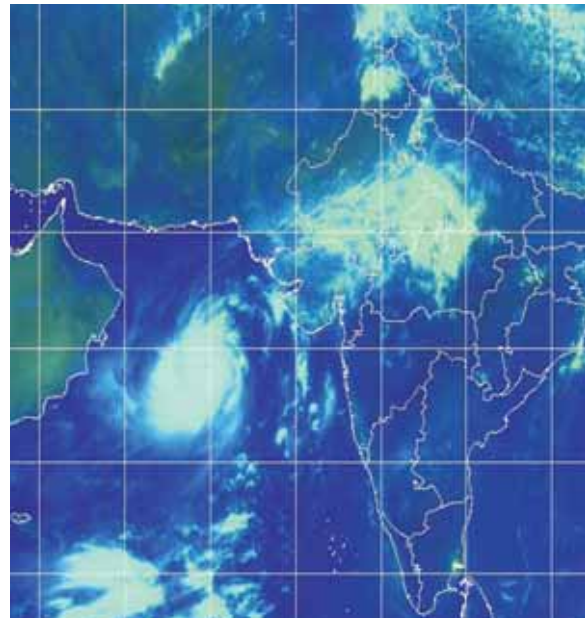
one each into very severe cyclonic storm and super cyclonic storm. Hence, there were four disturbances with cyclonic storm and above intensity against the normal of five. The tracks of the system are shown in the above figure.

(a) Cyclonic storm ‘Akash’ over the Bay of Bengal during 13-15 May, 2007

During the onset phase of southwest monsoon, a low pressure area formed over south Andaman Sea on 11 May, 2007. It concentrated into a depression over east central Bay of Bengal on 13 May and into a cyclonic storm, named “**Akash**” on 14 May. The cyclonic storm continued to move in a north-northeasterly direction under the influence of upper tropospheric trough in westerlies and crossed south Bangladesh coast close to south of Cox’s Bazar between 0100 and 0200 UTC of 15 May. The system then weakened gradually, while moving in the same direction. The system caused heavy rainfall over Myanmar, Bangladesh, and the northeastern states of India.



INSAT imagery at 0900 UTC of 14 May, 2007



INSAT imagery at 0600 UTC of 4 June, 2007

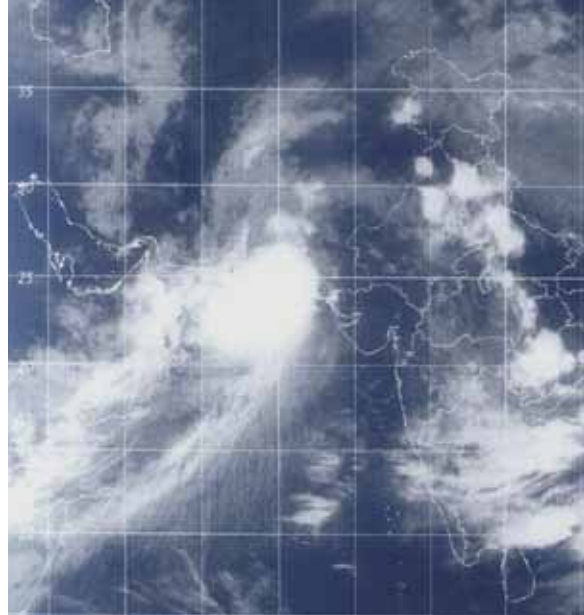
(b) Super Cyclonic Storm “GONU” over the Arabian Sea during 01-07 June, 2007

A low pressure area was developed over east central Arabian Sea on 31 May, 2007. It concentrated into a depression over the same area and then into a cyclonic storm named “GONU” at 1200 UTC of 1 June. It further intensified into a very severe cyclonic storm at 1800 UTC of 3 June and into a super cyclonic storm at 1500 UTC of 4 June. The INSAT Kalpana imagery indicated a circular eye of the storm. The system then moved in a west-northwesterly direction and weakened gradually due to relatively colder sea surface temperatures and increasing vertical wind shear. It crossed Oman coast as a very severe cyclonic storm around 0300 UTC of 6 June. After crossing Oman

coast, it emerged into the Gulf of Iran, weakened gradually and moved in a north-northwesterly direction. It made second landfall over Iran coast near long. 58.50° E between 0300 and 0400 UTC of 7 June, 2007 as a Cyclonic Storm. The system caused loss of life and property in Oman and Iran due to heavy rainfall, strong winds and storm surge.

(c) Cyclonic Storm “YEMYIN” over the Arabian Sea during 25-26 June, 2007

From the remnant of a deep depression which developed over west central Bay of Bengal on 21 June, 2007 and moved west-northwestwards across south India during 22-23 June and emerged into the Arabian Sea as a low pressure area, a depression formed over northeast Arabian Sea at 0300 UTC of 25 June. The system further intensified into a deep depression at 1200 UTC of the same day and into a Cyclonic Storm named “Yemyin”, in the early morning of 26 June. The system moved in a northwesterly direction and crossed Pakistan coast near long 64.0° E between 0200 and 0300 UTC of 26 June. The system caused extensive damage over south Pakistan due to heavy rain and strong winds. INSAT imagery at 0000 UTC of 26 June, 2007 showed deep convection in association with the system as shown in the figure.



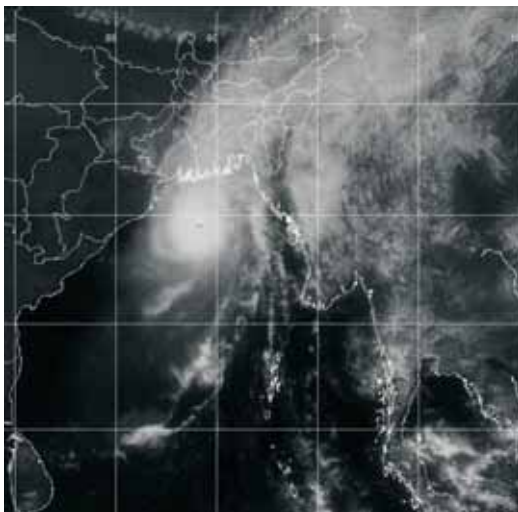
INSAT imagery at 0000 UTC of 26 June, 2007

(d) Very Severe Cyclonic Storm “SIDR” over the Bay of Bengal during 11-16 November, 2007

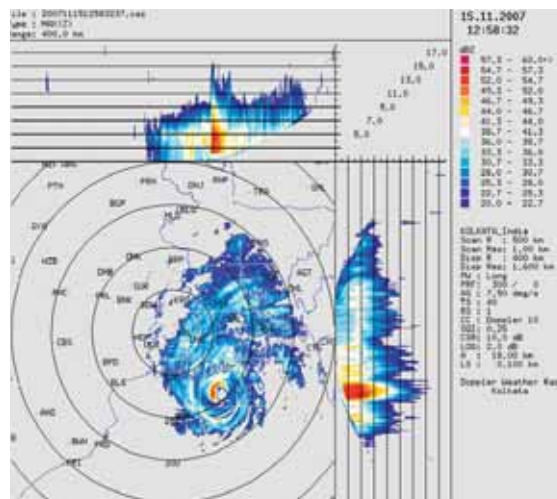
An upper air cyclonic circulation lay over southeast Bay of Bengal and the adjoining area of south Andaman sea during 8-10 November, 2007. Initially, a moderate upper-level wind shear inhibited the set in of organized convection but subsequently a strong diffluence aloft aided in developing the convection. During this period, easterly wave was active and vertical wind shear decreased gradually. Under the influence of these, a low pressure area formed in the morning of 11 November over southeast Bay of Bengal and neighbourhood. It concentrated into a depression and subsequently into a deep depression. Moving in a northwesterly direction, it intensified into cyclonic storm named “SIDR” and lay centred at 0830 hrs IST of 12 November, about 220 km southwest of Port Blair. It further intensified into a severe cyclonic storm and very severe cyclonic storm. It continued to move in a northerly direction. The Doppler Weather Radar (DWR) imagery from DWR Kolkata and the INSAT- Kalpana_1 imageries showed Central Dense Overcast region with closed eye pattern and cloud elongated towards north-northeast of the system. It then moved

north-northeastwards and crossed the west Bangladesh coast near longitude 89.8° E around 2230 hrs IST of 15 November. It weakened rapidly into a cyclonic storm while moving northeastwards. It lay as depression centred at 0830 hrs IST of 16 November; about 50 km north of Agartala. It was seen as a well - marked low pressure area over northeastern states in the same evening and further became unimportant in the late evening of same day. The system caused extensive damage to life and property in Bangladesh. It also caused damage over coastal areas of West Bengal due to strong winds and heavy rainfall.

Adequate warnings were issued to concerned Govt. and non-Govt. agencies in association with above system. Also, special Tropical Weather outlook and Tropical advisories were issued to WMO/ESCAP Panel member countries of the region, as and when required.



INSAT imagery at 0600 UTC of 15 November, 2007



Kolkata doppler weather radar picture at 12:58 UTC of 15 November, 2007

Southwest Monsoon 2007

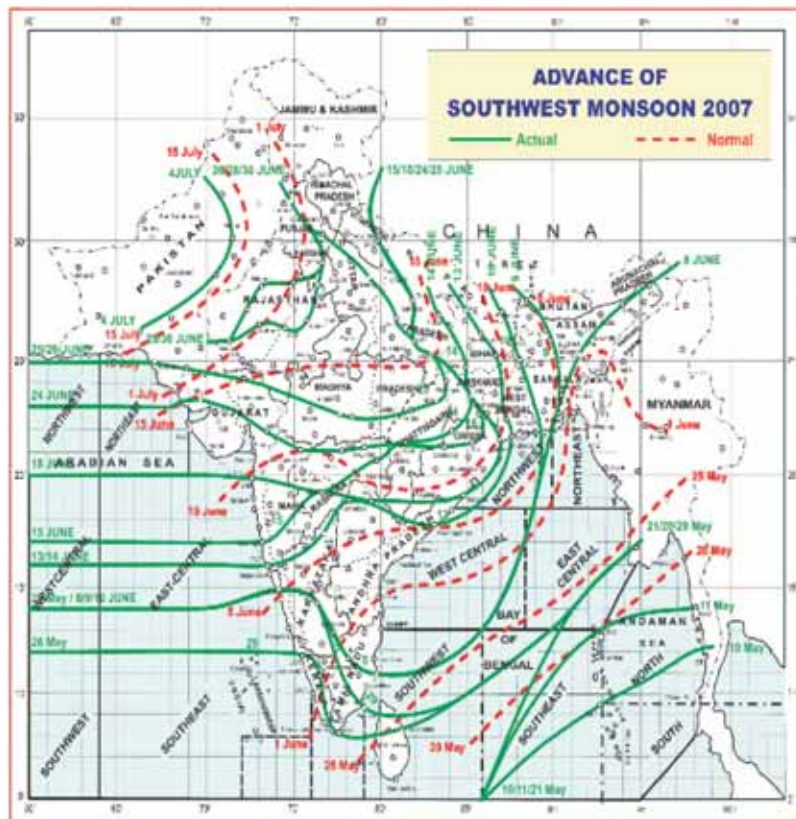
- For the country as a whole, the seasonal rainfall from 1 June to 30 September, 2007 was 105% of its long period average (LPA).
- Seasonal rainfall was excess by 26% over South Peninsula. It was deficient (15% below LPA) over Northwest (NW) India, 8% above LPA over Central India and 4% above LPA over Northeast (NE) India.
- Out of the 36 meteorological sub-divisions, the seasonal (June-September) rainfall was excess in 13 and normal in 17 sub-divisions. However, it was deficient in 6 sub-divisions.
- Out of 513 meteorological districts for which data were available, 72% of the meteorological districts received excess/normal rainfall and the remaining 28% received deficient/scanty rainfall during the season. 77 districts (15%) experienced moderate drought and 30 districts (6%)

experienced severe drought at the end of the season.

- Five sub-divisions (viz. West Uttar Pradesh, Haryana, Chandigarh and Delhi, Punjab, Himachal Pradesh and east Madhya Pradesh) experienced moderate drought conditions (rainfall deficiency of 26% to 50%) at the end of the season.
- IMD's long range forecasts for July rainfall over the country as a whole and the 2007 seasonal rainfall over NW India and NE India were proved to be accurate. However, the 2007 monsoon seasonal rainfall over the country as a whole was more than the predicted value.

Onset of Southwest Monsoon

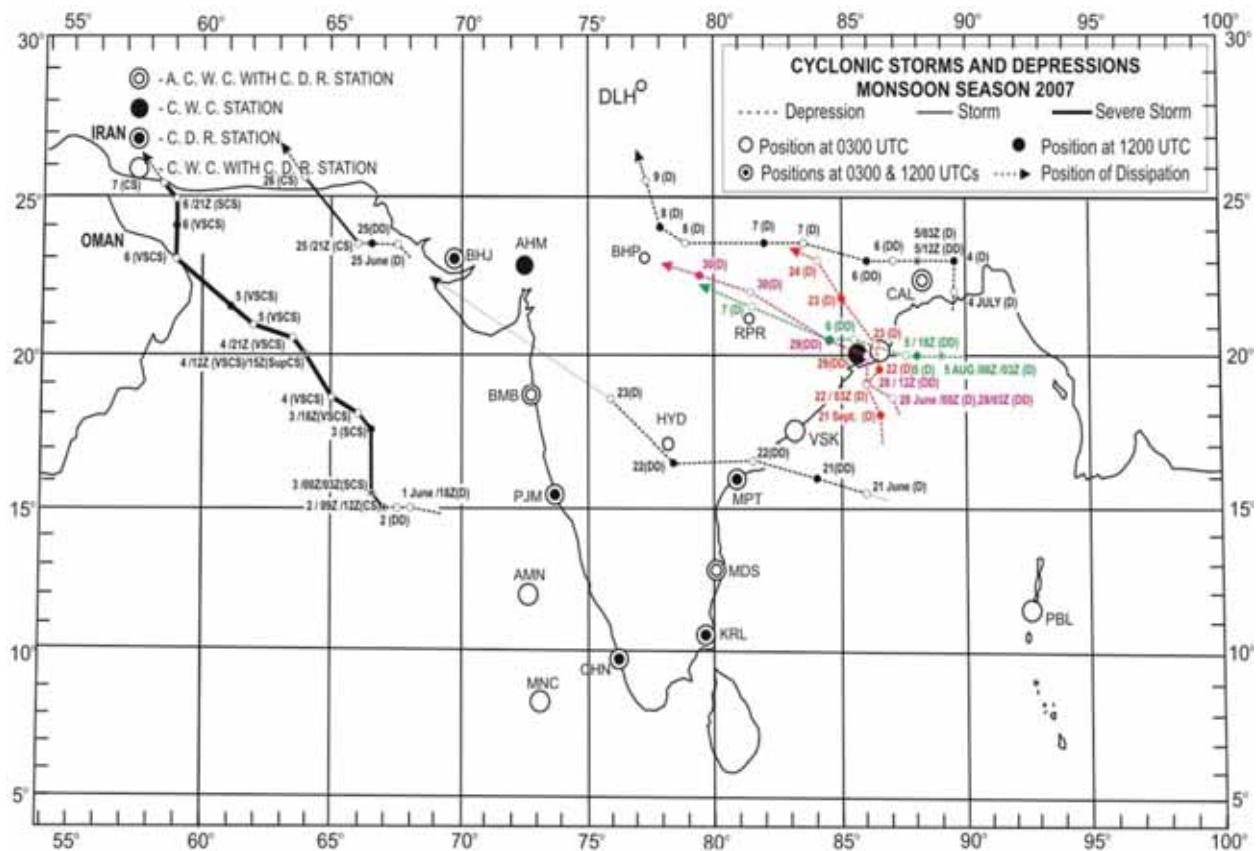
Southwest monsoon advanced over the south Andaman Sea, Nicobar Islands and parts of southeast Bay of Bengal on 10 May, about 5 days ahead of its normal date. This was associated with the formation of a depression over the north Andaman Sea (3–5 May) and the strengthening of the cross equatorial flow. However, the subsequent advance, was delayed by the formation of the cyclonic storm 'Akash' (13–15 May) over the east central Bay which had an unconventional origin in the mid-latitude westerlies, which moved northeastward into Bangladesh and then once again due to the Super Cyclonic Storm, 'Gonu' which was formed over east central Arabian Sea (1–7 June) and crossed Oman and subsequently the Makaran coast. Further advance of monsoon took place on 8 June, after a hiatus of 9 days. It covered the north-eastern states by 10 June, Peninsular and Central India by 25 June and subsequently the entire country on 4 July, nearly 11 days ahead of normal date. The above figure gives the isochromes of advance of southwest monsoon 2007.



Progress of Southwest Monsoon - 2007

Synoptic Features

Formation of two intense low pressure systems over the Arabian Sea in the month of June 2007 has never occurred earlier, barring the years 1948, 1930, 1925 & 1907. Gonu was also the first ever Super Cyclone formed over the Arabian Sea. The Cyclonic Storm, 'Yemyin' (25-26 June) formed from the remnants of a Deep Depression which formed over the Bay of Bengal and emerged into the Arabian Sea as a low pressure area after traversing the peninsula. This system moved away north-westwards and crossed Pakistan coast, without affecting the weather over the country. Apart from the above two Cyclonic Storms, 11 more low pressure systems, including 4 Deep Depressions, 1 Depression, 4 well marked low pressure areas and 2 low pressure areas formed during the season. Most of these systems formed over the Bay of Bengal and moved generally in a west-northwesterly to northwesterly direction, giving rise to extremely heavy rainfall (25 cm or more) many a times over Orissa, Gangetic West Bengal, Bihar, Andhra Pradesh, Chhattisgarh, Madhya Pradesh, Rajasthan, Gujarat and also in Maharashtra and Karnataka. Only one well-marked low pressure area (23 – 25 September) formed over the Arabian Sea in September. Tracks of the Cyclonic Storms and Depressions during the season are shown in the figure given below.



Tracks of the low pressure systems over Indian seas during the Southwest Monsoon Season– 2007

Rainfall Distribution during Monsoon Season

The southwest monsoon rainfall (June to September) for the period 1 June to 30 September, 2007 for the country as a whole and the four broad homogeneous regions are as follows:

Region	Actual (mm)	Normal (mm)	Percentage Departure
All-India	936.9	892.2	5%
Northwest (NW) India	520.8	611.6	-15%
Northeast (NE) India	1485.9	1427.3	4%
Central India	1073.8	993.9	8%
South peninsula	907.3	722.6	26%
Northeast (NE) India	1485.9	1427.3	4%

In 2007, the southwest monsoon seasonal (June to September) rainfall over the country as a whole was 105% of its LPA. Seasonal rainfall over NW India was below its LPA by 15%. However, over south Peninsula, the seasonal rainfall was above its LPA by 26%. Similarly, Central India and NE India also experienced above average seasonal rainfall (8% and 4% above LPA, respectively). The above - average performance of the monsoon rainfall over the country was mainly due to the excess rainfall observed over South Peninsula and Central India.

The cumulative rainfall from 1 June to 30 September, 2007 was excess in 13, normal in 17 and deficient in 6 meteorological sub-divisions. The sub-divisionwise cumulative rainfall distribution has been shown in the figure below. Five sub-divisions (West Uttar Pradesh, Haryana, Chandigarh and Delhi, Punjab, Himachal Pradesh and east Madhya Pradesh) experienced moderate drought conditions (rainfall deficiency of 26% to 50%) at the end of the season. Arunachal Pradesh received deficient rainfall (20% below its LPA).

Out of 513 meteorological districts for which data were available, 144 districts (28%) received deficient rainfall (rainfall deficiency more than 19%) during the season, out of which 77 districts (15%) experienced moderate drought conditions (rainfall deficiency 26% to 50%) and 30 districts (6%) experienced severe drought conditions (rainfall deficiency 51% and more). The rainfall was excess (actual rainfall higher than LPA by 20% or more) over 164 districts (32%) during the season.

Month-wise distribution of rainfall departure over the country as a whole is given below:

June: 19% above LPA

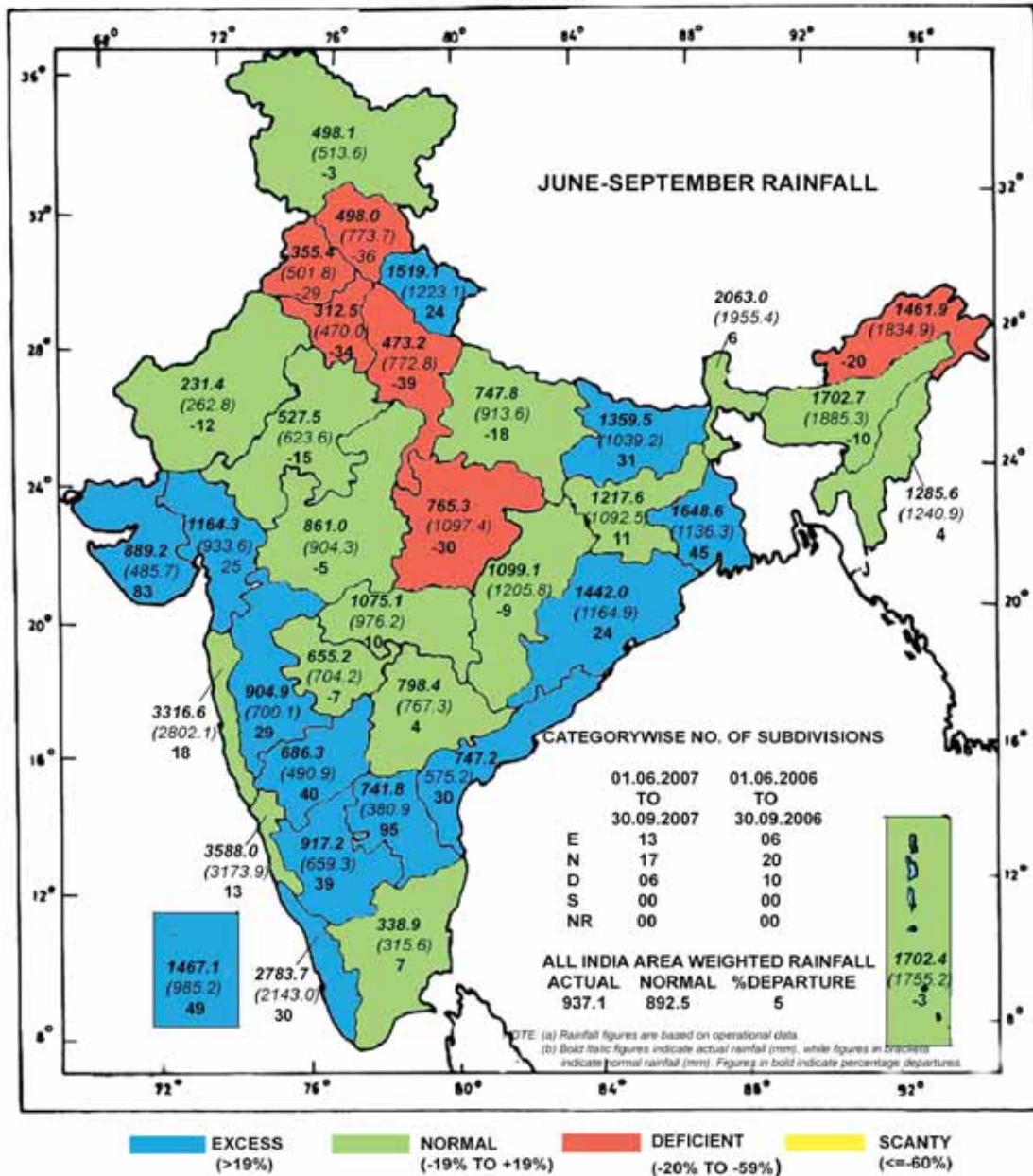
July: 3% below LPA

August: 1% below LPA

September: 18% above LPA

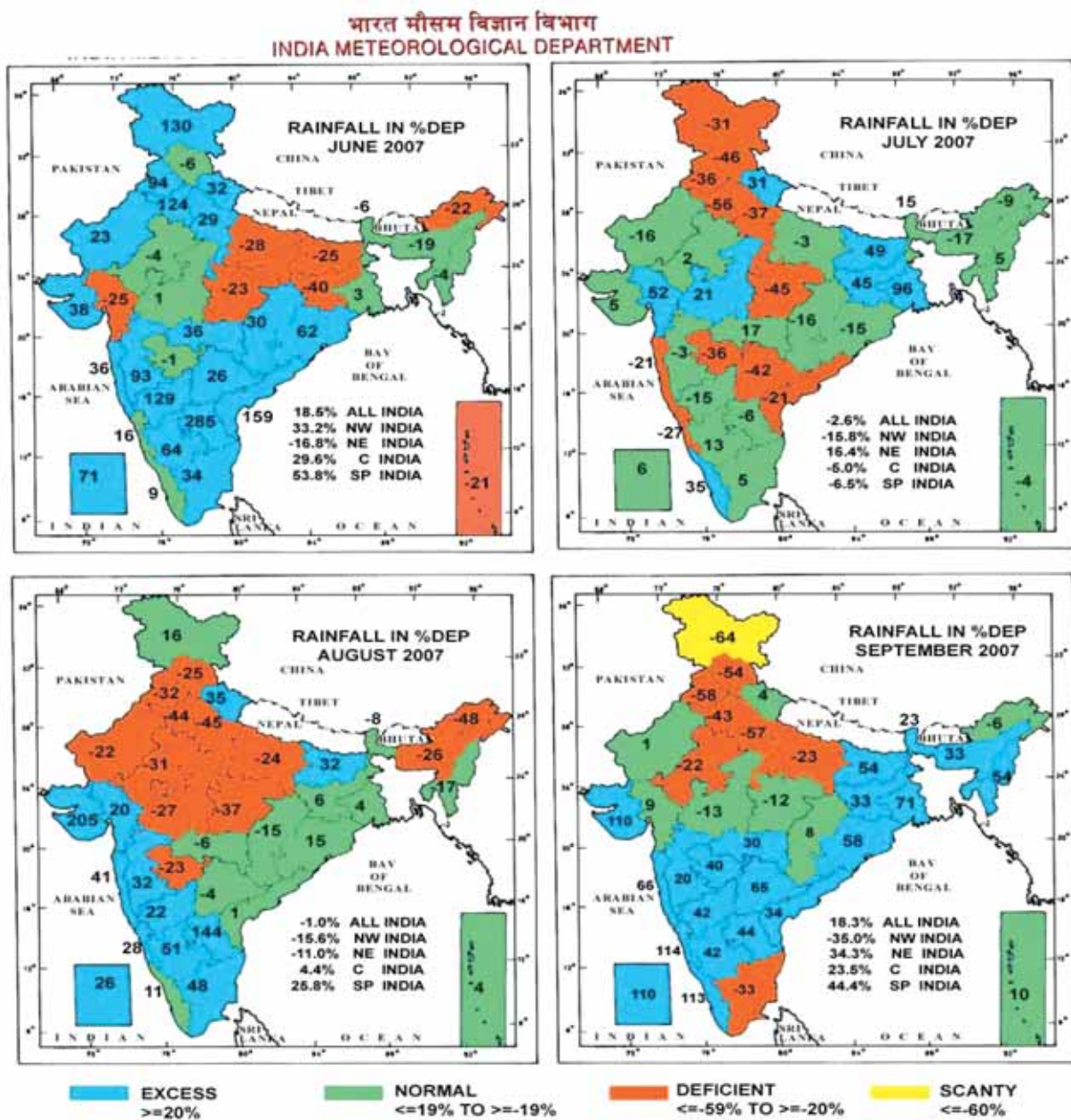
भारत मौसम विज्ञान विभाग INDIA METEOROLOGICAL DEPARTMENT

MONSOON 2007



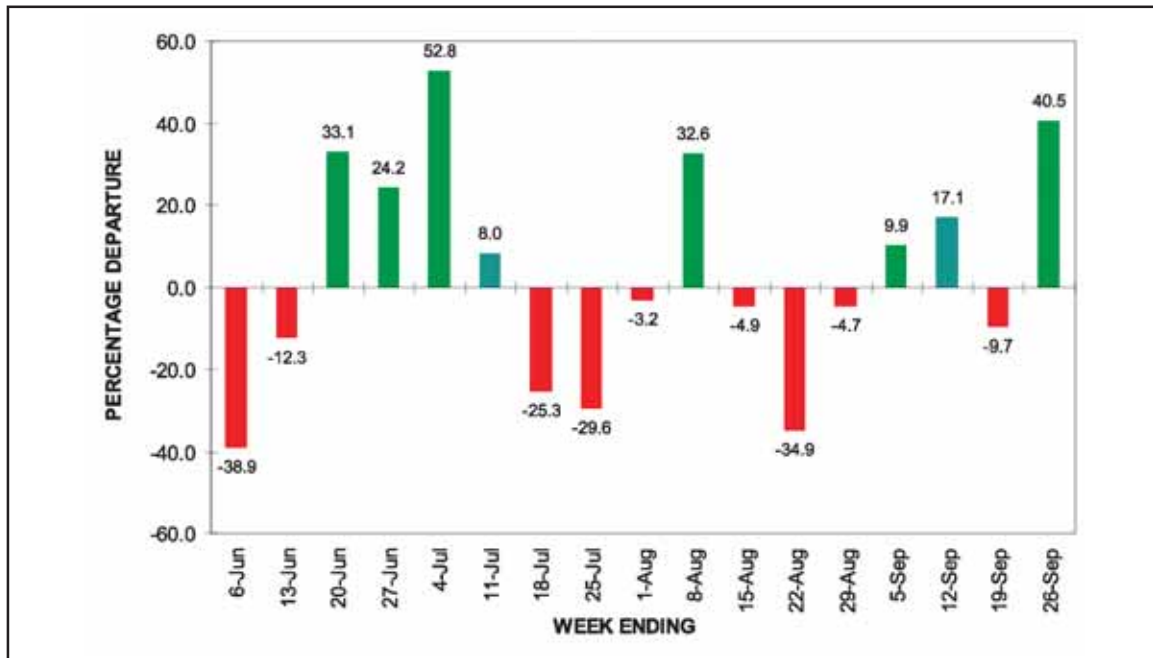
Sub-divisionwise cumulative rainfall distribution over India during southwest monsoon season (June to September) – 2007

The sub-division wise distribution of monthly rainfall is shown in the figure below.

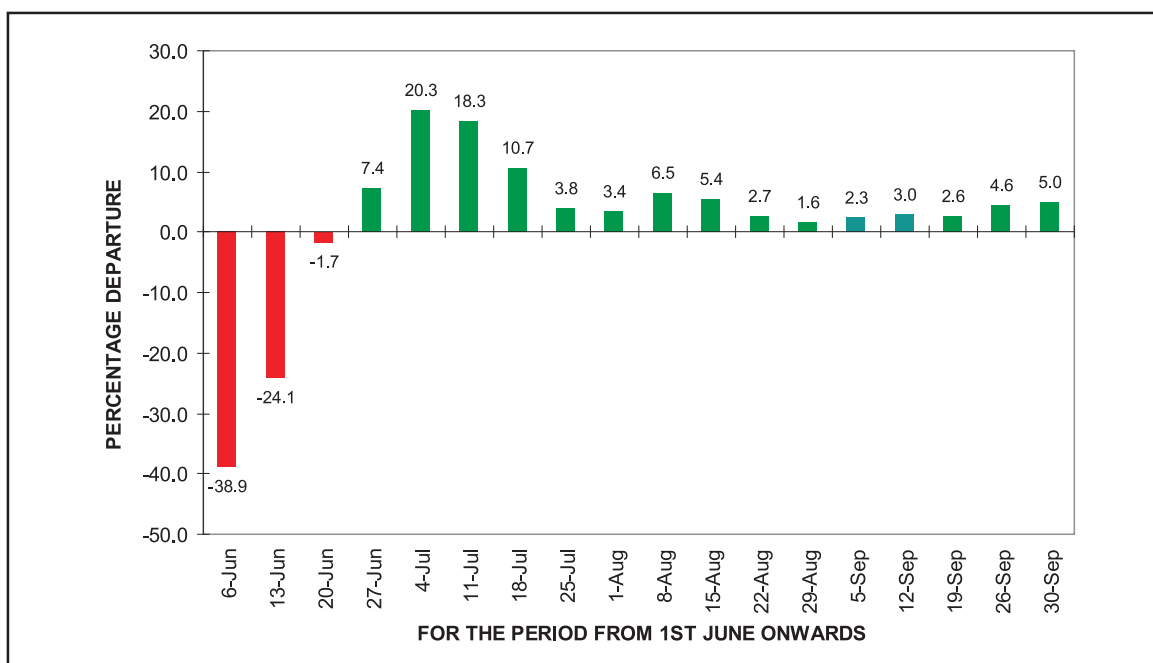


Sub-division wise monthly rainfall distribution over India during south west monsoon season – 2007

The figures given below depict the monsoon rainfall as received week by week and the cumulative rainfall during the season respectively.



Progress of the weekly monsoon rainfall - 2007



Progress of the weekly cumulative monsoon rainfall - 2007

In June, the weekly rainfall was below normal during the first two weeks and above normal during the remaining weeks. In July, the rainfall was above normal during the first two weeks and below normal during the remaining weeks. In August, the rainfall was below normal during all weeks, except the first week. In September, the rainfall was below normal during the 3rd week and above normal during all other weeks. A large rainfall deficiency was observed during the 1st week of June, 3rd and 4th weeks of July and 3rd week of August. During the season, cumulative seasonal rainfall over the country as a whole remained always above normal since last week of June (see figure below on pre-page) . By this week, the cumulative seasonal rainfall was above normal by 7%. At the end of subsequent week (1st week of July) the cumulative seasonal rainfall increased and became above normal by 20%. However, by the end of July, the cumulative seasonal rainfall decreased and became 3% above normal. At the end of August, the cumulative seasonal rainfall was 2% above normal, and it became 5% above normal by end of the season.

Flood Situations

The uneven distribution of rainfall in space and time caused flood situations in many states, viz. Assam, Meghalaya, Arunachal Pradesh, Manipur, Tripura, Andhra Pradesh, Kerala, Karnataka, Maharashtra, Orissa, Chattisgarh, Gujarat, Rajasthan, Madhya Pradesh, West Bengal, Jharkhand, Bihar, Uttar Pradesh, Himachal Pradesh, Uttarakhand, Jammu & Kashmir, Punjab and Haryana during various parts of the season.

Withdrawal of Southwest Monsoon

This year, there was an unusual delay in the withdrawal of monsoon from extreme west Rajasthan, due to the prevalence of cyclonic circulations, availability of moisture and sporadic rainfall over the region. However, the southwest monsoon withdrew from western parts of Rajasthan and some parts of Punjab and Haryana on 30 September. The normal date of withdrawal from west Rajasthan is 15 September. During the period 1960-2006, the most delayed date of monsoon withdrawal from extreme west Rajasthan was 28 September, which occurred in the years 1964 and 1970. In the year 1990 also, the withdrawal started as late as 27 September.

Long Range Forecast of Monsoon Rainfall

In May 2007, using an indigenously developed statistical model, IMD predicted that monsoon onset over Kerala would take place on 24 May with a model error of ± 3 days. This year, the monsoon onset over Kerala was on 28 May, four days earlier than its normal date of 1 June.

As per the long - range forecast for the 2007, southwest monsoon seasonal rainfall issued in April, the seasonal rainfall for the country as a whole was expected to be 95% of LPA with a model error of $\pm 5\%$. In the updated forecast issued on 29 June, the forecast for the country as a whole was revised as 93% of LPA with a model error of $\pm 4\%$. The season ended with the area-weighted rainfall for the country as a whole at 105% of the LPA, more than the error limit of the IMD's long-range forecast. Considering 4 broad homogenous regions of India, rainfall was expected to be

90% of its LPA over NW India, 96% of LPA over Central India, 98% of LPA over NE India and 94% of LPA over South Peninsula with a model error of $\pm 8\%$. The actual rainfall over these 4 regions was 85%, 108%, 104% and 126% of the LPA respectively. Thus, the seasonal rainfall over NW and NE India was well-predicted, whereas the rainfall over both Central India and South Peninsula was higher than prediction.

IMD also issued the long-range forecast for rainfall over the country as a whole in July 2007 as 95% of its LPA. The actual rainfall in July 2007 was 97% of LPA, very close to the predicted value. The Table below gives the summary of the verification of the long-range forecasts issued for the 2007 southwest monsoon.

Details of long range forecasts and actual rainfall

Region	Period	Issued on	Forecast	Actual
All India	June to September	19 April 2007 29 June 2007	95% of LPA $\pm 5\%$ 93% of LPA $\pm 4\%$	105% of LPA
All India	July	29 June 2007	95% of LPA $\pm 9\%$	97% of LPA
Northwest India	June to September	29 June 2007	90% of LPA $\pm 8\%$	85% of LPA
Northeast India	-Do-	29 June 2007	98% of LPA $\pm 8\%$	104% of LPA
Central India	-Do-	29 June 2007	96% of LPA $\pm 8\%$	108% of LPA
South Peninsula	-Do-	29 June 2007	94% of LPA $\pm 8\%$	126% of LPA

Project Parwat

Twenty-two surface met observatories and three upper air stations have been equipped with the state-of-art instruments under phase-I of the project for Western Himalayan Region. The project has fully achieved its objectives and is now being continued in an ongoing operational mode. Data so received is being utilized for issuing weather bulletins/analysis.

A fresh project (PARWAT-CENTRAL) has been undertaken for improving observatory network and accuracy of weather forecast over the Central Himalayas. Three upper air stations and fifteen surface field observatories will be established with the state-of-art equipments. The project will be integrated in the overall modernization plan of the Department.

Meteorological Services to Aviation

Meteorological Services for aviation are provided for safe and efficient operations of national and international flights. These services are provided through a network of four Meteorological Watch Offices (MWOs) located at the four major international airports at Chennai, Kolkata, Mumbai and

New Delhi and other aviation meteorological offices located at the other airports in the country. A Tropical Cyclone Advisory Centre (TCAC) is also functioning at NHAC, New Delhi to provide advisory information on tropical cyclones. The aviation meteorological offices provide current weather reports, various forecasts and warnings for safety, economy and efficiency of aircraft operations. 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.

- Installation of Integrated Automatic Aviation Meteorological Systems (IAAMS) for automatic collection, processing, display and dissemination of current weather information at 8 airports was started.
- Procurement process for IAAMS for twenty more airports initiated with target date of commissioning as March 2009.
- Digital Distant Indicating Wind Equipment (DIWE) installed at Hubli and Calicut airports.
- Digital Current Weather Instruments System installed at Diu, Delhi, Calicut and Lucknow airports.
- Analog DIWEs converted into Digital DIWEs at Jabalpur, Indore, Madurai, Trichy, Bhubaneshwar, Jamshedpur, Barapani and Cooch Behar airports.
- Letter of Agreement for provision of Aviation Meteorological Services at airports was signed with Airports Authority of India as per the ICAO guidelines.
- Web-based On-line Pilot Briefing System was started from the Airport Meteorological Offices Chennai and New Delhi.

Hydro Meteorological Services

Rainfall Monitoring

Real time monitoring of districtwise daily rainfall distribution is one of the important functions of IMD. A network comprising a large number of raingauge stations are utilised under the District Rainfall Monitoring Scheme (DRMS). Based on the real time daily rainfall data, weekly and seasonal rainfall distribution summaries are prepared districtwise, sub-divisionwise and statewide in the form of rainfall tables and maps providing actual, normal and percentage departures of rainfall. Subsequently, updated monthly, seasonal and annual rainfall summaries are also prepared regularly. This information is supplied to various government agencies for their scientific and operational use.

Flood Meteorological Service

IMD has established 10 Flood Met. Offices, at Ahmedabad, Asansol, Agra, Bhubaneswar, Guwahati, Hyderabad, Jalpaiguri, Lucknow, New Delhi and Patna in the flood - prone areas. These offices render their services to the 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, Godawari, 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 - catchmentwise / sub-catchmentwise and
- Areal precipitation during the past 24-hours catchmentwise / sub-catchmentwise

Design Storm Studies

Design storm studies are being conducted to study rainfall magnitude and its time distribution for use as a main input for design engineers in estimating design flood for hydraulic structures, irrigation projects, dams etc. on various rivers. The probable maximum precipitation values are also evaluated for optimum utilisation of water resources. In the year 2007-08, design storm study in respect of 39 projects has been completed. Important project authorities along with central / state government agencies are NIH Roorkee, J.P.Industries, Reliance Energy Ltd., NHPC, WAPCOS, etc.

Storm Analysis Studies

Based on the recommendation of Khosla Committee of Engineers, a Storm Analysis Unit is functioning to provide design estimates of short - duration rainfall in different sub-zones of the country for the purpose of construction of small and medium hydraulic structures such as railway and road bridges, culverts, etc. Hydromet data for a number of river catchments are analysed for return periods of very heavy rainfall for design flood estimation. The studies in respect of 25 sub-zones (out of total 26 sub-zones) have so far been completed and the flood estimation reports for the seven sub-zones have been revised. The work on "All India Atlas of Statewise Isopluvial Maps" of different durations was also taken up and Part-1 of the Atlas of Southern Peninsular States is under publication. These maps can be used to derive 24-hours rainfall estimates for specific return periods at any desired location in India.

Glaciological Studies

To conduct glaciological studies, important information on snow accumulation and snowmelt in the upper watersheds of Himalayan rivers is being collected by ground observations through network

of 21 snowgauges, 10 raingauges and one class-I Departmental Observatory has been installed in the Western Himalayas. The strengthening of network of AWS, ARGs in Central and Eastern Himalayas is under process.

World Bank Funded Hydrology Project

The phase – II of the hydrology project has been approved by the Government of India in May 2006. The objective of this project is quality data base (useful for drought monitoring, flood forecasting and disaster weather warning like cloud burst, etc.). The project cost of IMD Component is Rs 31.64 crores. The project is planned to be implemented over a period of six years and the target of completion is 2011. IMD proposed to install 1 Radar, 20 AWS and 200 ARG in Hydrology Project Phase-II. In the year 2007-08, 23 observers, 12 supervisors and 12 executives from the states of Punjab, Himachal Pradesh, Goa & Puducherry were imparted training in hydrometeorology.

12.2 Specialized Services

Meteorological Support to Agriculture

- IMD continued to render Agromet Advisory Services to the state governments and farmers by issuing weekly / bi-weekly bulletins prepared jointly with the State Agricultural Departments. These advisories were tailored to meet the requirements of farmers based on the 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.
- All India Agromet Advisory Bulletins were prepared by Indian Agromet Advisory Service Centre (IAASC), Pune and issued to the Ministry of Agriculture and other users in the country to help make policy make 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.
- Weekly Medium Range Weather Forecast for 107 AMFUs was communicated for preparation and dissemination of Agromet Advisory Service Bulletins.
- Action has progressed to open 24 new Agromet Field Units (AMFUs) to cover the hitherto

unrepresented agroclimatic zones.

- Annual inspection and maintenance of lysimeters and soil moisture equipments at 42 ET stations and 15 soil moisture observatories was carried out. Annual inspection of agromet observatories under SAU set-up was carried out.
- Research work was continued in the areas of dry farming, soil moisture, studies and crop pests and diseases in relation to weather.

Drought Research and Crop Yield Formulation

- 15 biweekly Aridity Anomaly Reports with maps for both the southwest and northeast monsoon seasons of 2007 covering the period June to December 2007 were prepared and sent to Ministry of Agriculture, New Delhi and other agencies. The information was also loaded in the Departmental website for the benefit of users. Besides weekly Aridity Anomaly Maps were also prepared for the southwest monsoon season for 2007.
- Report on monthwise aridity conditions with maps were prepared for the southwest monsoon season 2007.
- Monthly sub-divisionwise quantitative yield forecast for kharif rice for 26 meteorological sub-divisions for August to December and for wheat for 16 sub-divisions for January to May were prepared and forwarded to HQs for onward transmission to the Directorate of Economics & Statistics, Ministry of Agriculture, New Delhi. Verifications of the forecast with the actual figures of yield were also done.
- Information on “Sub-divisionwise incidences of drought during monsoon 2006” was provided as input for SAARC News Letter, July-December, 2006.

Earthquake Monitoring

India Meteorological Department (IMD) being the nodal agency of Government of India for monitoring seismicity, continued its operation of the National Seismological Network for keeping a round the clock vigil on seismic activity occurring in and around the country. The operational task of the department is to quickly determine the earthquake parameters immediately after its occurrence and disseminate the information to all the concerned state and central government agencies responsible for carrying out relief and rehabilitation measures. The earthquake information is also transmitted to public information channels, press, media, etc. and posted on IMD's Websites (www.imd.gov.in and www.imd.ernet.in).

Ministry of Earth Sciences has set up an Early Warning System for Tsunamis at the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad. As part of the Early Warning System for Tsunamis, Real Time Seismic Monitoring Network (RTSMN) has been established by India Meteorological Department. The network is designed and shown in the figure below to monitor

and report, in the least possible time, the occurrence of earthquakes capable of generating Tsunamis from the two probable Tsunamigenic sources, viz. the Andaman-Nicobar-Sumatra Island arc region and the Makran coast in the north Arabian Sea area. The data from the 17 broadband seismic field stations is received simultaneously in real time through V-SAT communication facilities at the Central Receiving Stations (CRSs) located at IMD, New Delhi and INCOIS, Hyderabad for processing and interpretation. The CRSs are equipped with the state-of-art computing hardware, communication, data processing, visualization and dissemination facilities.

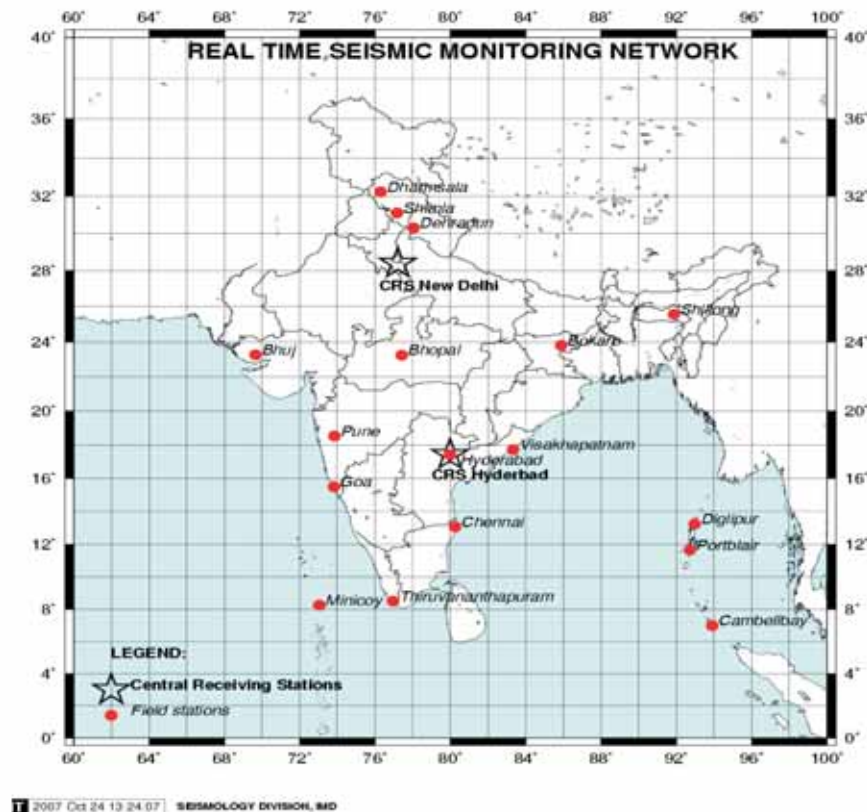


Figure 13: Real time seismic monitoring network (RTSMN)

In addition to the above, following are a few specific achievements:

- A delegation of scientists from IMD, NGRI, WIHG and DST visited various institutes in Iceland to discuss and plan cooperation between India and Iceland in earthquake prediction research. The project document for Indo-Iceland collaboration in the field of 'earthquake prediction research' has been finalized.
- As part of collaboration established with National Council for Science and Technology of United Mexican State, Mexico, in the field of seismology, India Meteorological Department is implementing two research projects on (a) Real-time estimation of source parameters of

earthquakes for evaluation of tsunami potential of offshore - earthquakes, and (b) Source characteristics of local earthquakes in Delhi and Mexico City based on dense array of seismographs and accelerographs.

- As part of the activities of the Indo-Russian Centre for Earthquake Research established in IMD, a borehole acoustic system has been installed at a depth of 100 meters at Kamala Nehru Ridge, Delhi to record high resolution acoustic signals associated with earthquakes. The system will help study precursory phenomena associated with earthquakes. A number of other R&D projects, as part of the Indo-Russian collaboration, are at various stages of implementation.
- The MoES is in the process of initiating a National Program on Earthquake Precursors (NPEP) as part of its Eleventh Plan activity. The national program will be implemented through a multi-institutional and multi-disciplinary mechanism under the umbrella of MoES and as the lead agency. The program is aimed at generating multi-parametric geophysical observations in critical geographical location on long - terms basis, as a basic scientific input for future earthquake prediction related studies. To concretize the action plan of the NPEP, a two-day National Workshop on Earthquake Precursors was organized during 28-29 June, 2007. The proposal is under active consideration.
- As part of implementation of the project on “Archival and Digitization of Seismic Analog Charts”, action for procurement of required capital equipment through open tendering and outsourcing of specialized services for raster scanning and vector digitization of analog charts has been initiated.

Environmental Monitoring

Air Pollution

IMD had 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 Global Atmosphere Watch, (GAW) 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.

These data from GAW stations provide reliable long-term observations of the chemical composition of the atmosphere and related parameters in order to improve our understanding of atmospheric chemistry leading to formulating environmental policy. Chemical composition of precipitation is useful in quantifying the level of pollution due to increasing anthropogenic activities.

Environmental Monitoring Unit

Environmental management is the key to sustainable development. Meteorological dispersal of pollutants is an important area to assess concentration of pollutants and determine the assimilative

capability of the atmosphere. The IMD was entrusted to provide advisory to the Government of India in matters concerning environmental impacts arising out of all kinds of developmental activities. The Environmental Meteorology Unit (EMU) evaluated one thousand six hundred & thirty three projects (thermal power, industrial and mining projects) and provided specific comments during the year 2007, the details of which are as under:

Climate Related Environment Monitoring (CREM)

IMD has initiated implementation of CREM, a multi-agency project for monitoring greenhouse gases (GHGs) and aerosols on a long-term basis. Such data are of vital interest to our country with regard to climate change studies and to create a sound database, which can be, used in future climate change negotiations in the UN framework.

A Climate Monitoring Station has been established at the Hill campus, of G.B. Pant University of Agriculture & Technology, Ranichauri, Tehri Garhwal, (Uttarakhand). An Automatic Weather Station was installed here in 2007. Air quality analysers have been tested and are being installed. The Sky Radiometer installed in New Delhi in 2005, is in operation.

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 ultraviolet 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. The routine measurements have been carried out to monitor Total Column Ozone, Vertical Ozone Profiles and Surface Ozone.

12.3 Deployment of State of the Art Technology

Modernization of IMD

A scheme was proposed in the year 2006-07 to undertake a comprehensive upgradation of observational and forecasting infrastructure of IMD to enhance its capabilities in regard to meteorological services. The Cabinet Committee on Economic Affairs has approved this proposal in December, 2007. The projects under this umbrella proposal are been taken up for implementation during 2008-2010, constituting the 1st phase of modernization. Some of the activities that were taken up under ongoing programmes but related to improvement of observational network have already been undertaken such as follows:

- 125 Automatic Weather Stations (AWS) have been deployed throughout the country.
- AWS data from these 125 AWS stations is being disseminated through GTS for operational utilization in NWP models.

- Procurement of 550 AWS and 1350 ARGs is in progress.
- Procurement of new Integrated Airport Meteorological Instruments for 20 airports and twelve Doppler Weather Radars is in progress.
- Development of indigenous radiosonde for upper air observations has been initiated.

Satellite Applications

IMD continued to receive and process meteorological data from two Indian satellites, namely Kalpana-1 and INSAT-3A. Both the se satellites have 3 Very High Resolution Radiometer (VHRR) channels for imaging the Earth in visible, near infra-red and infra red parts of the spectrum with a resolution of 2X2 km in visible and 8X8 km in IR. Derived products such as Cloud Motion Vectors, Sea Surface Temperature, Quantitative Precipitation Estimation, etc. were routinely generated to serve as inputs to numerical weather prediction, flood warning and high impact weather events monitoring. The cloud imageries are regularly put up on IMD website and archived in the National Satellite Data Centre (NSDC), New Delhi.

Meteorological Data Dissemination (MDD)

Meteorological data consisting of satellite cloud imageries, conventional meteorological. data and analysed weather charts are provided to various field stations through the MDD network. At present, there are 33 MDD stations in India and one each in Maldives and Sri Lanka. MDD signals are also received by IAF and Indian Navy. During cyclone situations, actual position of system and its intensity and related forecast are also being transmitted to field stations every hour. The system is being upgraded to Digital MDD in International LRIT/HRIT format with the facility of uplinking from IMD office. Transmitting station and four DMDD stations have been commissioned in phase -1. The second phase is in progress.

Cyclone Warning Dissemination System

The Cyclone Warning Dissemination System (CWDS) with 252 analogue receivers uses the INSAT platform for communication. Satellite-based communication is more reliable than the terrestrial links which are affected during severe weather conditions. Cyclone warning messages are disseminated to the affected areas in local languages. The scheme is very successful and has saved thousands of lives and property during the cyclone occurrences. 100 more Digital CWDS receivers based on digital technology were deployed in Andhra Pradesh under the World Bank Project in 2003. It is planned to replace all the 252 analogue CWDS receivers by the Digital CWDS.

New Satellite-based Observations

- IMD had commissioned five. Global Positioning Stations (GPS) at New Delhi, Chennai, Kolkata, Mumbai and Guwahati, along with main processing system at New Delhi in

2007 for measurement of Integrated Water Vapour Pressure (IPWV) at these locations. The results obtained from these stations are being validated. The data will be used in Numerical Weather Models for forecasting. Fifty more such GPS stations will be installed in 2008-09.

- A new Geostationary Meteorological Satellite INSAT-3D is being designed by ISRO. It will have a six channel advanced imager and a nineteen channel sounder. In addition to satellite imageries in six channels, several new derived products useful in NWP and in day-to-day weather forecasting will be available in the new system. Vertical profiles of atmospheric temperature, moisture and ozone will be available for the first time from an Indian Satellite. The satellite is scheduled for launch in last quarter of 2008.

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 ultraviolet rays. To strengthen the existing radiation network, IMD installed pyrgeometer at Ranchi as well as Amritsar. pyrhelimeter and pyrgeometer and automatic solar tracker (SMT) were also installed in Pune. The Handbook on Solar Radiation has been prepared and will be released soon.

The network of 45 radiation measurement stations is currently being upgraded by inducting digital pyranometers connected to dataloggers for recording data at very high time resolution. The new data will be of much use in engineering applications of solar energy utilization.

12.4 Other Activities

Climate Monitoring and Climate Information Services

- IMD undertakes real time climate monitoring and publication of Climate Diagnostics Bulletins and reporting of major anomalous climate events.
- Studies are conducted for development of new objective methodologies for drought monitoring over India.
- Prepares climate related databases, data products and atlases for the user community.
- High-resolution gridded terrestrial climate of India has been released for the users.
- Climatological summaries for districts and states are regularly updated.

National Data Centre (NDC)

The NDC is the national repository of all meteorological data collected on a routine basis and through special campaign programmes. The total holdings of meteorological data in the archives as of date is 103.5 million records.

NDC receives queries for data supply from numerous parties including government departments, private institutions, industries, and research and operational users. During the period under 348 million records were retrieved and supplied to different users.

Marine Climatology

The area of responsibility for collecting and processing the meteorological observations from sea areas, assigned to India by the Fourth Congress of WMO in 1963, is north of latitude 15° S and between longitude 20° E and 100° E of Indian Ocean. Marine Climatology Section (MCS), established in IMD in 1971, is the responsible unit for this. The MCS forwards the formatted observations of Indian VOF to Global Collecting Centres (GCCs) on quarterly basis. The global data received from GCC are archived at the National Data Centres (NDC) and used for the preparation of climatological summaries/ surface marine climatological atlas. Specialized observational data obtained during Antarctica and Sagar Kanya cruises are also processed by MCS and archived at the NDC.

- Work regarding preparation of Marine Climatological Summaries for the years 2001-2005 has been taken up.
- IMD recruited 166 Voluntary Observing Ships (VOS) which record meteorological observations and transmit to IMD on real time basis as well as in delayed mode.
- 23 special ships have been recruited by IMD under WMO/VOSCLIM Project for providing quality and reliable observations to study climate change and provide inputs for numerical models.
- The error evaluation of Indian Voluntary Observing Ships / VOSCLIM Ships and necessary remedial action were undertaken. Also, the performance of individual ships, which have transmitted and submitted their ship log books in time and also transmitted real time data during depression / cyclonic storms, were evaluated for IMD awards (Excellent and Certificate of Merit).
- TURBOWIN software has been installed at 35 ships for automation of synoptic observation with the touch of a button and quick transmission.
- Various ongoing WMO programmes like Global Ocean Observing System (GOOS), Global Maritime Distress Safety System (GMDSS), Marine Pollution Emergency Responses Support System (MPERSS) and Ships of Opportunity (SOT), etc. were co-ordinated.
- A section exclusively for marine meteorology was put up on website (www.imdpune.gov.in). The information is useful for mariners in recording weather observations. It also provides necessary guidance to Port Meteorological Officers.

Antarctic Scientific Programme

- IMD continues to operate its Meteorological Observatory at Maitri, Antarctica. Observational data and forecasts are regularly updated on IMD's website (www.imd.gov.in).
- One Automatic Weather Station has been installed and commissioned at Maitri.
- A two - member IMD team is participating in the current 27th Antarctic Expedition.

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. The Centre routinely publishes the Indian Astronomical Ephemeris which provides authentic data on positions of celestial objects with the desired accuracies for various applications in astronomy, space engineering, geodetic and other survey work, etc. It also publishes the Rashtriya Panchang in 14 Indian languages. The Centre supplies 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. and also acts as national agency for determination of dates of festivals of all communities in India, for declaration of official holidays.

The Centre contributed in popularising astronomy by displaying Star-Charts, Astronomical Bulletins, information on panchang matters and current astronomical events etc. on website and by organising sky viewing and other popular programmes.

Weather Channel

A project "Launch of a dedicated weather channel in India" was approved by MoES . Project Management Board (PMB), Project Management Council (PMC) and Project Committee were constituted to supervise the progress of the project. Hiring of a consultant to formulate a Detailed Project Report for the selection of a private partner is in progress.

13. NATIONAL CENTRE FOR MEDIUM RANGE WEATHER FORECASTING (NCMRWF)

13.1 Global Modelling

1. The new experimental global data processing-assimilation system (T254L64) has been made operational from 1 Jan, 2007. The initial condition generation for T254L64 was improved by ingesting QSCAT observations and high density GOES BUFR winds in the assimilation system. New GFS products were compared with operational T80 model during Jan-March 2007 and were found to be better in all aspects. Similarly, a detailed inter-comparison of T80 and T254L64 models was carried out for the summer monsoon of 2007. Various model products influencing the dynamics of monsoon have been critically examined. The new model was found to simulate the Indian monsoon better in all aspects. Verification of the analyzed and predicted track of the monsoon lows and depressions indicated that track errors in T254L64 are lower than those in T80 by about-21% in 24 hr, 15% in 48 hr and 31% in 72 and 96 hr forecasts.

2. Assimilation of GOES high density winds (BUFR) in T254L64 assimilation system was started from December 2007.

3. To further improve T254L64 model, sensitivity studies have been undertaken to examine the impact of high-resolution orographic representation on T254L64 model system. Preliminary investigations have suggested significant impact on the simulation of Indian monsoon.

4. Joint NCMRWF-UKMO collaborative science projects have been identified. Since 2005, NCMRWF and UKMO have been interacting at an informal level to evaluate the performance of the UKMO global model over the Indian monsoon region. The UKMO model has a horizontal resolution of 40 km and has 50 levels in the vertical. NCMRWF regularly receives the UKMO NWP products. These products are also provided to IMD for use at their end. The UKMO analyses and forecasts have been found to be consistently better compared to operational models of NCMRWF over Indian region. In particular, a case study of very heavy rainfall event over Mumbai during 26-27 Jul, 2005 has shown that the NCMRWF meso-scale models with UKMO initial and boundary condition could capture the event reasonably well.

NCMRWF and MoES have been making efforts towards working out a formal collaborative agreement with UKMO. A science plan which includes several projects of mutual interest has been prepared jointly by NCMRWF and UKMO scientists. As a part of this science plan, it is envisaged to implement the UKMO end-to-end NWP suite at NCMRWF and use it for guidance on a routine basis.

13.2 Data Assimilation

1. A new WRF assimilation system has been installed at NCMRWF. The capability for assimilating Indian DWR data in the WRF assimilation system was further improved by developing preprocessors. Radiance data over Indian region (AMSU-A) is used in the WRF assimilation system for computing new radiance biases.
2. Preprocessor modules were developed and tested for GPS COSMIC data. COSMIC data is assimilated over Indian region.
3. A study was undertaken on the analysis, validation, impact-study of Global Positioning System (GPS) radio occultation integrated water vapour over the East Asian region. From this study, it has been found that the NCMRWF analysis, Japanese 25 years re-analysis (JRA25) and NCAR re-analysis are significantly drier than GPS observation. This work was examined with GEONET (GPS Earth Observation Network) data obtained from Japan. The GPS nationwide project GEONET launched by Japan in 1997 consists of more than 1200 GPS permanent stations as on today and is one of the largest GPS networks of the world. In addition to radiosondes, GPS ground measurements are also used to obtain integrated precipitable water vapor under all weather conditions. The project indicates that the GPS soundings are able to provide sufficient high accuracy moisture information. It has been planned to adapt the GPS soundings on OCEANSAT-II that will carry ROSA developed by the Italian Space Agency (ASI). The forthcoming high accuracy moisture data would be useful in further improving NCMRWF assimilation forecast system in future.
4. Presently, NCMRWF is using NCEP decoder that was implemented on a cluster of computers that include Alpha, Param systems. The machine dependence of the decoder was removed by successfully porting on to a simple Linux PC. Test runs of this version are going-on.
5. Direct satellite radiance assimilation has been started from the monsoon 2007 season. At present, AMSU-A, AMSU-B and HIRS data sets from NOAA series of satellites are being used. These data sets are made available by getting direct access to the data server of NOAA through a special arrangement. Scripts were developed to download the data without human intervention. The level 1B data is converted to NCEP BUFR format for which navigation and calibration are involved. Preliminary impact study of these data sets conducted for the month of April 2007 has shown encouraging results. A detailed study for the 2007 monsoon season is being carried out.
6. In the present operational GFS code, fast radiation transfer model CRTM version 5.1 is used, covering about 532 channels. It has been planned to include some more channels into this system to augment forecast model input data volume. At present modules are developed to include METOP and NOAA-18 MHS data sets in CRTM. The possibility of implementation is being examined.

7. Development of 4D VAR assimilation system is under progress. The difficult part of this work is the development of adjoint for the forecast model. A prototype 4D VAR is being developed with a simple three - level quasi-geostrophic model. If this effort proves successful then a 4D VAR with operational T80 model will be attempted. Although T254 has become operational, T80 is chosen for this exercise since writing adjoint for a parallel code (T254) is much more difficult and the idea is to test the all in-house exercise before implementation.

13.3 Other Data Related Activities

1. Comparison of observational data reception at UKMO & NCMRWF. Results show that NCMRWF receives comparable amount of conventional observations (except aircraft) but the reception of satellite observations at NCMRWF are little compared to that at UKMO.

2. Studies on the meteorological features associated with Indian drought during 2002 using JRA25-high resolution model T106 are under progress. Computation of various mean circulation indices for the extreme years with the Japanese high resolution model and examination of the back-trajectory analysis in the low-level circulation during July 2002 are under progress.

3. A Planning Workshop on Instrumental Aircraft for Forecasting Demonstration Project (FDP) of land falling Tropical Cyclones over Bay of Bengal was organized.

4. Coordination with IMD (for conventional data) and ISRO (for non-conventional data) is important. Data group is playing a crucial role in adapting to the new IMD observation system. Transmission and assimilation of IMD radar data (for mesoscale assimilation) is a beginning, for which quality control will be developed. Data group is closely working with ISRO for assimilation of satellite observations. A project on utilization of scatterometer surface wind data on OCEANSAT II has been sanctioned and work will start soon. In the near future Data group scientists will assimilate Radio Occultation data from ROSA instrument placed on the same satellite. Active collaboration with ISRO is also on for assimilation of radiance data from MADRAS and SAPHIR instruments on MEGHA TROPIQUES satellite when it will be available, and further down the road assimilation of INSAT3D data is also on agenda.

13.4 Meso-scale Modelling

1. WRF-ARW model was setup to run at 27-km horizontal resolution and 38 vertical levels using initial and lateral boundary conditions with T254L64 global model from June 2007. Until now WRF-ARW model was run using the initial and lateral boundary conditions from the T80 global model. After the new global model T254L64 was implemented, the WRF model was re-implemented to accommodate high resolution (50Km) input from T254. The experimental runs were carried out through 2007 monsoon season on daily basis. Preliminary evaluation studies indicated that the model predicts all the heavy rainfall amounts missed out in the global model. However there is further scope for improvement via regional assimilation which is currently being addressed.

2. WRF-NMM model was installed and was run with 27-km horizontal resolution and 38 vertical levels in experimental mode for the case studies during monsoon and tropical cyclone seasons of 2007. Evaluation of comparative performance of ARW and NMM versions is under progress.
3. Sensitivity studies were conducted with WRF NMM to test various deep convection schemes for tropical cyclone prediction. It has been found that Kain-Fristch scheme simulates better the mesoscale variability associated with tropical cyclones and allied high rainfall.
4. Performance verification of WRF models during Indian monsoon 2007 is under progress.

13.5 Ocean State Forecasting

1. The latest version of Global WAM model (Cycle-4) has been installed on a Linux PC and PARAM Padma for assessment of global ocean status within 75°S-75°N with a spatial resolution of 1°x 1°. Simulations were done for all days of 2005 using T80 model inputs. The outputs were verified against Buoy location and WAVE WATCH-III outputs that was re-run for all days of 2005 with warm start option Preliminary results indicate that WAVEWATCH-III outputs are slightly better than WAM. And also the WAVEWATCH runs with warm start option is found to be better compared to the results using cold start option.
2. In order to assess the quality of the initial state input given to WAM model, the quality of T80 surface wind analysis over the tropical Indian Ocean during 2005 were examined by comparing it with satellite derived surface winds from NASA QuikSCAT satellite. In general, the model wind speeds are underestimated. However in seasonal comparisons, winds in winter months over Arabian Sea are stronger by about 1-2 m/s where as over south Indian Ocean and Bay of Bengal the model winds are weaker by 3-4 m/s. In pre-monsoon months over Arabian Sea and Bay of Bengal the model winds strengthen by 1-3 m/s from Day-1 to Day-5 forecasts whereas over Indian Ocean model wind speeds are weaker by 3-4 m/s. In monsoon months over Arabian Sea the model winds are underestimated by 3-4 m/s in the analysis. In the forecasts (Day-1 to Day-5) wind speeds are overestimated over Arabian Sea and underestimated by 2-3m/s over equatorial Indian Ocean. During post monsoon months the model wind speed are underestimated by 3-5 m/s over southern and equatorial Indian Ocean. Similarly, the T80 and Eta model forecasts were compared with wind speeds from Buoy observations using Triple-collocation method. Results suggest that ETA predicted values are closer to the Buoy measurements, compared to T80 model predicted values.
3. Modifications were made in the source code of the WAM model to extract the normalized wave stress and frictional velocity required for coupling the wave model with T80 atmospheric model. In this work the feedback of the waves on the winds is being modeled via a wave dependent Charnock parameter, which enters in the formulation of the surface roughness used to determine the atmospheric surface stress over the ocean ($Z_0 = C u^2 /g$).

13.6 Ocean And Climate System Modelling

1. A fully thermo-hydrodynamic numerical model of the Indian Ocean was driven by observed fluxes (including river flow) for four years (2001-2004) at a horizontal resolution of 10 km and with 20 vertical levels. The experiments showed a vigorous horizontal circulation regime in the deeper layers of the Bay of Bengal and also the possibility of undercurrents near and in the pycnocline. Integration of the model for 50 years with observed data to study the inter-annual variability of hydro-physical fields in the Indian Ocean is going on.
2. The first experimental version of the 4D Variational Ocean Data Assimilation system with assimilation procedures for SST and Sea Surface Topography data was put into trials with real data.
3. Installation and testing of HYCOM based global/regional ocean modelling and corresponding data assimilation work has been undertaken. Initial joint work with HYCOM consortium has been worked out and will be formalized soon.

13.7 Climate Variability Modelling

1. Various global re-analysis datasets (NCEP, NCEP-II, ERA40 and JRA25) were examined and research was carried out using available observed data over the Indian region to document the varied representation of hydroclimate over the Indian region by global re-analysis datasets. This work forms the scientific basis for carrying out a high-resolution regional re-analysis over south Asia.
2. The T80 global model has been integrated for 24 monsoon seasons with 10 ensemble members for each season to understand the response of the model to observed sea surface temperature forcing. Skill of the model in simulating interannual variability of the Indian monsoon rainfall is being examined.
3. The NCMRWF medium-range ensemble prediction system was evaluated and relationship between systematic errors of the model and ensemble spread was documented.
4. Structure and role of internally generated variability in the T80 global model during different monsoon seasons is under study to develop a probabilistic seasonal prediction system.
5. The NCMRWF seasonal prediction for application to society (SeaPrAS) system was used in real-time to predict the monsoon rainfall for 2007 and was provided to IMD.
6. Couple model results from IPCC models were examined over the Indian region and strength and weaknesses of these models in simulating climatology, annual cycle and interannual variability

over the Indian region were identified. This study forms the basis of climate modelling and simulations of the NCMRWF's climate change programme.

13.8 Environmental Modelling

Satellite observations of Aerosol Optical Depth (AVHRR, TOMS, MODIS) were systematically analysed to describe the global and regional features of multi-year changes and annual cycles. This was interpreted in combination with transport modelling and precipitation distribution. A decrease in AOD coinciding with the collapse of industrial production in the East European countries the first half of 1990s could be detected, but no causal relationship could be established.

Miscellaneous Scientific Works

- Extended range forecast for monsoon was provide to IMD for four monsoon months during 2007 monsoon season.
- Compilation of monsoon report for 2007 comparing the new T254L64 and earlier coarse resolution global models have been completed.
- NCMRWF participated in SPIM project sponsored by DST to examine the predictability of Indian monsoon from various available AGCMs.
- NCMRWF participated in Min. of Agriculture sponsored project on ERFs at CAS IITD.
- NCMRWF is participating in DST/ICRP project CTCZ.
- Algorithm to prepare merged satellite and gauge daily rainfall data with INSAT, KALPANA and Microwave rainfall data as input has been tested.
- The MoES Multi-Model Ensemble (MME) project has been undertaken at NCMRWF. It is a joint activity of NCMRWF, IMD and IITM. Under this project algorithm and data for short and medium range forecasts will be available for operational real time use for the Indian region. NCMRWF will participate in international consortium TIGGE.
- Evaluation of rainfall forecasts from T254L64 and UKMO has been started.

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

The Institute of Tropical Meteorology (IITM) was separated from the India Meteorology Department in 1962 and was established as a Centre for Research in the year 1971. Its primary functions are to promote, guide and conduct research in the field of meteorology in all aspects and advance the prediction of tropical weather and monsoon climate. Since its inception the Institute has been providing its input to the India Meteorological Department for the forecast of seasonal monsoon rainfall of the country. IITM has widened its objectives and scope of research activities, from time to time, to meet the critical challenges and the national needs of providing information relating to various aspects of atmosphere and looks into the increasing concern of the government and general public about a variety of environmental issues.

In tune with the mandate of basic research for advancing the prediction of tropical weather and monsoon climate, the IITM made fundamental and noteworthy contributions during the year under report in the areas of monsoon prediction, monsoon variability, climate change & climate variability, atmospheric chemistry modelling and air quality measurements.

Following were some of the important research contributions during the year:

- IITM has been playing a leading role in the development of empirical models for long-range prediction of seasonal mean monsoon rainfall and has taken major initiatives for the prediction of seasonal mean Indian summer monsoon rainfall and its variability by using atmospheric model as well as by developing an intermediate atmosphere-ocean coupled model.
- For the first time in the country, projections of Indian summer monsoon under different climate change scenarios have been made through downscaling with the latest version of Hadley Centre Regional Climate Model. The scenario data products have been distributed to several impact assessment groups in the country.
- 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 and its connection with global warming has been projected.
- Discovered a coupled feedback between the tropical Indian Ocean circulation and the southwest monsoon winds, on sub-seasonal/intra-seasonal time-scales, which is pivotal in forcing long-lasting breaks in the monsoon rainfall over India and occurrence of droughts over the subcontinent.
- LIDAR Group at IITM has developed “An Excimer Laser-based DIAL (Differential Absorption LIDAR) Technique for Vertical Profiling of Ozone up to Stratospheric Altitudes” and measurements of vertical profile of ozone were carried out at Pune for the first time in the Country.

14.1 Recognitions for Research

- A joint research programme between IITM and University of Reading, U.K. on 'Science of Regional Climate Change, Variability and Impacts' has been selected for a 'Major Award' under UK-India Education and Research Initiative (UKIERI). Dr K. Krishna Kumar received the award on behalf of the Institute from the Chancellor, Mr Gordon Brown, at a function organized by the British Council in New Delhi on 18 January, 2007. Prof. Julia Slingo, University of Reading is the convener from the U.K. side. Prof. B.N. Goswami is the convener and Dr. K. Krishna Kumar and Dr. G. Srinivasan, are the Co-conveners from the Indian side.
- Dr. G. Beig, has been conferred with the prestigious national level Maharana Udai Singh Award-2007, constituted by the Maharana Mewar Foundation, Rajasthan, for his contribution to the field of environmental protection, hand-in-hand with future development.
- Dr. K. Krishna Kumar was invited to be a panelist in Session III on Impacts, Vulnerability and Adaptation Assessments of the Inception Workshop' for India's Second National Communication to the United Nations Framework Convention on Climate Change held in New Delhi on 28 May, 2007.
- Dr. K. Krishna Kumar received the 'Certificate of Merit' Award for the year 2007 of the Ministry of Earth Sciences, Govt. of India, for his outstanding contributions in the field of atmospheric sciences.
- Dr. K. Krishna Kumar has been elected Fellow of the Indian Academy of Sciences (IAS), Bangalore, 2007.
- Dr. P.C.S. Devara has been elected President of the Executive Committee of the Indian Aerosol Science and Technology Association (IASTA), and Dr. P.E. Raj and Dr. P.S.P. Rao have been elected as Members of IASTA which is the only professional scientific association dedicated for research in all aspects of aerosols and gases in the country.
- Dr. G. Beig organized a Symposium as a Convener of the Joint Symposia JAS008 entitled 'Long Term Trends and Changes in the Atmosphere-Ionosphere System' as a part of General Assembly of IUGG at Perugia, Italy on 6 July, 2007. He chaired a session in General Assembly. Dr. Beig delivered a solicited talk entitled 'Solar Influence on the Composition and Climatology of the Mesosphere and Lower Thermosphere' at the General Assembly of International Union of Geodesy and Geophysics (IUGG) at Perugia, Italy, and an invited talk entitled "Long Range Transport of Ozone Pollutants" at the University of Brescia, Brescia, Italy during 9-13 July, 2007.
- Dr. C.G. Deshpande participated in the First Indian Scientific Expedition to Arctic Region, organized by the National Centre for Antarctic and Ocean Research (NCAOR), Goa, during 2 August – 6 September 2007. He worked for a project proposal entitled 'Measurement of atmospheric aerosols and ions in the Arctic region' of the Ministry of Earth Sciences during

the expedition. Dr. Deshpande made measurements of size distribution of sub-micron sized aerosols, atmospheric electric field and conductivity at the International Arctic Research Base, Ny-Alesund, Svalbard, Norway. These measurements have been undertaken first time in the Arctic region in the field of atmospheric sciences by an Indian scientist.

- A “Brainstorming Workshop for the Development of a National Programme on Climate Change Research”, was jointly organized by the IITM, Pune and the Ministry of Earth Sciences, New Delhi, at CSIR Science Centre, New Delhi on 1 June, 2007. The Workshop was attended by senior scientists and policymakers from several ministries, departments and institutions. A proposal was made to establish a dedicated **Centre for Climate Change Research** at IITM, Pune to address the science of climate change issues and to integrate other institutions through coordinated network.
- The IITM Research Report No. RR 109, 2006 entitled, ‘Influence of El Nino on the Biennial and Annual Rossby Waves Propagation in the Indian Ocean with Special Emphasis on Indian Ocean Dipole’ by B.H. Vaid, C. Gnanaseelan, P.S. Polito and P.S. Salvekar, 2006 has been cited by the United Nations Development Programme (UNDP) report on Human Development 2007/2008: Fighting Climate Change - Human Solidarity in a Divided World. The report is available online at http://hdr.undp.org/en/media/hdr_20072008_en_notes_biblio_indic.pdf.

14.2 Field Observational Programmes

- Optical, physical and radiative characteristics of aerosols at Indian Antarctic station, Maitri and Larsemann Hill was recorded during the participation in 26th Indian Antarctic Expedition, between December 2006 and March 2007.
- A special observational field campaign was organized for the study on characterization of aerosols and trace gases at (i) Sinhagad, a high-altitude site (~1400 m AMSL) during December 2006, January and February, 2007 to measure sun/sky radiance at five spectral channels and precipitable water content and down-welling solar flux, co-located observations of aerosol number-size distribution and black carbon concentration and observations of TSP and mass size distribution of aerosols; (ii) Space Physics Laboratory, Thiruvananthapuram during February – March, 2007; (iii) Space Application Centre, Ahmedabad during April 2007; and (iv) National Atmospheric Research Laboratory, Gadanki, Tirupati during April – May, 2007.
- A field campaign was launched to monitor the levels of suspended particulate matter, sulphur dioxide, ozone and its precursors (NO_x, CO and NMHCs) in the vicinity of the sugar factory in the Pune District, when in operation in February 2007.
- Under the DST - sponsored project ‘STORM’ a field campaign was organized at Guwahati to measure various atmospheric electrical parameters such as electrical field, Maxwell current, electric field change, charge and size of raindrops during April – May, 2007 for the study of

electrical characteristics of severe thunderstorms occurring in the northeastern region of India.

- A field programme on the tree-ring sample collection was organized at Madumalai Forest Division of Tamilnadu in collaboration with the Centre for Ecological Sciences, Indian Institute of Sciences, Bangalore, during 22-30 May, 2007.
- A field programme was organized during 26 November – 12 December 2007 for collection of tree-ring samples from Karnataka forest, under Asia Pacific Network (APN) project “Collaborative Studies in Tropical Asian Dendrochronology: Addressing Challenges in Climatology and Forest Ecology”.

14.3 Manpower Development and Academic Activities

Trainings

The In-House Training in Atmospheric Science started in 2006 was continued must have been conved and its seemed phase was organized during 20 August – 26 December, 2007 for the rsearch fellows, research associates, and scientists of the Institute. Statistical Techniques and Observational Techniques were the compulsory subjects, and the Large Scale Air-Sea Interaction was the optional subject. There were 40 participants for the compulsory subjects and 51 participants for the optional subject.

Ph.D. and M.Tech. Programmes

Seven scientists/research fellows received Ph.D. degrees and five theses have been submitted to the University of Pune, Pune. A total of 18 students of M. Tech. in Atmospheric Physics/ Atmospheric Sciences/Space Science from the University of Pune, and other Universities as, Cochin, Andhra and Sri Venkateswara University were provided facilities for their projects, including research guidance..

Science Popularization Programmes

IITM participated in the Science Expo-2007 organized by the Nehru Science Centre, Mumbai, during 13-17 January, 2007 and in the exhibition organized on the occasion of Science Congress of the Pimpri-Chinchwad Science Park, held during 28 February –2 March, 2007 at Ramakrishna Prekshagriha, Chinchwad, Pune. IITM celebrated National Science Day on 28 February 2007, World Water Day on 22 March 2007 and World Meteorological Day on 23 March 2007 at its premises by organizing Scientific Exhibitions, Popular scientific lectures, Scientific Film Show, Open Day for general public and visit of students from schools/colleges to IITM, Radio programme, etc. Some of the IITM scientists delivered lectures at various colleges on the occasion of National Science Day.

Official Language Implementation

In-house Hindi Workshops were organized for the Institute's employees during 26-27 March and 10-14 December, 2007. Hindi Week was celebrated during 10 – 17 September, 2007. On this occasion, competitions in poetry, quiz, anathakshari, noting & drafting, etc. were conducted. The prizes were given Dr G.B. Pant, Scientist G, IITM, who the Chief Guest of the Closing Ceremony of Hindi Week. A lecture on "Rashtra-Bhasha Karyanvayan – Bhasha Vigyan ke Paripekshya Main" by Dr. Prashant Pardeshi, Professor of Linguistics, Kobe University, Japan was arranged on 4 January 2007. IITM scientists participated in Hindi Workshops/Seminars organized by other Institutes and presented papers. Inspection of the status of official language implementation in the Institute was carried out by Shri R.S. Rawat, Deputy Director (Implementation), Department of Official Language, Mumbai on 14 December 2007.

Foundation Day

46th Foundation Day of the Institute was celebrated on 17 November, 2007 at its premises at Pashan. Prof. U.R. Rao, Former Chairman of Indian Space Research Organisation (ISRO) and Space Commission was the Chief and Prof. V.K. Gaur, Former Secretary, Department of Ocean Development, Govt. of India and Distinguished Professor, Indian Institute of Astrophysics was the Guest of Honour. The function included presentation of Annual IITM Silver Jubilee Awards for the scientific research papers and the Excellent Performance Awards to the administrative, technical and non-technical maintenance personnel. Heads of various local institutions, important dignitaries and ex-employees including former Directors of the Institute participated in the function. Prof. U.R. Rao, delivered a lecture on "Space Technology for Atmospheric Research". Prof. Gaur delivered the Foundation Day lecture on "Earth's Changing Climate through the Aeons". Dr. R. Krishnan delivered the Silver Jubilee Award lecture. On this occasion tree plantation by Prof. Gaur and other dignitaries was arranged. Prof. B.N. Goswami, Director presented mementos to the Institute employees who had completed 25 years of service in the Institute. The function was concluded by a cultural programme in the evening.

14.4 Research Activities

- **Climate Variability and Climate Dynamics**
- **Asian Monsoon Variability and Predictability**
- **El Nino Southern Oscillation and Winter Precipitation Extremes over India**

Analysis of data for 102 years (1901-2002) on daily rainfall in winter season over south-east peninsular India showed that the frequency and intensity of winter precipitation extremes do not show a significant long-term trend. ENSO index can be used to predict the frequency and intensity of extreme precipitation events 4-6 months in advance

Asian Monsoon Variability in WCRP CMIP3 Simulations

The output of the 22 coupled climate models performing coordinating experiments leading to the Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC AR4) was examined. Six models, viz. CGCM3.1 (Canada), CNRM-CM3 (France), ECHAM5/MPI-OM (Germany), MIROC3.2 hires and medres (Japan), UKMO-HadCM3 (UK) from the IPCC AR4 database that generate the most realistic monsoon climate over India have projected an average increase of 8.2 % in monsoon precipitation. These models have also suggested possible extension of the monsoon period into early-autumn. The increase in precipitation could be attributed to the projected intensification of the heat low and monsoon trough during the establishment phase of the southwest monsoon and the projected decline in snowfall over western Eurasia. The projected precipitation increase over East Asia may be attributed to the projected intensification of the monsoon circulation, North Pacific Subtropical High and the Meiyu-Changma-Baiu frontal zone.

Extended Range Prediction of Monsoon

Asian Monsoon Variability and Predictability – Parameterization

A study was undertaken on the onset phase of southwest monsoon over the Indian region (EQ-30°N, 50°-100°E) for drought year cases during the past 30 years, by computing dynamical and physical parameters using NCEP re-analyzed daily horizontal wind, temperature and humidity data throughout the troposphere. The analysis was carried out for the period 15 May –15 June of 20 years (1987-2007). The dynamical and physical parameters over the region were found to have large-scale distribution during the onset week period for all the years 1987-2007, except for the years 1987, 2002 and 2004, which were the drought years. From the computations of dynamical and physical parameters, it was clearly indicated that, if all the parameters have synoptic scale distribution near the onset date, then the total seasonal monsoon performance would be either normal or above normal, whereas if the see parameters have mesoscale structure, then the total monsoon rainfall would be below normal (drought year).

Asian Monsoon Variability and Predictability “ Data Assimilation

Objective analysis of the upper ocean (up to 100 m) was carried out for the north Indian Ocean basin using the available ARGO, XBT, and CTD profiles during January 2000 - September 2007 using Optimum Interpolation method. A monthly climatology of upper ocean temperature (1° X 1°) has been prepared for the north Indian Ocean using this analysis. Interannual variability in the upper ocean temperature was studied. Anomalous IOD pattern was observed in the surface and subsurface (at 100 m) temperature during 2006 and 2007.

Asian Monsoon Variability and Predictability – Modelling

Non-linear Error Energy Budget of a Forecast Model in Medium Range Tropical Weather Forecast

Predictability of the lower tropospheric planetary scale waves over the tropics was studied in terms of the systematic error energetics of GFS and NCMRWF models to identify the reasons of poor predictability of well-observed lower tropospheric ultra long waves in the global tropical region. Investigations on the spatial and spectral distributions of the error kinetic energy as well as evolution of the error growth through the process of scale interactions in terms of the participating triads have shown two sources of the uncertainty in the tropical ultralong waves in the lower troposphere.

Extreme Indian Monsoons and Dipole Mode

The association between the summer monsoon rainfall over India and the dipole mode over the Indian Ocean was examined by computing lead/lag correlations using data for a 132-year period (1871-2002). Results reveal that numerically the relationship is stronger following the monsoon, suggesting that the summer monsoon has more influence on the dipole mode during autumn than vice-versa.

Application of Satellite Data in Weather Forecasting and Large Scale Hydrological Modelling

Antarctic Sea-Ice Extent Association with Indian Summer Monsoon Rainfall

DMSP-SSM/I derived monthly sea-ice extent in different five sectors of Antarctica was compared with the Indian summer monsoon rainfall for the period 1988-2005. Highest correlation of 0.52 between WP-SIE sector and ISMR was obtained in the month of March. Wavelet analysis showed a 2 -3 year dominant period in both the series, giving more confidence in the relationship. A teleconnection between sea-ice extents of Antarctica of the western Pacific sector in the month of March with that of Indian summer monsoon variability was revealed with a time lag of 3 months.

Study of Important Forcings Associated with an Early Onset over Andaman Sea and Advance to Indian Mainland

An observational study was carried out to understand the important forcings, i.e. mid-latitude upper-layer temperature oscillations and the rising phase of the northward propagating intraseasonal oscillations, associated with the onset over Andaman Sea and advance to the mainland.

Characteristics of Hydrological Wet Season over Continental Core Monsoon Area of India

Longest possible instrumental area-averaged monthly, seasonal (winter JF, summer MAM, monsoon JJAS and post-monsoon OND), sub-seasonal (JA, JJA, ON, M-O) and annual rainfall series have been developed for the Continental Core Monsoon Area of India (CCMAI: 15°-32°N, 72°-89°E) using highly quality-controlled data from well-spread network of 246 raingauges.

Hydrometeorological Studies of River Basins for Applications in Water and Power Resource Projects

Spatial and Temporal Variations in Rainfall Occurrences during Wet Periods in India

Climatology and fluctuations of 4 parameters (starting date, ending date, duration and rainfall intensity) of five wet periods contributing 10%, 25%, 50%, 75% and 90% to the annual total were studied across the country and for eight major river systems of the country using daily rainfall data for the period 1951-2003 (1° x 1° resolution).

Hydrometeorological Analyses for the Preparation of Generalized Probable Maximum Precipitation (PMP) Atlases of Indus Basin and Krishna basin in India.

For the preparation of the Generalized PMP Atlases of the Indus basin in India and the Krishna basin PMP estimates and precipitation data analyses at individual stations in different catchments by various methods were carried out under the sponsored projects from the Central Water Commission (CWC), New Delhi.

Short-Term Climate Diagnostics and Prediction

Forecast of Indian Summer Monsoon 2007

Experimental forecasts for All India seasonal mean monsoon rainfall (JJAS) of 2007 have been attempted at IITM by four empirical and dynamical models.

Pathway

The dynamical link between ENSO and Indian monsoon rainfall variability is not yet fully understood. Based on an ensemble of GCM simulation experiments and detailed diagnostic analysis of observations, a new pathway for the ENSO-monsoon connection was identified.

Impact of Global Warming on Onset Characteristics

The high resolution regional simulations generated using the Hadley Centre Regional Climate Model PRECIS (Providing Regional Climate for Impact Studies) at ~50 km resolution for the two time slices, 1961-1990 and 2071-2100 were analyzed to find different characteristics of the onset phase of southwest monsoon in the present as well as towards the end of the 21st century.

Palaeoclimatic Investigations

Drought Sensitive Tree-ring Chronologies from South India

Dendroclimatic analysis of Kerala tree-ring chronologies of teak (*Tectona grandis*) indicated has significant positive relationship of tree-ring chronologies with monsoon (JJAS) and annual rainfall of Kerala. The relationship was further enhanced in all India rainfall series. Though, the temperature is an important parameter in tree growth climate relationship, the direct influence of temperature on peninsular India was not evident.

More than 50% significant low growth years (LGY) [$<(\text{Mean}-\sigma)$] in Kerala tree-ring chronology were also found to be associated with deficient Indian rainfall (DIR) records, based on the observed and historical data since 1791 A.D.

Development of Teak Tree-ring Chronology from Kerala

Tree-ring data from two sites of Kerala were analyzed by crossmatching and dating of tree-ring core samples of teak (*Tectona grandis*) from Wayanad and Sunkham sites. Out of 48 core samples studied from Sunkham site, 25 could be well dated. Out of 26 core samples from Wayanad, 19 were dated accurately. The frequency of occurrence of false rings was found to be relatively more and confined to both earlywood and the latewood zones. Pre-monsoon showers, followed by prolonged dry spell in the beginning of growing season of teak may cause high frequency of earlywood false rings.

Short - Term Climate Prediction

Climate Studies and Monsoon

Climate Change Simulations over Northeast Monsoon Region

During the period October-December, South Asian region receives a good amount of rainfall due to northeast monsoon activity. The study has discussed the projections of precipitation and surface air temperature over South Asian region during the NEM season by IPCC AR4 models and one regional model PRECIS. The analysis has shown that 6 out of 14 AO-GCMs have reasonable skill in simulating the present day climate of NEM over the South Asian region.

Dynamical Prediction System of Seasonal Mean Monsoon Rainfall

Extended Range Predictability of Indian Summer Monsoon

Different methods were studied to capture different non-linear phases of precipitation ISO using the combination of a sufficiently large number of dynamical variables and thereby developing a prediction scheme in the extended range. Nonlinear states of the large scale circulation isolated at the self-organized map (SOM) nodes without involving any information on rainfall, were found to be strongly linked to different phases of evolution of the rainfall ISO, including the active and break phases.

Internal Feedbacks from Monsoon-Midlatitude Interactions during Droughts in Indian Summer Monsoon

While there is a growing recognition that the seasonal predictability of the Indian summer monsoon rainfall tends to be limited by atmospheric internal-dynamics; aspects relating to monsoon internal-dynamics are not fully understood. One of the unresolved issues pertains to the role of monsoon-midlatitude interactions during droughts in the Indian summer monsoon. This problem was investigated using a 20-year simulation of a high-resolution AGCM forced with climatological SST boundary condition; along with supplementary data-diagnostics and simplified model experiments.

Evaluation of Several Different Planetary Boundary Layer Schemes within a Single Model, A Unified Model and a Multimodel Superensemble

This research addresses the forecasts of latent heat fluxes from five different formulations of the planetary boundary layer (PBL). Different formulations are deployed within the Florida State University global spectral model. Hundreds of short-range forecast experiments are carried out using daily data sets for summer 2002 with each model with a primary goal to compare the performance of the diverse family of PBL algorithms for the latent heat fluxes within the PBL.

Experimental Superensemble Forecasts of Tropical Cyclones over Bay of Bengal

This study entails the implementation of an experimental real time forecast capability for tropical cyclones over the Bay of Bengal basin of North Indian Ocean. This work is being built on the experience gained from a number of recent studies using the concept of superensemble developed at the Florida State University (FSU).

Extended Range Prediction of Active and Break Spells of Monsoon

Assessing the Role of Large-scale Dynamics in the Extended Range Predictability of Indian Summer Monsoon

The nonlinear convectively coupled character of the summer monsoon intraseasonal oscillation (ISO) that manifests in its event-to-event variations is a major hurdle for skillful extended range prediction of the active/break episodes. Convective coupled character of the monsoon ISO implies that a particular nonlinear phase of the precipitation ISO is linked to a unique pattern of the large-scale variables. Different methods are being studied to capture different non-linear phases of precipitation ISO using a combination of a sufficiently large number of dynamical variables and thereby developing a prediction scheme in the extended range.

Cloud Radiative Impacts during Evolution of Monsoon Breaks

A characteristic feature of the evolution of the monsoon intra-seasonal variability is the appearance of suppressed convection, with scarce cloud cover, over the South Eastern Tropical Indian Ocean (SETIO), nearly 7-10 days prior to the commencement of a break spell over India. A detailed analysis was carried out to understand if cloud radiative effects, associated with such convection changes over the tropical Indian Ocean, can exert impact on monsoon break spells.

Influence of Large-scale Dynamical Indices in the Event-to-Event Modulation of Active Break Cycle

The intraseasonal variability of Indian summer monsoon rainfall pattern is largely dependent on the nonlinear convective coupled relationship among various large-scale dynamic parameters. An attempt was made to find out the role of six large-scale dynamical parameters in shaping the spatial distribution and intensity of monsoon rainfall (active and break cycle) in the intraseasonal scale by defining statistically robust indices derived from the NCEP data of 53 years (1951-2003). IMD rainfall data for 1951-2003 over land were used. Different types of nonlinear coupling among the six large-scale dynamical parameters were found to be able to yield different shades of active and break patterns.

Alternative to Prediction of Seasonal Mean All India Rainfall

While prediction of seasonal mean all India rainfall may be useful in getting an outlook of the agricultural production of the country as a whole, it is not useful for individual farmers, as the rainfall anomaly is highly inhomogeneous over the country during 'normal' monsoon years. Further, due to the existence of significant 'climate noise' in the region, the skill of prediction of seasonal mean Indian summer monsoon may remain poor. Thus, there is a profound need for an alternative strategy to prediction of seasonal mean AIR even if it is with a shorter lead time. Predicting the phases of the monsoon sub-seasonal oscillation (active and break spells) 3–4 weeks in advance is such an alternative strategy. Such predictions would be more useful for regional hydro-meteorological applications.

Forecasting of Summer Monsoon Subseasonal Variability

Based on the premise that the monsoon intraseasonal oscillations exhibit regularity in their evolutions and similarity in the spatial patterns, an empirical real-time forecasting strategy based on the event-to-event similarity in the properties of monsoon intraseasonal oscillations (ISOs), to predict the subseasonal variations of the Indian summer monsoon up to four–five pentads (20–25 days) in advance, has been developed.

Atmospheric GCM and Slab Ocean Coupled Model Experiments

An attempt was made to run the atmospheric general circulation model (from Hadley Centre for Climate Prediction and Research, U.K.) coupled to slab ocean. In order to obtain a realistic representation of SST and sea-ice, a corrective heat flux called, the heat convergence, must be included to account for the lack of ocean dynamics and errors in the surface fluxes. Slab calibration run was required to generate these data.

Study of Secondary Heat Sources over India during Southwest Monsoon 2002

To understand the reason for the failure of Monsoon 2002, an analysis of Q1 and Q2 have been made.

Evolutionary Changes in Marine Atmospheric Boundary Layer (MABL)

To examine the evolutionary features of the dynamic and thermodynamic characteristics of the marine atmosphere over the southeast Arabian sea (SEAS) just two to three days prior to the onset of southwest monsoon over Kerala, the surface and radiosonde data (high-resolution) collected onboard ORV Sagar Kanya at 9.22°N,74.51°E during ARMEX-2003 were analysed.

The Response of Cyclonic Storm to MABL over Bay of Bengal

The thermodynamic characteristics of a system of formation of a tropical storm over the southwest Bay of Bengal during 12-16 June 1996 and its moving in a north-northeasterly direction was examined using surface and upper air data onboard ORV Sagar Kanya.

Formation of Onset Vortex

Formation of the onset vortex over the southeast Arabian Sea is not a regular feature of the southwest monsoon. To understand the mechanism of irregularity of onset vortex, weekly SST distribution over the Arabian Sea for the period 2000-2005 has been analyzed.

Basic Physics through Observations

Aerosol and Climate Studies

Dual Polarization Micro Pulse LIDAR (DPMPL) view of Interplay between Atmospheric Boundary Layer Aerosols and Clouds and CALIPSO Satellite Data Validation

The dual polarization micro pulse LIDAR (DPMPL) at the Institute has been operated extensively during the winter of 2005-2006 and monsoon months of July and August, 2007, and collected more than 6000 LIDAR backscatter intensity profiles have been at superfine resolution of 1 second in time and 2.4 metres in altitude. These voluminous data archived during clear-sky, cloudy and light drizzle conditions have been analyzed to derive the night-time boundary layer structure and stratification, cloud macro-physical parameters (cloud horizontal and vertical heights and in-cloud structures), phase (water or ice or mixed phase) of stratus clouds, and isotropy/anisotropy (spherical/non-spherical) properties of aerosol particles.

LIDAR-Radar Observation of Aerosol Stratification in Lower Troposphere over Pune

LIDAR observations of aerosol vertical distributions in the lower troposphere along with observations of horizontal and vertical winds from collocated UHF radar (Wind Profiler) over a tropical Indian station, Pune during the pre-monsoon season (March-May) of 2006 as part of an ISRO-GBP national campaign (ICARB) have been examined.

UHF Radar Derived Vertical Motions and Turbulence during Pre-monsoon Thunderstorm – A Case Study

The high-resolution UHF wind profiler data collected during a pre-monsoon thunderstorm which occurred over Pune in the evening hours on 16, May 2004 was analyzed. The extent of the enhancement observed in time-height variation of vertical velocity, echo power, spectral width and horizontal wind shear in the height range from 1.05 to 8 km during 0800 to 2100 hrs local time was studied.

Lidar - Radar Investigations of Tropical Stratosphere-Troposphere Exchange Processes

The stratosphere-troposphere exchange (STE) processes around the tropical tropopause layer (TTL) have been investigated by operating the collocated LIDAR and radar facilities at NARL, Gadanki (13.45°N, 79.18°E).

DIAL Ozone Profiling

An ultra-violet (UV) rare-gas halide XeCl excimer-Raman laser-based ozone lidar system has been developed and installed at the Indian Institute of Tropical Meteorology (IITM), Pune (18°43'_N, 73°51'_E, 559 m above mean sea level), India. This system essentially operates in the differential-absorption-lidar (DIAL) mode with laser emission at 308 nm ('on') wavelength as well as reference ('off') wavelength of 353 nm generated by stimulated Raman shifting (SRS) the 308 nm radiation in hydrogen.

Seasonal Asymmetry in Diurnal Variation of Aerosol Optical Characteristics over Pune, Western India

There is a large day-to-day variability in aerosol optical properties due to varied meteorological conditions that exhibit different diurnal asymmetry in different synoptic seasons. Aerosol optical depth (AOD) is found to be higher in the morning and lower in the afternoon during winter, mainly because of higher relative humidity, calm winds, and associated ground-based inversions that are conducive for haze, which persists till noon.

Aerosol Characterization Experiments Using LIDAR and Sun Photometer over Sofia, Bulgaria

The vertical aerosol structures and aerosol optical depth (AOD) observations have been carried over the city of Sofia (an urban area situated in a mountain valley), western Bulgaria by means of a ground-based aerosol LIDAR. The LIDAR measurements were accompanied by measurements of AOD in the visible and infra-red regions of the spectrum performed in October, 2004, using Microtops II radiometers.

Aerosol and Pre-cursor Gas Characterization at Antarctic Station, Maitri and at Larsemann Hill during 26th Indian Antarctic Expedition

To investigate the optical, microphysical and radiative properties of aerosols including their radiative forcing and heterogeneous chemical effects, extensive observations have been carried out by using spectral solar radiometers (at discrete wavelength from UV to near IR) and a white band short wave pyranometer which measures incoming global (direct + diffuse) radiative flux spectral bands from 0.38-3.0 micrometre during the 26th Indian Antarctic Expedition. Observations were made at Maitri (70° 75'S, 11°73'E) from 1 December, 2006 to 22nd February, 2007 and thereafter during 07-15 March, 2007 at Larsemann Hill (69°40'S, 76°18'E). The experimental facilities deployed were Microtops-II (both sunphotometer and ozonometer) and pyranometer. These instruments were thoroughly calibrated before they were installed at the above experimental sites in the Antarctica region. Simultaneous observations of columnar aerosol optical depth (AOD at 380, 440, 500, 670, 875 and 1020 nm), total column ozone (TC), precipitable water content (PWC)

were carried out at 10 min interval from morning till evening hours, and SW radiative flux at 1 minute interval on all clear-sky days.

Solar Dimming over India

Monthly mean surface reaching solar radiation (S) under all-sky conditions has been evaluated for 12 stations, which are widely distributed over the Indian region, for the period 1981-2004.

Aerosols over Southern Indian Ocean

Analysis of a number concentrations and size-distributions of aerosols in the range 0.5 - 20 μm diameter, made during a severe cyclonic storm in the Southern Hemisphere at 53.3°S, 52.5°E on 19 February, 2004 showed that in conformity with the past observations, total aerosol number concentration increases with the increase in wind speed from 4 to 11 m/s measured at 10-m above sea level.

Airborne Measurements of Aerosols over Bay of Bengal

Analysis of airborne measurements of number concentrations and size distributions of aerosols from 13 to 700 nm diameter made at 0.5, 1, 2 and 3 km altitudes across a coastline extending ~ 100 km over land and ~ 150 km over ocean at Bhubaneswar (20° 25'N, 85° 83'E) during the Integrated Campaign for Aerosols Gases and Radiation Budget (ICARB) showed that the aerosol number concentrations varied from 2200 to 4500 / cm^3 at 0.5 km level but were almost constant at ~ 6000 / cm^3 and ~ 800 / cm^3 at 2 km and 3 km levels, respectively. At 1 km level, aerosol number concentration showed a peak of 18070 / cm^3 around coastline. Most of the aerosol size distribution curves at 0.5 km and 1 km levels were monomodal with a maxima at 110 nm diameter shifting to 70 nm diameter at 2 km and 3 km levels.

Cloud Modeling and Parameterization

Simulation of Heavy Precipitation over Santacruz, Mumbai on 26 July, 2005, using Mesoscale Model

An attempt has been made to simulate the unprecedented heavy precipitation of 94.4 cm in a day over Santacruz, Mumbai during 0300 UTC 26 July to 0300 UTC 27 July, 2005. Three experiments have been conducted using Advanced Regional Prediction System model developed by Centre for Analysis and Prediction of Storms at Oklahoma University, USA.

Middle Atmosphere Dynamics

Seasonal Variation of Mesospheric Inversion Layer, Thunderstorm and Ozone over India

Temperature and ozone volume mixing ratio profiles obtained from Halogen Occultation Experiment (HALOE) aboard Upper Atmospheric Research Satellite (UARS) during the period 1991-2001, were analyzed to study the characteristic features of mesospheric Inversion Layer (MIL) and its relation with ozone mixing ratio. The lightning flashes measured by the Optical Transient Detector (OTD) onboard the MicroLab-1 satellite for the period April 1995 - March 2000 and ground-based thunderstorm data collected from 78 widespread Indian observatories for the same period were also analyzed to show that MIL and thunderstorm activity are correlated.

Long-term Mean Vertical Motions and Their Time-height Variations in the Lower Troposphere Obtained from UHF Wind Profiler at Pune

A 404 MHz wind profiler (UHF radar) system has been in continuous operation since June 2003 at Pune. The system enables the measurement of all three components (zonal, meridional and vertical) of a vector wind with height coverage from 1.05 km to about 10 km and a height resolution of 300 m.

Evidence of the Secondary Meridional Circulation Associated with QBO in MLS Ozone and Temperature

Spatio-temporal characteristics of the quasi-biennial oscillation (QBO) in ozone and temperature over the tropical-subtropical stratosphere (40°S-40°N) have been examined by analyzing data from the Microwave Limb Sounder (MLS) for the period 1992-1999. A combination of regression analysis and wavelet analysis has been used as an accurate QBO filter.

Studies of Interaction between Cloud and Environment, and Formation of Precipitation

Scavenging of Sea-Salt Aerosols by Rain Events over Arabian Sea during ARMEX

Scavenging coefficients have been computed for sea-salt particles at different rainfall intensity of 5, 10, 15, 20 and 45 mm/h. Evolutions of size distributions for sea-salt particles by precipitation scavenging were simulated using theoretically estimated scavenging coefficients.

Seasonal Variation of Black Carbon (BC) Aerosols at Pune and Sinhadgad

Concentrations of black carbon (BC) at Pune were found to be maximum during winter (DJF), followed by those in the post-monsoon (ON). Minimum concentrations were observed in the

monsoon (JJAS). Average value in the winter was double than that in summer and post-monsoon and was about 6-times more than in monsoon.

Atmospheric Electricity

Evolution of Lighting in Tropical Thunderstorm

Evolution of lightning activity in a tropical hailstorm of moderate intensity has been studied from the measurements of surface electric field, the Maxwell current and thunder.

Intermediate Ions at Maitri, Antarctica

Analysis of the atmospheric ion data obtained at Antarctica has brought out some chief features of the concentration of different categories of ions. Small and large ion concentrations do not show any systematic diurnal variations and variations in them are almost similar to each other. Variations in the intermediate ion concentrations are independent of variations in the small/large ions and exhibit a diurnal variation, which is similar to that in atmospheric temperature on fair weather days with a maximum during the day and minimum during the night hours.

Measurements of Atmospheric Electricity Conducted during Arctic Expedition

The atmospheric electrical instruments were installed at Arctic on 8 August, 2007 on ground on the rear side of Norwegian Polar Institute building and the data acquisition system was installed inside the laboratory. Measurements of the atmospheric electric field and conductivity were conducted using vertical electric field mill and Gerdien's apparatus, respectively. Measurements of aerosol concentrations and size distribution of particles in the range of 0.5 - 20 μ m in size were carried out continuously with Aerodynamic Particle Sizer (APS, TSI, USA). A large amount of valuable data were collected up to 3 September, 2007.

Analysis of STORM Data

Analysis of the electric field data obtained below a severe thunderstorm at Kharagpur on 10 May, 2006 showed that during the active phase of thunderstorm, the peak lightning flash rate had reached about 35 flashes per minute.

Studies on Influence of Electric Field on Deformation of Water Drops

Investigations on deformation of the uncharged water drops freely suspended in a vertical wind tunnel and subjected to vertical, horizontal, or no external electric field have revealed that electric field elongates the drop along its direction, and the elongation increases with the increase in the electric field.

Atmospheric Electric Field and Radon Ion Production

The variation of surface electric field has been studied with respect to the atmospheric inversion conditions.

Urban Air Pollution and Middle Atmosphere Dynamics: Observations and Modelling

Study of Temporal and Seasonal Patterns of Observed Surface Ozone and its Precursors

Trends in Tropical Tropospheric Column Ozone from Satellite Data and MOZART Model

Trend analysis of tropical (30°S-30°N) tropospheric columnar ozone (TCO) has been done using Nimbus 7 and Earth Probe satellite -Total Ozone Mapping Spectrometer (TOMS) data for the period 1979-2005, using multifunctional regression model. The TCO trend coefficient was found highest over the South Asian region led by part of China, Taiwan and Thailand and followed by India, Japan, Indonesia and Malaysia, where significant trend is of the order of 7-9 (± 3.4 -4.6) % per decade. This is attributed to increasing high emissions of ozone precursors over the region. Among different marine regions, ozone trend is found to be highest (4-6 % per decade) over the Bay of Bengal which is largely explained by the large scale wind systems causing massive transport of continental pollutants over this region. The maximum increase in TCO obtained over the South Asian region is around 8-12 DU during the past two and a half decades. This increase in the tropospheric ozone will result in a radiative forcing of about 0.3-0.5 W/m² over the tropics, which may have caused significant climatic implications.

Global Change induced Trends in Ion Composition of Troposphere to Lower Thermosphere

This study has shown that a decrease in NO number density up to -80% for the double-CO₂ scenario in the mesosphere is one of the major reasons for the modelled variations in ionized parameters for this region. In addition, cooling up to about -14°K, produces decrease in the acetonitrile number density (-10% at 40 km), and an increase in the water vapor by 5-15% in the stratosphere which are major factors found to cause variations in stratospheric charged species for the double-CO₂ scenario. Acetonitrile cluster ions in the upper stratosphere are likely to increase, whereas NO⁺ and NO⁺(H₂O) in the MLT region are expected to decrease for double CO₂ scenario. It was also found that the atmospheric density of pyridinated cluster ions is fast rising in the troposphere.

Growth Rate of Black Carbon Emissions in India

The study on growth rates of black carbon (BC) emissions from all sources over India has revealed an increase from around 835.50 Gg in 1991, which increased to 1343.78 Gg in 2001. The decadal change from coal source is around 57% and it contributes to nearly 50 % of total BC emission in India. The estimated BC emissions from petrol and diesel sources are around 218 Gg and 462 Gg for the years 1991 and 2001, respectively with 112 % decadal growth for 1990s due to rapid increase in number of vehicles, especially in urban areas. Maximum change was noticed over Indo-Gangetic Plain (IGP) area and some parts of Western India and Southern India. All the metropolitan cities such as Delhi, Mumbai, Kolkata and Chennai has shown high BC values, possibly due to high vehicular BC emissions and more demand of energy.

CO₂ from Space: Evaluating Results using Model Simulations and Aircraft Measurements

CO₂ mixing ratio derived from space-borne measurements of the TOVS instrument onboard NOAA-10 available for the time period 1987-1991 were evaluated against modelling results and aircraft measurements.

Study of Aerosol Transport through Precipitation Chemistry over Arabian Sea

Precipitation samples collected over the Arabian Sea during ARMEX during pre-monsoon and monsoon seasons of 2002–2003 were examined for major chemical species and the acidity of rain water.

Development of GIS-based Methodology for Gridding Black Carbon Emissions in India

A gridded (1°x1°) emission inventory of black carbon for the Indian geographical area has been prepared for the base years 1991 and 2001, using geographical information system (GIS) tool.

Seasonal Distribution of Ozone and its Precursors over the Tropical Indian Region using Regional Chemistry-transport Model

An off-line regional chemistry-transport model (REMO-CTM) was applied for the first time to the Indian geographical region to simulate the distribution of ozone and its precursors at the boundary level. The model accounts for the assimilated winds from ECMWF and latest emission inventories of the ozone precursors for the year 2003.

Threshold Exceedances and Cumulative Ozone Exposure Indices at Tropical Suburban Site, Pune

Threshold exceedances and cumulative ozone exposure indices at Pune, a tropical suburban site in India, have been investigated.

Detection of Surface Emission Hotspots, Trends and Seasonal Cycle from Satellites Retrieved NO₂ over India

Tropospheric NO₂ concentration derived from space-borne measurements of GOME and SCIAMACHY, respectively for the period 1996-2006 have been used to identify major NO₂ emission hotspots, trends and seasonal cycle over different regions of India.

Evidence of the Secondary Meridional Circulation associated with QBO in MLS Ozone and Temperature

Spatio-temporal characteristics of the quasi-biennial oscillation (QBO) in ozone and temperature over the tropical-subtropical stratosphere (40°S-40°N) have been examined by analyzing data from the Microwave Limb Sounder (MLS) for the period 1992-1999.

A total of 84 papers were published in peer reviewed journals (Cumulative Impact Factor 117.675)

Papers published in Proceedings, Books, Reports etc.: 43

Papers presented in Seminars, Symposia, Workshops etc: 106

15. International Cooperation

Since ratification of UN Convention on Law of the Sea in June, 1995, India has been playing a key leadership role in the international forums pertaining to oceanic 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 at all fronts. India was elected as member on sub-commissions established to examine the submissions by New Zealand and Australia towards the delineation of continental shelf and actively contributed to the deliberations of sub-commissions. India participated in the States Parties on Law of the Sea held in New York during 19 - 23 June, 2007.

The XXX Antarctic Treaty Consultative Meeting (ATCM) was hosted at New Delhi from 30 April to 11 May, 2007. It was for the first time since joining the Antarctic Treaty System that India hosted the ATCM. The meeting was inaugurated on 30 April by Shri Kapil Sibal, Hon'ble Union Minister for Science & Technology and Earth Sciences. Distinguished space scientist Prof. U. R. Rao was elected as the Chairman, ATCM. More than 300 delegates and experts from over 46 countries and organizations participated in the two-week event. Over 40 working papers and more than 130 information papers on such diverse themes as Environmental Protection, Antarctic Tourism, Global Climate change were deliberated upon. The closing ceremony was presided over by Shri Pranab Mukherjee, Hon'ble Union Minister of External Affairs.

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 Programs (COMNAP), and Standing Committee of Antarctic Logistics and Operations (SCALOP).

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 was 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 hosted a workshop on 'Polymetallic Nodule Mining Technology- Current Status & Challenges Ahead', jointly organised by Ministry of Earth Sciences & International Seabed Authority during 18-22 February, 2008 at National Institute of Ocean Technology, Chennai. International experts from 16 countries deliberated on future prospects of deep sea mining.

Regional Cooperation

India is assisting Myanmar in the exercise of delineation of their continental shelf. A workshop in this regard was conducted in National Centre for Antarctic and Ocean Research (NCAOR), Goa for the Myanmar scientists.

Indo-Russian Cooperation Programme

The Ministry of Earth Sciences is the nodal body for implementation of Programme on 'Oceanology & Geo – hydrates' under Integrated long term programs (ILTP) with Russia . The meeting of ILTP was held on 11-12 October, 2007 in Moscow in which the progress of work in oceanology and earth sciences as a part of collaborative endeavour, was presented.

Intergovernmental Oceanographic Commission (IOC)

India is the founder member of IOC and also a Member of its Executive Council. Director, INCOIS as a Member of Executive Council, contributed to the effective working of IOC, Hyderabad.

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 5 November, 2002, IOGOOS membership has grown from 19 to 25 institutions from 15 countries. Some of the major initiatives of IOGOOS are: (i) setting up of Indian Ocean Panel (ii) Data and 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. Dr. Shailesh Nayak, Director, INCOIS, was elected as the new Chairman of IOGOOS.

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 was established to promote implementation and integration of global oceanographic activities. POGO has 26 institutional members from 16 countries. INCOIS is a member of POGO since 2004 and Director, INCOIS is the Members of its Executive Committee since 2006.

Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)

India participated in the 26th Meeting of CCAMLR held in Hobart, Australia from 22 October, 2007 to 2 November 2007. India was elected as Chairman of the Standing Committee on Administrative & finance (SCAF) of CCAMLR.

16. Awareness Programme

16.1 Exhibitions and Fairs

With a view to promote awareness about ocean and atmospheric science and technology (OAST) among the public and students, the Ministry participates in major national and international exhibitions held in India and abroad. The useful products derived for user communities from the research and development activities undertaken by the Ministry were brought out in the form of brochures, in English, Hindi and local languages. It also supported seminars, symposia, workshops and conferences, etc to exchange information among scientists and user communities.

During the year 2007-08, guest lectures in ocean science and technology, atmospheric science and technology were organized by inviting eminent personalities / scientists / senior government officers for the benefit/intellectual interactions of the officers/scientists of the Ministry.

In order to recognize and encourage the scientists working in the Ministry, eleven scientists were selected for award of Certificate of Merit in the areas of ocean science and technology, atmospheric science and technology. Certificates of merit was given to seven officials of the Ministry from Groups “B”, “C” and “D” for the outstanding services rendered by them.

16.1.1 Exhibitions in India

Science & Technology Promotional Exhibitions and Fairs

- Exhibition on the Foundation Day (27 July, 2007) at Vigyan Bhawan, New Delhi.
- “58th International Astronautical Congress, 2007” at Hyderabad, (24-28 September, 2007).
- “Team Tech 2007” at I I Sc, Bangalore, (4 –6 October, 2007).
- “2nd Asian Ministerial Conference on Disaster Risk Reduction (Development without Disasters)” at Ashok Hotel, New Delhi (7 - 8 November, 2007).
- R&D 2007 at FICCI, New Delhi, (5 – 6 December, 2007).
- “95th Indian Science Congress” at Visakhapatnam (3 – 7 January, 2008).
- “National Exhibition on Earth Science- 2008” at Dhanbad, Jharkhand (8 – 11 January, 2008).
- “4th International Aqua Show, 2008” at Kochi (1 – 5 February, 2008).
- Science & Technology Fair at Kolkata (15 – 24 February, 2008).

Educational Exhibitions and Fairs

- “Earth Day, 2007” and “International Polar Year” were celebrated at World Wide Foundation, New Delhi on 22nd April 2007. On this occasion, a calendar on Polar Sciences was released by Hon’ble Minister of Earth Sciences.
- “5th Infra Educ 2007” at Jaipur (5 - 6 May, 2007).
- “Multidisciplinary Developments” at Faridabad, Harayana, (21 -24 September, 2007).
- The exhibition organized by the Ministry for school children at National Science Centre, Pragati Maidan, New Delhi (13 – 31 December, 2007).
- “Rajasthan Infrastructure Development Expo” at Jaipur, Rajasthan (18– 20 January, 2008).

Deliverables to User Community through Exhibitions

- “Rashtriya Pragati Mela 2007” at Haora, West Bengal (9 -12 May, 2007).
- “Ganga Festival 2007” at Sovabazar, Kolkata, (18 -20 August, 2007).
- “IITF 2007” at Pragati Maidan, New Delhi, (14th -27th November, 2007).
- “Bhartiya Vigyan Sammelan & Expo 2007” at Bhopal (21st -26th November 2007).
- “Agro vision 2007” at Nagpur (15 –18 October, 2007).
- “Krishi 2007- International Agriculture Trade Fair” at Nasik, Maharastra (29 Nov – 3 Dec, 2007).
- “Asom International Trade Fair” 2008 at Khanapura, Guwhati (5 – 17 February, 2008).

Exhibitions for Rural Areas

Localized weather information necessary for specific crops in the locality was organized for the benefits of the farmers, etc at following places:

- Meerut, 26 – 27 October, 2007
- Jhansi, 3– 4 November, 2007
- Agra, 1 – 2 November, 2007
- Kanpur, 5 – 6 November, 2007
- Allahabad, 14–15 November, 2007
- Varanasi, 20– 21November, 2007
- Faizabad, 28–29 November, 2007

Participation in Exhibitions Abroad

- “India Fair 2007” at Melbourne, Australia, 29 March – 1 April, 2007.

- “India Tech Pavilion”, ‘Made in India Show’ at Cairo, Egypt during 20-23 November, 2007.
- “Planet Earth” at Paris, France, during 24 Oct.- 2 November, 2007.

16.2 Seminars/Symposia/Conferences/Workshops

To exchange information in the areas of ocean and atmospheric sciences and technologies(OAST) among scientists, engineers, technologists, experts, social scientists, user communities such as agriculture farmers for localized weather information products, marine fishermen for ocean state information, the Ministry supported 70 national and international seminars, symposia, workshop, conference, meetings, etc. The beneficiaries included Indian Institutes of Technology / Indian Institute of Management (4 events), national research laboratories (3 events), universities (25 events), non government organizations (6 events), government bodies (5 events), scientific societies (9 events), and colleges (8 events).

A few major topics which received the supports were: (i) climate change and extreme weather events, (ii) celebrating the Monsoons, (iii) marine microbial extractions, (iv) global warning, (v) vistas in algal research, (vi) impact of climate change with particular reference to agriculture, (vii) Indian Basin – Geotraces, (viii) complex systems in fluid flows and sedimentation processes, (ix) fisheries and aquaculture strategic outlook for Asia, (x) ocean electronics, (xi) fluvial and marine processes in cenozoic and formation of placer, (xii) Indian Aerosol Science and Technology, (xiii) coastal erosion remedial measures and management, (xiv) Tropment 2007 - Advances in meteorology and their applications, (xv) international conference on e-Science and Grid Computing, (xvi) conference on luminescence and its application, (xvii) Science of Life - The New Horizon, (xviii) current scenario of microbial technology, (xix) advances in manufacturing technology, (xx) frontiers of atmospheric physics and technology, (xxi) digital geography-spatial technology, (xxii) geology and hydrocarbon potential of the neoproterozoic Cambrian Basins in India, etc. and (xxiii) emerging trends in space and aviation meteorology.

16.3 AWARDS

The Ministry celebrated the Foundation Day on 27 July, 2007, and various awards were presented to scientists, technologists and other staff members in recognition of their outstanding contributions.

National Awards

- The 4th National Award in Ocean Science and Technology for the year 2007 was awarded to Dr. Abraham Ebenezer Muthunayagam, Ex-Secretary, Department of Ocean Development, Government of India.
- The First National Award in Atmospheric Science and Technology was awarded to Prof. Dev Raj Sikka, Ex- Director, Indian Institute of Tropical Meteorology, Pune.

Certificates of Merit

Ocean Science and Technology

- Dr Balakrishnan Nair, Scientist D, Indian National Centre for Ocean Information Services, Hyderabad
- Dr Rahul Mohan, Scientist C, National Centre for Antarctica and Ocean Research, Goa
- Shri Sushant Naik, Scientist B, National Centre for Antarctica and Ocean Research, Goa
- Shri Ramji, Scientist C, National Institute of Ocean Technology, Chennai
- Dr S. V. S. Phani Kumar, Scientist D, National Institute of Ocean Technology, Chennai

Atmospheric Sciences

- Dr. M. Rajeevan, Director, India Metrological Department, Pune
- Dr. E. N. Rajagopal, Scientist F, National Centre for Medium Range Weather Forecasting
- Dr. Krishna Kumar, Scientist E, Indian Institute of Tropical Metrology, Pune
- Dr. R. Suresh, India Metrological Department, Chennai
- Shri K. G. Suresh Kumar, India Metrological Department, Chennai
- Dr. R. K. Jenamani, Director, Regional Metrological Centre, India Metrological Department, New Delhi

Awards for Best Production of Work

Employees from Group B

- Shri S. Sreekumar, Private Secretary, Centre for Marine Living Resources Ecology, Kochi
- Shri Y. N. Garg, Astd. Meteorologist II, CATS, India Metrological Department, Bamrauli, U.P.

Employees from Group C

- Shri Manwar Singh, UDC, Ministry of Earth Sciences
- Shri J. Tamil, Mech. Gr. 1., CSO, Shillong

Employees from Group D

- Shri Jagdish Singh, Peon, Ministry of Earth Sciences
- Shri Partap Ram, Peon, Ministry of Earth Sciences
- Shri Ajmer Singh, Peon, National Centre for Medium Range Weather Forecasting, Noida
- Shri A. H. Marathe, Peon, Office of ADGM (R), India Metrological Department

16.4 Lectures

During the year 2007-08, the Ministry has taken a new initiative of organizing Guest Lectures by inviting eminent personalities/scientists/ senior government officers to deliver lectures in the areas of their specialization/expertise for the benefit/intellectual interactions of the officers/scientists of the Ministry. During the year, 12 lectures were organized.

Speaker	Title of Lecture	Date & Venue
Dr Ajit Tyagi, Air Vice Marshal, Air Head Quarters, New Delhi	Meteorological Observations in Indian Air Force – The Present and Future Scenario	9 March, 2007, IMD Head Quarters, New Delhi.
Dr R. S. Dattarayam, Director, IMD	Earthquake Precursory Studies in India	22 March, 2007, IMD Head Quarters, New Delhi
Dr R. K. Dutta, Project Director (RTD), NCMRWF	Meteorology: From Empiricism to Mathematical Modelling	17 October, 2007, Ministry of Earth Sciences, New Delhi
Prof. Sumant Nigam, Department of Atmospheric Science and Earth System Science Interdisciplinary Center (ESSIC)	Warm-Season Hydro Climate Variability over the US Great Plains: Land and Ocean Influences	21 September, 2007, Ministry of Earth Sciences, New Delhi
Dr. R. R. Sonde, Executive Director NTPC Ltd. NOIDA	Technologies to address increasing global energy needs and climate change paradox: India centric action plan on carbon capture and sequestration	19 September, 2007, Ministry of Earth Sciences, New Delhi.

16.5 Popularisation of Ocean and Atmospheric Sciences and Technologies on TV and through Print Media

A TV series on Ocean and Atmospheric Sciences and Technologies for the general public, entitled “Science Safari” – Co-funded by the Ministry and produced by National Geographic Channel, was telecast on DD-1 under Naye Disha Programme, and on the National Geographic Channel.

The Ministry sponsored a publicity campaign of its achievements in developing the abundant resources of our ocean through a bi-monthly publication entitled “Geography and You” in English and “ Bhugol aur Aap” in Hindi, by organizing essay competitions and, quizzes among school children.

17. USE AND PROMOTION OF HINDI

The Ministry is constantly working for the promotion and propagation of Official Language. During 2007-08 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, Outcome 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 material like quarterly newsletters of Ministry were published in Hindi also. Ministry organised a three-day Hindi workshop from 10.09.2007 to 12.09.2007 for the officers and staff of the Ministry to overcome their difficulties in the official work in Hindi.

The Ministry organized Hindi fortnight from 14 to 28 September, 2007. During the period, various competitions, including Hindi essay writing, noting, drafting, debate and poetry were held. About 50 staff members and officers participated in these competitions. Secretary gave away the prizes and certificates to the winning officials during the closing ceremony. It was followed by a *Hindi Kavi Goshthi*, wherein six reputed poets enthralled the audience.

India Meteorology Department, New Delhi, and Indian Institute of Tropical Meteorological (IITM), Pune, were inspected by an Inspection Committee of the Ministry during 2007-08 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 the 16th National Scientific Hindi Seminar on the topic "Global Warming" on 12 November, 2007 at New Delhi. Shri VL Chopra, Member Planning Commission inaugurated the Seminar. Sixteen scientists/professors from various institutions presented their papers in the Seminar. On this occasion, a Hindi book titled "Antarctic Abhiyaan (Rajat Jayanti)", a compilation of research papers of seminar held in 2006, was also released.

Under the Prithvi Vigyan Mantralaya Maulik Pustak Lekhan Yojana-2007, the Ministry awarded first, second and third prizes to the books titled (i) *Hamari Arthik Samridhi Ki Adhar: Mansoon* by Shri Shyam Sunder Sharma and Dr. Rajeev Nigam; (ii) *Prakritik Aapdayen Aur Vigyan* by Dr. C.L. Garg, and (iii) *Akshaya Nidhi (Prithvi Aur Sagar)*, by Dr. D.D. Ojha and were given Rs 50,000/-, Rs 40,000/-, and Rs 30,000/- respectively as the prize money.

18. Parliament Work

The Parliament Standing Committee on Science and Technology, Environment and Forests met on 3 April, 2007 at New Delhi to consider the Detailed Demand for Grants in respect of the Ministry for 2007-08.

Between April to December 2007, Ministry replied questions as below in the Parliament.

1	Lok Sabha Starred Questions	06
2	Lok Sabha Unstarred Questions	55
3	Rajya Sabha Starred Questions	06
4	Rajya Sabha Unstarred Questions	25

19. Administrative Support

The sanctioned strength of the Ministry of Earth Sciences, including attached offices was 281 during the year 2007-08. The detailed break-up is given below:

Offices	Scientific/Technical Posts	Non-Technical Posts	Grand Total
Ministry Headquarters	23	111	134
National Centre for Medium Range Weather Forecasting (NCMRWF), Noida	52	41	93
Centre for Marine Living Resources & Ecology (CMLRE), Kochi	20	11	31
Integrated Coastal and Marine Area Management, (ICMAM), Chennai	15	8	23
Total	110	171	281

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, and other backward classes, etc. However, the Ministry has been taking due care to ensure adequate representation of minority communities while making recruitments to various posts. Adequate representation to the officers belonging to the minority communities is invariably given on the Selection Committees 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 per se. 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 have been provided on website of the Ministry. To address the grievances of female employees, a lady officer has been nominated, as per the guidelines issued by the Ministry of Human Resource Development (Department of Women & Child Development).

No grievance from the general public appeared in the grievances column of any newspaper in 2007-08.

Department is implementing 3% reservation in government jobs for physically challenged persons.

Gender Budget

Most of the activities undertaken by the Ministry in 'Earth Sciences' are in the nature of research and technology development and demonstration projects. However, the Ministry through its autonomous institute, NIOT, Chennai, has taken up certain programmes on mariculture to improve the livelihood of the women folk. NIOT 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 Islands Administration, the NIOT shall continue to provide technology and 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 has been put on website. Central Public Information Officer and Assistant Public Information Officer have been nominated in respect of the Ministry and its attached/subordinate offices and autonomous bodies. During the period April to December 2007, 42 requests under the Right to Information Act, 2005 have been received and replies have been sent to all of them.

Vigilance Activities and Achievements

Shri Prakash Kumar, Joint Secretary 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 12-16 November 2007 with the taking of pledge by the officers and staff members and organizing competitions like Slogan and Essay Writing and Short Lecture during the Awareness Week.

Training for 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:

SI No.	Designation	Programme	Place	Duration
1.	Sr.PPS/PPS	Training Programme for Professional Development	National Productivity Council (NPC), New Delhi	4-15 Feb, 2008
2.	Account Officer	Five day Workshop on Comprehensive DDO Package (CompDDO)	National Informatics Centre, New Delhi	5 days
3.	Sr. Scientists/ Officers	Orientation Workshop on Effective Management	Dr. Ambedkar Institute of Hotel Management, Catering & Nutrition, Chadigarh.	2-4 Nov, 2007

Foreign Deputations

S.No	Name	Date	Purpose
1.	Dr Pulak Guhathakurta, Director	4-6 April,2007 China	To attend the 3 rd Session of the Forum on Regional Climate Monitoring
2.	Shri Sanjay Gehlot NIC Shri Mirza Javed Beg	9-11 April,2007 Argentine	Antarctic Treaty Secretariat, Buenos Aires, Argentina
3.	Shri R.S. Dattarayam, Director	16-22 April,2007 Mexican	To attend the Indo-Mexican Workshop on Earthquake and Seismicity
4.	Prof. B. N. Goswami, Director	23-25 April,2007 China	To participate in the Asian Monsoon Year (AMY08)
5.	Dr. S. Rajan Sct. F	30April to 4 May, 2007, USA	Meeting with delegations of various countries in connection with elections to UN Commission of the Commission on the Limits of the Continental Shelf
6.	Shri R.C.Bhatia, DG Dr (Mrs) Swati Adv. Dr T. A. Khan DDGM Shri B. Mukhopadhyay, Director	6-30 May, 2007 14-25 May, 2007 6-15 May, 2007	15 th World Meteorological Congress and the 59 Session of Executive Council of WMO
7.	Shri Rahul Saxena Shri Kuldeep Srivasta	16 April 6 July 2007 14 May 6 July 2007 USA	Training in Estimation of Basin Precipitation using GSI
8.	Dr B. R. Subramanian	29-31 May,2007 Brazil	To participate in the 3 rd Meeting of the Indo–Brazil Science Council
9.	Shri R. C Bhatia, DGM	Geneva, Switzerland	Fifteenth World Meteorological Congress at Geneva
10.	Shri M.R. Ranalkar, DDGM	22-25 May, 2007 Colombo, Sri Lanka	To participate in the International Roundtable Conference on Lightning Protection
11.	Shri Dinesh Kumar, Director Shri D. Rajashekhar, Sct, E	4-6 June, 2007 4-7 June, 2007 Genova, Italy	Progress of Work towards Construction of a new technology demonstration vessel Sagar Nidhi
12.	Shri R.K. Sharma, Sct, F	5-7 June, 2007 Geneva Switzerland	To attend the First Session of the Global Platform for Disaster Risk Reduction
13.	Dr M. Rajeevan, Director	4-7 June, 2007Spain	To participate in the World Climate Research Programme (WCRP) Workshop on Seasonal Prediction
14.	Dr S.K. Peshin, Director	4-8 June, 2007 Northwich	To participate in the 10 th Biennial WMO/GAW Brewer Users Group Meeting
15.	Shri M. K. Bhatnagar, Director	6-8 June, 2007 Bangkok, Thailand	To participate in the Fifth Meeting of ASIA /Pacific OPMET Management Task Force of CNS/MET

16.	Shri B. Bhattacharjee Shri U.N. Panjiar, Secy Shri H. S. Brahma, Add Secy Shri Q. Ravi, JS Shri R.K. Sharma, Sct, F	5 -7 June, 2007 Genova	Integrating Disaster Risk Reduction into Preparedness
17.	Dr S. K. Roy Bhowmik, Director Shri S. Balachandran	10-11 June, 2007 Male, Maldives	To attend the SAARC Workshop on the use of NWP & Satellite Products in day-to-day forecasting operation organized by SMRC
18.	Dr S.K. Das, Sct,G Dr M.P. Wakdikar, Sct, F	18-22 June,2007 New York	Meeting of Status Parties on Law of the Sea
19.	Shri Arun Kumar Rath, SS&FA Shri Dr. M. Gandhi, Director (L&T)	25-29 June,2007 New York	To attend the UN Open-ended Informal Consultative Process on Oceans and the Law of the Sea
20.	Dr P. S.Goel, Secy Dr S. Kathirolu, Director Dr Shailesh Nayak, Director	21-26 June, 2007 21-26 June, 2007 18-28 June, 2007 Paris and Italy	Meeting of the 24 th Session of the Assembly of the IOC
21.	Shri A. K. Srivastava, Director	2-5 July, 2007 Malaysia	To participate in the WHO/WMO Workshop on Climate Change and Health in South East and East Asian Countries
22.	Shri B. Arul Malar Kannan	9-20 July, 2007 Maryland, USA	Indo USAID Disaster Management Support Project Climate Forecasting System
23.	Dr S.K.Das, Sct, G Dr M.Sudhakar, Sct, F Ms Neeru Chadha, Counsellor (LA)	9-20 July, 2007 2-16 July, 2007 9-20 July,2007 Jamaica	To attend the 13 th Session of International Seabed Authority (ISBA)
24.	Shri Rasik Ravindra, Director Dr N. Khare Sct, E	9-14 July, 2007 Washington	To attend the XIX Meeting of Council of Managers of National Antarctic Programme DROMLAN Steering Committee Meeting and Larsemann Hills ASMA Parties Meeting
25.	Shri Kapil Sibal Dr S. Kathirolu, Director Shri Deepak Chaudhary, OSD	9-10 July, 2007 Genoa, Italy	For launching of Technology Demonstration Vessel, Sagar Nidhi
26.	Dr K.K.Singh	9 July to 28 Sept, 2007USA	Training on Extreme Temperature Climate data Processing.
27.	Dr R. K. Jenamani, Director	11-13 July, 2007 Bangkok	To Participate in the ICAO Training Seminar on Asia / Pacific SIGMET
28.	Shri G. Suresh, Director.	21 July to 2 Aug, 2007 USA	To participate in the two Training Programmes in Tsunami Science and Preparedness in Seattle USA
29.	Dr A.K. Bohra, Sct, G	25-26 July, 2007 Tsukuba, Japan	To attend 5 th Meeting of the Asian Regional Committee of THORPEX
30.	Shri Arun Kumar Rath, SS&FA Dr M. Gandhi, Director (L&T)	25-29 July, 2007 New York	To attend the UN open ended Informal Consultative Process on Ocean and Law of the Sea

31.	Shri P. Madeswaran Sct. E Dr R. Venkatesan, Group Head	25-27 July, 2007 20-21 August, 2007 Colombo, Sri Lanka	To attend the ICRAN/SACEP Regional Coordination Workshop
32.	Shri S.R. Ramanan, Director and Dr G.C. Debnath Director	5-7 August, 2007 Dhaka, Bangladesh	
33.	Shri O.P. Sreejith	6-10 August, 2007 Italy	To attend the Targeted Training Activity Programme in Seasonal Prediction of South Asian Monsoon
34.	Dr Shialesh Nayak, Director	21-24 August, 2007 Beijing, China	To participate in the Annual Joint Meeting of the Technical Commission IV on Geo-databases and Digital Mapping of International Society of Photogrammetry and Remote Sensing (ISPRS)
35.	Dr S. Rajan, Sct, F	27 Aug to 14 Sept., 2007 New York, USA	To attend the 20 th Session of the Commission on the Limits of the Continental Shelf
36.	Shri R. S. Dattatrayan, Director IMD	25 Aug. to 1 Sept., 2007 Iceland	Discussions related to developing Indo-Iceland Programme of Earthquake Prediction Research
37.	Shri D. Chakrabarti, DDGM	4-7 September, 2007 UK	To participate in the Inter-Commission Coordination Group on the WMO Information System (ICG-WIS)
38.	Dr (Mrs) Surinder Kaur	6-8 September, 2007 Bali, Indonesia	Asian Water Cycle Initiative (AWCI) International Coordination Group
39.	Dr S. D. Attri, Director	10-13 September, 2007 Helsinki, Finland	To attend the 14 th WMO/IAEA Meeting of Experts on Carbon Dioxide and Other Greenhouses and Related Tracer Measurement Techniques.
40.	Dr M. P. Wakdikar, Sct, 'F'	12-13 September, 2007 Colombo, Sri Lanka	To attend the Consultations on Delineation of Continental Shelf.
41.	Shri A. K. Bhatnagar, ADGM Shri N. K. Pangasa, Director	12-15 September, 2007, 10-12 September, 2007 Russian Federation	Meeting on the Global Telecommunication System (GTS)
42.	Shri A. K. Bhatnagar, Addl DGM	10-12 September, 2007 Russian Federation	To participate in the implementation Coordination Meeting on the Global Telecommunication System (GTS) in Region –II
43.	Shri Rasik Ravindra, Director, NCAOR	3-5 October, 2007 Cambridge, UK	To attend the meeting of the Executive Committee of Managers of National Antarctic Programme
44.	Dr S. Kathirolu, Director, NIOT Dr M.P. Wakdikar, Sct,F Dr R. S. Dattatrayam, Director, IMD	11-12 October, 2007 Moscow, Russia	To attend the 14 th Session of Indo-Russian Joint Council for ILTP
45.	Shri John P. George, Sct 'D' NCMRWF Dr Praveen Kumar, Sct 'D'	29-31 October, 2007 Dhaka, Bangladesh	For implementation of NWF Model in Bangladesh

46.	Shri A. K. Rath, AS&FA Dr V. N. Sanjeevan, Sct 'E' Shri P. Madeswaran, Sct 'E'	21 Oct.- 2 Nov.,2007 Hobart, Australia	To participate in the 26 th meeting of the Commission for the Conservation of Antarctic Marine Living Resources
47.	Dr P.S. Goel, Secretary	23-26 October, 2007 Tokyo, Japan	To participate in the 17 th Convocation of the International Council of Academies of Engineering and Technological Science.
48.	Dr S. K. Das, Sct 'G' Dr S. Kathirol, Director, NIOT Shri M.L. Sharma, DS Shri D. Rajasekar, Sct, NIOT	2-6 November,2007 Genova, Italy	For comprehensive review of ship Construction
49.	Shri R.C.Bhatia, DG, IMD	4-5 November 2007 Bangladesh	To attend 13 th Meeting of Governing Board of SAARC Meteorological Research Centre
50.	Dr G.Srinivasan, Director, IMD	12-17 November 2007	Valencia, Spain To attend 27 th Session of the Inter-governmental Panel on Climate Change (IPCC)
51.	Dr Shailesh Nayak, Director, INCOIS	14.November,2007 Malaysia	To attend Workshop on 'The User and GEOS Aarchitecture XVII Earth Observation to Benefit Tsunami?
52.	Dr V.S.Rao Chintala, Sct 'G',	20-23 November, 2007 Egypt	To participate in the 'Made in India Show
53.	Dr P.S.Goel, Secretary, MoES Dr Sahilesh Nayak, Director, INCOIS	30 Nov.- 3, Dec.2007 Thailand	To participate in the IOGOOS Workshop, 5 th Annual Meeting (IOGOOS-V) and 2 nd meeting of high level representatives of the countries/organizations putting observation system in the region
54.	Dr R.V.Sharma, Dy/DGM, IMD, RMC, Chennai	3-5 December,2007 Switzerland	To participate in the international Symposium on Public Weather services'
55.	Dr G.Srinivasan, Director, IMD	9-14 December,2007 Indonesia	To participate in the United Nations Framework Convention on Climate Change (UNFCCC)
56.	Dr S.Kathirol, Director, NIOT	9-10 December,2007 Italy	For taking delivery of Technology Demonstration vessel 'Sagar Nidhi'
57.	Shri M.C.Rastogi, Director, IMD	18-20 December,2007 Thailand	To participate in the WMO-IOC Workshop on the Global Telecommunication Systems for Effective Exchange of Tsunami Warnings
58.	Dr A.K.Bohra, Head, NCMRWF Shri Gopal Iyengar, Sct E, NCMRWF	6-12 January,2008 UK	For discussions with UK Met Office scientists for development of a plan for the Implementation of Unified Model of UKMO at NCMRWF
59.	Dr A.P.Pandey, Met Gr.II, IMD	9 Jan to 8 March, 2008 Japan	To participate in the Group Training Course on Global Seismological Observation
60.	Dr S.Rajan, Sct F, NCAOR	21-25 January,2008 New York	To participate in the 20 th Session of the CLCS
61.	Shri Rasik Ravindra, Director, NCAOR	5-14 February,2008 Australia	As Member of the Indian Delegation led by Shri Kapil Sibal, Honourable Minister for Earth Sciences

62.	Dr Shailesh Nayak, Director, INCOIS	19-20 February,2008 France	To participate in the first meeting of 'Working Group on the Future of Intergovernmental Oceanographic Commission'
63.	Dr V.S.Prasad, Sct E, NCMRWF	3-5 March,2008 Japan	To participate in the international workshop 'Prevention and Mitigation' of Meteorological Disasters in Southeast Asia
64.	Dr B.R.Subramanian, PD-ICMAM Dr K.Somasundar, Sct E, MoES Dr M.Balakrishnan Nair, Sct D, INCOIS; and Representative of NIO, Goa	10-14 March,2008 South Africa	To attend the Workshop on Oceanography, being held under the auspices of IBSA, a trilateral cooperation programme of India, Brazil and South Africa

20. Finance

The total budget allocation for the Ministry of Earth Sciences for the year 2007-08 was Rs. 887.00 crore, which includes Rs. 690.00 crore for the Plan Scheme and Rs. 197.00 for Non Plan Schemes. The Revised Estimate for the Ministry of Earth Sciences have been fixed at Rs. 655.00 crore (Rs. 437 crore for Plan and Rs. 218 crore for Non-Plan activities). The Budget estimates for Non-Plan schemes for 2008-09 are Rs. 221.00 crore. The details of BE and RE 2007-08 are given in the following table:

	Major Head	Plan	Non -Plan	Total	Plan	Non -Plan	Total
	Revenue	417.09	196.40	613.49	369.54	217.44	586.98
	Capital	272.91	0.60	273.51	67.46	0.56	68.02
	Total	690.00	197.00	887.00	437.00	218.00	655.00
1.	Secretariat - Economic Services	3451	0.00	11.43	11.43	0.00	13.39
2.	Oceanographic Research						
2.1.	Oceanographic Survey (ORV and FORV) and Marine Living Resources (MLR)	3403	4.00	26.59	30.59	4.00	43.01
2.2.	Antarctic Research / Polar Science	3403	20.00	0.00	20.00	35.00	0.00
2.3.	Coastal Research Vessel	3403	5.00	0.00	5.00	5.00	0.00
2.4.	Drugs from Sea	3403	5.50	0.00	5.50	4.13	0.00
2.5.	Polymetallic Nodules Programme	3403	15.00	0.00	15.00	9.92	0.00
2.6.	Other Programmes						
2.6.1	Assistance for Research Projects	3403	4.30	0.00	4.30	11.10	0.00
2.6.2	Coastal Ocean Monitoring & Prediction System	3403	2.00	0.00	2.00	1.75	0.00
2.6.3	Exhibition and Fairs	3403	1.00	0.00	1.00	2.00	0.00
2.6.4	Assistance for Research Seminars Symposia	3403	1.00	0.00	1.00	0.95	0.00
2.6.5	Manpower Training	3403	0.20	0.00	0.20	0.20	0.00
2.6.6	Marine Non-Living Resources Programme (MNLR)	3403	2.00	0.00	2.00	0.00	0.00
2.6.7	Integrated Coastal & Marine Area Management (ICMAM)	3403	3.75	0.00	3.75	3.75	0.00

		5403	1.25	0.00	1.25	1.25	0.00	1.25
	Total	5.00	0.00	5.00	5.00	0.00	5.00	
2.6.8	Information Technology & Computers	3403	1.00	0.00	1.00	2.50	0.00	2.50
2.6.9	Ocean Observation & Information Service	3403	15.00	0.00	15.00	15.00	0.00	15.00
2.6.10	Ocean Data Buoy Programme	3403	15.00	0.00	15.00	7.00	0.00	7.00
2.6.11	National Institute of Ocean Technology	3403	20.00	0.00	20.00	20.00	0.00	20.00
2.6.12	Continental Shelf Programme /Research	3403	1.00	0.00	1.00	0.75	0.00	0.75
2.6.13	Comprehensive Swath Bathymetric Survey	3403	5.00	0.00	5.00	5.00	0.00	5.00
2.6.14	Gas Hydrates	3403	10.00	0.00	10.00	4.00	0.00	4.00
2.6.15	New Research Vessel	3403	100.00	0.00	100.00	106.00	0.00	106.00
2.6.16	Tsunami and Storm Surge Warning System	3403	35.00	0.00	35.00	30.00	0.00	30.00
2.6.17	National Center for Antarctic and Ocean Research	3403	15.00	0.00	15.00	15.00	0.00	15.00
2.6.18	Indian National Center for Ocean Information Services	3403	35.00	0.00	35.00	24.00	0.00	24.00
2.6.19	Sea Front Facility	3403	10.00	0.00	10.00	0.50	0.00	0.50
2.6.20	Development of Manned Submersible	3403	5.00	0.00	5.00	1.90	0.00	1.90
2.6.21	Installation of MCS System	3403	5.00	0.00	5.00	1.00	0.00	1.00
2.6.22	Expedition to Arctic	3403	1.00	0.00	1.00	1.00	0.00	1.00
2.6.23	Desalination Project	3403	10.00	0.00	10.00	1.00	0.00	1.00
2.6.24	National Oceanarium	3403	0.95	0.00	0.95	0.25	0.00	0.25
2.6.25	Demonstration of Shore Protection Measure through Pilot Project	3403	1.00	0.00	1.00	0.60	0.00	0.60
2.6.26	Integrated Ocean Drilling Programme	3403	4.00	0.00	4.00	2.50	0.00	2.50
2.6.27	Ice Class Research Vessel	3403	1.00	0.00	1.00	0.75	0.00	0.75
2.6.28	Head Quarter Buildings	5403	10.00	0.00	10.00	10.00	0.00	10.00
2.6.29	MLR Vessel, Dedicated Berthing and associated facility	5403	0.05	0.00	0.05	1.00	0.00	1.00
2.6.30	Marine Research and Technology Development (MRTD)	3403	0.00	0.00	0.00	0.00	0.00	0.00
		5403	0.00	0.00	0.00	0.00	0.00	0.00
	Total		0.00	0.00	0.00	0.00	0.00	0.00
2.6.31	NIOT Extension Centre, West Bengal	3403	0.00	0.00	0.00	0.00	0.00	0.00
2.6.32	R&D in Earth and Atmospheric Sciences	3403	0.00	0.00	0.00	0.00	0.00	0.00

2.6.33	Centre for Climate Change	3403	0.00	0.00		0.00	0.00	
2.6.34	Dedicated Weather Channel and Commonwealth Games	3403	0.00	0.00	0.00	0.00	0.00	0.00
2.6.35	Multi-hazards Early Warning Support System	3403	0.00	0.00	0.00	0.00	0.00	0.00
	Total Other Programmes		315.50	0.00	315.50	270.75	0.00	270.75
	Total Oceanographic Research		365.00	26.59	391.59	328.80	43.01	371.81
3.	Meteorology							
3.1	Direction & Administration	3455	0.00	13.96	13.96	0.00	12.94	12.94
3.2	Training	3455	0.54	2.03	2.57	0.48	1.62	2.10
3.3	Research & Development Programme	3455	0.87	13.31	14.18	0.77	13.47	14.24
		5455	2.51	0.00	2.51	0.51	0.00	0.51
	Total		3.38	13.31	16.69	1.28	13.47	14.75
3.4	Satellite Services	3455	5.72	7.08	12.80	5.18	6.71	11.89
		5455	4.28	0.00	4.28	2.94	0.00	2.94
	Total		10.00	7.08	17.08	8.12	6.71	14.83
3.5	Observatory and Weather Stations	3455	10.72	76.97	87.69	11.00	74.34	85.34
		5455	11.25	0.50	11.75	19.00	0.47	19.47
	Total		21.97	77.47	99.44	30.00	74.81	104.81
3.6	Other Meteorological Services	3455	9.10	37.09	46.19	8.10	39.64	47.74
		5455	6.00	0.10	6.10	2.10	0.09	2.19
	Total		15.10	37.19	52.29	10.20	39.73	49.93
3.7	Other Programmes	3455	1.94	1.63	3.57	1.46	1.58	3.04
		5455	8.45	0.00	8.45	0.16	0.00	0.16
	Total		10.39	1.63	12.02	1.62	1.58	3.20
3.8	Modernisation	3455	16.00	0.00	16.00	0.50	0.00	0.50
		5455	223.62	0.00	223.62	25.00	0.00	25.00
	Total		239.62	0.00	239.62	25.50	0.00	25.50
3.9	India Meteorological Department (IMD)							
3.9.1	Modernisation of IMD (Communication, Observation, Cyclone Warning, Forecasting, Aviation Services, Instrumentation, Infrastructural Development)	3455	0.00	0.00	0.00	0.00	0.00	0.00
		5455	0.00	0.00	0.00	0.00	0.00	0.00
	Total		0.00	0.00	0.00	0.00	0.00	0.00
3.9.2	Other Schemes in IMD	3455	0.00	0.00	0.00	0.00	0.00	0.00
		5455	0.00	0.00	0.00	0.00	0.00	0.00
	Total		0.00	0.00	0.00	0.00	0.00	0.00
	Total Meteorology		301.00	152.67	453.67	77.20	150.86	228.06
4.	Other Scientific Research							
4.1	National Centre for Medium Range Weather	3425	5.50	2.31	7.81	7.50	2.74	10.24

	Forecasting	5425	5.50	0.00	5.50	5.50	0.00	5.50
	Total		11.00	2.31	13.31	13.00	2.74	15.74
4.2	Indian Institute of Tropical Meteorology, Pune	3425	13.00	4.00	17.00	18.00	8.00	26.00
	Total Other Scientific Research		24.00	6.31	30.31	31.00	10.74	41.74
	Grand Total		690.00	197.00	887.00	437.00	218.00	655.00

21. Report of the Comptroller and Auditor General of India for the Year ended March 2006

India Meteorology Department

Wasteful expenditure

Deputy Director General Meteorology placed an order on a firm for supply of 4.00 kg of Ni span sheets in March 2001. After placing the order, the indenter informed IMD in April 2001 that since the firm, on whom the order was placed was neither a manufacturer nor a supplier of the item in the past, the firm may be asked to produce an authorization certificate before opening the letter of credit. The firm intimated that they could supply low expansion alloy 43 PH which was equivalent to precision-C in cold rolled annealed condition. The firm supplied 379 kg of alloy 43 PH in May 2002, which was found to be not confirming to the specifications and therefore, the indenter rejected the material. The firm thereafter did not replace the material procured by IMD could not used for intended purpose resulting in wasteful expenditure of Rs. 33.08 Lakh.

Abbreviations

AVHRR	Advanced Very High Resolution Radiometer
BoB	Bay of Bengal
CAS	Centre for Atmospheric Sciences
CCM-3 AGCM	Atmospheric General Circulation Model
CMAP	CPC (Climate Prediction Centre) Merged Analysis of Precipitation
C-MMACS	Centre for Mathematical Modelling and Computer Simulation
CRS	Central Receiving Station
CSIR	Council of Scientific and Industrial Research
DOS	Department of Space
DST	Department of Science and Technology
ECMRWF	European Centre for Medium Range Weather Forecast
EDB	Electronic Display Board
EEIO	Eastern Equatorial Indian Ocean
ENSO	El Niño and Southern Oscillation
E-OSF	Experimental Ocean State Forecast
FSI	Fishery Survey of India
GFDL	Geophysical Fluid Dynamics Laboratory
GIF	Graphic Interchange Format
GOOS	Global Ocean Observing System
GRAND	GOOS Regional Alliances Networking Development
GTS	Global Telecommunication System
HC	Heat Content
HLL	Hindustan Lever Limited
IAST	International Argo Steering Team
ICG/IOTWS	International Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System
IISc	Indian Institute of Science
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
IOD	Indian Ocean Dipole
IODE	International Oceanographic Data Exchange
IOGOOS	Indian Ocean Global Ocean Observing System
IOM	Indian Ocean Model
IOP	Indian Ocean Panel
ISRO	Indian Space Research Organization
IRS	Indian Remote Sensing Satellite
ITWC	Interim Tsunami Warning Centre
KPP	K-Profile Parameterization
MDT	mean dynamic topography
MLD	Mixed Layer Depth
MODIS	Moderate Resolution Imaging Spectroradiometer
MOM	Modular Ocean Model
MOM	Modular Ocean Model
NCEP	National Centre for Environmental Prediction
NCMRWF	National Centre for Medium Range Weather Forecasting
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
NPOL	Naval Physical Oceanographic Laboratory
NRSA	National Remote Sensing Agency
NW	North West
OCM	Ocean Color Monitor
OGCM	Oceanographic General Circulation Model
PBL	Planetary Boundary Layer
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
SAC	Space Applications Centre
SATCORE	Satellite Coastal and Oceanographic 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 Nearshore
T/P	Topex/Poseidon
TMI	Microwave Imager (TMI)
TRMM	Tropical Rainfall Measuring Mission
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WAM-3GC	Wave Model – 3
WEB-GIS	Web based Geographical Information System
WMO	World Meteorological Organisation
XBT	Expendable Bathy Thermograph
IAE	Indian Antarctic Expedition
IMD	Indian Meteorological Department, New Delhi
NPL	National Physical Laboratory, New Delhi
IIG	Indian Institute of Geomagnetism, Mumbai
GSI	Geological Survey of India
NGRI	National Geophysical Research Institute, Hyderabad
NIO	National Institute of Oceanography, Goa
NHO	National Hydrographic Office, Dehradun
SASE	Snow & Avalanche Studies Establishment, Chandigarh
BSIP	Birbal Sahani Institute of Palaeobotany, Lucknow
DIPR	Defence Institute of Physiological Research
ARMEX	Arabian Sea Meteorological Experiment
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
PRL	Physical Research Laboratory
SCAR	Scientific Committee on Antarctic Research
COMNAP	Council of Managers of National Antarctic Programs
SCALOP	Standing Committee on Antarctic Logistics and Operations

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