

Annual Report 2009-2010



सत्यमेव जयते

Ministry of Earth Sciences
Government of India

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1 An Overview of the Ministry of Earth Sciences (MoES)

The Ministry of Earth Sciences (MoES) was established in the year 2006 by bringing the meteorological agencies and ocean development department under one umbrella considering the importance of coupled ocean-atmosphere processes for understanding the variability of weather, climate and hazards. The MoES aims at looking at the planet in a holistic way so as to develop a comprehensive understanding of interplay of earth processes. The vision of the Ministry is to emerge as a knowledge and information technology enterprise for the earth system science (atmosphere, hydrosphere, cryosphere and geosphere) realm for the Indian subcontinent and Ocean. 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.

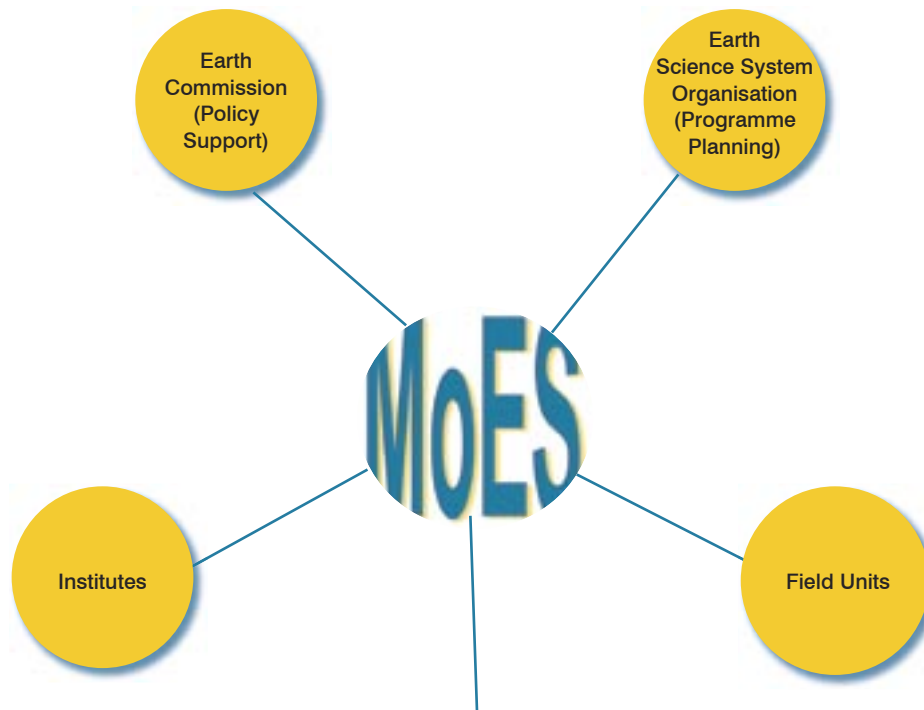
The earth system science is a science of national importance. We need to develop scientific understanding of the earth system and earth processes as well as their response to the natural and human-induced changes. We need to record various environmental variables which record the vital signs of change and their causes. It is essential to distinguish between the variability and changes of the earth system. This is vital to improve prediction of the climate, weather and natural hazards.

India has a coastline of about 7500 km, and Exclusive Economic Zone (EEZ) of about 2.02 million sq km (our landmass area being about 3.27 million sq km) which also forms a key multi-disciplinary research which is again closely linked to societal benefit.

Thus a wide range of activities are covered contributing to various societal benefits in the areas of Weather (General), Weather advisories specific to agriculture, aviation, shipping, sports, etc, Monsoon, Disasters (cyclone, earthquake, tsunami, sea level rise), Living and non-living resources (fishery advisory, poly-metallic nodules, gas hydrates, etc), Coastal and Marine Ecosystems and Climate Change. The programmes of the ministry have been recast broadly into various categories viz., (i) Atmospheric Science & Services; (ii) Ocean Science & Services; (iii) Cryosphere/Polar Science; (iv) Ocean Resources; (v) Ocean Technology; (vi) Coastal Marine Ecology; (vii) Climate Change Science; (viii) Disaster Support; (ix) Vessel Management; (x) R&D in Earth Sciences; and (xi) Outreach.

In view of this mandate, the Ministry supports focused process studies, development of earth system models, information system for societal, environmental and economic benefits. The major agenda is to promote discovery of a new perspective on earth system science, better understanding of earth processes and apply knowledge for sustainable use of earth resources.

1.1 The Organisational Chart



- Indian National Centre for Ocean Information Services, Hyderabad
- National Institute of Ocean Technology, Chennai
- National Centre of Antarctic and Ocean Research, Goa
- Indian Institute of Tropical Meteorology, Pune
- Centre for Climate Change Research, Pune

India
Meteorological
Department
(subordinate
office)

- Integrated Coastal and Marine Area Management, Chennai
- Centre for Marine Living Resources and Ecology, Kochi
- Earthquake Risk Evaluation Centre, New Delhi
- National Centre for Medium Range Weather Forecasting, Noida

2 Atmospheric Science and Services

2.1 Introduction

Meteorological services through forecasting is an age old practice which in recent decades has assumed vital importance in country's economy. The impact of meteorological services on society in general and on safety of life and property in particular is profound in terms of financial and social value. Weather services in general have very early origins in this country and currently engage the India Meteorological Department (IMD), National Centre for Medium Range Weather Forecasting (NCMRWF) and the Indian Institute of Tropical Meteorology (IITM) in an integrated manner. While IMD provides the National Weather Service, NCMRWF and IITM are specialised centres undertaking developmental work in the field of numerical weather modelling and basic research in the field of meteorology, respectively, for improving weather and climate services of the country.

The advancement of science in recent years indicates that a combined approach involving land, ocean and atmospheric processes holds the key to improving the longer ranges of forecasts to provide a credible policy tool. On the other hand, intensive monitoring and analysis of cloud systems using satellite and radar technology can help to accurately gauge the severity of an impending calamity, thereby prompting the selection of

appropriate measures. The MoES has taken positive steps to implement a comprehensive developmental programme on these lines involving all the three agencies.

2.2 Weather Services

General weather forecasts have been issued in the current year along with precautionary warnings for hazardous weather like fog, cyclonic storms, heavy rainfall, squalls, etc. for the entire country throughout the year in the short and medium range scale. These have been issued from the two main forecasting centres of the country viz. from Delhi and Pune, besides six Regional Meteorological Centres and Meteorological Centres at State headquarters. The weather reports are disseminated through media, passed on to all relevant Government agencies, hoisted on the Web and published in the Indian Daily Weather Report. The forecasts provided in the medium and short range scale were reasonably good. The year 2009 was the warmest year on record since 1901 with an annual average of 24.64°C which is 0.91°C above normal.

2.3 Monsoon Monitoring and Prediction

2.3.1 Salient Features of Monsoon 2009

1. The forecast of southwest monsoon is given in Table 2.1.

Table 2.1: Summary of the long range forecasts southwest monsoon, 2009

| Region | Period | Issued on | Forecast | Actual |
|------------------|-------------------|------------------------------|------------------|------------|
| All India | June to September | 17 th April, 2009 | 96% ± 5% of LPA | 78% of LPA |
| | | 24 th June, 2009 | 93%± 4% of LPA | |
| All India | July | 24 th June, 2009 | 93%± 9% of LPA | 96% of LPA |
| All India | August | 24 th June, 2009 | 101% ± 9% of LPA | 73% of LPA |
| North-West India | June to September | 24 th June, 2009 | 81% ± 8% of LPA | 65% of LPA |
| North-East India | | | 92% ± 8% of LPA | 77% of LPA |
| Central India | | | 99% ± 8% of LPA | 80% of LPA |
| South Peninsula | | | 93% ± 8% of LPA | 94% of LPA |

2. The monsoon set in over Kerala on 23rd May, one week before its normal date of 1st June. During 8-20th June, there was hiatus in the advancement of monsoon and subsequently advanced rapidly to cover the entire country by 3rd July, compared to its normal date of 15th July. As in the previous two years, the withdrawal of monsoon from west Rajasthan was delayed and it commenced only on 25th September compared to its normal date of 1st September.
3. Out of 511 meteorological districts for which data are available, 217 districts (42%) recorded excess/normal rainfall and the remaining 294 districts (58%) recorded deficient rainfall during the season.

2.4 Agrometeorological Services

Agrometeorological Services are rendered to the State Governments and farmers by issuing weekly/bi-weekly bulletins as well as district level weather forecast and advisories through Agromet Field Units. These advisories are tailored to meet the requirements of farmers based on past and anticipated weather conditions and are 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. The following are salient achievements:

- Consolidated All India Agromet Advisory Bulletins were prepared and issued to the Ministry of Agriculture and other users in the country to help policy decisions.
- Processed agro-climatic data were provided to end users like the Ministry of Agriculture, State Departments of Agriculture, and Scientists of Agricultural Universities/Institutes for planning agricultural strategy and research work.
- Weekly Medium Range Weather Forecast for 630 districts were communicated through RMCs/MCs for preparation and dissemination of Agromet Advisory Service bulletins.
- Training pertaining to various levels of agricultural personnel (from observers to senior level officers/scientists/professors)

was conducted as per the approved academic calendar.

- Research work continued in the areas of crop weather relationship studies, dry land farming, soil moisture and weather based forewarning of crop pests and diseases, and climate change adaptation strategies for agriculture.
- Agromet advisories have been regularly issued at the state and district level for the benefit of farmers and various other users in the entire Himalayan region from Jammu & Kashmir up to Tripura. Special care is being taken to prepare the advisories as per the requirements of the users particularly for the plantation crops and livestock along with their real time dissemination.

2.4.1 Drought Research and Crop Yield Formulation

Based on aridity indices, bi-weekly Aridity Anomaly Reports for southwest monsoon season for the whole country and for north-east monsoon season for the five meteorological sub-divisions, viz. coastal Andhra Pradesh, Rayalaseema, south interior Karnataka, Tamil Nadu, Puducherry and Kerala, are prepared and sent to various agricultural authorities of State and Central Governments, and research institutes on operational basis for their use in agricultural planning and research purposes. The bi-weekly Aridity Anomaly maps are also uploaded on the IMD website. These Aridity Anomaly Reports help to assess the moisture stress experienced by growing plants and to monitor agricultural drought situation in the country.

Based on the crop yield forecast models, monthly quantitative forecast of interim and final yields are prepared every year during respective crop growing season and issued to Directorate of Economics and Statistics, Ministry of Agriculture and Cooperation, New Delhi on operational basis for national food planning.

2.5 Mountain Meteorology Forecast

In the context of Indian subcontinent, Himalayas govern the climate and weather of the region and drive the major weather system, viz. Western

Disturbances (WDs) during winter time and monsoon phenomenon during summer time. Heavy snowfall events over the Western Himalayan region and the subsequent avalanches over the region affect life and property of the habitats. It also has a strategic importance for army operations. The impact of weather events is enhanced by topography which makes the area more prone to cloud bursts, flash floods and landslides.

The existing observational network over these regions (surface, upper air, radar etc.) is very sparse. Twenty-six Automatic Weather Stations (AWS) have been established in the Western Himalayan region under the multi-institutional project PARWAT for sustained real time collection of meteorological data. Three upper air stations are also established at Jammu, Manali and Sasoma to meet weather forecasting requirements of the specific region.

Customised forecast for mountaineering expeditions were issued with constant interaction with expedition teams and coordination with their headquarters. The forecast bulletin for mountain expeditions for Mt. Dhaulagiri to Army Adventure Wing and for Mt. Everest to the Nehru Institute of Mountaineering was issued from 20th April. Meteograms for the Mount Satopanth, the Mount Stok Kangri, the Mount Chaukhamba and the Mount Shivling as requested by Army Adventure Wing were provided.

2.6 Hydrometeorological Services

This service provides necessary technical and operational support to various Central/State Government organisations and other agencies in the field of Hydromet design of flood forecasting, water management and agricultural planning through compilation of rainfall statistics, hydrometeorological analysis of different river catchments for project authorities and providing meteorological support for flood warning and flood control operations to field units of Central Water Commission. In addition, Design Storm Analysis, Rainfall Frequency Analysis and Quantitative Precipitation Forecast are the ongoing hydrometeorological activities. Based

on real time daily rainfall data, weekly district wise, sub-division wise and state wise/season wise rainfall distribution summaries are prepared in the form of rainfall tables and maps. District wise and sub-division wise rainfall statistics provide important information useful to the agricultural scientists, planners and decision makers.

The inputs on rainfall to Central Water Commission (CWC) through 10 Flood Meteorological Offices (FMOs) established in different parts of India for operation Flood Forecasting. Flood, QPF (Quantitative Precipitation Forecast) were issued by FMOs and supplied to Central Water Commission for flood forecasting purposes. A MOS technique is being developed for QPF with a pilot project on Mahanadi basin.

Design Storm Studies were conducted to evaluate design storm estimates (rainfall magnitude and time distribution) for various river catchments/projects in the country, for use as main input for design engineers in estimating design flood for hydraulic structures, irrigation projects, dams etc. on various rivers. During the current year, 49 projects have been completed and results communicated to concerned project authorities.

2.7 Aviation Services

The aviation meteorological offices provide current weather reports, various forecasts and warnings for safety, economy and efficiency of aircraft operations. Meteorological services for aviation continue to provide for national and international flights for safe and efficient operations. 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 other airports in the country. Some of the additional aspects of the aviation services undertaken in this year include:

- Opening of a new Airport Meteorological Office at Shimla Airport.
- Issuance of 30-hour Terminal Aerodrome Forecast for international flights concerned.

- Fog monitoring and forecasting service for IGI Airport was provided on IMD's website where current visibility and Runway Visual Range along with two hourly trend forecast was made available for users.

2.8 Location Specific Forecast

The **System of Air Quality Forecasting and Research (SAFAR) for Air Quality Forecasting for Commonwealth Games (CWG) is being accomplished for the first time in India along with** establishing forecast and nowcast system for the Games through commissioning of Automatic Weather Stations, Doppler Weather Radar and other observing systems that will provide forecast products specific to venues. The entire system will provide and display the information on weather and air quality on real time and forecast the future weather and level of pollution at various key locations (outdoor: 12 and indoor: 4) of CWG 2010 through wireless true colour digital display panels. The real time and forecasting will include the air pollutants, e.g. Ozone, NO_x, CO, PM_{2.5}, PM₁₀, Black Carbon and Benzene. In the recent past, only a few developed countries have demonstrated the strength to develop this kind of system during major games like during the Olympic Games in Beijing, China and Melbourne, Australia.

World Meteorological Organization (WMO) through their programme Global Atmospheric Watch (GAW) Urban Research Meteorology and Environment (GURME) has recognised "SAFAR" as their pilot activity implying this effort is at par with international standard as stipulated by stringent scientific guidelines for confidence in quality control and quality assurance. This has also led MoES to represent Asian region in the Scientific Advisory Committee for Global Atmospheric Watch-Urban Research Meteorology and Environment (GAW-GURME).

2.9 Environmental Monitoring

The network for Air Pollution Monitoring comprises monitoring stations at Allahabad,

Jodhpur, Kodaikanal, Minicoy, Mohanbari, Nagpur, Port Blair, Pune, Srinagar and Visakhapatnam that continue to collect rain samples for chemical analyses and measurement of atmospheric turbidity with the objective of documenting the long-term changes in composition of trace species of the atmosphere. The wet precipitation samples are analysed at Central Chemical Laboratory for pH, conductivity, major cations (Ca, Mg, Na, K, NH₄) and anions (SO₄, NO₃, Cl).

Atmospheric Turbidity indicating the columnar aerosol load of the atmosphere continued to be measured at Allahabad, Jodhpur, Kodaikanal, Nagpur, Port Blair, Srinagar, Pune, Mohanbari, Minicoy and Visakhapatnam. These data provide reliable long-term observations of the chemical composition of the atmosphere and related parameters in order to improve understanding of atmospheric chemistry.

Specific services pertaining to environment are rendered to the Ministry of Environment and Forests and other Government agencies in the assessment of likely air pollution impacts arising from thermal power generation, industries and mining activities. Atmospheric diffusion models developed for carrying out air quality impacts of multiple sources located in different climatic and geographical conditions are being utilised for siting of industries and adoption of air pollution control strategies.

2.10 Satellite Meteorology

2.10.1 INSAT Data Reception and Processing

At present, IMD is receiving and processing meteorological data from two Indian satellites, namely Kalpana-1 at 74°E and INSAT-3A at 93.5°E. At present, about 48 satellite images are taken daily from Kalpana-1 which is the main operational satellite and 9 images are taken from INSAT-3A. Imaging from CCD is done five times during daytime only. All the received data from the satellite is processed and archived in National Satellite Data Centre (NSDC), New Delhi.

INSAT Meteorological Data Processing System (IMDPS) is processing meteorological data from INSAT VHRR and CCD data, and supports all operational activities on round-the-clock basis. Cloud Imagery Data is processed and transmitted to forecasting offices of the IMD as well as to the other users in India and foreign countries. Apart from generating half hourly cloud imagery, IMDPS produces satellite data derived products from the processed data, viz. Cloud Motion Vectors (CMVs), Water Vapour Winds (WVWs), Sea Surface Temperatures (SSTs), and Quantitative Precipitation Estimates (QPE). Special sector images are created for special events such as the Amarnath Yatra, cyclones, other special weather phenomena and satellite launches from SHAR Centre, Sriharikota.

The processed INSAT cloud imagery are broadcast through INSAT-3C, every three hours. Meteorological data consisting of satellite cloud imagery, T/P data (conventional met. data) and fax charts (analysed weather charts) are provided to various field stations. During cyclone situations, actual position of system and its intensity and related forecast are also transmitted to field stations every hour. The system transmits data in International LRIT/HRIT format through own transmitting station at New Delhi. Receiving stations have also been set up in Nepal, Sri Lanka and Maldives in 2009.

2.11 Augmentation of Atmospheric Observation Network

A comprehensive upgradation of observational and forecasting infrastructure of IMD to enhance its capabilities with regard to meteorological services has been taken up. This aims at commissioning state-of-the-art observing systems throughout the country, network and integrate all the existing as well as the new observing systems to receive, process and archive all observations in digital form at a central information processing facility, and disseminate all processed information in digital form to forecasters of the various regional centres, state capitals to value add and generate/ disseminate the same to the multisectoral user communities in the most efficient manner. Various

mechanisms like internet, TV, AIR and print media including local newspapers in vernacular languages etc. are already being utilised for the dissemination purpose. With the commencement of district level forecasts, dissemination through district level extension agencies consisting of district agricultural offices. The 1st Phase of Modernisation includes commissioning of 10m GPS sondes, 550 AWS, 1350 ARGs, 10 Lightning detection systems, 13 Doppler Weather Radar apart from development and commissioning of indigenous Radiosondes for upper air observations. In addition to above, an important component of the Modernisation of IMD involves a complete end-to-end forecasting system that includes connectivity of the various instruments and observing systems, their real time transmission and linkage to a central data processing system, their utilisation in the numerical models, providing a state-of-the-art IT based forecasting environment to all forecasters throughout the country. This involves integration of all observations and overlaying them on model outputs and synoptic charts along with proper visualisation and finally dissemination of weather forecast to the end users. Modules have been developed to monitor observation quality from all the Indian radiosonde stations based on its departure from model generated first guess.

About 75% integration has been achieved for the newly commissioned observing systems like AWS, ARG and GPS sondes. By December 2010, all observing systems including Doppler Weather Radars will be commissioned. Introduction of GPS radiosonde in the upper air observation network at 10 places has been able to improve the data quality substantially that has been acknowledged worldwide.

Most of the equipment under VARSAMANA project have been commissioned and four systems (Upper air, AMSS, Synergie and PWS) are already installed and running on operational basis. The new Automatic Message Switching System 'TRANSMET' of RTH New Delhi running on operational basis from 28th October, 2009 is capable of exchanging 1 Terabyte (1000 GB) of weather data and processed information every day.

A new system of visualisation will have capabilities to visualise multiple layers of observation and forecast overlaid on each other, thus, providing to the forecaster the capability to assimilate terabytes of information before issuing weather forecast.

A new Public Weather Service System is now operational at IMD, New Delhi. It will enable the forecaster to generate in custom-built presentation form and automatic delivery of products to the newspaper, TV, commercial airlines, farmers, shipping, etc.

IMD Hq. in Delhi is housing the Central Information Processing System with a super-computer at the back-end. It is running global and regional numerical weather prediction models on 24x7 basis.

High-computing system to analyse large amount of data and generate numerical weather forecast as well as for atmospheric and ocean process studies have been installed at IMD, NCMRWE, IITM and INCOIS.

2.12 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 holding of meteorological data in the archives as of date is 103.5 million records. NDC received a lot of queries and requests for data supply from numerous parties that include Government, private institutions, industries, research and operational users. The required data were retrieved from the computer archives, and supplied to the users on CDs, in printout forms in the desired formats. During the period under consideration, 1080.6 million records were retrieved and supplied (during 2009-10) to different users.

2.13 Numerical Weather Prediction

2.13.1 Data Assimilation and Management

- The Gridpoint Statistical Interpolation (GSI) Analysis Scheme has been

successfully implemented in Global Forecast System (GFS)-T254L64 and made operational from 1st January, 2009.

- Data pre-processing suite for Global Positioning System Radio Occultation (GPSRO) data from Champ and COSMIC series of satellites has been ported and test runs were made on PARAM PADMA for GFS T265L64. The GPSRO is an addition to the existing data mobilisation for global model.
- An encoder for coding integrated precipitable water (GPSIPW) data into NCEP BUFR was developed and observational system experiment was conducted for a month with July 2008 data. Parallel experimental runs are being carried out to assess the quality and impact of GPSIPW data.
- The software for calculating coefficients for a given satellite channel in fast radiative transfer (RTTOV) model was acquired from NWP-SAF (Satellite Application Facility) for computing coefficients for Indian Satellite sensor and for upgrading RTTOV with this information. With this, the ability of assimilating any satellite radiances data (particularly Indian satellites) that was operated with limited capability so far has been enhanced.

2.13.2 Weather Modelling

Implementation of UKMO Model

The necessary know-how is acquired through six weeks familiarisation programme at UK Met Office (UKMO). The programme includes tutorials, observation processing system, variational data assimilation, installation and testing of various packages, preparation of ancillary datasets, configuration of subversion in server mode etc. All Graphical User Interfaces (GUI) of UM suite have been made accessible to individual scientists through their Linux desktops. The model would be implemented on newly acquired HPC.

Multi Model Ensemble (MME) Forecast

To take care of the uncertainties in the initial conditions, model dynamics and model physics, Multi Model Ensemble (MME) forecasting is done on daily basis in real time, providing useful

guidance for 5 days utilising NCMRWF, National Centre for Environmental Prediction (NCEP), UKMO and Japan Meteorological Agency (JMA) products. During 2009, useful forecast were provided for the monsoon rainfall changing from a dry to wet condition, and then continuation of wet condition for some days.

Studies on Convection Scheme

The Relaxed Arakawa Schubert (RAS) convection scheme was incorporated and tested for a case study in T254L64 model. The results were briefly compared with the current operational run which has Simplified Arakawa Schubert (SAS) convection. Preliminary results do not show any significant difference. Detailed comparison is being undertaken.

2.14 Climate Monitoring and Climate Information Services

The following products were generated and supplied to the users:

- Real time climate monitoring and publication of Climate Diagnostics Bulletins for the Indian region and reporting of major anomalous climate events.
- Detailed special monsoon reports.
- High resolution daily gridded rainfall data ($1^{\circ}\times 1^{\circ}$) & ($0.5^{\circ}\times 0.5^{\circ}$).
- High resolution daily gridded temperature data ($1^{\circ}\times 1^{\circ}$).
- High resolution gridded terrestrial climate of India.
- Climatological summaries for districts and states.

2.15 Climate Variability Prediction

Development of a System for Seasonal Prediction of Monsoon based on the inputs from statistical and dynamical model is continuously monitored and evaluated for further improvement. **Continuous research work is being carried out for improving monsoon inter-annual variability using coupled models. Extended Range Predictability of Monsoon Intra-seasonal Variability (Active/**

Fig. 2.2: The Hon'ble Minister Shri Prithviraj Chavan inaugurating the High Performance Computer.



Break Monsoon Spells) is being investigated. Critical role of BSISO (Boreal Summer Intra-seasonal Oscillations) in modulating the seasonal mean summer monsoon has been seen. ***Role of Stratiform rainfall in modifying the northward propagation of monsoon intra-seasonal oscillation is studied.***

An analysis of daily rainfall over India during 1951-2007 reveals an increased propensity in the occurrence of 'monsoon breaks' over the subcontinent both in the duration and frequency of monsoon breaks over the subcontinent – the causes for which were investigated using *in situ*, satellite and re-analysis data products. While noting that the increasing trend of break monsoon condition is consistently related to changes in large scale monsoon circulation and vertically integrated moisture transport, the findings point to the role of sea surface temperature (SST) warming trend

(0.015°C per year) in the tropical eastern Indian Ocean in inducing anomalous changes favourable for the increased propensity of monsoon breaks.

Characteristics of wet spells (WS) and intervening dry spells (DS) are the most useful information in water-related sectors. The information assumes greater significance in the wake of global climate change background and climate change scenario projections. There is a tendency for the first WS to start ~6 days earlier across the country and the last WS to end ~2 days earlier but this shift in dates of the rain spells is also mostly not significant.

2.16 Aerosol and Climate Studies

For monitoring of Greenhouse Gases (GHGs) and aerosols, a network of stations in India is being set up to generate primary data on GHGs and aerosols on a long-term basis needed for climate change studies. A Climate Monitoring Station has been established at Hill Campus, G.B. Pant University of Agriculture & Technology, Ranichauri, Tehri Garhwal, Uttarakhand along with AWS and Air Quality Gas Analysers (SO₂ & NO_x), pH Conductivity Meter and radiation equipment recently.

The routine measurements are being carried out to monitor total column ozone, vertical ozone profiles and surface ozone. The characteristics of surface ozone pollution in Delhi are examined using *in situ* measurements. It is seen that daily maximum and daytime ozone levels are increasing, while night-time ozone levels are decreasing in Delhi. It is argued that both the positive trend during daytime and negative trend during night-time is due to the increasing NO₂ levels in Delhi. These measurements give a broad picture of the likely levels of ozone exposure experienced in the surrounding region and are, to date, found useful for the assessment of ozone effects on vegetation and human health. It is further seen that ozone concentration in Delhi can be influenced by transport of the ozone and precursors from the northern plain of India under the favourable meteorological conditions.

A multi-year, multi-institutional programme Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX) programme is intended to address the intricacies of the aerosol-cloud-rainfall interactions. It has two components, viz. (1) understanding Cloud-Aerosol interaction; and (2) Precipitation Enhancement.

During Phase I of the CAIPEEX, all the cloud microphysical and aerosol measurements were carried out using the instrumented aircraft. Many Radiosonde flights and aircraft flights were conducted at various stations in various parts of India such as Hyderabad, Bangalore, Bareilly, Nanded, Baramati, Guwahati, Pathankot etc. The observations were taken in 140 days covering 220 flying hours. Results of the observations will be useful for designing the cloud seeding operations in India and also for modelling the rainfall processes which will play a major role in improving the forecast.

2.17 Middle Atmosphere Dynamics

The vertical structure of temperature observed by Sounding of Atmosphere using Broadband Emission Radiometry (SABER) aboard Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED) and sprites (Lightning-induced optical emissions) observations made during the Eurosprite 2003-07 observational campaign were analysed. It was observed that the vertical structure of temperature shows evidence for a Mesospheric Inversion Layer (MIL) on those days on which sprites were observed. A few events were also reported in which sprites were not recorded, although there is evidence of a MIL in the vertical structure of the temperature. It was proposed that breaking gravity waves produced by convective thunderstorms facilitate the production of: (1) sprites by modulating the neutral air density; and (2) MILs via the deposition of energy. The same proposition is used to explain observations of lightnings as well as both MILs and lightning arising out of deep convections.

3 Ocean Science and Services

Wide range of ocean information services, ocean data, information and advisory services are being provided to society, industry, government and scientific community through sustained ocean observations, and constant improvements through systematic and focused research, data, information management and ocean modelling.

3.1 Potential Fishing Zone Advisory Service

The advisories generated using the satellite data, thrice a week (Monday, Wednesday and Friday) on cloud free days during non-fishing ban days, were disseminated to the fishermen of the country using innovative electronic display boards installed with fishing harbours, information kiosks in the fishing villages, Doordarshan, print media, emails, telephone, Fax, SMS on mobile phones and through INCOIS website.

The service is provided in eight local languages to **136** nodes spread in the coast of India. The use of PFZ advisory resulted in the reduction of search time up to 70% in the case of pelagic fisheries.

During the past year, **87** Integrated PFZ advisories were generated for the sectors of east and west coast of India. To strengthen the dissemination systems, during the past year, seven new generation Electronic Display Boards (EDBs) were installed.

During the past year, rapid progress on issuing experimental forecasts for Tuna fishery was made. Thirty-three experimental advisories, were generated and provided to designated Tuna long liners on Tuesdays and Thursdays in map and text form together with satellite images via emails.

To educate the fishermen on how to use and benefit from the Potential Fishing Zone Advisories,

workshops were conducted at Nochikuppam–Santhome on 30th October, 2009 and 20th November, 2009 at Thiruvanmiyur Kuppam on 11th December, 2009 and at Purseine Association office at Bhatkal and Honnavar, on 06th November, 2009. The first two workshops were in Tamil Nadu and the third was in Karnataka.

In addition to the awareness workshops for fishermen, a four-day long training programme on “Fish Forecasting–Generation and Dissemination” was also conducted for the delegates from the Malaysia during 16-19th November, 2009 at INCOIS on request from Malaysian Fishery Department.

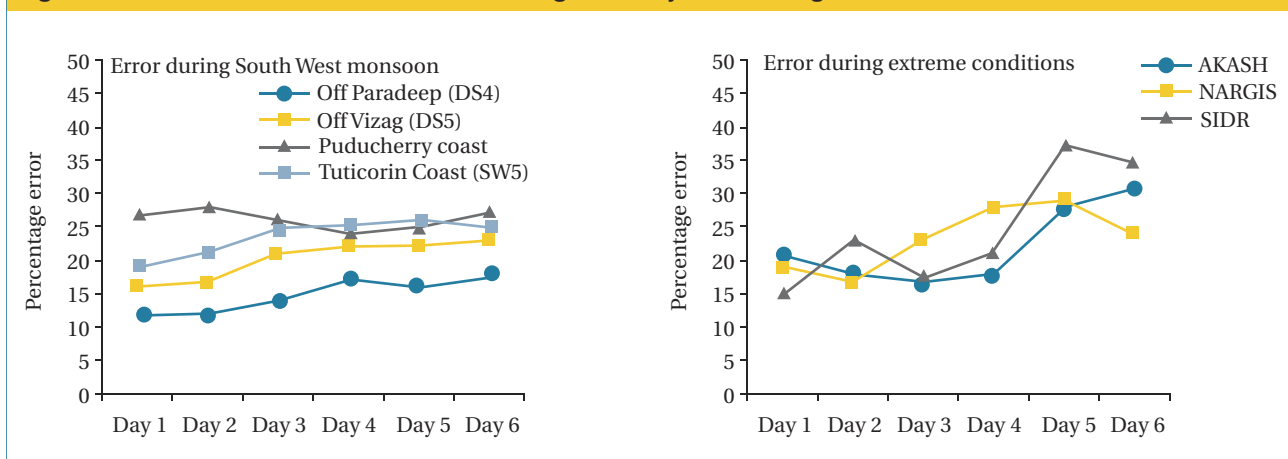
3.2 Ocean State Forecast

This service informs the community about the state of the ocean

The forecasts of ocean state represented by wave heights and wave directions were continued. Reliable forecast of the ocean state is vital for shipping, fishery, offshore industries, ports and harbours as well as for Navy and Coast Guards.

The forecasts on wave heights and directions (separately for swells and waves) were provided for five days at six hourly intervals. The forecasted winds from NCMRWF are used to forecast the waves over the global at 1° x 1° spatial resolution. Regional forecast are made available at 0.5° x 0.5° spatial resolution for seven days at three hourly intervals. The forecasts are disseminated through website. The forecasts are also given for the nine coastal regions adjoining the nine coastal states of India at a finer resolution of 0.25° x 0.25° for seven days at three hourly intervals. Validation of the forecast is done regularly using both *in situ* observations from moored buoys and satellites derived wave heights (Fig. 3.1).

Fig. 3.1: Error estimate of wave forecast using the buoy data during SW monsoon and extreme conditions



Four new parameters, namely, sea surface currents, MLD, depth of thermocline and SST were also added to Ocean State Forecasting services. The ocean general circulation model, Regional Ocean Model System (ROMS), has been set up and adopted for the Indian Ocean region for this purpose. Five day forecasts of surface currents, sea surface temperature, mixed layer depth and depth of 20°C isotherm (as an indicator of the depth of thermocline) are made available for five days in advance over the Indian Ocean region at 0.25°x 0.25° spatial resolution. The forecasted winds and air-sea fluxes available from NCMRWF are used to force the model.

A new web interface was designed to disseminate the forecasts together with the forecasts on waves and winds.

3.3 Ocean Data Management and Dissemination

INCOIS the dissemination of moored buoy data to the users [IMD (Delhi and Chennai), Directorate of Naval Oceanology and Meteorology (Mumbai, Port Blair, Vizag, Goa, Kochi), and Coast Guard (Chennai)] by email and also continued to receive, process and archive the remote sensing data from AVHRR (NOAA-17,18) and MODIS (Aqua and Terra) data in real time. The data products (SST, Chlorophyll, Aerosol Optical Depth, Clouds etc) were generated and published in real time on

INCOIS website as well as provided to the users as per their requirement.

The following *in situ* data from various PIs and institutions were added to the database. The data are processed, quality checked and added to the existing database.

- CTD (677 stations during 1998-2002), ADCP and Sea-truth data from CMLRE
- Wave rider buoy data off Gopalpur (May 08-Jun 09) from ICMAM
- AWS onboard ORV Sagar Nidhi (Jul 2009-till date)
- Hydrographic Data for the Indian Ocean 1976-2005 from NIO
- SeaWifs (1999-2003).

One of the major achievements of the data management group during the past year is the development of an 'Integrated *in situ* data and information system' and its integration with the existing data base. This allows the user for querying, searching, visualising and downloading of *in situ* data from wide variety of *in situ* ocean observing systems.

Other notable achievements are: (i) development of software application for automatic data reception from AWS, conversion, processing and loading that in oracle database; (ii) generation of the metadata from moored buoys in OceanSITES format; (iii) development of codes for the processing of data

from the Argo floats with near surface temperature measurement capability; (iv) publication of the technical report on ‘Mixed layer depth climatology for the Indian Ocean based on Argo Observations’; and (v) the development of software tools for visual quality control of Argo T/S profiles and moored buoy data.

3.3.1 Computational and Communication Facilities

One of the major achievements during the year is the installation and commissioning of High Performance Computing System (HPC) facility. HPC system installed at INCOIS is built over 64 Bit Risc based SMP cluster architecture which delivers peak performance of 7.2 tera-flops with a total of 512 Power 6 processor cores working together and 2 TB of memory including 166 TB usable storage. The system is backed up by reliable and redundant technical support services viz. DG power, UPS power, precision ACs, water process cooling system on 24x7 basis. (Fig. 3.2)

During the year, the web-server was upgraded to achieve better performance and the mail server

was secured with server mail security appliances (CISCO).

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) Ocean State Forecast; and (iv) IOGOOS.

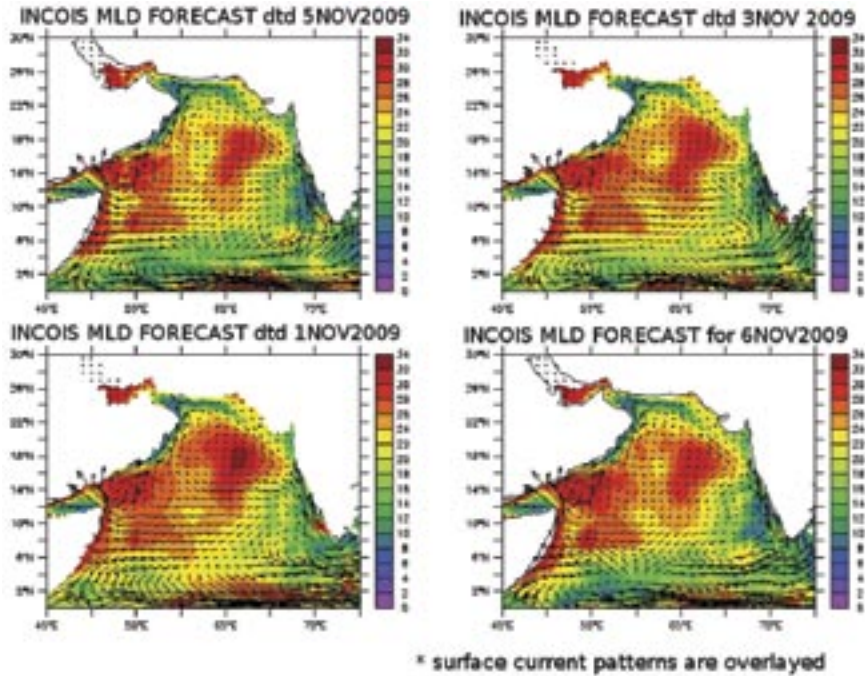
3.4 Ocean Modelling

The ocean modelling activities to forecast the behaviour of Indian Ocean were continued. In order to select a suitable ocean general circulation model for the Indian Ocean Forecasting System (INDOFOS), a model inter-comparison exercise was carried among the five models used and evaluated. After detailed inter-comparisons, Regional Ocean Modelling (ROMS) was selected for INDOFOS. This model was further improved by experimenting with vertical stretching parameters, viscosity and diffusion coefficients. At present, the model is forced with the five-day forecasted surface winds and atmospheric fluxes available

Fig. 3.2: HPC and Technical Facilities



Fig. 3.3: INCOIS MLD and Surface current forecast for 5th-6th November, 2009



from NCMRWE. The INDOFOS gives the forecasts on sea surface currents, sea surface temperature, mixed layer depth and the depth of the 20 degree isotherm. These forecasts are also being validated on a continual basis. (Fig. 3.3)

3.5 Ocean Observation System

An Automatic Weather Station (AWS) was installed onboard ORV Sagar Nidhi to measure wind, air temperature, humidity, air pressure,

long wave and shortwave radiation and SST. The data are being received at INCOIS in real time through INSAT. This was undertaken as a pilot experiment for establishing a network of ship mountable AWS in the Indian Ocean region with real time data transmission through INSAT. The data are used for real time validation of ocean forecasts as well as for weather predictions. (Fig. 3.4)

3.5.1 Argo Network

INCOIS continued to act as Argo Regional Data Centre (ARC) for the Indian Ocean region. 15 floats that use Iridium communication and 22 floats that use ARGOS communication were procured during the year. Eighteen Argo floats with facility for the measurement of near surface temperature were deployed in the Indian Ocean; of which seven were deployed in the Bay of Bengal.

Seventy-nine out of 175 floats deployed by India over the past years are providing subsurface temperature and salinity data. At present, together with the deployments of other countries, 621 floats are active in the Indian Ocean.

Fig. 3.4: AWS onboard ORV Sagar Nidhi



The maps of MLD, temperature at 50, 100, 150 m levels and the depth of 20 deg isotherm, are being used in the experimental tuna forecasts.

The surface currents using Argo drift locations for the past 5 years was estimated which was compared with other climatologies based on ship drifts and surface drifters. The surface current derived from Argo floats are overestimating the surface currents of climatology.

Ocean temperature and salinity data from Argo profiling floats, satellite measurements of sea surface height (altimeter) and the time variable gravity field (GRACE) were used to investigate the causes of Indian Ocean mean sea level rise between 2003 and 2008. It was found that the total sea level rise in the Indian Ocean is due to the contribution of both thermal expansion and increase in water level due to the ice melt.

3.5.2 Other Observations

Twenty drifting buoys and four additional deep sea current meter moorings were deployed in the Indian Ocean during 2009. The XBT and XCTD observations were also continued on a routine basis along major shipping lines (412 XBT profiles and 56 XCTD profiles).

As part of efforts establishing the Bay of Bengal observatory, one mooring consisting of current meters and CTDs at different levels (up to 100m) was deployed in the northern Bay of Bengal during November 2009. This mooring will provide the high frequency temperature, salinity and currents in the top 100 m layer.

RAMA moorings were deployed using organising cruises on board Sagar Kanya and Sagar Nidhi. The cruise organised onboard Sagar Kanya in April 2009 was abandoned due to operational reasons after the recovery of 2 ADCP moorings and the deployment of one. The cruise organised onboard Sagar Nidhi during August-September 2009 (33 days) deployed 6 ATLAS, 2 flux and 6 ADCP moorings and recovered 1 flux, 2 ATLAS and

4 ADCP moorings.

3.6 Ocean Colour Research

Under the programme closely linked with the international initiatives such as ChloroGIN and Indian Ocean GOOS (IOGOOS) continued the generation and dissemination of satellite data products at near real time for the Indian Ocean region countries, namely, India, Sri Lanka, Iran, Kenya, Maldives, Oman, Tanzania and Thailand. An automatic data processing chain (ADPC) was set up at INCOIS to generate ocean colour products using MODIS – Aqua data.

The *in situ*, sampling established along nine transects in the Indian coastal waters continued the sampling once a month. At each station, the Satlantic™ hyperspectral radiometer (Hyper-OCR II) was operated together with the collection of water samples for the estimation of chlorophyll, CDOM and TSM following appropriate sampling protocols and standard operation procedures of deploying the radiometers.

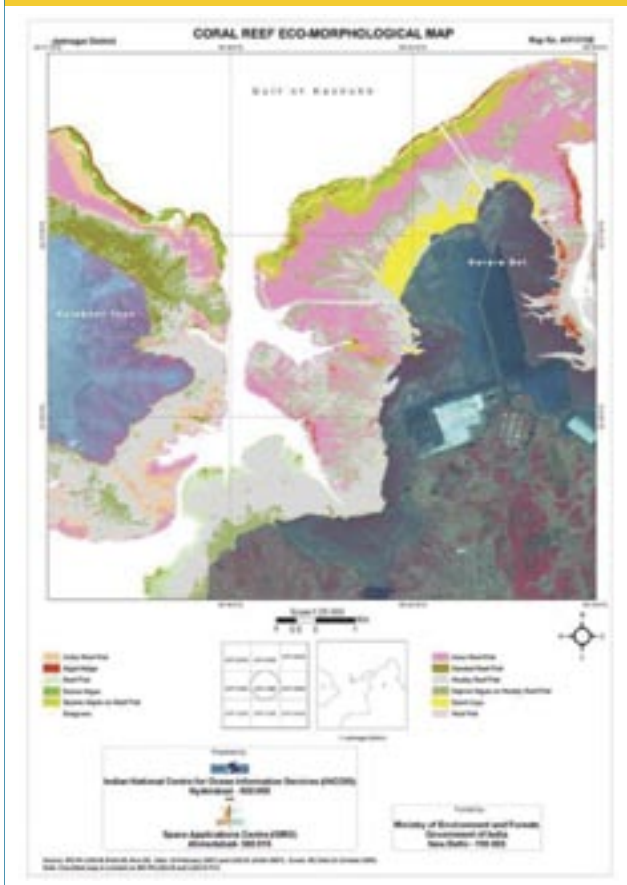
The development of an index based on MODIS – Aqua data to identify the harmful algal bloom in the Indian waters also is in progress.

3.7 Coral Reefs Research

Coral reef enables the formation of associated ecosystems which supports essential habitats, fisheries and livelihoods. In addition, coral reefs also provide an accurate record of the climate change and help in extending our knowledge of seasonal climate variability in many remote tropical oceans.

The activities undertaken towards the research on coral reefs culminated in the preparation of an atlas on eco-morphological classification of coral reefs on 1:25000 scale. The key activities include the eco-morphological classification using IRS-P6/LISS-III and IV data and the validation of classification results through *in situ* campaign.

Fig. 3.5: Eco-morphological classes of coral reefs at Gulf of Kachchh



The Coral reef map for Gulf of Kachchh, one of the study areas, is shown in Fig. 3.5.

The coral health indices were computed using sea surface temperature (SST), suspended sediment concentration and the seasonal eco-morphological classes as variables. The health indices were developed at selected operational ecosystem reference points (OERPs). The OERPs are categorised into three classes – leading, coincident and lagging OERPs. The leading OERPs are the early warning signs of an impending adverse impact, while the coincidental OERPs reflect the current status of the health and the lagging OERPs indicate the extent of existing damage. Annual health bulletins on coral reefs are planned to be published. Such a system enables the decision makers to detect and quantify the changes and attribute the changes to the possible causes.

4 Polar Science and Ocean Research

Scientific research expeditions on annual basis to Antarctica have been launched since 1981 to utilise its singular environment as a great natural laboratory for scientific investigations. India established its first station at Dakshin Gangotri (lat 70°05' South, long 12°00' East) in 1983. The second permanent station Maitri was established at the Schimacher Ranges (lat 70°46' south, long 11°50' East) in 1989. The Dakshin Gangotri station is now being used as supply base and transit camp. The Maitri Station is manned throughout the year for scientific activities. The Antarctic programme is a multi-disciplinary and multi-institutional endeavour. Scientific investigations and researches are undertaken to understand the various phenomenon and processes at the Antarctica and link of some of these with Indian and global processes particularly those of climate and weather. Investigations and observations are also being pursued at the Arctic through the station 'Himadri' at the Norwegian location at Svelbard.

4.1 28th Indian Scientific Expedition to the Antarctica

The 28th Indian Scientific Expedition to the Antarctica was completed on 6th January, 2009, when the last batch of the team sailed on board a chartered vessel *M.V. Emerald Sea*. The team included four foreign personnel (one scientist from Estonia and three helicopter crew members) who joined the expedition in Cape Town, South Africa and 36 scientists and logistic personnel drawn from 23 organisations. (Fig. 4.1)

4.1.1 Scientific Achievements during 28th Expedition

As per the scientific programme approved by the Expert Committee and the National Coordination

Committee on the Antarctic Programme (NCAP), various studies were undertaken in the Larsemann Hills and Schirmacher Oasis, Antarctica. A summarised account is as follows:

4.1.1.1 Meteorology and Atmospheric Sciences

An Automatic Weather Station (AWS) installed onboard the vessel continuously recorded hourly synoptic weather observations which were provided to various institutions for analysis. Uninterrupted synoptic data collection, launching of radiosonde and ozonesonde balloons continued at 'Maitri'.

Magnetic observations using Digital Fluxgate Magnetometer (DFM), 30 MHz analog Rio-meter and a Proton Precession Magnetometer (PPM) were continuously undertaken by IIG scientists. To understand the electrical climate of the Antarctica plateau and some of the problems associated with global change, the Global Electric Circuit (GEC) experiments were also undertaken. Measurements of atmospheric current density, atmospheric electric field and conductivity were made using various instruments.

Fig. 4.1: Prince Albert II of Morocco visit at Maitri



The GPS data is used for various studies, i.e. crustal deformation, ionospheric monitoring, tropospheric water vapour content, etc.

Indian Institute of Tropical Meteorology (IITM) conducted experiments to study the behaviour of ozone and its precursors in marine and polar boundary layer. Aerosol distribution and their temporal variation over ocean were also studied.

The **Space Application Centre (SAC), IIT Kanpur and NCAOR** studied the impact of anthropogenic land-based coarse particles on the Antarctic shelf.

Experiments to study short and long-term variation of ionosphere and the magnetospheric-ionospheric coupling between high and low latitudes during space weather events were conducted by **NPL and the Barkattulah University**. For this, a digital Ionosonde system with two cross delta antennas were installed at Maitri.

4.1.1.2 Earth Sciences

Regional geological mapping over 250 sq km area was undertaken by the **Geological Survey of India**. Geological mapping between latitude 71°59' and 72°07' South and longitude 02°51' and 02°28' East was carried out in the Gjelsvikfjella mountains using Norwegian station 'Troll' as a base. The area is entirely covered by rugged peaks and saddles with the highest peak rising 2000m above m.s.l. Geological studies/observations were also carried out in the Zweissel Mountains using helicopter drop points. A total of 19 drop points were covered in two days. A total of approximately 150 rock samples were collected for further petrological, geochemical and magnetic studies.

Geophysical studies pertaining to seismotectonics and geodynamical processes between the Antarctic and the Indian Peninsula, i.e. Continuous GPS monitoring constitutes a long-term project of **NGRI**. (Fig. 4.2)

Survey of India completed the task of large scale topographical mapping in the Larsemann Hills Region and continued the geophysical studies

Fig. 4.2: Sediment coring in epishelf lake (E12)



for neo-tectonics and monitoring of inter-plate movement in the Antarctic region. Large scale mapping of the designated area in Schirmacher Oasis on 1:5000 scale and contour interval of 5m was completed.

Under a project on building late quaternary Palaeoclimatic history of Schirmacher and Larsemann Oasis, East Antarctica, **Birbal Sahni Institute of Palaeobotany (BSIP)** carried out a multi-proxy approach based on lake sediments collected from the lakes in these areas. The Institute collected moss peat, fossil soil, varves samples to establish an absolute chronology by C^{14} and AMS dating technique.

4.1.1.3 Glaciology

During the year 2009, **NCAOR** collected on surface and sub-surface snow samples from the coastal and inland regions of East Antarctica to study the spatial and temporal variability in snow accumulation and its characteristics from the ice edge to inland polar plateau region as also to evaluate the natural background of aerosols accumulated in the Antarctic snow, their source and the processes involved in controlling the biogeochemical cycling of various species. (Fig. 4.3)

Geological Survey of India embarked upon a long-term project on delineation of the Land-Ice Sea (LIS) interface (Hinge-line) around Schirmacher Oasis, Central Dronning Maud Land (CDML), East Antarctica.

Fig. 4.3: GPR profiling on Polar Ice Cap with 35MHz antenna



Ground Penetrating Radar (GPR) surveys on polar ice sheet using 200MHz and MLF at 35MHz antenna configuration to determine the LIS interface were carried out.

GPR survey using 200MHz antenna was also carried out in the shelf region at the India Bay region. Preliminary studies indicate that the shelf thickness varies from about 28m at the berthing site of ship.

Snow and Avalanche Studies Establishment (SASE) carried out studies related to impact of climatic variability on cryosphere of the Antarctic and Himalaya. SASE and SAC together carried out field study of snow pack in and around the Larsemann Hill and the Maitri area to understand the surface and sub-surface features of snow/ice cover.

Fig. 4.4: Moss Sample (Balsud, Maitri)



An aerial reconnaissance up to the Wohlthat Mountains was taken up to know the surface characteristics of continental ice/snow.

4.1.1.4 Environmental Sciences

Environmental monitoring and impact assessment studies at the proposed location of the third Indian Station at the Larsemann Hills and the adjoining islands of McLeod and Fisher and the peninsula of Broknes and Stornes was continued. The studies included monitoring of ambient air quality before construction of the new station, water quality evaluation of lakes and seawater, and determination of characteristics of soil/sediments and rocks as an aid to collection of environmental data for construction of the station. Assessment of Mercury in air and water bodies at the Maitri and Larsemann Hills was undertaken. Studies on the Influence of Ultraviolet-B radiation on the survivorship and pigment concentration of flora over the Schirmacher Oasis were also conducted. FRI and the Avadh University scholars participated in these studies.

Lichen and moss samples (Fig. 4.4 and 4.5) were collected from various regions of the Schirmacher oasis. The samples were studied for changes in UV absorbing compounds and photosynthetic pigments.

4.1.1.5 Biological Sciences

Zoological Survey of India (ZSI) collected 36 samples of soil and water bodies simultaneously

Fig. 4.5: Lichen Sample (Kailash Hill, Maitri)



for biological studies. Moss inhabiting invertebrate fauna of the Schirmacher Oasis and terrestrial invertebrates at Larsemann Hills were studied for understanding the population dynamics of the available invertebrate fauna at some selected sites. Micro and macro fauna were studied in the Thala Fjord and the Quilty Bay and the continental shelves adjoining the proposed Indian station.

Wildlife Institute of India (WII) monitored birds and mammals during the sea journey and at areas close to stations. Data such as species, location and density (number) were recorded along with data on relevant environmental variables.

At the Larsemann Hills, land based surveys were carried out at the proposed site of the Indian station, the Fisher and Stornes islands, for birds and seals. Aerial surveys were carried out along the coastline from the Clements Bay to western part of the Stornes Island and at the India Bay, and aerial surveys were carried out along the ice shelf (10° 40' E to 13° 30'E) for estimating the population of seals in that stretch.

During the sea journey from Cape Town to the Larsemann Hills, 36 species of birds and 6 species of mammals (hump backed whales, fin whales and others) were recorded. During the sea journey from the Larsemann Hills to the India Bay (Maitri), 21 species of birds and 4 species of mammals were recorded. Significant change in the distribution and abundance of birds has been observed at different latitudes.

Institute of Science undertook physiological responses on the Antarctic krill due to temperature changes. Krills were collected between 55°S and 70°S. Water samples, zooplanktons and bird feathers were also collected during the voyage to and from the Larsemann Hills.

4.1.1.6 Human Medicine and Physiology
Defense Institute of Physiology and Allied Sciences (DIPAS) studied the effect of the Antarctic environment on the Immune Response of 28th Indian Expedition members. It was observed that the level

of cytokines of the summer expedition members were much higher on board in comparison to level at Maitri. The number of sea sick patients also increased on the way back. All the samples were carried to DIPAS lab for further analysis.

4.2 29th Indian Scientific Expedition to Antarctica

4.2.1 Launching of the 29th Expedition

The year 2009 marked the preparation of our plans for the construction of the 3rd Indian Research Base at the Larsemann Hills, East Antarctica. Expedition was planned and executed for putting in place the infrastructure/equipment necessary for the construction of the new station in coming years as well as for undertaking the ongoing scientific activities at the Maitri entailing the necessary logistics for maintaining the year round station.

The 29th expedition team has 53 members (30 for Summer and 23 for Winter) including 29 members for the Larsemann Hill expedition for undertaking activities related to the establishment of the 3rd Indian station. The team is drawn from IIG, CGHS, SASE, NGRI, NPL, IMD, DEAL, ITBP, NCAER, BRO, GSI, SAC, IITM, SIIRM, WII, SOI and NHO. Most of the logistic personnel of winter over team and the summer scientists, led by the expedition leader Mr. P. Elango along with necessary scientific equipment and provisions, were flown to Maitri in November 2009. The Leader and the first batch of 29th Indian Antarctic Expedition was flagged off on 5th November, 2009 by Director, IIG. Scientific activities are in progress as per schedule and ground preparation for installation of Imaging Rio-meter at the Maitri site has been completed.

In order to overcome the unpredictability of the extent of sea ice in space and time in the Larsemann Hill region, two ships, an Ice Breaker and a multi-purpose cargo vessel were engaged. A team of 29 members led by the voyage leader, Mr. Rajesh Asthana, was flagged off for the Larsemann Hills by the Secretary, Dr. Shailesh Nayak in Cape Town on 29th November, 2009 on

board MV Ivan Papanin in the presence of Shri Rasik Ravindra and Shri R. K. Sharma, Director, NCAOR and Adviser, MoES, respectively (Fig. 4.6).

The team reached Larsemann Hills in the close vicinity of our station site on 11th December 2009. After making due assessment of the fast ice conditions, the Ice Breaker Vladimir Ignatjuk led the expedition vessel to as close as 25m of the landing site cutting through multi layered, thick fast ice ranging from 1.2 to 2.2m through the virgin seas over a distance of nearly 40 nautical miles (Fig. 4.7). All the heavy cargo that included 50 ton crane, dozers, vehicles, living modules, etc. have been stationed at the proposed construction site. The approach road from landing site to construction site has been completed as also the helipads.

A three member delegation comprising Dr. Shailesh Nayak, Secretary, MoES; Shri R. K.

Sharma, Adviser, MoES and Shri Rasik Ravindra, Director, NCAOR visited Antarctica from 1-2nd December, 2009 to assess the infrastructure facility and other conditions.

4.3 Indian Arctic Expeditions

The first Arctic expedition of the country was launched during August 2007. During the second Arctic expedition (June-August 2008, India established a research station at Arctic named 'Himadri' at Ny-Alesund in the Svalbard region of Norway. Two phases of the 3rd Indian Arctic Expedition have been launched during June-July 2009 and August 2009. The third phase of the expedition is scheduled to be launched during March-April 2010.

Salient studies at Arctic undertaken during the year are:

Diversity of heterotrophic bacteria in arctic water and sediment with special reference to phosphate solubilisers (CUSAT, Cochin): Sampling was carried out along Kongsfjord for assessment of the culturable diversity of heterotrophic bacteria, coliforms and vibrios. Coliform analysis was carried out to determine the level of microbial pollution in the Kongsfjord. One hundred and fifty three isolates of heterotrophic bacteria, 80 isolates of Vibrios and 70 isolates of coliforms were characterised for determination of their potential role in phosphate solubilisation which is under process.

Genetic diversity of Marine *Vibrios* and other organisms isolated from Arctic realms/fjords (Rajiv Gandhi Centre for Biotechnology, Trivandrum): Sampling of the lake and fjord of Ny-Alesund was carried out to enumerate the *Vibrios*. Total genomic DNA of the sediments were isolated for the study of arctic microbial biodiversity and genomic diversity.

Sulfur cycling in the Arctic environment - Changes in the sulphate reducing activity with fluctuation in temperature (Goa University,

Fig. 4.6: Launching of the 29th Expedition



Fig. 4.7: Chartered ship MV Ivan Papanin on way to Larsemann Hill area



Goa): Samples (water and sediment) were collected for analysing the sulphate reducing activity along Kongsfjord. Measurements were also carried out to estimate the sulphide and sulphate concentration.

Time series and dynamic modelling of plankton organic carbon cycling at the marginal ice edge zone (Visva-Bharati University): To prepare a conceptual model of the role of phytoplankton in organic carbon cycling in ice edge zone of arctic environment, a study on phytoplankton in the coastal ecosystem of Kongsfjorden was carried out during the summer of 2009. Plankton survey was conducted to determine the total count and diversity. The predominant phytoplankton belong to the groups Cryptophyta, Dinoflagellata, Prymnesiophyta, Crysophyta, Bacillariophyta and Chlorophyta.

Diversity of Arctic cyanobacteria (CCMB): Observations of thin cyanobacterial mats were recorded during the beginning of the summer which gradually becomes thicker and darker in colour. Cyanobacterial samples were collected from many lacustrine, glacial and hydro terrestrial habitats to evaluate the abundance and diversity of the regions.

Earth Sciences and Glaciological studies: Scientists from the **Geological Survey of India** carried out a survey on the density profiling of snow sections around station. Various geomorphological features and landforms were demarcated in the pro-glacial area with the help of GPS. Snout limit was demarcated by hand held GPS and comparison of data vis-a-vis that of August 2008 has shown a marginal recession of the Vestre Broggerbreen glacier. The impact of climatic history pattern of the Ny-Alesund region in various sedimentary deposits of the Quaternary period and the Pre-Quaternary geological formations was taken up by scientists from **BSIP**. New Quaternary sites were selected at some altitudinal difference for the palynology and other multi-proxy based palaeoclimatic reconstruction.

Studies on the crustal deformation of Arctic Region using GPS measurements were initiated during 2009-10. A geodetic GPS network comprising three stations was established during August 2009. All the sites were selected in the open area on the ground.

Studies on snow-pack production of carbon monoxide and its diurnal variability over Arctic were initiated during March 2008 by scientists from **National Physical Laboratory (NPL)**. These studies were continued during the summer months of 2008 and 2009. The measurements during 2009 show that the CO concentration varies between 60ppb and 110ppb and surface ozone concentration between 10ppb and 38ppb.

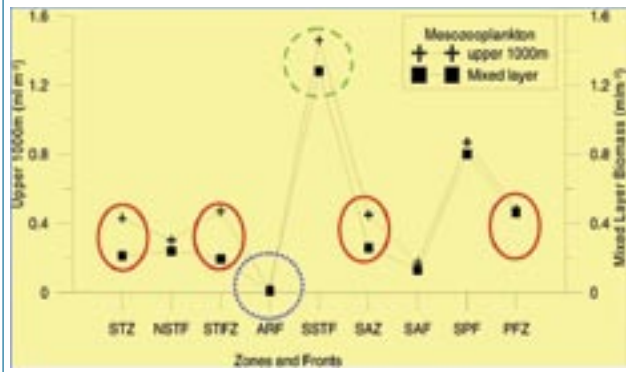
4.4 Southern Ocean Expeditions

The 3rd Southern Ocean expedition was launched onboard chartered ship R. V. Boris Petrov in February 2009. Several research institutions, namely IMD, IITM, SPL, IISc, NIO-Kochi, FSI, CMFRI, SAC, PRL, NHO, KBCAOS, CMLRE, NCAOR and universities of Annamalai, Goa, Karnataka, Gujarat and CUSAT have participated in these expeditions. Some of the salient findings of the expedition are:

Hydrography and productivity characteristics

The Indian Ocean sector of the Southern Ocean includes circumpolar zones and fronts with distinct hydrographic and trophic regimes, i.e. Subtropical Zone (STZ), Subtropical Frontal Zone (STFZ), Sub Antarctic Zone (SAZ), Polar Frontal Zone (PFZ), North Subtropical Front (NSTF), Agulhas Retroflexion Front (ARF), South Subtropical Front (SSTF), Surface Polar Front (SPF), and Subsurface Polar (SSP) Front. Seasonal variations in the solar irradiance and day length, stratification, lack of micronutrients like iron and increased grazing pressure are the major factors that influenced or constrained biological production in this region. Even though broad differences in these controlling factors exist in time and space between the zonal regions, the upper 1000 m of the water column of the

Fig. 4.8: Variations in the mesozooplankton biomass (ml.m⁻³) in the fronts and zones. Uniform biomass can be seen at 4 major zones



main zones, STZ, STFZ, SAZ, PFZ, supported almost identical standing stocks of mesozooplankton during the austral summer (Fig. 4.8).

Oxygen isotope and salinity variations

A combined study of stable oxygen isotopes $\delta^{18}\text{O}$ and salinity of surface ocean waters collected from the Southern Indian Ocean during the late austral summer and early fall helped to trace atmospheric and oceanic processes. Near the equator, a very clear signature of the domination of evaporation-precipitation process was seen, while a precipitation dominated zone was located between two evaporation dominated zones south of the equator. The signature of the Agulhas Front (AF) and the Subtropical Front (STF), recognisable by the sharp decrease in salinity and dissolved oxygen in the surface waters were identified at 41°S and 44°S in February. In March, these two fronts had merged and were located at 41°S.

Vertical structure of temperature

Vertical profiles of temperature along 57°30'E meridional section at 35°31'S, 42°20'S, 47°40'S and 54°S to understand variability of temperature and salinity from different regions have been compared.

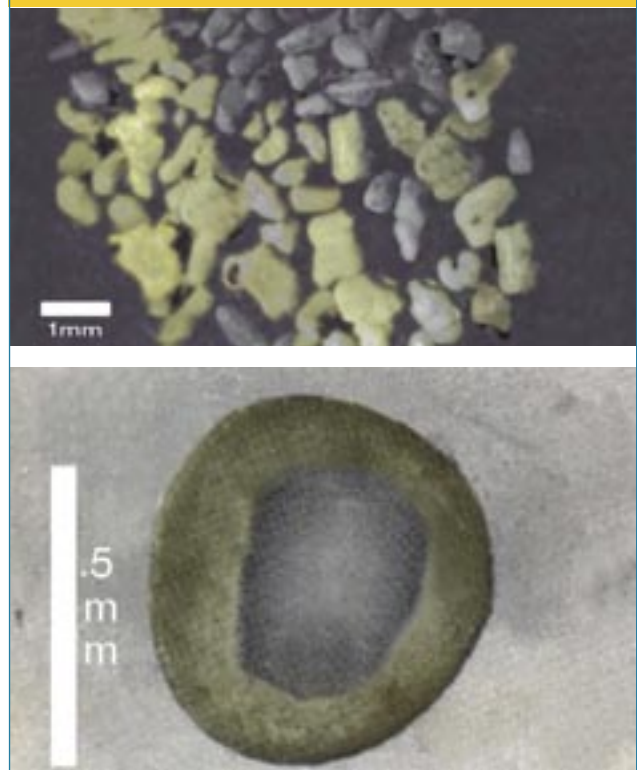
Sedimentology of Enderbyland

Sedimentological analyses carried out at the shelf of the Enderby land showed that the shelf, texturally

follows the normal continental shelf sequence, i.e. shallower depth sediments consisting of gravel, pebbles+ sand, followed in the deeper parts by sand, silty sand and clayey sand. The existence of Oolites in the sand part of the sediment at 220 to 420 m water depth has also been observed (Fig. 4.9).

Under a project linked to IPY, the monitoring of the upper ocean circulation, transport and water masses between Africa and Antarctica was carried out by **NCAOR**. Expendable Conductivity Temperature and Depth (XCTD) probes were utilised by which the temperature and conductivity profiles in the upper 1000m of the water column were obtained. Eighty observations were made along the cruise track from Cape Town, South Africa to the Larsemann Hills in Antarctica.

Fig. 4.9: Light yellow and light white coloured Oolites off Enderbyland shelf, Antarctica (left panel). Cross section of an Oolite showing yellow outer rim enveloping translucent white inner core/nucleus (right panel).



4th Southern Ocean Expedition

The 4th Southern Ocean Expedition consisting of 19 scientific and 1 technical personnel from different national institutions was launched from Goa on the 12th January, 2010 on board TDV Sagar Nidhi for continuing the time series and other scientific investigations in the southern ocean region. Dr. Anil Kumar, Scientist-D, NCAOR is the Chief Scientist of the expedition. The expedition is on its voyage back. The following scientific investigations are being undertaken during the current expedition include biogeochemistry, hydrodynamics, palaeoceanography ocean-atmosphere interaction, carbon dynamics, etc.

4.5 In-House Research and Development

4.5.1 Antarctic Ice Core Research

Field studies to collect Ground Penetrating Radar (GPR) data to study the glaciological features and to decide the ice core drilling locations are underway in the central Dronning Maud Land during the current Indian Antarctic Expedition.

An integrated study using instrumental data from the Halley station and an ice core from the Central Dronning Maud Land in East Antarctica revealed that switches in the Southern Annular Mode (SAM)-temperature relationship are more likely to reflect natural variability in the long wave patterns over the Southern Ocean rather than the influence of an anthropogenic forcing.

The high resolution isotopic and accumulation studies covering a period of past two decades using a shallow firn core were undertaken in combination with the instrumental data of Novlazarevskaya station in the Central Dronning Maud Land region.

Microbiological studies in fresh snow deposits in the coastal Antarctica revealed the crucial role of bacteria in the air-snow biogeochemical cycling in this region.

Glaciochemical and microbiological study of snow from coastal Larsemann Hills, East Antarctica

revealed that elevated nutrient concentrations in ice cap snow are responsible for the observed high bromide concentration in snow related to the enhanced growth of microalgae in snow and subsequent production of bromo-carbons.

4.5.2 Linkages of Indian Monsoon with Southern Indian Ocean and Southern Ocean

Several palaeoclimatic studies have suggested strong correlation between the Indian summer monsoon and northern hemisphere high latitude climate for the past several thousand years. But the linkages of Indian monsoon with the southern hemisphere have received little attention in spite of the fact that the SST and the upper ocean heat content of the southern Indian Ocean is the key factor for the evolution of boreal monsoon and plays a major role in moisture convergence and its supply to the Asian summer monsoon. The Southern Ocean plays an important role in governing earth's climate through formation of major deep and intermediate water masses (e.g., Antarctic Bottom Water, Circumpolar Deep Water, Antarctic Intermediate Water etc.) and through air-sea interactions (such as air-sea fluxes of heat, momentum, freshwater etc.) processes. Present day climatological studies have shown that the Southern Ocean exerts control over Indian monsoon via coupled atmospheric-oceanic pathways. It has been observed that Southern Annular Mode (SAM) in its strong positive phase causes increased SST over the subtropics (~20-35°S) and middle latitudes (~50-60°S), which in turn is followed by enhanced SST in the equatorial Indian Ocean, which weakens the Indian monsoon. But the question remains whether this relationship is persistent and what was its response to past periods of climatic changes. During the ongoing expedition to the Southern Ocean, cores are being collected from the strategic locations on which high resolution isotopic and chemical studies will be carried out that would aid in exploring this correlation. For carrying out isotopic analysis of seawater samples, a new **Marine Stable Isotope lab** is coming up at NCAOR.

5 Ocean Resources

Oceans are important to us in many ways. Oceans are huge storehouse of resources like minerals, oil, food and energy. The greatest unexploited mineral resources on earth are on the deep sea floor, including manganese nodules; cobalt-rich manganese crusts that contain nickel, copper, cobalt, and manganese; and hydrothermal deposits that contain copper, lead, zinc, gold and silver.

5.1 Polymetallic Nodules (PMN) Programme

India is the first pioneer investor to have been allotted a site of 1,50,000 sq km in the Central Indian Ocean Basin (CIOB) by International Sea Bed Authority (ISBA) of United Nations for harnessing the Polymetallic Modules (PMN) lying on the seabed at 4000 to 6000 m water depth. We have retained 75000 sq km area for detailed survey. A comprehensive PMN Programme consisting of four components viz. Survey and Exploration, Environmental Impact Assessment (EIA) Study, Technology Development (Mining and Extractive Metallurgy) is being implemented.

5.1.1 Survey and Exploration

A comprehensive resource analysis has been carried out by sampling at grid interval of 100 km x 100 km, 25 km x 25 km, 12.5 km x 12.5 km of the retained area of 75000 sq km and subsequently at 6.25 km x 6.25 km interval in selected blocks. Bathymetric maps were made for almost the entire 75,000 km² of the Retained Area for nodules in the Central Indian Ocean.

The retained area was mapped with multi-beam survey and sea bottom topography with high resolution acoustic systems. Slow scan mapping

as a part of the First Generation Mine site has been carried out. An area of about 13,965 sq. km has been identified in the Central Indian Ocean Basin (CIOB) based on consistent abundance of high grade nodules found during the survey and exploration work within the Retained Area for the possible location of the first generation mine site. Detailed chemical analyses, interpretation of the samples collected during survey and exploration were also undertaken.

5.1.2 Environment Impact Assessment Study

In order to study the effects of sediment re-suspension and resettlement, monitoring of the environmental parameters were carried out by collection of samples at the test and reference areas for the benthic disturbance experiment periodically. As a part of this study, a dimensional model for sediment dispersion has been developed and integrated with the graphical user interface. Initial runs of the model have been carried out for testing the model set-up using constant current flux along the open boundaries. The Model is capable of predicting suspended and bed load sediment movement for any geographical locations including deep sea sediment sludge disposal into seawater, dispersion of plume and settling. The model can be used for either continuous or instantaneous plume sedimentation sources and the model takes into account processes including advection and dispersion.

During the year 2009, one cruise was conducted for environmental data collection in the Central Indian Ocean Basin (CIOB) involving box coring operations and CTD data collection. Onboard analyses of samples for environmental parameters are continuing.

5.1.3 Technology Development (Extractive Metallurgy)

A demonstration pilot plant activities were completed successfully for extracting copper, nickel and cobalt at Hindustan Zinc Limited (HZL), Udaipur. The data generated during the demonstration campaigns is being used for evaluation and validation of process packages.

Various R&D campaigns were carried out at the participating laboratories [Institute of Minerals and Materials Technology, Bhubaneswar (Formerly Regional Research Laboratory (Bhubaneswar) RRL(B)) and National Metallurgical Laboratory, Jamshedpur (NML(J)) for further refinement of package developed by both laboratories.

Institute of Minerals and Materials Technology (IMMT), Bhubaneswar, continued its R&D activities directed towards value addition of manganese bearing product, alternative uses of leach residue generated from its own process and various technology improvements.

The following activities were carried out at National Metallurgical Laboratory (NML), Jamshedpur during 2009:

- Reduction roasting of sea nodules with coal and leach ammoniacal leaching on 1 Kg scale were completed with metal recoveries of Copper and Nickel >90% and Cobalt >70%.
- Ammoniacal leaching of coal reduced sea nodules at 10 Kg scale with metal recoveries of Copper and Nickel >90%, Cobalt >70%.
- Reduction smelting of sea nodule with variation of coke was optimised on 20 Kg scale with metal recovery value of Cu: 91%, Ni: 93% & Co: 85%.
- By addition of elemental sulphur, matte containing 20-24% sulphur was produced from the Cu-Ni-Co-Fe alloy.
- Acid pressure dissolution of matte with >97% Cu and >98% Co and Ni recoveries were achieved.
- Cu extraction from leach solution using solvent DEPHA and LIX84 was achieved with more than 99% separation efficiency.

5.2 Delineation of Outer Limits of Continental Shelf

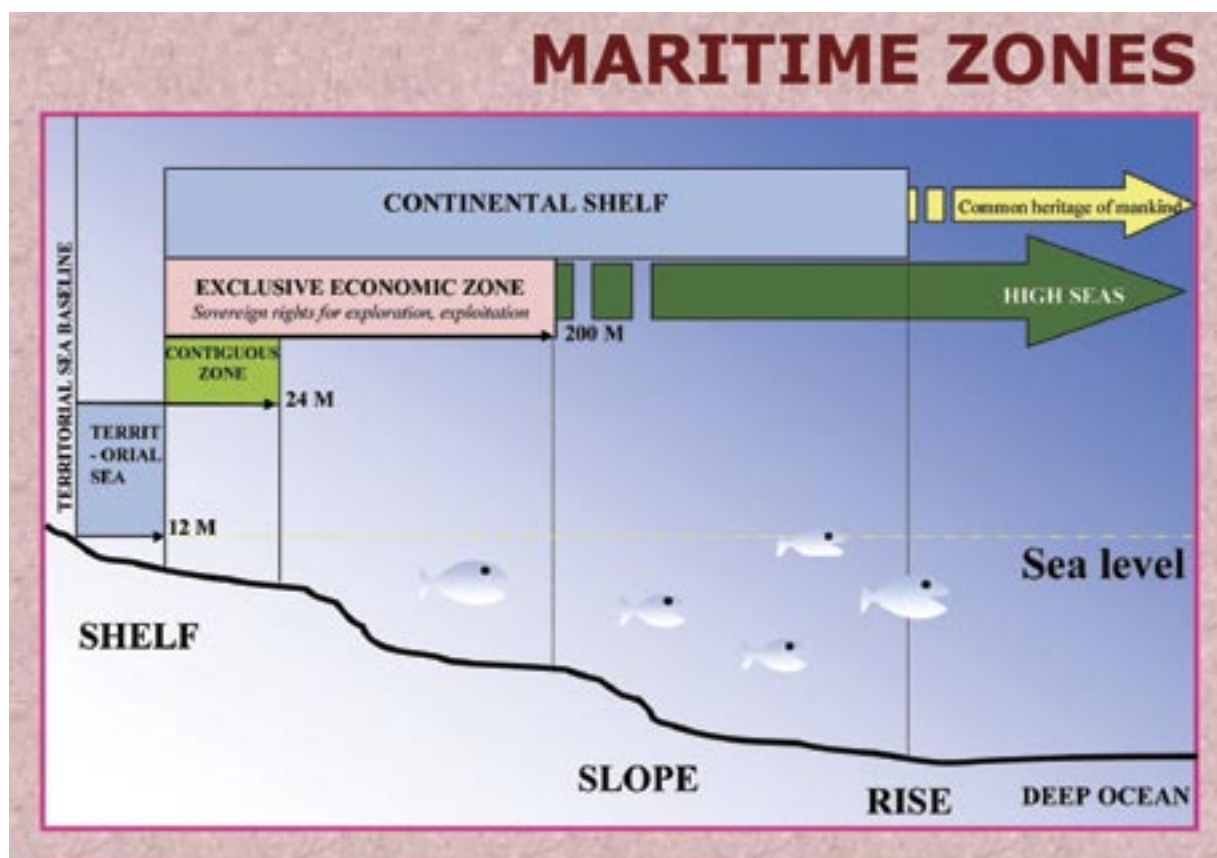
The United Nations Convention on Law of the Sea (UNCLOS) allows coastal states to establish boundaries of the territorial sea, the contiguous zone and Exclusive Economic Zone (EEZ) from their baselines. The EEZ extends up to 200 nautical miles (M) (1 nautical mile is about 1.85 km), where the states can exercise exclusive economic rights over the resources of the water column as well as of the seabed and subsoil thereof.

The continental shelf as defined under UNCLOS comprises the seabed and subsoil of the submarine areas of a coastal State that extend beyond its territorial sea throughout the natural prolongation of its land territory to the outer edge of the continental margin (comprising the geological shelf, slope and rise), or to a distance of 200 M from the territorial sea baselines where the outer edge of the continental margin does not extend up to that distance. (Fig. 5.1)

The outer limits of the Continental Shelf where it extends beyond 200 M have to be established by physical surveys involving the determination of the water depth and the thickness of the sediments.

Considering that India's continental shelf extends beyond 200 M from the territorial sea baselines, a major multi-institutional national programme was undertaken of collecting, processing, analysing and documenting the requisite scientific and technical information for delineating the outer limits of the continental shelf in the Arabian Sea and the Bay of Bengal including the western offshore areas of the Andaman and Nicobar Islands. The task was implemented by the National Centre for Antarctic and Ocean Research as a lead agency in association with Naval Hydrographic Office, National Institute of Oceanography and National Geophysical Research Institute, Geological Survey of India, Directorate General of Hydrocarbons, and Oil and Natural Gas Corporation.

Fig. 5.1: Schematic representation of various Maritime Zones



In one of the largest ever marine geophysical surveys conducted by India, over 31,000 line km of multi-channel seismic reflection, gravity and magnetic data together with bathymetric information were acquired along 42 pre-determined profiles. In addition, 100 Ocean Bottom Seismometers (OBS) were deployed with a significant retrieval rate of 92% and high quality wide angle seismic reflection and refraction data were obtained at critical locations.

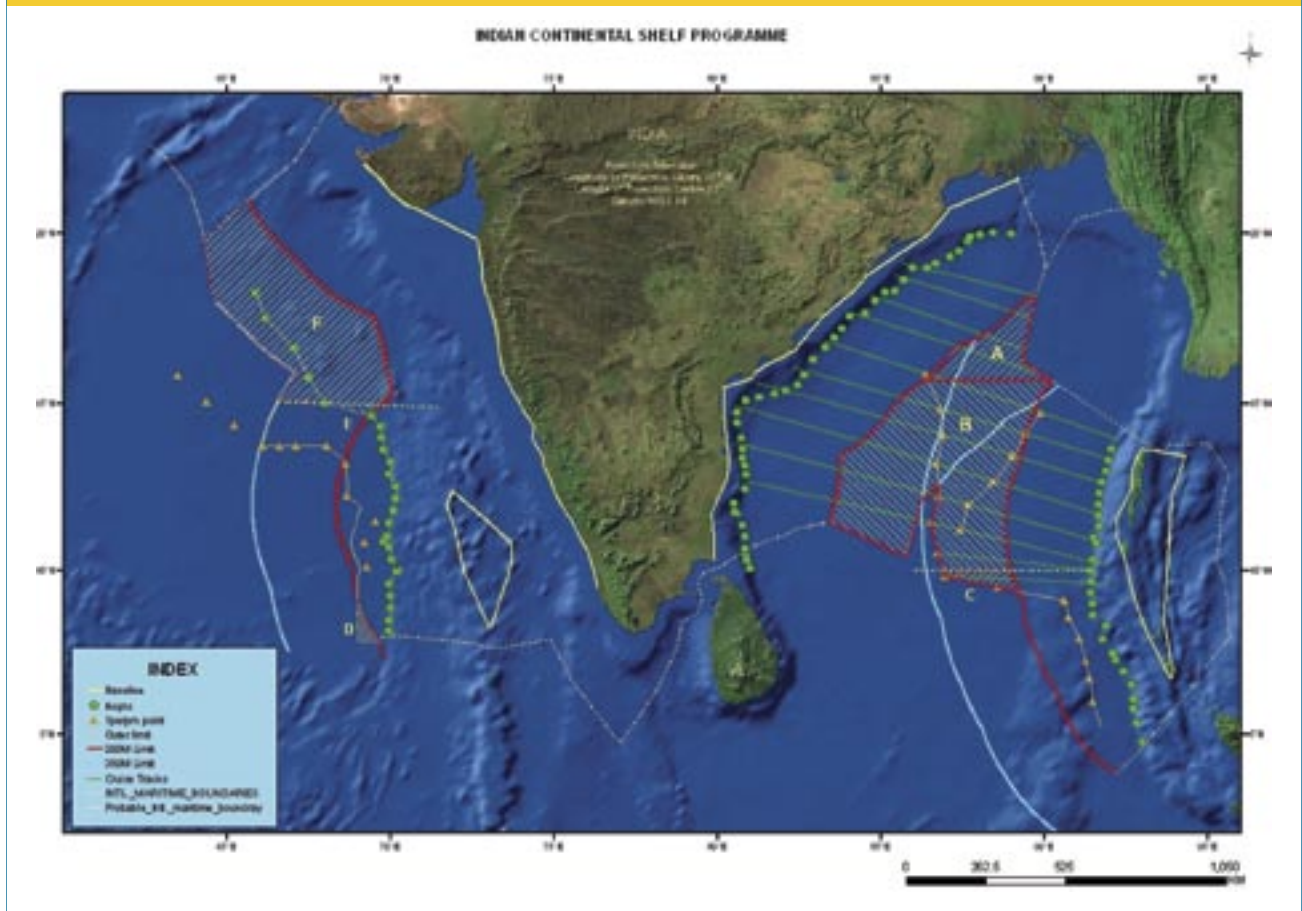
The integration of the analytical results and their documentation in accordance with the Scientific and Technical Guidelines of the UN CLCS were carried out at the National Centre for Antarctic and Ocean Research (NCAOR) by a team of scientists from several institutions. The final documents were again reviewed by a Group of Experts constituted by the Ministry of Earth Sciences. The entire

data has been organised on a suitably structured RDBMS, as a centralised national facility.

On 11th May, 2009, India filed to the CLCS, her first partial submission under the provisions of Article 76 for a continental shelf extending beyond 200 M from the Indian baselines (Fig. 5.2).

The Data Centre currently in an advanced stage of development would describe the content, format and access methodology with abundant metadata describing the primary details in terms of when and how the data was collected, the nature of data collected, how the data was processed, necessary supporting information that went in to the processing, etc. The database format is also planned to be flexible enough to allow for both vertical and lateral growth. In addition, it would facilitate: (i) migration of data

Fig. 5.2: The partial claim of India over the continental shelf extending beyond the 200 nautical miles of Exclusive Economic Zone. The claim is indicated by region A & B with closely spaced oblique lines in the Bay of Bengal (bound by the red lines) and in Arabian Sea extending beyond the red lines in region F.



from its various formats to the database; (ii) customised GIS-based interface for easy retrieval of data based on various scientific inputs; (iii) easy data input interface to insert new data from time to time; (iv) queries based on different scientific inputs; (v) input of historical data for the purpose of comparing and analysis; and (vi) web based input/output interface to facilitate the application to run on internet/intranet with login authentication.

5.3 Comprehensive Topography Survey of Exclusive Economic Zone (EEZ)

India has an Exclusive Economic Zone (EEZ, extending to 200 M from the coast) of about

2.02 million sq km. Our EEZ has many economically exploitable minerals and hydrocarbon resources. The project on the topographic survey of EEZ is a continuation from X Plan, being implemented by three national institutions, viz., National Centre for Antarctic and Ocean Research (NCAOR, Goa), National Institute of Ocean Technology (NIOT, Chennai) and National Institute of Oceanography (NIO, Goa).

The main objective is to prepare a comprehensive seabed topographic map for the entire EEZ of the country using multi-beam swath bathymetric systems which will be a boon for the defence, communication, navigation, oceanographic research, etc.

The work carried out by NCAOR, NIO and NIOT are summarised below:

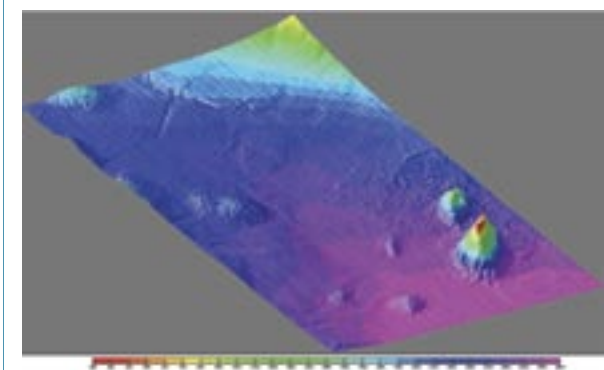
| Organisation | Deep water beyond 500m Total area about 1.5 million sq km | Shallow water up to 500m Total area about 0.5 million sq km | Area covered |
|--------------|--|--|---|
| NCAOR | 3.1 lakh sq km area surveyed | - | Andaman and Nicobar, Lakshadweep |
| NIO | - | About 4000 sq km area surveyed | off Marmagoa, off Bombay High and off Malpe, Karnataka coasts |
| NIOT | - | 8300 sq km area surveyed | off Pulicat, Sri Harikota, Ennore, Cuddalore, Kovalam, Nagapattinam region etc. |

Major findings of the survey are presented below:

- i) The survey confined between Ninety east Ridge to its west and Andaman Trench in east, revealed the presence of a long river channel exhibiting meandering disposed more or less in NNW-SSE (North North West – South South East) direction.
- ii) High resolution acoustic seafloor geophysical mapping studies, involving swath bathymetry and shallow acoustic seismic sediment profiling carried out in the Lakshadweep region, revealed the presence of two seamounts as shown in Fig. 5.3.
- iii) Several mound-like features were found in the survey area to the west of Kilthan Island.

- iv) The survey also provided the first detailed description of pockmarks noticed off-Goa continental slope ($15^{\circ}34'N$, $72^{\circ}50'E$) of the eastern Arabian Sea at approximately water depth of 200m.
- v) A 3D map of a submarine terrace in Mumbai high area off Tarapur was obtained through the multi-beam echosounding survey. Further, a near oval shaped, extremely even (slope 1:10) Fifty-Fathom-Flat (FFF) is a prominent topographic feature along the west coast off Mumbai, India. This has been mapped.
- vi) Gaveshani bank and another coral bank (3D map) off the Karnataka coast have also been mapped.

Fig. 5.3: Site I: Seamounts off Lakshadweep



5.4 Gas Hydrates Exploration

Gas hydrates with their abundant resource potential is emerging as a potential fuel resource. The preliminary assessment of geological condition and limited available seismic data suggests high possibility of occurrence of large quantity of gas hydrates within the EEZ of India.

The multi-channel seismic data collected by various organisations has been evaluated and based on the data, two promising sites of 100 km x 100 km were identified in the Krishna-Godavari (KG) and the Mahanadi basins for detailed survey.

The following are the major outcome of the gas hydrate studies:

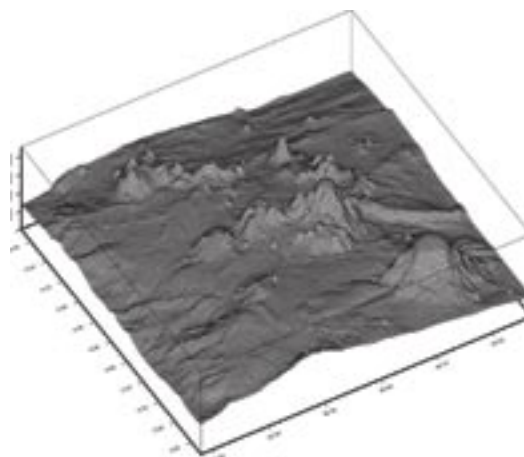
- Acquisition of high resolution sparker data has been done in KG Basin on Cruise during the year 2009.
- Developed techniques for:
 - Demarcation of the lateral extension of gas hydrates and free-gas bearing sediments based on velocity anomalies across the Bottom Simulating Reflectors (BSR) along a seismic line in the Makran accretionary prism.
 - Quantification of 12-14.5% gas hydrates and 4.5-5.5% free-gas in the Arabian Sea using cooperative travelttime inversion and amplitude modelling.
 - Estimation of ~35% gas hydrates in the fractured shale in the KG Basin for the first time based on sophisticated effective medium modelling of sonic log data.
 - Demonstration through a field example in western Indian margin that hydrate-bearing sediments have low attenuation. This aids in detecting gas hydrates and qualifying a BSR for gas hydrates.

5.5 Studies on Cobalt Crusts Exploration

In view of growing industrial importance of cobalt (Co) and absence of land-based workable ore deposits of cobalt in India, the preliminary exploration for cobalt-enriched seamount ferromanganese crusts was launched during the X Plan. The results of this exploration provided preliminary indications of occurrence of such deposits on the Afanasiy-Nikitin Seamount of Equatorial Indian Ocean.

Multi-beam bathymetric mapping of the Afanasiy-Nikitin Seamounts (ANS) has been carried out only for the northernmost region of the ANS. One cruise was undertaken and around 20000 sq km of the southern ANS area was surveyed. The data was merged with those previously surveyed (northern 10000 sq km) and a first multi-beam (3D bathymetric) map of the ANS (Fig. 5.4) was

Fig. 5.5: Multi-beam bathymetric of the northern 10000 sq. km area of the Afanasiy-Nikitin Seamounts. Both 3D-Colour and Mesh maps are presented along with a regional reference map showing location of these seamounts in the Equatorial Indian Ocean.



(The reference map is from NGDC DATA CENTRE, USA, and the ANS Maps are published by the Cobalt Crust Team in J. Earth Syst. Science, 2007)

generated. This has provided the basis for planning future sampling work.

Preliminary exploration had identified a monotonous plateau region in the southern part of ANS. The initial reconnaissance sampling during Cruise (June-July 2009) has yielded few crust samples containing up to 0.5% cobalt as against average of 0.65% cobalt in northern region. The results of this cruise and follow-up analysis work indicated a possibility of occurrence of crust deposits in the southern plateau region also.

5.6 Studies on Hydrothermal Sulphides

The Ridge project was initiated to understand the tectonic and oceanic processes along the Indian Ridge system and backarc basin. Carlsberg Ridge (CR), Central Indian Ridge (CIR) and the Andaman Backarc Spreading Centre (ABSC), representing slow, slow-intermediate, and backarc environment ridge systems were chosen as the areas of study.

One cruise was conducted during 2009 to the Carlberg Ridge. Mapping and tracking of the hydrothermal plume, close grid water sampling, and Conductivity, Temperature and Depth (CTD) survey along with multi-beam mapping have been carried out during the cruise. Processing

and analysis of data acquired during the first Ridge cruise has also been carried out. The results provided evidence for the occurrence of an active vent field over the Carlsberg Ridge in the northern Indian Ocean.

6 Ocean Technology

The Ministry has been pursuing multi-disciplinary technology developments towards harnessing the resources from oceans in sustainable manner primarily through NIOT, an autonomous institute under the MoES. Details of significant technology developments during this year are provided below:

6.1 Deep Sea Mining Technology

Oceans are endowed with deep ocean resources such as Polymetallic Nodules (PMN) rich in manganese, copper, nickel and cobalt, and gas hydrates, a potential energy source of the future. The challenging tasks that daunt the exploitation of the reserve are primarily the deep ocean depths and very high pressure.

6.1.1 Remotely Operable Submersible

Submersible is a type of underwater vehicle that is transported to its area of operation typically by

a mother vessel. The submersible equipped with cameras and mechanical devices such as movable arms is normally used for researching the ocean and ocean floor. They aid in conducting undersea surveys, searching for new mineral deposits, performing salvage, and monitoring installations such as oil rigs and pipelines.

Considering these requirements, a remotely operable submersible ROSUB, an electric work class underwater vehicle was developed in collaboration with Experimental Design Bureau of Oceanological Engineering (EDBOE), Moscow. The remotely operable vehicle, ROSUB-6000, is a heavy work class under water vehicle with a depth rating of 6000m. The first deep water *qualification* sea trial of ROSUB-6000 system was conducted during April 2009 at Chennai offshore. Interfaced sensors were tested and qualified for their envisaged functionality during the deep water sea trials (Fig. 6.1 and Fig. 6.2).

Fig. 6.1: a, b, ROSUB and its operation

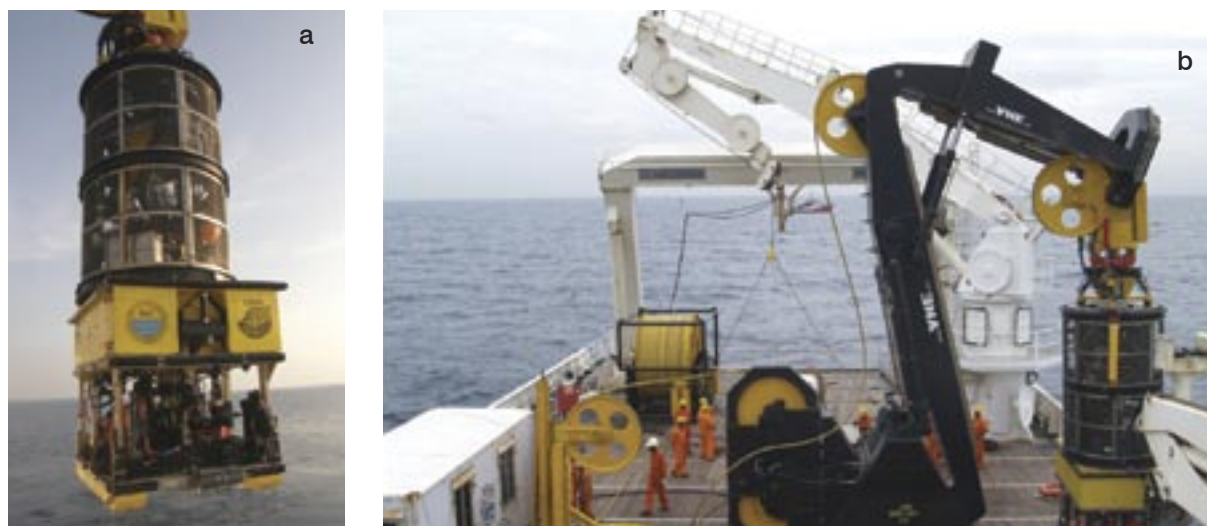
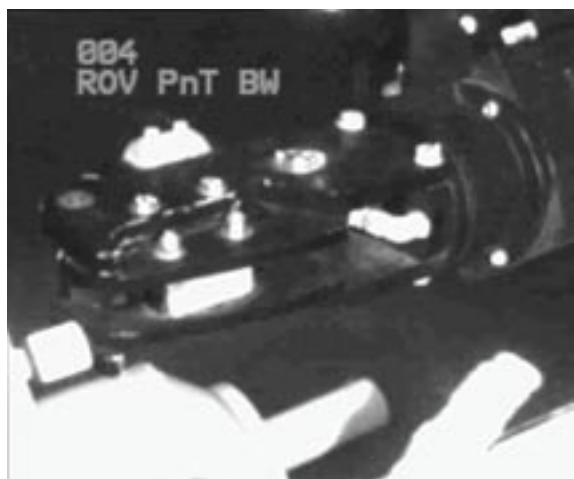


Fig. 6.2: Water sample collection using robotic arm of ROSUB in deepwater



The second deep water exploration trial of ROSUB-6000 system has been performed during October 2009 at the gas-hydrate site in the KG Basin off Kakinada. During this trial, the vehicle has been manoeuvred to acquire under water videos, bathymetry, water sample, sediment core sample and several other useful data. Interfaced sub-sea sensors were tested and qualified during the deep sea work. Deep water organisms such as holothurians, serrated whip coral colony, fishes and shrimps were observed first time in Indian deep waters, in real time. These organisms, indirectly, indicate the presence of nearby methane venting sites.

6.1.2 Deep Sea Mining System

Earlier, NIOT had developed a crawler for qualification at 500m depth. This existing deep sea crawler at NIOT is being modified with the addition of collector, crusher, enhanced slurry pump and hydraulic power pack to the crawler. Its estimated weight in air with collector-crusher system is approximately 16 tons. The nodule collecting device of this system would pick up manganese nodules from the deep ocean floor, separate the sediments, and convey them to the next stage of crushing. The nodules collected by the collector would be transferred to the crusher through a belt conveyor. The

details of various sub-components are briefly provided below:

Pick up device

A mechanical tinned pick up device has been designed, fabricated and tested. The total structure was built with aluminium except the tines to reduce its weight. The system is operated hydraulically. The comb like structure conveys the nodules collected from the sea bed to the collector conveyor belt. Initially, a single unit was fabricated and tested in a bentonite tank to evaluate its performance. Based on the performance tests, two more units were fabricated. The pick up unit was integrated with the developed collector and crusher system and tested with the new sub sea valve pack. The integrated test along with collector, pick up and crusher system is being tested in a separate test set up in a bentonite tank with actual manganese nodules.

A collector unit having a belt conveyor was designed and fabricated indigenously. The structure similar to pick up device is completely built of aluminium to reduce the overall weight and the same was tested for its performance. Integrated tests with pick up and crusher are being carried out.

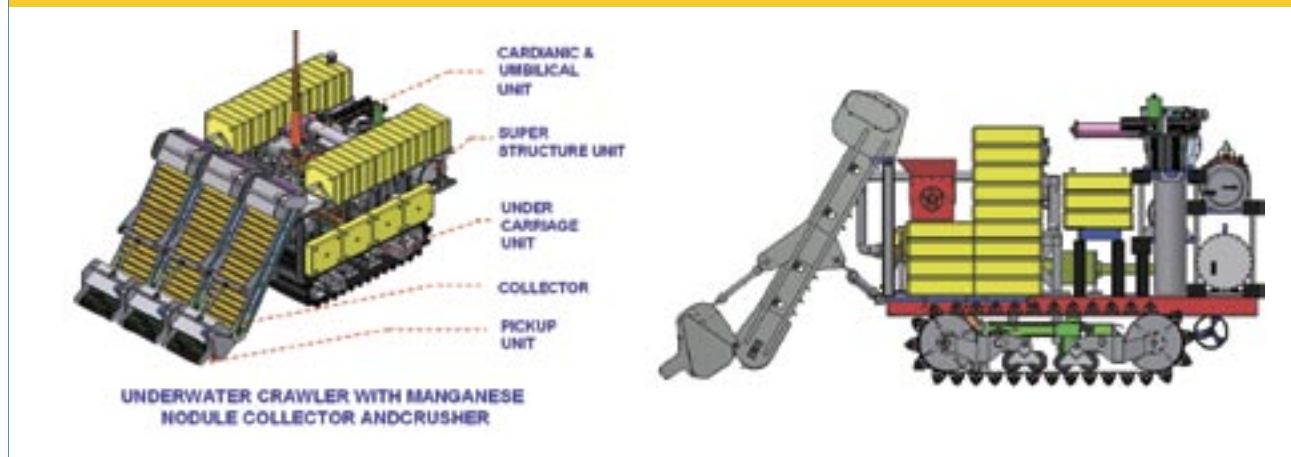
Pumping system

The pump has been designed and developed with a S-transfer type head to handle solids of 30 mm size. The pump is undergoing tests at the hydro transport test set up developed at IIT, Madras. At present, pumping trials of solids up to 20m were done. Experimental studies were done for flow rates varying from 8.72 – 58.55 m³/hr for pumping clear water and for slurry flow from 40 to 60 m³/hr.

Instrumentation and control

The Underwater Data Acquisition and Control (DAC) system is one of the most important component in the control of underwater mining machine on seabed. The existing DAC system was augmented to meet the requirement of the new collector and crusher system. Due to the expansion of the system, the hardware is split/distributed

Fig 6.3: Assembled unit of mining system



in two parts having two separate pressure rated enclosures.

Fig. 6.3 shows the overall view of the assembled unit of mining system. The integration of collector, crusher and crawler systems is under progress.

6.1.3 Autonomous Coring System (ACS)

Remotely operated Autonomous Coring System (ACS) is a device equipped with tool handling system and cam gate assembly to drill each section of about 3 m [approximately 100m sediment core], retrieve the sample, and store in magazine at the seabed in deep sea operation [3000 m]. The system is first of its kind and it is under development in collaboration with M/s Williamson & Associates (W&A), USA since August 2007.

The system has been designed for ground truth validation of gas hydrate occurrence in Indian continental margins. It is capable of collect 100 m long cores from ocean basins up to a maximum depth of 3000 m. ACS employs wire-line drilling technology and the project ensures complete technology transfer (from design to system realization) and sea trials in India.

ACS Trials

Integration of the components was done and their performance was tested for stability, during the parking lot testing and sea trials at the Puget Sound, in Seattle, U.S.A (Fig. 6.4). The ACS system

was tested for its envisaged functionality when it could drill 67.27m through a cemented floor, during June 2009. A total of 112m of cement core has been drilled and recovered using the system on land. An under water core of 35.59 m in length was obtained during first shallow water sea trial at the Puget Sound on July 2009. A 55.14m long core was drilled during the second phase of shallow water trials at the Puget Susan in Seattle, during August 2009. The system has been qualified for operation in water depths of a maximum of 100m.

Fig. 6.4: ACS system being deployed at the Puget Sound



The existing *in situ* soil testing system is being upgraded for soil testing up to a depth of 6000m in ocean.

6.2 Desalination

6.2.1 Thermal Power Plants

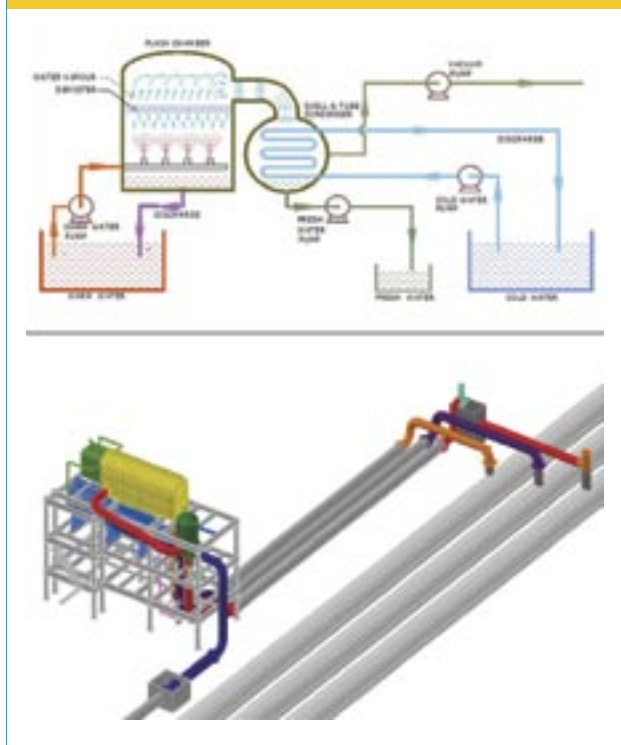
Thermal power plants discharge warm water from their condensers. The process that involves transfer of tremendous levels of energy usually includes heat recovery systems like cooling towers or heat dissipating open channels before the condenser-reject-water is discharged back into the surrounding environment at acceptable temperatures. Consequently, the resultant thermal pollution by the power plants is a serious issue today. An efficient way to utilise the heat available in the condenser-reject-water would reduce the load on the cooling towers and in turn the resultant thermal pollution. One of the aspects of Low Temperature Thermal Desalination (LTTD) is that it transfers the available heat from warmer water to the colder water while generating fresh water from the warm water. This aspect could therefore, be aptly used in thermal power plants resulting in the double benefits of cooling the condenser reject-water and generating the fresh water. A small temperature gradient of about 8°-10°C, as is the case with most power plants, would be sufficient to utilise the concept.

This concept has been demonstrated in North Chennai Thermal Power Station (NCTPS). The 600 MW NCTPS plant discharges about 100,000 m³/hr of condenser-reject-water at about 37°C. In order to reduce the thermal pollution issues arising out of mixing this water with the nearby seawater at 29°C, NCTPS lets the water run through a long open channel where the water is brought down to about 33°C.

A conceptual and schematic view of the plant is shown in Fig. 6.5.

Here, the salinity of the freshwater was reduced from 35000 ppm of the seawater to about 24 ppm, the quality well suited for drinking water as well as the use in the boilers.

Fig. 6.5: Conceptual and Schematic view of LTTD plant installed in NCTPS



6.2.2 Desalination Plants at Islands

After successful commissioning of land-based demonstration plant in Kavaratti producing more than 1 lakh litre per day of freshwater in May 2005, similar plants in three more islands are being established at the Agatti, Andrott & Minicoy islands of Union Territory of Lakshadweep.

The major work of welding and deployment of pipe for the cold water intake has been completed at all the three islands. The construction of sump at Agatti is in final stages and it is ready to be placed in its location. The bridge connecting plant to the shore is in progress in full swing at Agatti. In Minicoy, sump has been placed in its location and the construction of bridge is in progress. The construction of plant structure at both the islands is in advanced stage. All the mechanical components required for the establishment of the plant have reached the site and commencement of erection of plant components will start shortly after the Reinforced Cement Concrete (RCC) plant structure has

been raised to 19m height. All these plants are expected to be ready by March 2011.

6.3 Marine Sensors and Electronics

The objectives of Marine Sensors and Electronics activities are to develop and demonstrate underwater electronics/sensor technologies for oceanographic applications. The major achievements are briefly detailed below:

The development of 250kW underwater motor was taken up in collaboration with M/s PSG Industrial Institute, Coimbatore. The design of the 250kW motor was completed and sub-components have been fabricated. The assembly and integration of the motor is under progress.

A Bottom Pressure Recorder (BPR) for Tsunami early warning system has been indigenously developed and successfully tested at the Acoustic Test Facility (ATF) of NIOT. The BPR was taken for field trials and tested at 160m water depth successfully.

In addition to these, many sub-components like diodes, capacitor, transformer and battery were successfully tested at 600 bar pressure for longer durations.

A 2-16kHz prototype indigenous sub-bottom profiler transducer for operating at 30 bar pressure has been developed and successfully tested with rubber encapsulation. These encapsulation would give more reliability and life. The work has been carried out in collaboration with M/s Vajra Rubber Products, Irinjalakkuda, Kerala. Further, a prototype laboratory model 5x10 Cymbal array operating in the frequency range 10-100kHz has been successfully developed and tested.

6.4 Demonstration of Shore Protection Measures

The objective of this project is to provide sustainable, environment-friendly solutions for stabilising the shorelines undergoing erosion

or accretion, as well as to provide solutions for improvement of the environmental quality. The implementation of this scheme is being carried out for Ennore. It is facing severe erosion to the north and accretion to the south of the Ennore port. The primary and secondary data collection, preliminary numerical modelling and preliminary design of a shore parallel, offshore low crested structure with geobags, have been completed. The data collected includes bathymetric, geophysical, geotechnical and oceanographic data. The details of data indicating locations and durations are provided Fig. 6.6. The data is being analysed and the mathematical models are being improved based on the site data.

An assessment for providing sustainable means for erosion prevention along a stretch of the Puducherry coast was carried out during 2007-08. The initial study suggested immediate stabilisation measures using sandbag revetments and long-term measures involving beach nourishments.

6.5 Ocean Science and Technology for Islands

The programme on Ocean Science and Technology for Islands (OSTI) is directed towards improving quality of life of islands. It includes six major activities such as Open Sea Cage Culture, Marine Micro Algal Biotechnology, Marine Microbial Biotechnology, Island Resource Information System, Marine Bioinformatics and Materials for Marine Applications. In addition to the above mentioned activities, two multi-institutional projects, namely, Development of Potential Drugs from Ocean (DPDO) and Coastal Ocean Monitoring and Prediction System (COMAPS) are also being conducted in the Andaman and Nicobar Centre for Ocean Science and Technology (ANCOST) at Port Blair. Some of the major activities are briefly enumerated below:

- a) **Open Sea Cage Culture:** Under this activity, a survey was conducted at the fish holding facility located near the Havelock Island and the Minnie Bay, Andaman Islands, for the initiation of fish culture in open sea

Fig. 6.6: The Ennore site



cages. Attempts are also being made to demonstrate open sea cage culture of seabass in collaboration with the Rajiv Gandhi Centre for Aquaculture and The Waterbase Limited, Nellore. Growth studies conducted on juveniles of black spot snappers and *carangids sp.* had shown encouraging results.

b) Marine Micro Algal Biotechnology: Mono-species cultures of 103 strains of marine micro algae isolated from the Bay of Bengal and the Andaman sea are being maintained in agar slant. Isolation of micro algae from the coastal water of the Arabian Sea was carried out onboard FORV Sagar Sampatha cruise No. 272. Experiment on doubling time and biomass production is in

progress. A total of 29 isolates were screened for growth, biomass and lipid production. The biomass and lipid production ranged between 50 and 418 mg/l and 4.4 to 30.93 mg/100 mg of dry biomass. Further screening experiments for biomass and lipid production by the marine micro algal isolates are in progress. A preliminary experiment on mass culture of marine micro algae in tubular photobioreactor has been carried out. Exponential increase in cell count and biomass was recorded on the second day. A maximum wet biomass of 4.4 Kg/tonne with a maximum lipid production of 240 mg/g was recorded on fifth day. Further experiments on selected algal isolates are in progress. Tubular photo bioreactor of 133mm diameter transparent polycarbonate pipe

1000 l capacity is being developed at the Kavaratti Island for experimental scale mass culture of marine micro algae using nutrient rich deep seawater drawn for low temperature thermal desalination plant. Evaluation of different carbon sources for heterotrophic and mixotrophic production of xanthophyll carotenoids from the green alga *Tetraselmis sp.* has been carried out. Highest biomass ($4.560 \pm 0.141 \text{ g/l}$) was obtained with the cultures grown with sodium acetate as carbon source and highest xanthophyll carotenoid content was obtained ($9.407 \pm 0.089 \text{ mg/l}$) under mixotrophic condition with ethanol as carbon source.

c) Marine Microbial Biotechnology: Symbiotic microorganisms (Actinomycetes) were isolated from six species of sponges collected from Chidiyatappu. Twelve Actinomycetes strains were isolated and screened for antimicrobial compounds. Bacteriocin (antimicrobial peptide) producing bacteria *Enterococcus faecium* was isolated from the Andaman waters and characterised by biochemical test. The purification of bacteriocin was carried out in C_{18} reverse phase column. The fractions were collected and the antimicrobial activity was confirmed by bioassay. Tricine-SDS-PAGE is being carried out for further characterisation of the bacteriocin. The 16S rDNA gene sequence of three bacterial strains isolated from coastal water and sediments of Andaman Islands were sequenced and the sequences were submitted in the Genbank (NCBI) database.

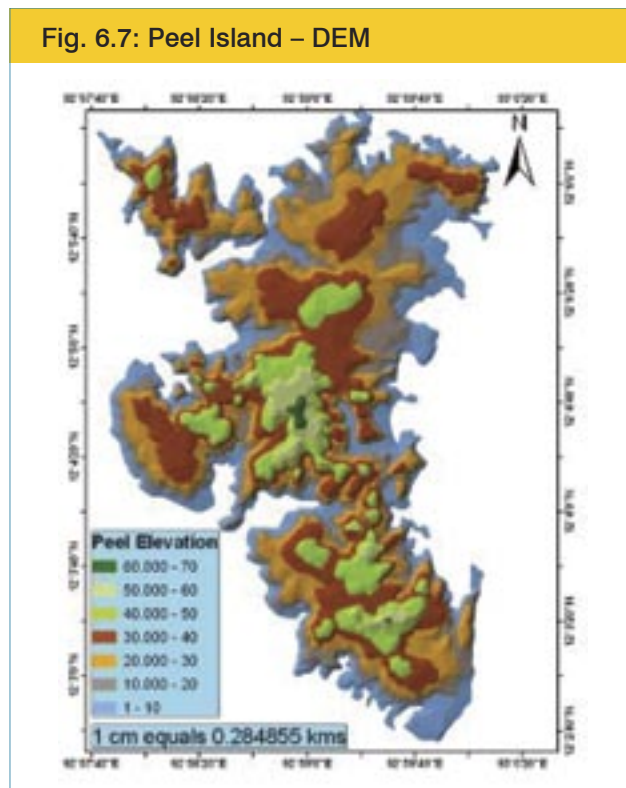
d) Island Resource Information System (IRIS): The Digital Elevation Models (DEM) have been developed for the Wilson, Peel, Inglis and John Lawrence Islands (Fig. 6.7) with 1:25,000 scale toposheets (Survey of India) with 10m contour interval using the GIS facility established at the Andaman Nicobar Centre for Ocean Science and Technology (ANCOST), Port Blair. These maps were prepared to study the site suitability for various marine related infrastructure developmental projects in A&N Islands and also to upgrade marine resource map through ground truthing.

Digitally classified images were used as base reference to study the present status of coral reef to an extent of 160 hectare area along the coast of Pongi Balu near Manjery in South Andaman. Visual interpretation in shallow region during low tide as well as scuba diving was followed to compare with satellite data to study the percentage cover of live and dead coral reef along the Pongi Balu coast.

e) Materials for Marine Applications and Antifouling Measures: Thirty microbial strains were isolated and screened for synthesis of metal nanoparticles. Among them, seven strains showed extracellular synthesis of silver nanoparticles. The nanoparticles synthesised were characterised using Atomic Force Microscope, Scanning Electron Microscopy and Energy Dispersive X-ray spectroscopy.

As part of the programme on development of eco-friendly antifouling coatings, 20 species of seaweeds were collected from the Gulf of Mannar and the Palk Strait regions of the Tamil

Fig. 6.7: Peel Island – DEM



Nadu coast. The seaweeds are being processed for extraction and screening of organic compounds for antifouling properties.

f) Marine Bioinformatics: Evolutionary relationship of agarolytic microbes isolated from the Andaman Islands was analysed using bioinformatics software and evolution of yolk protein in crustaceans was studied. Systematic classification of lobsters was compiled under the marine taxonomic tree database with special reference to the Indian lobsters. Studies on screening and phylogenetic analysis of chitinolytic vibrios are in progress.

g) Development and Deployment of Artificial Reef: A Mild Steel (MS) mould for construction of artificial reef was designed and fabricated. Test artificial reef structures were constructed with the MS moulds and the structures were tested for stability and handling. Further work towards the deployment of artificial reef in the Orissa coast is in progress.

h) Light Emitting Diode (LED) Beacon Lamp: A low cost solar powered beacon light was developed indigenously for use on artificial reef area marker buoys, Fish Aggregation Devices (FADs) and fish cages. The system is being tested outdoors to evaluate the efficiency and longevity of the design and material. The entire system is designed to work with 4V, 5Ah battery of 35mm x 75mm size. The battery will be charged through a single 1Watt solar panel. For lighting, 4 numbers of 5mm, 110mw white to

amber coloured LEDs are used in this system. The system is designed to work continuously for more than five days, after full charging, even in the absence of solar energy.

6.6 Coastal and Environmental Engineering

This includes projects primarily targeted towards infrastructure developments and industrial application. The major achievements are provided below:

i) As part of the Tsunami Early Warning System, installation of Long Range HF Radars commenced along the coastline of India. Eight HF Radar stations have been installed as of December 2009 and online data is received at NIOT and INCOIS.

ii) The project 'Technical Criteria Atlas' aims to provide a ready reference of various environmental parameters required for planning, analysis and design of coastal infrastructures. Bathymetry for Indian Ocean was prepared from the secondary data sources such as ETOPO2, CMap, and in-house data. The secondary database required for model forcing such as surface wind, atmospheric pressure, cyclone track details, tide, sea ice, etc. was prepared. The sensitivity analysis of grid size and time step were carried out. Test runs of the model were carried out with varying formulations to calibrate the model. The model results were validated with available data.

7 Coastal and Marine Ecology

A national coordinated research and development scheme on “Coastal Marine Ecology” has been implemented. It addressed the following thrust areas: (i) Coastal erosion and protection measures; (ii) Drugs from sea; (iii) Aquaculture and Mericulture; (iv) Harmful Algal Bloom; (v) Ecosystem modelling; and (vi) Coastal Water quality monitoring.

7.1 Coastal Erosion and Protection Measures

Several places along the coastal belts are subjected to severe erosion due to natural forces and alteration of coastal processes by man-made structures established along the shoreline. Hence, technological tools/interventions based on comprehensive studies and analysis of the problem of erosion and accretion need to be developed so as to prescribe effective coastal protection measures/ Shoreline Management Plan (SMP).

7.1.1 Development of Shoreline Management Plans (SMP)

- i) The numerical model studies for Muthalapozhi sector have been calibrated and validated with the data collected during pre-monsoon, monsoon and post-monsoon. Waves, near-shore circulation and sediment transport have been simulated for the entire study area of St. Andrews-Nedunganda coastal stretch of Muthalapozhi.
- ii) Four sites along Karnataka coast (Devbhag: Karwar, Pavinkurve: Honnavar Kundapur Kodi: Kundapur, Uliargoli Padukere: Malpe) have been selected to develop SMPs, in association with NIO, Goa. Data on tides, waves, currents, sea levels and beach profiles along with shoreline mapping were carried out at monthly intervals from April–December 2009. River discharge measurements were also carried

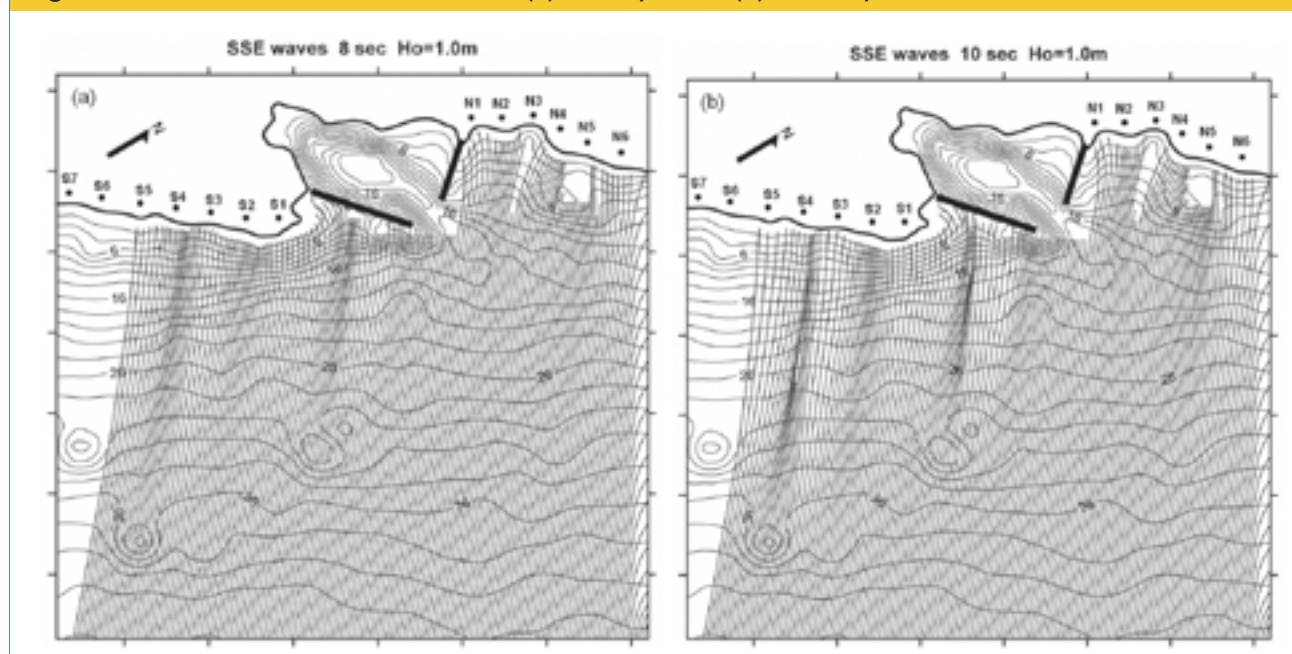
out in June and July 2009 near the mouth of the Kali river (Karwar), the Saravathi River (Honnavar) and the Udayavara river (Padukere) to understand the influence of fresh water on coastal current and sediment transport. Based on the data collected, numerical modelling of the hydrodynamics and wave transformation studies have been initiated.

- iii) **SMP for Gopalpur Coast:** The seasonal data collection programme includes deployment of a wave rider buoy, tide gauge and current metre at 8m, 18m and 23m depths at four locations. The beach profiles and shoreline positions were also collected at monthly intervals. One year observation of wave climate indicates that swells approach mostly from S-SE-SSE and wave heights are fairly high during southwest monsoon months. On an annual basis, the most dominant wave heights are 0.5 to 1m with time period 12-20 seconds.

Monitoring of beach profiles and shoreline at monthly intervals indicated that southern beaches of the port are accreting in a year up to 140m width, while northern beaches are eroding up to 70m width near the newly constructed groins and the effect is felt up to 2km on both sides.

- iv) **SMP for Gangavaram Coast:** A detailed climatology of Gangavaram has been prepared based on the previous research studies. Past data on predominant wave characteristics and currents along the coast for different seasons were collected. Preliminary beach survey was conducted during September 2009 and December 2009 along the coast on either side of the study area (Gangavaram port). Coastline changes were monitored using LANDSAT multi-temporal images (1988 to 2009). The nearshore wave refraction patterns are studied using a Numerical Wave refraction

Fig. 7.1: Wave refraction for SSE waves: (a) 8 sec period, (b) 10 sec period



model. (Fig. 7.1) It could be noted that convergence of wave rays occur near the south breakwater of the port and also at a few other locations still further southward.

The sediment deposition is clearly observed at R.K. Beach and Palm beach but near the submarine museum and further northward towards Lawson's Bay the beach is undergoing erosion. At Yarada, the shoreline is observed to have been shifted by about 3m landward, denoting deposition; but further northwards erosion has been observed. Similarly at the Appikonda Beach (south of the Port), there is erosion near the Pigeon Hill to the extent of 40m wide beach over length of 0.8 km, while further south deposition is observed.

7.2 Drugs from the Sea

The marine organisms are a very high potential source for bioactive compounds to develop drugs for human therapeutic purposes. In this context, a national coordinated research programme on "Development of potential drugs from the Ocean" has been implemented under the leadership of Central Drugs Research Institute (CDRI),

Lucknow. This multi-institutional programme is being carried out with the active participation of following reputed national/state R&D laboratories and academia:

National R&D Labs: (a) Central Drug Research Institute (CDRI), Lucknow; (b) National Institute of Oceanography (NIO), Goa; (c) Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar; (d) Indian Institute of Chemical Technology (IICT), Hyderabad; (e) Institute for Minerals and Materials Technology (IMMT), Bhubaneswar; (f) National Institute of Ocean Technology (NIOT), Chennai; (g) Advanced Centre for Treatment, Education and Research (ACTREC), Mumbai; and (h) Central Institute of Fisheries Education (CIFE), Mumbai.

State Government Institutions: (a) Department of Fisheries, Government of West Bengal, Kolkata and (b) Topiwala National Medical College, Mumbai.

Universities: (a) Andhra University, Visakhapatnam; (b) Calcutta University, Kolkata; (c) Annamalai University, Parangipettai; and (d) University of Madras, Chennai.

The major achievements made during 2009-2010 under this programme are:

CDR 134D123 (Anti-Diabetic agent) Phase-I Single Dose and Multiple Dose clinical trial studies completed successfully and a dossier was compiled and submitted to DCGI. It was licensed to M/s. TVC Sky Shop Limited for fast track marketing through AYUSH.

The queries from Investigational New Drugs (IND) Committee of DCGI were received for CDR 134 F194 (anti-diabetic agent) and presentation of various clarifications of IND committee was made in December 2009. In February 2010, IND committee has suggested some changes in the protocol and requirement for fresh clearance from Ethics Committee.

Regulatory toxicity studies of CDR-267-F-018 (anti-dyslipidaemic agent) in monkeys to be initiated for the product development. Permission from Institutional Animal Ethics Committee (IAEC) is awaited.

7.3 Aquaculture and Mericulture

Marine ornamental fish trade is a rapidly growing sector that relies almost exclusively on the collection of these animals from coral reef

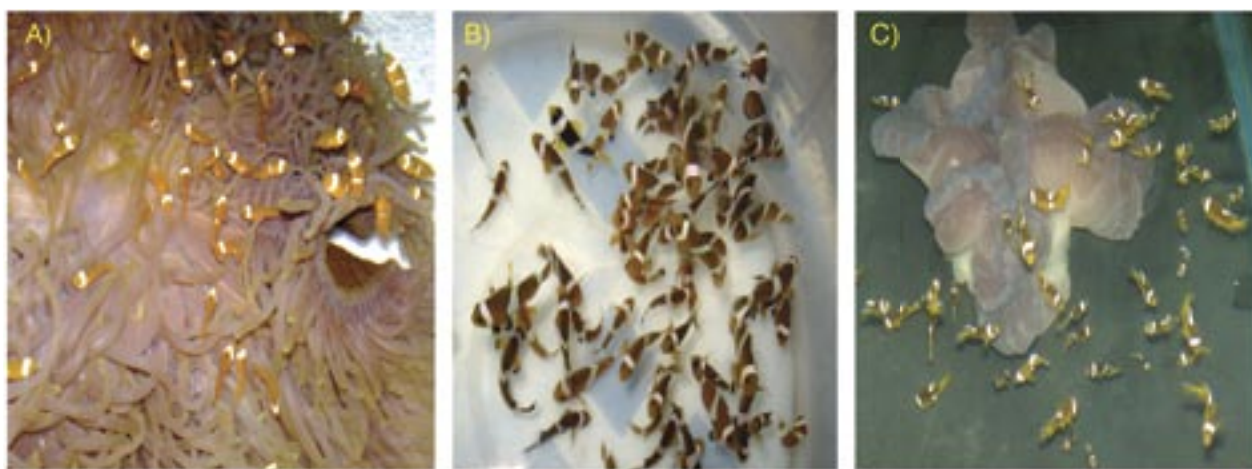
ecosystem. Among the marine ornamental fishes, clown fishes are considered to be the most popular attractions of aquarists, and they are important in the aquarium trade in view of their bright colour, interesting display behaviour and their ability to adapt in captive condition. In view of enhancing the livelihood opportunities to the coastal fishermen communities, a research project under Marine Living Resources (MLR) programme in Lakshadweep Islands, through Centre for Marine Living Resources and Ecology (CMLRE), Kochi has been implemented. The significant achievements made under during 2009-10 are as given below:

7.3.1 Hatchery production of Marine Ornamental Fishes in the Lakshadweep Islands

Among the 28 clown fish species distributed worldwide, *Amphiprion sebae*, *A. ocellaris*, *A. percula*, *A. clarkii* and *A. nigripes* are the commonly occurring species in the Indian waters.

In the first phase of this project, CMLRE has successfully completed the standardisation of the hatchery technology for five species of clown fish (*Amphiprion sebae*, *A. ocellaris*, *A. percula*, *A. clarkii*, *A. nigripes*) and one species of damselfish (*Dascyllus trimaculatus*). (Fig. 7.2) Juveniles grow to a length of about 0.8-1.0 cm in one month, 1.5-2.0 cm in two months and reach marketable size of 2.0-2.5 cm after 3 months.

Fig. 7.2: *Amphiprion nigripes* (A-C) hatchery reared juveniles



7.3.2 Black Pearl Spat production and Pearl farming

The life cycle of *Pinctada margaritifera* was closed by achieving spat production in the hatchery during February 2009. After repeated trials this success was achieved mainly through the exclusive use of the diatom *Pavlova salina* as feed. The other critical factor was the quality of the seawater. With the commissioning of the pressure sand filter and the cartridge filters (10 to 1.0 μ) mortality was considerably reduced totally to 25000 spat production in the hatchery.

Pearl Farming

A new wooden raft with surgical implantation facility was deployed in Panighat in Port Blair. This raft now holds more than 1500 adult oysters and hatchery produced spats (Fig. 7.3).

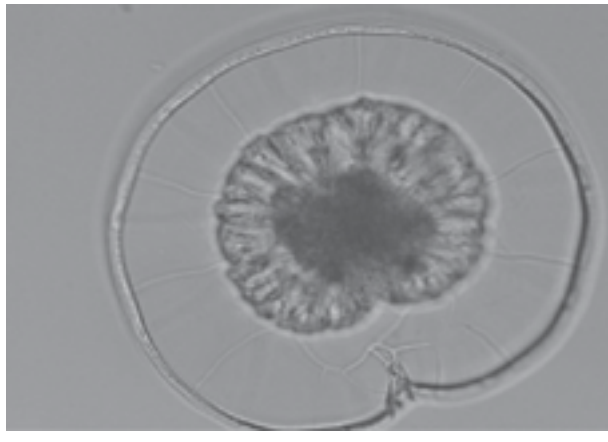
Fig. 7.3: Hatchery produced spat



7.4 Harmful Algal Bloom (HAB)

During 2009-10 Harmful Algal Blooms were recorded from 10 locations in the Indian EEZ, mainly in the Kerala–Karnataka coast. Extensive *Trichodesmium* blooms were encountered off Goa and Mangalore (April: Sagar Kanya), off Kollam, off Kochi, off Kannur (June 09) just prior to the onset of SM upwelling. The occurrence of the nutrient depleted Arabian Sea High Saline Water (ASHSW) is expected to be the causative factor for the blooming of *Trichodesmium* species. It is well known that *Trichodesmium* can fix atmospheric nitrogen and hence occurrence of *Trichodesmium* blooms along the SW coast during pre-monsoon can be an adaptation to recycle nitrates to the ocean.

Fig. 7.4: *Pyrophacus steinii* 400 x

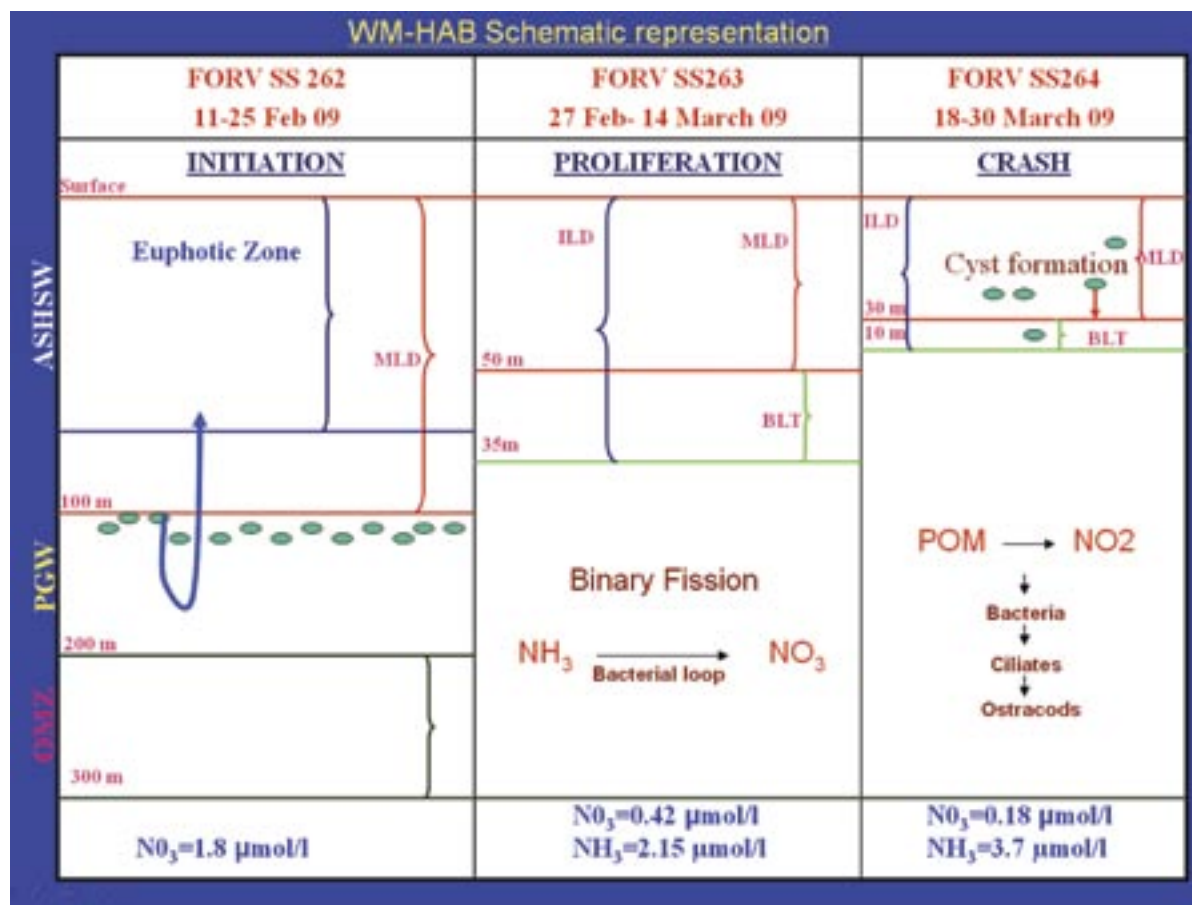


A mono-specific bloom of dinoflagellate *Pyrophacus steinii* (Fig. 7.4) was observed off Mangalore on 1st October 2009 without any discolouration of the surface waters. This was, to our knowledge, the first record of bloom of *Pyrophacus sp.* in the Indian waters.

Chattonella marina bloom with rusty brown discolouration of the surface water was observed off Kochi on 23rd September 2009.

Detailed investigations were carried out onboard FORV Sagar Sampada to study the extensive algal blooms occurring along the northwest coast of India during the fag end of winter monsoon and early spring inter monsoon seasons. The bloom forming species along the NW coast was identified as the green *Noctiluca (N. scintillans)* with its associated endosymbiont *Pedinomonas noctilucae*. Blooms were monitored during the initiation, spreading and crash stages. Bloom initiation was associated with deep mixed layer (>100m) which brings the cysts to the euphotic zone where cell proliferation occurs in presence of relatively high nutrient load. During the spreading stage the nitrate levels are maintained by regenerated production through the microbial loop and vertically shoaling *Rhizosolenia* mats. Towards the end of the crash stage nitrate levels in the surface waters reach very low values (0.18 $\mu\text{mol/litre}$). A theoretical model to explain the open ocean blooms of the NW coast, is being refined (Fig. 7.5).

Fig. 7.5: Theoretical model to explain the open ocean blooms



7.5 Ecosystem Modelling

7.5.1 Ecosystem Modelling for Chilika Lake

The Chilika Lake productivity is governed by catchment modifications together with the opening of new mouths. In order to understand the hydrodynamics and biogeochemical changes that are prevalent in the ecosystem and the resultant changes on productivity, the present project has been taken up. The major aim of the project is to develop an ecosystem model in stages to predict primary, secondary and tertiary production and changing environmental conditions.

a) Hydrodynamics modelling

A 2-dimensional depth integrated MIKE 21 hydrodynamic flow model was used to simulate the water levels and flow field in the Chilika Lake. The field data collected at five stations

simultaneously over a period of 30 days under NE monsoon conditions was used for calibrating and validating the model results. Based on HD model results the tidal propagation into the lake was studied. The tide excursion into the lake underwent drastic spatial variations. Based on the simulated hourly data over a period of 48 hours obtained from the model results, water and salt fluxes across the four sector regions (open channel, north sector, central sector and southern sector) were calculated. Results indicate that a net water flux of 413 cu.m/s and salt flux of 5797 cu.m/s was noticed in the central sector which indicates that the central sector is favourable for biological production when compared with the other sectors. It is estimated that a quantum of 2196 Million cu.m. is discharged into the lagoon from the gauged stream/ rivulets of the Western Catchment during 2009-10.

The streams/regulates from the Western Catchment flowing into the lagoon carries high quantum of sediment. It has been estimated that a total of 337954.70 mt of sediment is deposited into the lagoon from the gauged streams of the Western Catchment during 2009-10.

b) Development of biogeochemical model and undertaking of required observations

During the year 2009-10, monthly observations on DO, salinity, pH, turbidity, nitrite, nitrate, ammonia, phosphate, chlorophyll, macro algae, sea grass, phyto and zooplankton were carried out at 36 locations in the lagoon. Phytoplankton grazing and benthic chamber experiments were also conducted. The salient observations made from the data collected during 2009-10 are given in brief below:

- i) Dissolved organic nitrogen (DON) continues to make up 78% of Total Nitrogen in catchments entering the Lake.
- ii) Spatial distribution of salinity and other water quality variables (SPM, turbidity, DO, pH, DIN, DON as well as phosphates and silicates) exhibited significant ($P < 0.05$) differences between the two seasons.
- iii) Grazing experiments have revealed that phytoplankton growth rate decreased significantly ($P < 0.001$) with increasing proportion of grazers. This was more prominent in the central and southern part of the lagoon.

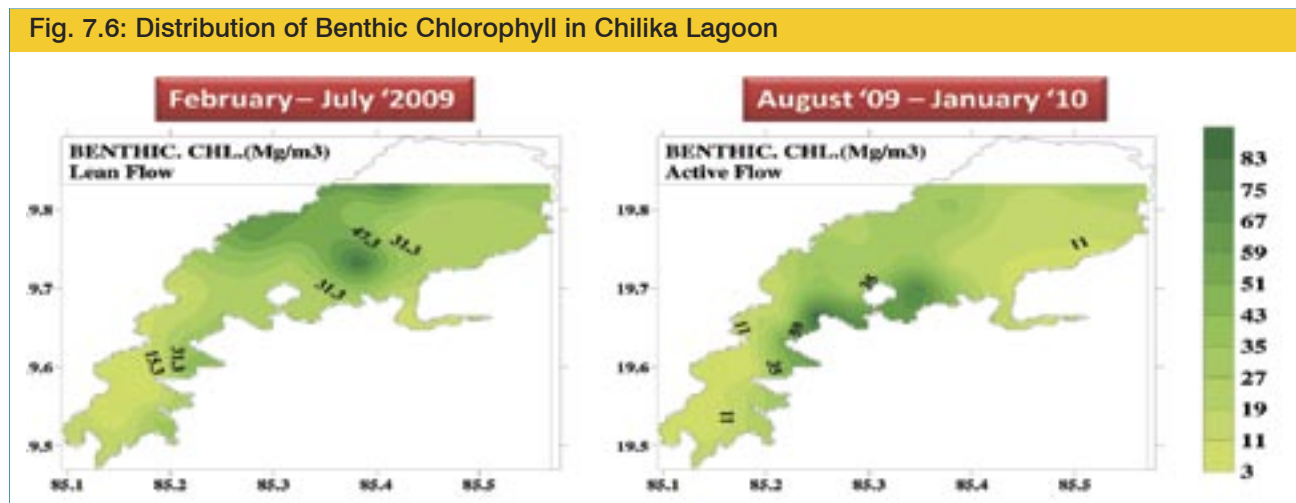
iv) Benthic Chlorophyll as a result of microphytobenthos continues to remain high ($>40\text{mg.m}^{-3}$) through most locations in the Lake (Fig. 7.6).

c) Carbon biogeochemistry in Chilika Lagoon

Carbon biogeochemistry is defined as the dynamic reactions in biological, physical, chemical and geological processes of carbon. Carbon parameters like dissolved inorganic carbon (DIC), dissolved organic carbon (DOC), particulate organic carbon (POC) and physico-chemical parameters were collected (36 stations inside the lagoon and 10 rivers empty at lagoon) from Dec-2008 to Dec-2009 to study the carbon flux from rivers, retention in lagoon and export to the atmosphere and the sea. The lagoon releases measurable amounts of CO_2 to atmosphere during post monsoon and stored significant amount of C in terms of sink in to the lagoon sediment.

7.5.2 Ecosystem Modelling of Kochi Backwaters

An ecosystem model for the entire Kochi backwaters is being developed. Collection of data on hydrodynamic parameters such as tides and currents, water quality parameters such as nutrients and biological parameters like photo and zooplankton have been completed for post-monsoon and summer months. Experiments such as phytoplankton grazing, photosynthesis



– Irradiance experiments to develop model coefficients have been conducted.

Growth rates of seven phytoplankton species commonly found in Cochin backwaters were determined in the laboratory using uni algal culture. Optimum growth ranged from 0.56 to 1.24 μ d⁻¹ (avg. 1.1 μ d⁻¹). Growth rate of two important aquaculture phytoplankton species were also studied because they were also taken for deriving grazing coefficients. For deriving phytoplankton optimum growth rate averages of phytoplankton occurring in Cochin Backwater were only taken and the other two *Chaetoceros calcitrans* and *Isochrysis galbana* were exempted.

Photosynthesis-Irradiance (P/I) experiments were carried out in the Cochin Backwaters (Fig. 7.7) by conducting a series of experiments at Fort Kochi and it was found that the optimum photosynthetic coefficient was 2.5.

Phytoplankton assimilation is expressed in (μ g C μ g Chl a⁻¹ h⁻¹) and light intensity (LICOR light meter) expressed in (μ E m⁻² s⁻¹).

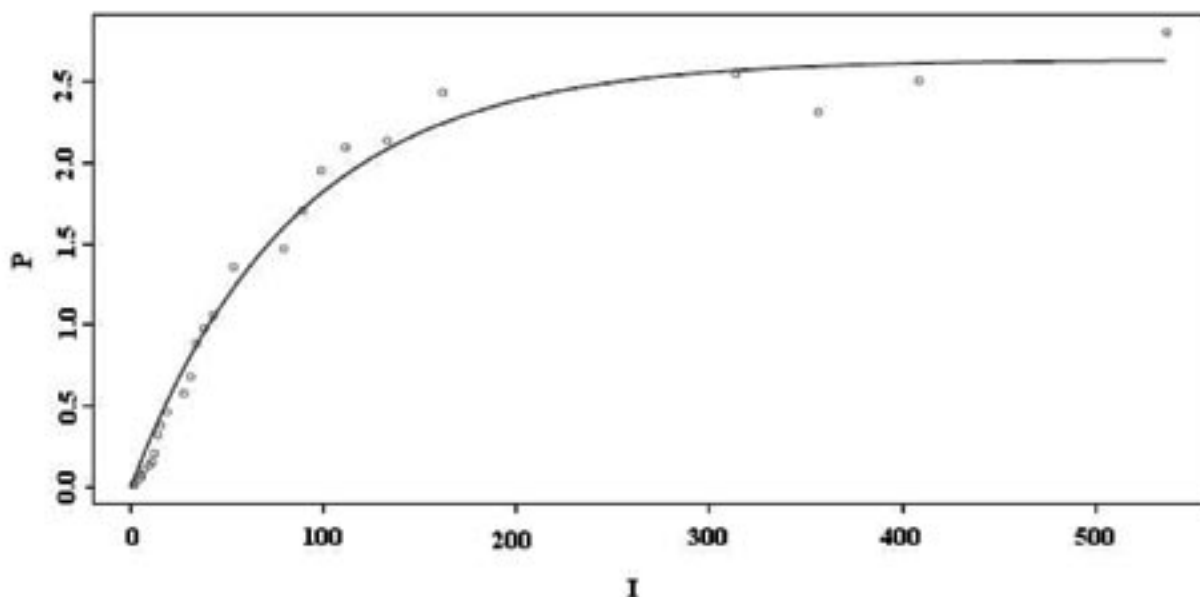
To study the predator-prey relationship, two herbivorous copepods such as *Psuedodiaptomus*

annandalie (1.2 mm) and *Acartia tropica* (0.8 mm) were allowed to graze different sizes of phytoplankton such as *Skeletonema costatum* (15 μ m), *Coscinodiscus centralis* (105 μ m), *Nitzschia closterium* (45 μ m), *Isochrysis galbana* (10 μ m) and *Chlorella salina* (6 μ m). These species are present throughout the season at varying density except *Isochrysis galbana* and *Chlorella salina*. It was found that *Psuedodiaptomus annandalie* preferred a prey size range of 10- 105 μ m, whereas for *Acartia tropica*, grazing rate decreased with increase in the size of the prey. The grazing rates for *Psuedodiaptomus annandalie* were 0.5 to 1.0 μ m³ x 10⁶ cells copepod⁻¹ h⁻¹ and for *Acartia tropica* were 0.3 to 0.9 μ m³ x 10⁶ cells copepod⁻¹ h⁻¹. The grazing coefficient calculated following ICES (2000) was 1.1 for *Psuedodiaptomus annandalie* and 0.8 for *Acartia tropica*.

7.6 Water Quality Monitoring

Monitoring the health of coastal seas is highly essential to assess the status of pollution, to detect radical changes of pollutants and to alert government and public institutions, of their implications. Data on 25 environmental parameters including physical, chemical, biological and microbiological characteristics of water and

Fig. 7.7: P/I curve for Cochin Backwater (Fort Kochi)



sediment at about 76 locations are being collected with the help of seven R&D institutions in the 0-10 km sector of the coastline of the country, covering the maritime states and UTs. The major activity is to monitor the coastal water quality to understand the trend of marine pollutants load, whether increasing or decreasing, due to anthropogenic activities. The achievements made during 2009-10 pertaining to water quality monitoring are as given below:

i) Gujarat

Water quality at the Porbandar and the Veraval fishing harbours continued to be degraded though conditions are relatively better at Porbandar. Though very low dissolved oxygen and high levels of ammonia and phosphate were observed at the Veraval fishing harbour, water quality off Veraval was healthy, indicating flushing of contaminated harbour water during monsoon. Overall observation at the Tapi indicated that the estuary is in stress condition due to build-up of nutrients and low levels of DO. The inshore of Okha and Diu continue to exhibit clean coastal water quality.

ii) Maharashtra

Monitoring was carried out at Mumbai, Bassein, Versova, Mahim (May 09, Sep 09 and Jan 10) and at Tarapur, Dabhol, Murud and Ratnagiri (Feb 10). At Bassein, build-up of nutrients (especially NO_2 and NH_4) and low DO values were observed in upper segments (Ulhas estuary), which may be due to consumption of DO for oxidation of organic material, which estuary receives mainly from industrial and domestic sources and the estuary is in stress condition with respect to organic load. At Versova, DO and pH continue to be low and DO was zero. NO_3 concentration was high as compared to earlier years indicating efficient oxidation of nitrogen to nitrate. At Mahim, concentration of all nutrients were high indicating high load of organic waste which continued to be discharged in the Mahim creek. Near zero value of DO and high NH_4 levels in the creek indicate deteriorating condition of Mahim creek. At Thane creek, water quality indicates that organic load is being discharged in the creek. However, DO of >2 mg/l throughout the study period indicated the revival of the creek.

iii) Goa

Monitoring was carried out at Mandovi (Sep 09 and Jan 10) during monsoon and post-monsoon seasons. High DO (5–8 mg/l) and low BOD (<2 mg/l) indicate well mixed waters. NH_4 and PO_4 levels were within normal range. High chlorophyll ($2-14$ mg/ m^3), primary productivity ($4-8$ mg/ m^3 /h) during monsoon indicate that the waters are very productive.

iv) Karnataka

Along the coast of Karnataka, sewage, industrial effluents, port and fishing activities are the major sources of pollution that affect coastal water quality. Monitoring was carried out at Mangalore (May 09 and Dec 09) and at Karwar (May 09). Though, nutrients showed moderate variation (high SiO_4 and PO_4) due to riverine influence, high DO (4–5 mg/l) and low BOD (<2 mg/l) indicate well aerated condition in nearshore and offshore regions. High levels of bacteria, especially E.Coli and faecal coliforms in inshore waters, suggests the presence of anthropogenic discharges.

v) Kerala

In Kerala, industrial effluents and domestic sewage are the major sources of pollution. During the period, monitoring was carried out at Kochi (May 09 and Oct 09), Vallarpadam (Oct 09), Veli (May 09 & Jan 10) and Kasargod, Calicut, Neendakare (May 09). At Kochi, moderate DO (4–5 mg/l) and BOD (2–3 mg/l) indicate influence of domestic wastes. At Vallarpadam, high levels of nutrients (TN: $49 \mu\text{mol/l}$), moderate DO (5 mg/l) and BOD (3 mg/l) indicate moderate water quality. At Veli, though the region was heavily influenced by the presence of untreated acidic effluents, the pH was normal (8) and DO and BOD levels were in normal range. The nearshore biological productivity was found to be low and the absence of benthos in shore region indicates that the nearshore pollution effect was not much fully recovered. A decrease in levels of bacterial pathogens indicate an improvement in water quality.

vi) Lakshadweep

Monitoring was carried out at Kavaratti during November 2009. High levels of DO (4–8 mg/l), low

BOD (<2 mg/l) and moderate levels of nutrients indicate that the water quality is fairly good. Bacterial populations were comparatively low throughout the study, except the helipad near shore region where the nutrient concentration was also higher, probably due to sewage disposal in the area.

vii) West Bengal

Along the West Bengal coast, discharges from various types of industries are the major sources of pollution, besides agricultural runoff and port activities. Coastal waters of Sandheads, the Hooghly estuary and the Haldia Port were monitored during June – November 2009. Continued high DO levels (6–8 mg/l) and low biochemical oxygen demand (<3 mg/l) were observed indicating good water quality. However, at Hooghly estuary, high levels of total nitrogen (92 μ mol/l) and SSC (1055 mg/l) were observed. High levels of bacterial pathogens (FC: 1200 cfu/ml) was observed at Sandheads inshore waters indicating contamination due to domestic sewage.

viii) Orissa

Along the Orissa coast, discharges from industries (mostly treated) and domestic sewage are the major sources of pollution besides untreated wastes from hatcheries, discharges from chromium and iron ore mining activities and agriculture. During the year, coastal waters of Mahanadi, Paradip and Puri were monitored (Jun and Nov 09). Coastal waters of Orissa are characterised by continued high DO levels (6 – 8 mg/l) and low biochemical oxygen demand (<3 mg/l) and low SSC (<15 mg/l) However, at Paradip, a moderate increase in levels of total phosphorous (23 μ mol/l) was observed indicating continued contamination from Paradip phosphate factory. Significant decrease in levels of bacterial pathogens was observed at Paradip indicating moderate improvement in water quality. In general, the coastal water quality along Orissa coast has improved as compared to last year.

ix) Andhra Pradesh

Along Andhra Pradesh coast, discharges from a variety of industries, agriculture and aquaculture

are the major sources of pollution besides fishing activities and domestic sewage. During the year, monitoring was carried out at Visakhapatnam and Kakinada (Mar and Oct 09) and along the coastal locations during December 09. The results indicate high levels of nutrients in the Visakhapatnam harbour channels and Kakinada due to influence of domestic sewage, industrial effluents and agricultural waste. Levels of nutrients were observed to be within ambient levels of coastal environment indicating that the coastal water quality along the Andhra Pradesh coast is fairly good.

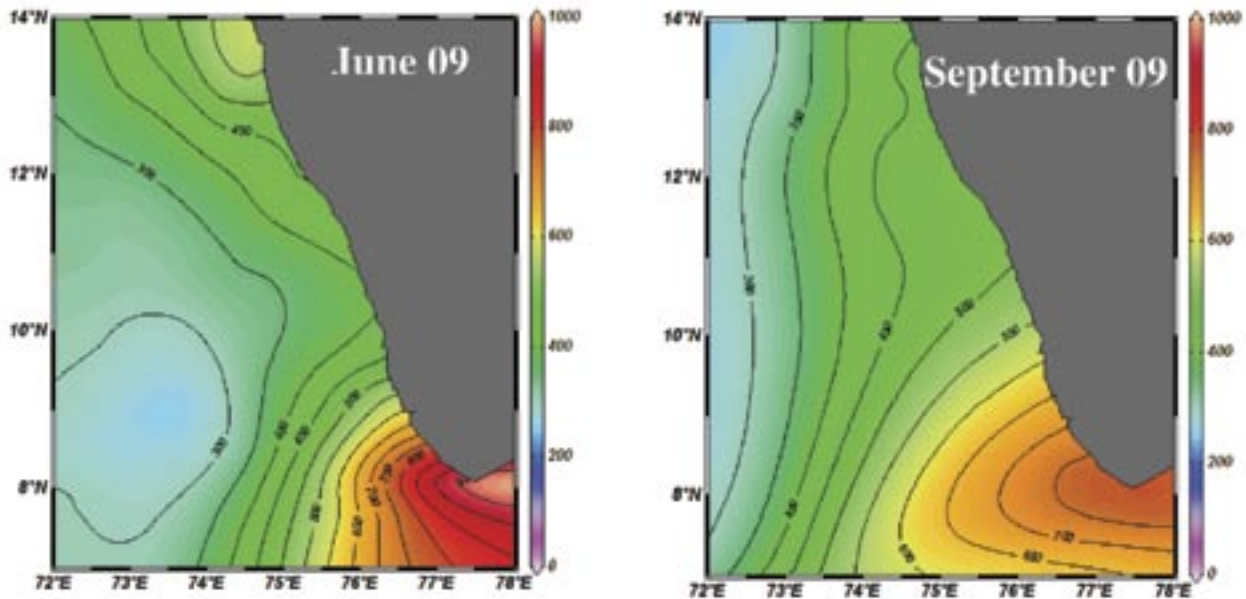
x) Tamil Nadu and Puducherry

In Tamil nadu and Puducherry, effluents from industries and domestic sewage are the major sources of pollution besides harbour activities. Along Tamil Nadu coast, coastal waters of Ennore, Chennai Harbour, Cooum, Muttukadu, Puducherry, Cuddalore, Karaikal, Nagapattinam and Tuticorin were monitored (Jul, Oct and Dec 09) and at other locations in Aug 09. As compared to last year, a moderate decrease in levels of suspended solids concentration (from <190 mg/l - <100 mg/l). Dissolved oxygen level was well within normal range (3.5–6.8 mg/l) and biochemical oxygen demand (<5 mg/l) in all stations. Nutrient levels were also found to be at moderate level. However, a significant increase in pathogenic bacterial populations was observed at many shore locations.

xi) Andaman & Nicobar

Increase in shipping activities, disposal of untreated wastes and sewage are the major causes of pollution. Monitoring was carried out in seven places in and around Port Blair (Jun, Aug and Nov 09) and Wandoor (Nov 09). Levels of DO (3.5–7.4 mg/l), BOD (0.13–3.58 mg/l) and SSC (19–58 mg/l) and petroleum hydrocarbons (0–12 mg/l) indicate that coastal water quality has improved as compared to last year. Though very high levels of pathogenic bacteria were observed during Jun and Aug 09, during Nov 09 (post-monsoon), the levels were very low (<10 cfu/ml) indicating dilution of domestic wastes by monsoon rainfall. In general, the coastal water quality of Port Blair is observed to be improved as compared to last year.

Fig. 7.8: Primary productivity (mgC/m²/day) estimated from satellite chl using Vertically Generalised Production Model (VGPM)



7.7 Marine Living Resources (MLR) Programme

The main objective of the MLR programme is to correlate living resources with the physical environment and establish response strategies of living organism to changes in the environment. Spatio-temporal progression of Summer Monsoon (SM) upwelling along the southwest (SW) coast and associated productivity patterns including the distribution and abundance of fish eggs and larvae and, the hydrography especially warming of the Lakshadweep area and its influence on MLR were studied. The studies indicate that, the forcing mechanisms and upwelling patterns are not homogeneous to the entire coast and shows high degree of variability both in time and space. Other activities under MLR includes preliminary assessment of the impact of closed fishing season on the marine benthos along the Kerala coast, studies on the marine mammal diversity and distribution and

establishment of Indian Ocean Biogeographical System (IndOBIS).

Primary production in the euphotic column was maximum (>1000 mgC/m²/day) during the initial phase (June) compared to the withdrawal phase (September) of the upwelling process (800 mgC/m²/day). (Fig. 7.8)

Highest density of fish eggs was recorded along 30m stations off Kochi followed off Valappad and off Trivandrum.

A dedicated site on Indian Ocean Biogeographic Information System (IndOBIS) has been established at CMLRE as the regional node of the Intergovernmental Oceanographic Commission (IOC) global biodiversity programme. The site currently holds information on the species diversity and abundance of 8722 species of marine animals and 1268 species of marine plants recorded from the Indian Ocean region.

8 Climate Change Science

8.1 Introduction

A coordinated research programme on Global and Regional Climate Change (GRCC) during the XI Plan has been launched to build a National Climate Change Monitoring and Research Network. A Programme Office is established at MoES Headquarters to operate GRCC Programme to integrate all envisaged activities in support of supplementing unified scientific response to the global warming launched by the Government of India under the National Action Plan on Climate Change (NAPCC).

As a part of GRCC, a dedicated Centre for Climate Change Research (CCCR) to undertake studies on science aspects of Climate Change at the Indian Institute of Tropical Meteorology (IITM), Pune has been established. CCCR is focusing on all scientific issues, including modelling the susceptibility of various agricultural crops, yield and diseases, water, nitrogen, ozone, GHG flux measurements and CO₂ cycle sequestration, etc.

Recognising the importance of the critical and challenging science issues of climate change, and need to launch urgent focused efforts to deal climate change issue in a holistic and comprehensive manner, a National Workshop was held during 18-19 May 2009 to discuss these issues threadbare and to build integrated national efforts.

Representatives of various institutions that have participated in the National Workshop have appreciated the efforts of MoES in launching a dedicated programme on GRCC during the current five-year plan along with the establishment of a new CCCR in the IITM, Pune Campus with all necessary infrastructures.

Update on the CCCR Establishment

- CCCR incubation centre was established in October 2009 in the campus of the Indian Institute of Tropical Meteorology (IITM), Pune.
- A new HPC facility with 7.2 Terra Flops (TF) peak-performance is commissioned and made fully functional.
- A nucleus of 14 identified IITM scientists (1-Scientist-‘E’; 5-Scientist-‘D’s; 4-Scientist-‘C’s and 4-Scientist-‘B’s), apart from designated In-Charge, have already been grouped to work on envisaged CCCR activities. In addition, six new scientists (2-Scientist-‘E’s and 4-Scientist-‘C’s) are recruited. In summary, present CCCR staff comprises 20 Scientists (six new recruitments and a nucleus of 14 scientists from IITM). A visiting scientist position has recently been offered for strengthening the activities further.
- A focused and well-defined roadmap for contributing to the Assessment Report-5 (AR5) of the Intergovernmental Panel on Climate Change (IPCC). Ensembles of regional model simulations are planned for downscaling the monsoon variability projections over the South Asian region. This will be the first time that projections based on model simulations conducted from India would be participating in the IPCC assessment.
- Ability to capture summer monsoon characteristics over South Asia within 17-ensemble member 20th Century simulations of Quantifying Uncertainty in the Model Projections (QUMP) involving United Kingdom’s Hadley Centre Coupled Ocean-Atmospheric Climate Model version 3 (Had CM3) is examined to select potential ensemble member fields, among the 17, which have most closely reproduced the observed summer monsoon climate variables.

Six among the 17-ensemble runs of QUMP experiment are found to be reproducing mean summer monsoon climate reasonably well and these fields are used to drive the Regional Climate Model (RCM)-PRECIS to generate 50 km grid scale under A1B Scenario (Medium Emissions) runs over South Asia continuously for the period 1961-2100.

The three-member ensemble runs of RCM-PRESIS are completed and the results are under critical evaluation and the simulations in respect of the remaining 3-ensemble QUMP members are currently underway. The results of this RCM monsoon climate response are critical components of the India's National Climate Change Assessment (INCCA) programme of the Ministry of Environment and Forests (MoEF) for generating various sectoral impacts due to such projected changes of future monsoon climate.

- A framework of three regional climate models (PRECIS, WRF and Reg CM) is currently built to examine the following spatial characteristics associated with the summer monsoon in coming decades up to 30-50 years.
 - a) To quantify future climate scenarios for India under different emission scenarios as well as “committed climate change” scenarios, during the 21st Century including various intermediate time slices
 - b) To develop ensembles of regional climate change scenarios and to quantify uncertainties.
 - c) To examine the nature of possible changes in the frequency and intensity of extreme weather and monsoon climate variability associated with the expected climate change over India

8.2 Climate Monitoring and Climate Information Services

IMD undertakes continuous global climate monitoring and generation of climate diagnostics for the Indian region to report major climate variability and climate anomalies on monthly and

seasonal scale. Following are the major activities of the climate monitoring and climate information service:

- Detailed special monsoon reports are being published every year.
- Generation of daily analysed rainfall data (at 1°x1° latitude/longitude and at 0.5°x0.5° latitude/longitude resolution – up to 2009)
- Generation of daily gridded temperature data (at 1°x1° latitude/longitude resolution - up to 2005) for various climate variability studies
- Drought Monitoring Indices and Drought Analysis
- Archival of climate related databases and data products (district/station normal's, normal's solar radiation parameters etc.)

The National Data Centre (NDC) is the national repository of all meteorological data collected on a routine basis and through special campaign programmes. The total holding of meteorological data in the archives as of date is 103.5 million records. NDC received a lot of queries and requests for data supply from numerous parties that include government, private institutions, industries, research and operational users. The required data were retrieved from the computer archives, within a short time and supplied to the users on CDs, in printout forms in the desired formats, following the usual formalities and as per department policy. During the year, 1080.6 million records were retrieved and supplied.

8.3 Monitoring Trace Gases

IMD is operating a Background Air Pollution Monitoring Network (BAPMoN) programme with an objective of documenting the long-term changes in composition of trace species of the atmosphere and 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 Visakhapatnam continued to collect rain samples for chemical analyses and measurement of atmospheric turbidity. Wet precipitation samples, collected

at GAW stations, are sent to Central Chemical laboratory at Pune where these are analysed for pH, conductivity, major cations (Ca, Mg, Na, K, NH₄) and major anions (SO₄, NO₃, Cl). Atmospheric Turbidity which indicates the columnar aerosol load of the atmosphere is measured at seven GAW stations (Allahabad, Jodhpur, Kodaikanal, Nagpur, Port Blair, Srinagar & Pune) using Microtop-II Multi-channel Sunphotometer at 368,500,675, 778 and 1028nm wavelength; three GAW stations (Mohanbari, Minicoy, Visakhapatnam) using Volz's Sun Photometers at 500nm wavelength.

8.4 Advance Training Centre in Climate and Earth System Science

Great strides have been made in India with regard to weather and climate forecasting in recent years by employing modern observation technology and advanced forecasting tools. Keeping in view the emerging needs of addressing critical scientific issues of climate and earth system science, there is a need to train adequate number

of highly skilled manpower to work in various institutions of the MoES. It is projected to have a large pool of trained and dedicated Climate and Earth System scientists (~400-500 are required in the immediate future) to remain at par with the best of the world. In view of the above, a world class training programme is being put in place exclusively in the field of Earth System Sciences and Climate with a view to understand the monsoon phenomena at various scales, climate and climate change science to build adequate level of technical and scientific capacity in the times to come.

The proposed programme will be oriented towards imparting M.Tech as well as Ph.D degrees. Students will also have the opportunity for training abroad. In addition, it will also offer special certificate course programme for the international students. The proposed training programme will be affiliated to an academic institution/university for offering a degree. Successful trainees can look for an assured career option in the institutions of the MoES.

9 Disaster Support

9.1 Introduction

The early warning services in respect of extreme weather phenomena such as cyclonic storms, heavy rainfall, squalls, thunderstorms, etc. as well as tsunami covering the entire country have been provided by the MoES Centres – IMD and INCOIS. The assessments in respect of these extreme weather and tsunami were disseminated through the Ministry of Home Affairs (MHA) to various state and district level authorities, media, as well as uploaded on to the Web Portal. The customised advisories to the neighbouring countries were also provided.

9.2 Hydro-meteorological Services

The compilation of rainfall statistics, hydro-meteorological analysis of different river catchments have been carried out. Meteorological support for flood warning and flood control operations to field units of Central Water Commission has been provided. Research Programmes in (a) Design Storm Analysis, (b) Rainfall Frequency Analysis and (c) Quantitative Precipitation Forecast (QPF) are the primary activities.

9.2.1 Rainfall Monitoring

Real time monitoring of district-wise daily rainfall is one of the important activities. A network comprising a large number of rain gauge stations is utilised under District-wise Rainfall Monitoring Scheme (DRMS). Based on real time daily rainfall data, weekly district scale, meteorological sub-division scale and state level rainfall distribution summaries are prepared. District and meteorological sub-divisional rainfall statistics provide important information useful to the crop-weather watch group discussions at the central and state government levels, agricultural

extension/agro-meteorological advisory services, planners and decision makers.

During Monsoon 2009, daily sub-division rainfall reports (153 reports in total during the season) were prepared and supplied to the Cabinet Secretary and other user departments/agencies in the central and state governments. District level scenario for the immediate past five-years were also loaded on the Website along with creation of sub-divisional rainfall maps for hands-on comparison of rainfall statistics for the successive monsoon seasons for the last five-years.

9.2.2 Flood Meteorological Service

Flood Meteorological Service provides the following inputs to Central Water Commission (CWC) through their 10 Flood Meteorological Offices (FMO) established in different parts of India in support of operational flood forecasting. During the Flood 2009, 3002 QPFs were issued by FMOs and supplied to Central Water Commission for flood forecasting purposes.

9.2.3 Design Storm Studies

Design Storm Studies are being conducted to evaluate design storm estimates (rainfall magnitude and time distribution) for various river catchments/projects in the country, for use as main input for design engineers in estimating design flood for hydraulic structures, irrigation projects, dams, etc. on various rivers. This estimation of design values is required for safe and optimum design of storage and spillway capacity. On the request of Central Govt./State Govt., private agencies, design storm values (probable maximum precipitation along with time distribution) are provided to users. In all, more than 500 projects have so far been completed and results communicated to the concerned project authority. During the current financial

year 2009-2010 (up to 31.12.2009), 49 projects have been completed and results communicated to concerned project authorities.

9.3 Drought Monitoring

Droughts are the result of acute water shortage due to lack of rains over extended periods of time affecting various human activities and lead to problems like widespread crop failure, unreplenished ground water resources, depletion in lakes/reservoirs, shortage of drinking water and, reduced fodder availability, etc. Often a region adapts itself to a certain level of water shortage based on the long-term climatic conditions experienced by it. Any negative departure from these levels creates conditions of drought, depending on the intensity and duration of this deficit. Thus drought conditions differ from region to region. In India, drought essentially occurs due to failure of south-west monsoon (June – September). Areas affected by drought need to wait till the next monsoon, as more than 73% of annual rainfall in the country is received during the SW Monsoon season.

The IMD carries out the function of drought monitoring and forecasting. Weekly scale monitoring of the district/sub-divisional/state level rainfall and temperature scenarios are analysed using all available observations and provided to the state governments. Rainfall forecast assessment at the sub-divisional scale is provided for the subsequent week on every Friday at the Crop Weather Watch Group (CWWG) meetings of the Agricultural Ministry at Delhi.

A weekly National Agro-meteorological Advisory Bulletin (NAAB) is prepared with a comprehensive analysis of the prevailing temperature and rainfall scenario and the forecast assessment of the rainfall for the next week along with specific crop advisories at the meteorological sub-division scale for regularly assessing the prevailing scenario/emerging prospects for the various weather dependent agricultural operations. NAABs are widely circulated to various central and state

government agencies for planning various contingency operations and market interventions as appropriate.

9.4 Cyclone Forewarning Services

The North Indian Ocean witnessed the formation of eight cyclonic disturbances during 2009 including one severe cyclonic storm, three cyclonic storms, one deep depression and three depressions. Out of these disturbances, five formed over the Bay of Bengal and three over the Arabian Sea. Out of four cyclones, the Bay of Bengal witnessed cyclonic storm, BIJLI during April, severe cyclonic storm, AILA during May, cyclonic storm, WARD during December and the Arabian Sea witnessed the only cyclonic storm, PHYAN during November 2009. The tracks of the cyclonic disturbances during 2009 are shown in Fig. 9.1. The salient features of these cyclones are discussed below.

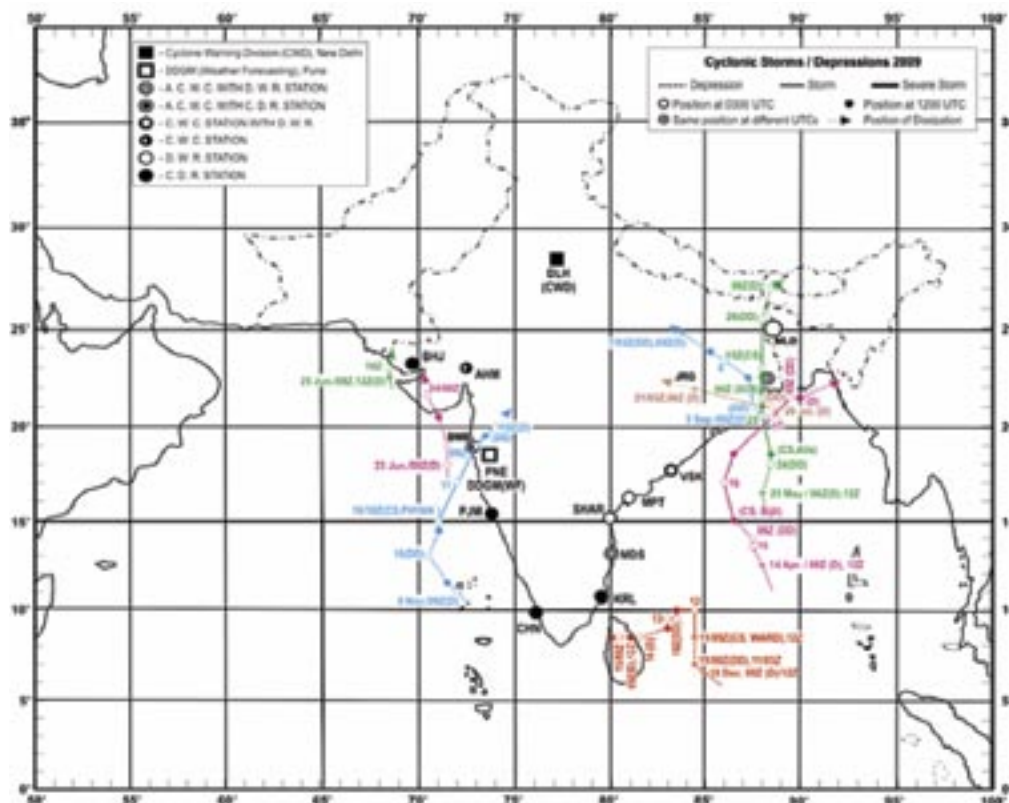
Cyclonic Storm - 'BIJLI' (14-17 April 2009)

The cyclonic storm, 'BIJLI' developed from a persistent convective cloud cluster over the southeast Bay of Bengal and the adjoining Andaman Sea from 10th April and the system concentrated into a depression on 14th April afternoon. Moving in a northwesterly direction, it intensified into a cyclonic storm "BIJLI" over the west-central Bay of Bengal on 15th April. It then re-curved in north-easterly direction towards Bangladesh coast on 16th April. However, it gradually weakened prior to landfall and crossed the Bangladesh coast close to south of Chittagaon around 2130h IST of 17th April 2009 as a depression. Climatologically, cyclogenesis during first fortnight of April is rare. Only a few number of cyclones have developed over the Bay of Bengal during 1891-2008 in April. The tracks of the systems were climatological in nature as most of the storms developing in the month of April during 1891-2008 have recurved towards north-east.

Severe Cyclonic Storm, AILA (23-26 May 2009):

The severe cyclonic storm, 'AILA' developed over the Bay of Bengal in association with the onset

Fig. 9.1: Tracks of the cyclonic disturbances during 2009



surge of southwest monsoon. A low pressure area formed over the southeast Bay of Bengal over 22nd May morning. It lay over east central and adjoining the west central Bay of Bengal on 22nd May evening. It concentrated into a depression and lay centred at 1130h IST of 23rd May about 600 km south of the Sagar Island. The depression moved mainly in a northerly direction and intensified into a deep depression in the morning of 24th May. It further intensified into a cyclonic storm 'ALIA' in the same evening. It continued to move in northerly direction and intensified into a severe cyclonic storm in the forenoon of 25th May over the northwest Bay of Bengal, close to the Sagar Island. The system crossed the West Bengal coast close to the east of the Sagar Island between 1330h and 1430h IST as a severe cyclonic storm with wind speed of 100 to 110 km/h. The lowest estimated central pressure was about 967 hPa at the time of landfall. After the landfall,

the system continued to move in a northerly direction, gradually weakened into a well marked low pressure area over the sub-Himalayan West Bengal and neighbourhood in the afternoon of 26th May and became less marked on 27th May. Following are the salient features of the cyclonic storm:

- i) The system moved in a near northerly direction throughout its life period.
- ii) Its intensification was rapid only a few hours before landfall.
- iii) The system maintained intensity of the cyclone even up to 15 hours after the landfall.
- iv) Widespread rain/thundershowers with scattered heavy to very heavy rainfall and isolated extremely heavy rainfall occurred over Orissa on 25th May, over West Bengal and Sikkim on 25th and 26th May. Widespread rainfall with isolated heavy to very heavy rainfall also occurred over Assam and

Meghalaya on 26th and 27th May. Apart from India and Bangladesh, Nepal also received heavy rain due to northward movement of the system.

- v) A storm surge of 3m (10ft) and 2m affected western regions of Bangladesh, Sunderban area, respectively submerging numerous villages.

Cyclonic storm “PHYAN” over the Arabian Sea (9-12 November, 2009)

The cyclonic storm “PHYAN” developed over the southeast Arabian Sea in association with active northeast monsoon surge. A low pressure area formed over the Comorin area on 7th November, 2009. It concentrated in to a depression in the afternoon of 9th November over southeast and the adjoining east central Arabian Sea, about 70 km west of Amini Divi. It moved initially in a north-northwesterly direction till 10th November morning and then recurved north-north-eastwards. It intensified into a deep depression at 0830h IST and into a cyclonic storm ‘PHYAN’ at 2330h IST of 10th November, 2009. Continuing its north-north-eastward movement, the cyclonic storm ‘PHYAN’ crossed the north Maharashtra coast between Alibag and Mumbai between 1530h and 1630h IST of 11th November. It moved then north-eastwards and weakened gradually into a well marked low pressure area over north Madhya Maharashtra and neighbourhood at 0530h IST of 12th November 2009. The cyclone, ‘PHYAN’ moved faster before crossing the coast. It moved about 450 km in 12 hours between 0530h and 1730h IST of 11th November, 2009 (about 38 kmph). Widespread rainfall with isolated heavy to very heavy falls occurred over Goa, Konkan and Madhya Maharashtra on 10th and 11th. Fairly widespread rainfall also occurred over the south Gujarat region due to the cyclone on 11th. Maximum surface wind was about 60-70 km/h along the Maharashtra coast at the time of landfall. Though it crossed as a cyclonic storm, it slightly weakened before the landfall.

Cyclone ‘WARD’ over the Bay of Bengal 10-15 December, 2009

The cyclone ‘WARD’ over the Bay of Bengal (10-15 December, 2009) formed in association with an active inter-tropical convergence zone (ITCZ). A low pressure area formed over the southeast Bay of Bengal on 7th December 2009. It slowly moved westwards and intensified into a depression on 14th December afternoon over southwest and the adjoining southeast Bay of Bengal. It further intensified into a deep depression in the early morning of 11th December. It then moved northward and intensified into a cyclonic storm ‘WARD’ in the same afternoon. It continued as a cyclonic storm and moved slowly northward till forenoon of 12th December. It then moved west-southwestwards and weakened into a deep depression at midnight of 12th December. Continuing to move in a west-southwesterly direction, it crossed the northeast Sri Lanka coast close to the south of Trincomalee between 1330h and 1430h IST of 14th December as a deep depression. It gradually weakened further into a well marked low pressure area over Sri Lanka in the morning, emerged into the Gulf of Mannar as a low pressure area in the evening of 15th December and became less marked in the afternoon of 16th December. Cyclone ‘WARD’ followed a rare track, as it moved initially in a northerly direction and then moved west-southwestwards across Sri Lanka. It was a slow moving system, as it travelled at the average rate of 200 km per day (8 km per hour). It weakened into deep depression over the sea before the landfall. In association with the cyclone, the northeast monsoon was vigorous over coastal Tamil Nadu and Puducherry during 13-16th December 2009. Widespread rainfall with isolated heavy to very heavy falls occurred over this region during this period.

Average Landfall Forecast Error During 2009

The average landfall forecast errors of cyclonic storms during 2009 based on the forecast issued are given in Table 9.1.

Table 9.1: Errors in Cyclone Land-fall Point Forecasts during 2009

| Name of the Cyclone | Forecast 12h | Forecast 24h | Forecast 36h | Forecast 48h |
|---------------------|--------------|--------------|--------------|--------------|
| BIJLI | 20 km | 40 km | 30 km | 155 km |
| AILA | 55 km | 110 km | 110 km | 110 km |
| PHYAN | 75 km | 250 km | - | - |
| WARD | 78 km | 78 km | 78 km | 78 km |

9.5 Early Warning System for Tsunami

9.5.1 Tsunami Monitoring

The tsunami warning centre operated on 24x7 basis. It detected and reported 125 major earthquakes during 01st Apr-31st Dec, 2009. The centre located the earthquake that occurred in the Samoa Island Region on 29th Sep, 2009 17:48:10 (UTC) 29th Sep, 2009 23:18:10 (IST), within four minutes and the initial bulletin/emails were disseminated at 23:28 IST (within 10 minutes) stating that “Tsunami threat does not exist for Indian Ocean region”. The centre also located the earthquake that occurred in the Southern Sumatra, Indonesia on 30th September, 2009 10:16:07 (UTC), 15:46:07 (IST) within 4 minutes and disseminated the first bulletin/email at 15:51 IST (after 6 minutes of the occurrence of earthquake). The second bulletin was issued after examining the model generated scenario at 16:24 IST (after 38 minutes of earthquake occurrence) with updated information on earthquake and the statement that “Model simulations do not indicate any significant change in water level at the Indian coast, there is NO tsunami threat for Indian Region”.

The data from 329 seismic stations (27 national and 302 international) were received and processed in Seiscomp software for real time detection of global earthquakes $M > 5.0$. 21 tide gauges installed and maintained by the Survey of India (SOI) are reporting to INCOIS in real time. Currently, INCOIS is receiving data from 60 international tide gauges stations in the Indian Ocean on real time. Data from three international DART buoys in the Indian Ocean are also received at INCOIS in real time. Data from seven CODAR (Machilipatnam of Andhra Pradesh

Coast, Cuddalore and Kalpakkam of Tamil Nadu Coast, Gopalpur and Puri of Orissa Coast, and Jegri and Wasi of Gujarat Coast) locations are received at INCOIS in real time.

9.5.2 Indian Ocean Wave (IO Wave 09) Exercise

India participated in the major Indian Ocean Wave 09 drill coordinated by IOC on 14th October, 2009. A table-top exercise was conducted on September 14, 2009 at 1400h in the Tsunami Warning Centre, INCOIS to test the procedures, bulletin formats and functionality of software. Later the Indian Ocean Wave (IO Wave 09) exercise was conducted on 14th October, 2009. The exercise was carried out in real time mode, during 6:30 IST and 18:30 IST (12 hrs), and the scenario of 26th December, 2004 tsunami of Northern Sumatra was taken as an example. INCOIS disseminated timely bulletins to MHA, MoES and RTWPs (Australia and Indonesia). INCOIS received timely tsunami information bulletins from PTWC and JMA. All Indian Ocean Countries participated in this exercise.

9.5.3 Tsunami Early Warning Web-site

Shri M. Shashidhar Reddy, Hon’ble Member of NDMA, launched the tsunami website during the inauguration of International Society of Photogrammetry and Remote Sensing (ISPRS) WG IV/1, IV/3 and VIII/1 workshop at INCOIS on 25th November, 2009. (Fig. 9.2)

Preparation of coastal vulnerability maps for Kerala, West Bengal and Maharashtra states are progressing. The case study for the multi-hazard mapping for Cuddalore area has been completed.

Fig. 9.2: Inauguration of the Tsunami EWS Website by Mr. M. Shashidhar Reddy, Hon'ble Member, NDMA, Govt. of India



occurrence of an earthquake and disseminated to all the user agencies including the concerned State and Central Government agencies. The earthquake information is transmitted to various user agencies including public information channels, press, media etc. using different modes of communication, such as SMS, fax, email, IVRS and also posted on IMD's Website.

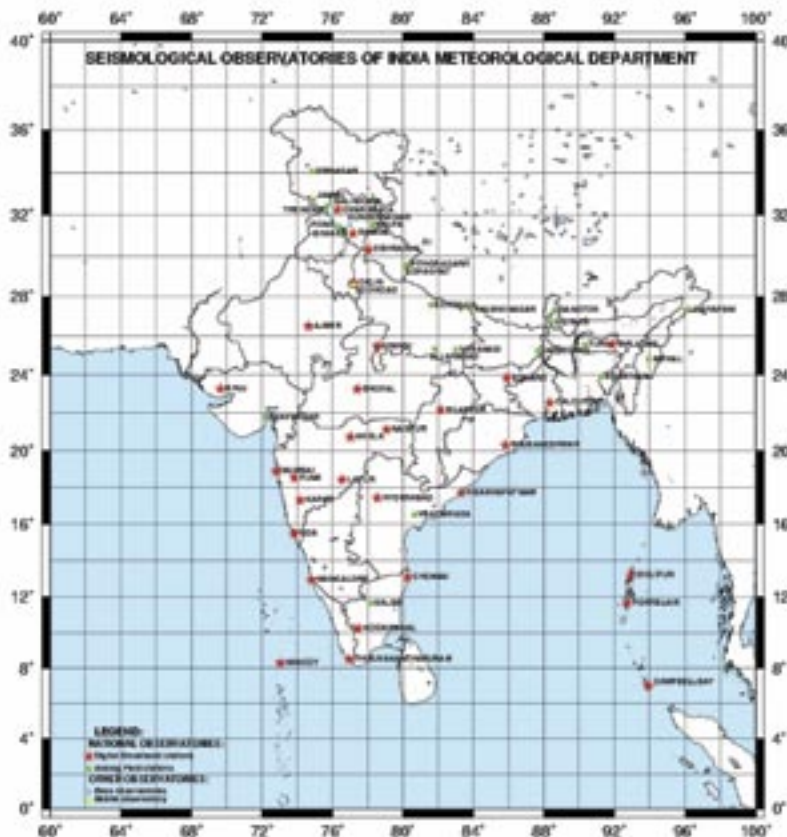
A national network of seismological observatories consisting of 55 stations (Fig. 9.3), which includes 17-stations of the Real Time Seismic Monitoring Network (RTSMN) has been maintained. IMD is also maintaining a 16-station, V-SAT based digital seismic telemetry system around National Capital Territory (NCT) of Delhi for close monitoring of seismic activity in the region. The RTSMN system is in successful operation for over a year now and has performed well in providing accurate and timely information on significant earthquakes.

9.6 Seismological Research

9.6.1 Earthquake Monitoring

As a part of this activity the earthquake source parameters are estimated immediately on

Fig. 9.3: Location of Seismic Observatories



Following are a few significant achievements made during the year 2009-10:

- i) The processed earthquake data was systematically archived and supplied, on request, to various user agencies viz. insurance companies, industrial units, power houses, river valley projects, relief and rehabilitation measures, disaster mitigation and management, seismic zoning, etc. Earthquake data was also supplied to various scientific, academic and R&D institutions in India and abroad for research purposes.
- ii) Seismology and earthquake prediction related research is currently being pursued with Russia and Mexico. Following are a few major contributions made in this regard:
 - a) As part of a collaborative project with Russia, entitled "Preparation of catalogue of Indian earthquakes and test for its completeness", earthquake data sets for different regions have been compiled and initial processing has been taken up jointly with Russian scientists.
 - b) For understanding the geodynamic processes in and around Delhi region a borehole seismic acoustic sensor has been installed at a depth of about 100 m at Ridge Observatory.
 - c) As part of a joint collaborative project with Mexico on "Near real time estimation of (a) long-period magnitude, (b) moment tensor and (c) tsunami potential of offshore earthquakes", preliminary analysis using the existing data sets has revealed that the ratio of broadband to high frequency contained in a seismogram can be utilised effectively to characterise the focal depth of an earthquake, which in turn would help assess the tsunamigenic potential.

9.6.2 Seismicity and Earthquake Precursors

The aim of the programme is to provide added thrust to the earthquake-related studies and also to generate inputs for earthquake disaster mitigation. Keeping in view that there is no

proven scientific technique available, as yet, to precisely forecast the occurrence of earthquakes in terms of location, magnitude and time, a new programme, "National Programme on Earthquake Precursors" (NPEP) has been launched for carrying out systematic study of different precursors and establish possible relationship between various earthquake precursory phenomenon and the earthquake generation processes.

The salient achievements made during FY 2009-10 are listed below:

- Analysis of seismic data from a 10-element digital telemetric system in the Uttarakhand region have indicated that presently seismicity is concentrated in a narrow belt between the Main Central Thrust (MCT) and the Main Boundary Thrust (MBT). Two anomalous regions have been identified, viz. Adibadri and East of Tapoban area, and Deoband.
- Neo-tectonic studies have been carried out in the Kangra region, the Soan Dun-Janauri anticline and the Pinjor Dun-Chandigarh anticline to understand the seismotectonics of the 1905 Kangra earthquake.
- Under a project on crustal studies of Bastar and Chhattisgarh basin using geophysical methods, Moho depths at Jeypore and Jagdalpur have been determined as 40 and 36 km, respectively, from receiver function analysis of seismic data. Mantle anisotropy has also been determined using shear wave analysis.
- Using the seismic data collected under a project in the Gujarat region the receiver function analysis reveals that the Moho depths varies from 33-43 km in Kachchh region, 31-38 km in the Saurashtra region, 27-34 km in the Khambhat basin, 28-36 km in the Narmada region and 40-42 km in the north and eastern part of Khambhat basin. These depths are consistent with previous gravity and deep seismic studies carried out in the region.
- For modelling the genesis of intra-plate earthquakes in the Indian shield region, seismic anisotropic nature of the Godavari rift zone has been studied using shear wave analysis. Studies suggest that the Godavari rift

is an intra-cratonic rift, which formed due to lithosphere stretching between the Dharwar and Bastar cratons.

9.6.3 Earthquake Risk Evaluation

Earthquake Risk Evaluation Centre (EREC) has been setup to guide national endeavour in mitigating the disasters impact of earthquake

and undertake/promote scientific task related to earthquake risk evaluation. In this regard EREC has completed seismic microzonation of NCT of Delhi on 1:50,000 scale integrating several thematic maps viz. geotechnical, geological, seismological and site response etc. EREC is now in the process of generating such maps, at higher resolution on 1:10,000 scale.

10 Extramural and Sponsored Research

The Ministry of Earth Sciences provides support to basic and applied research in the universities/institutes for promotion of front-ranking research in the specialised areas of earth system sciences and related subjects.

10.1 Ocean and Atmospheric Science and Technology Cells (OASTC)

The objectives are:

- To create adequate expertise in various disciplines of ocean and atmospheric science and technology for the benefits of society.
- To maximise the benefits that our country could realise 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.

These objectives are achieved through the following nine Ocean and Atmospheric Science and Technology Cells (OASTC).

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

The Ocean and Atmospheric Science and Technology Cells (OASTCs) regularly organise advanced training programmes and workshops to generate skilled manpower in the identified areas of ocean sciences. The cells at the Goa University and the Annamalai University are functioning as Centres of Excellence (CoE) in Marine Microbiology and Marine Biology, respectively.

10.2 Focused Research Activities

The Ministry has started funding projects to various academic/research organisations and universities in the following areas:

1. Atmospheric Research
2. Coastal and Marine Ecosystem
3. Climate Change
4. Disaster Management
5. Atmospheric Technology
6. Geoscience
7. Ocean Science and Technology

The following research projects were funded in 2009-10:

- i) **“River Dynamics and Flood Risk Evaluation of the Kosi river, North Bihar Plains: An Integrated Approach”** to IIT Kanpur. The proposal is aimed at understanding river dynamics and flood risk evaluation of the Kosi River in north Bihar and development of flood management strategies.
- ii) **“Development of a Framework for Systematic Model Diagnosis”** to be implemented by IIT Delhi. The project proposes to build a diagnostic framework using modern programming tools for application to a variety of Earth System models. The framework will be eventually used by the NCMRWF and IMD.

- iii) **“Study of Contamination of Earth (Soil and Ground Water) through Leaching of Sewage Waste from Heavily Loaded Unlined Drains in Delhi”** to Amity University which intends to estimate the possibility and extent of soil and ground water contamination through leaching of sewage waste from heavily loaded drains of Delhi.
- iv) **“L-moments Based Regional Extreme Rainfall and Flood Frequency Analysis for Hydro-meteorological Sub zones 2(b) and 2(c) of India”** to be implemented by NIT Silchar. The outcome of the project will help to estimate return periods of floods, using L-moment methods for each of the identified homogeneous regions. The information of estimation of return period is required by design engineers for any infrastructure development over NE region.
- v) **Monsoon Driven Changes as Preserved in Marine Sediments off Gujarat and Konkan Coasts During the Past 20 Kyr”** to be implemented by IIT Kharagpur. The proposal aims to reconstruct past Indian monsoon variability at high resolution using sediment cores from the eastern Arabian Sea.

10.3 Building Indigenous Capability through Joint Developmental Projects

The Ministry of Earth Sciences and CSIR are working jointly in the field of Meteorological and Oceanic Sciences and Technology and supporting specific projects of direct relevance to MoES through joint funding, a specific NMITLI project on mesoscale modelling for monsoon related weather predictions. Phase II had been funded.

A second NMITLI joint project on Biofuel from Marine Microalgae has been recently agreed upon.

10.4 Human Resource Development & Capacity Building

IIT Delhi

Under the existing MoU for sponsored M Tech and PhD programmes in the field of **Earth &**

Atmospheric Sciences, the first batch of M Tech students will graduate by the end of 2009-10.

IISc, Bangalore

To encourage research in Earth Sciences and also to augment capacity building in the field of Earth Sciences, a project proposal entitled **“Research, Education & Manpower Development in the Discipline of Earth Sciences”** to Indian Institute of Science (IISc), Bangalore. The aim of the proposal is to strengthen the infrastructural facilities for earth science research and training at the newly created Centre for Earth Sciences at IISc Bangalore apart from initiating an M Tech Programme.

10.5 Establishment of MoES Distinguished Chair Professorship

- i) Under the established Sir Gilbert Walker Distinguished Chair Professorship Programme Prof. T. N. Krishnamurti, FSU, USA visited IIT Delhi during December 2009 as the first MoES Chair Professor.
- ii) MoES Panikkar Professorship has been established under the aegis of NGRI, Hyderabad for carrying out research in the field of earthquake including microzonation, precursors, tsunami, palaeotsunami, tectonics etc. Prof. Harsh Gupta is the first Professor under this scheme.

10.6 Awareness and Outreach Programmes

In order to propagate and bring awareness about the programmes and achievements among the public, students and user communities, the Ministry participated in major National and International exhibitions held in India and supported Seminars, Symposia, Workshops and various National Science Centres of National Council for Science Museum and States Council for Science and Technology of Governments of Himachal Pradesh, New Delhi, Jammu & Kashmir, etc. The “Earth Day” is celebrated with the participation of school children, screening

science safari films on Doordarshan, supporting the seminar Symposia, etc to create platform between scientist, engineers, social scientists and user community to exchange information and knowledge.

10.6.1 Exhibitions

The Ministry has been actively participating in various exhibitions in India as well as abroad, highlighting the research and development programmes and achievements.

a) International Exhibition in India

The Ministry participated in the India International Trade Fair 2009 (IITF 2009) at Pragati Maidan, New Delhi, MAP India 2010 at Gurgaon, North India International Trade Fair 2010 at Kanpur, INMEX 2009 at Mumbai, MAP-Asia 2009, Singapore; MAP-Africa 2009, Johannesburg, South Africa; India Show at St. Petersburg, Russia; 9th SAARC Trade Fair at Thimpu, Bhutan. (Fig. 10.1)

b) Rural Exhibitions

This year the Ministry had participated in Krishi 2009 at Nasik, Maharashtra; Uttarakhand Mahotsav at Dehradun, Uttarakhand; Science & Rural Technology Expo-2010” 1st Destination, Rajasthan 2010, Jhunjhnu, Rajasthan 2010; National Science Exhibition 2010 at Sambhal, UP; “National Expo XIII at Kachari Maidan, Barasat, Kolkata; 15th All India National Expo 2009 at Kolkata, West Bengal; Vigyananen tu Samridhhi at Pauri Garhwal, Uttarakhand; Uttarakhand Mahotsav at Dehradun, Uttarakhand.

Fig. 10.1: 97th Indian Science Congress (Ministry's pavilion won the Best Design Award)



c) Exhibition during Annual meeting of Chief Secretaries

Chief Secretaries of all states came, for the first time, to attend the annual meeting at Vigyan Bhawan, New Delhi which was inaugurated by the Hon'ble Prime Minister of India. The Ministry was assigned to coordinate the exhibition of all the scientific departments and Ministries of the Government of India.

10.6.2 Earth Day Celebration

To preserve the planet earth and bring awareness among the public, Earth Day 2009 was celebrated on 22nd April across the country in 200 centres of Argomet services, National Science Centres, National Museums, OASTC Centres, etc. and painting competitions were organised among three age groups. The winners of painting competition from three categories of age groups were awarded prizes at each centre. (Fig. 10.2-10.4)

Participation in International Earth Science Olympiad

This year the Ministry supported participation of Indian students in the 3rd International Earth Science Olympiad held at Taipei, Taiwan. Four students of the Indian team bagged Bronze Medals and three got Special Recognition Certificates.

10.6.3 Popularisation on Television and Print Media

- The film “Science Safari” in regional television channels in local languages on various activities of Ocean and Atmospheric Science and Technology, produced by the National Geography channel was screened.
- The articles related to earth system services were published in “Geography and You” in English and “Bhugol aur Aap” in Hindi which is being distributed to various central schools.

10.6.4 Seminars, Symposia, Conferences & Workshops

About 200 events were supported in area of earth system science to provide platform to scientists,

Fig. 10.2: 1st prize: Master Pulak Samanta, Class V, Contai Model Institution, West Bengal



Fig. 10.3: 2nd prize: Miss Jyoti Nagpal, Class V, Amity International School, Vasundhra, Ghaziabad



Fig. 10.4: 3rd prize: Master Pranjal Singh, Class V, K. V. Aliganj Lucknow



engineers, technologists, experts, social scientists and user communities. The beneficiaries are Indian Institute of Technology/Indian Institutes of Management, CSIR labs, universities, non governmental organizations, government bodies, etc.

Few major areas where the Ministry supported were climate change and impact on health; weather modification technology and disaster management; coastal dynamics; aquaculture; environmental pollution and its effects on agriculture and production and human health; marine ecosystem; disaster management; agrometeorological services, space technology and applications; geological science; snow and avalanches processes; mathematical modelling and simulation; fish development, etc.

10.7 Awards

a) National Awards

In recognition of significant contributions on Ocean Science and Technology and Atmospheric Science, the Ministry gave National Awards for lifetime contribution to scientists. Each of these awards carries with it a cash prize of Rs. 1.00 lakh along with a citation.

This year the National Awards were given to:

- i) **Dr. George Joseph**, Director of 'Centre for Space Science and Technology Education in Asia and the Pacific' (CSSTEAP) affiliated to the United Nations for **Ocean Science & Technology**
- ii) **Prof. S. K. Dube**, Former Director of IIT Kharagpur for **Atmospheric Science**

b) Certificate of Merit

Outstanding scientists and engineers working in autonomous institutes of the Ministry and attached offices were also awarded for their outstanding contributions in the field of Ocean, Atmospheric Science and Technology. The awardees were:

Certificate of Merit for Young Scientists/Engineers in Ocean Sciences

- i) Shri K. Mullai Vendhan
- ii) Dr. Pattabhi Rama Rao
- iii) Shri A. J. Luis
- iv) Shri D. Mohan
- v) Shri D. Saravanane

Certificate of Merit for Young Scientists/Engineers in Atmospheric Sciences

- i) Dr. N. Chattopadhyaya

- ii) Dr. M. Mohapatra
- iii) Dr. Munmun Das Gupta
- iv) Dr. A. K. Sahai

c) Best Employees Awards

Group "B" Employees:

- i) Smt. Naresh Chopra
- ii) Shri B. L. Koli
- iii) Shri Abraham Philippose

Group "C" Employees

- i) Shri Bishamber Dutt
- ii) Shri Angshuman Kundu

Group "D" Employees

- i) Shri Om Prakash
- ii) Shri Inderjeet
- iii) Shri Subhash Singh Sajwan
- iv) Shri Har Singh

11 Vessel Management

The Ministry of Earth Sciences (MoES) has a fleet of scientific research vessels to conduct the oceanographic research programmes/projects of the country. Presently, there are six research vessels in operation; undertaking scientific research activities in the Arabian Sea, Bay of Bengal and the Indian Ocean. Oceanographic Research Vessel (ORV) Sagar Kanya is undertaking scientific programmes in the areas of survey and exploration of non-living ocean resources and the Fisheries Oceanographic Research Vessel (FORV) Sagar Sampada.

The two coastal research vessels, CRV Sagar Purvi and CRV Paschimi are used for the implementation of Coastal Ocean Monitoring and Prediction System (COMAPS) and Integrated Coastal and Marine Area Management (ICMAM) programmes. These vessels also provide services to many other user agencies like; universities and research institutes in the country for oceanographic surveys and for marine scientific data collection. The BTV Sagar Manjusha is actively involved in the logistics for timely execution of desalination projects at islands, in addition to the National Data Buoy programmes. The TDV Sagar Nidhi is catering to the on-going and several new programmes of the MoES such as; the deep sea mining programme, demonstration of Remotely Operable Vehicle

(ROV), Autonomous Underwater Vehicle (AUV) etc. It is also catering to other projects of the NIOT and various R&D institutes in the country.

11.1 Oceanographic Research Vessel (ORV) Sagar Kanya

During this year, three significant cruises were undertaken by the vessel for the Deep Swath Bathymetric Surveys in the Indian Exclusive Economic Zone (EEZ), two cruises for studying biogeochemistry and hydrodynamics of the Tropical Indian Ocean (TIO) during summer and winter; and one cruise each for CTCZ in Bay of Bengal, Trichodesmium Bloom studies in the Arabian Sea, PMEL-INCOIS RAMA moorings, Equatorial current-meter moorings and UNEP-SACEP training programme, (ICARB-Winter campaign and Satellite Validation).

11.2 Fisheries Oceanographic Research Vessel (FORV) Sagar Sampada

It had undertaken eight scientific cruises (FORV 265 – FORV 272) in the Indian Exclusive Economic Zone during the period from April 2009 to mid October 2009, involving 137 days of sailing. Scientists from Centre for Marine Living Resources and Ecology-Kochi, Goa University-Goa, Annamalai

| Vessel | No. of cruises | Days of operation | Port stay | Maintenance |
|--------------------|----------------|-------------------|-----------|-------------|
| ORV Sagar Kanya | 10 | 308 | 44 | 13 |
| FORV Sagar Sampada | 09 | 159 | 38 | 167 |
| TDV Sagar Nidhi | 14 | 314 | 19 | 32 |
| BTV Sagar Manjusha | 04 | 268 | 46 | 50 |
| CRV Sagar Purvi | 16 | 239 | 93 | 33 |
| CRV Sagar Paschimi | 14 | 275 | 40 | 50 |

University-Tamil Nadu, National Institute of Oceanography-Goa, Central Marine Fisheries Research Institute-Kochi, Cochin University of Science and Technology-Kochi and Department of Biotechnology- Andhra University participated in these cruises. The focus of the scientific cruises was: a) to understand the dynamics of the harmful algal blooms occurring along the NW coast during spring inter-monsoon and explain the biogeochemical changes associated with these blooms; b) to capture the spatio-temporal progression of the Summer Monsoon upwelling along the southwest coast and associated changes in the productivity patterns; c) to understand the abundance and distribution of fish eggs and larvae in the up-welled waters; and d) assessment of impact of closed fishing season (15th June to 30th July) on marine benthos etc.

From mid October 2009, the vessel is under, lay-up repair for installation of new winches and associated hydraulic systems. The vessel is expected to be operational from March 2010.

11.3 Technology Demonstration Vessel (TDV) Sagar Nidhi

Technology Demonstration Vessel (TDV) Sagar Nidhi (Fig. 11.1) is the latest addition to the fleet of Scientific Research vessels. It is equipped with technologically advanced scientific equipment and associated facilities to undertake multi-disciplinary oceanographic research activities. The vessel is equipped with dynamic positioning

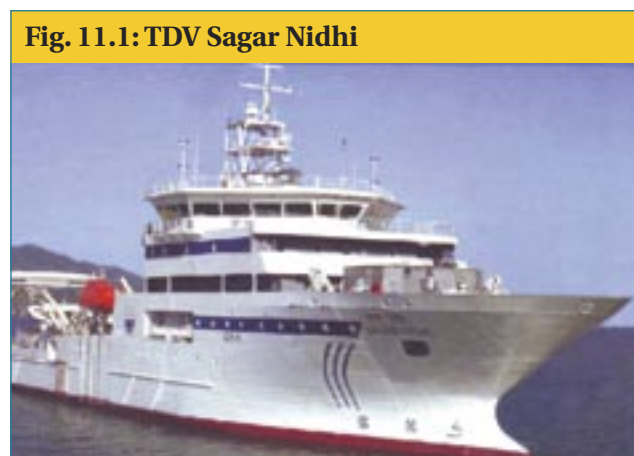


Fig. 11.1: TDV Sagar Nidhi

system for precise operations at sea and has an endurance of about 45 days to cruise up to 10,000 nautical miles at a stretch.

During the period April 2009 to February 2010, the vessel has undertaken 14 scientific cruises, with the participating scientists from INCOIS, Hyderabad; NIO, Goa; IISc, Bangalore; IIT, Madras and NIOT, Chennai. Launching of ROV to a depth of 3,000 meters; ADCP moorings; deployment and retrieval of Tsunami Buoys; Bathymetric survey of Indian EEZ and CTCZ studies are the main programmes accomplished by the vessel during this period. It is on Southern Ocean scientific cruise at present to reach up to 67 degrees south latitude.

To mark the 50th Anniversary of Inter-governmental Oceanographic Commission of UNESCO, India launched a dedicated Cruise during the period 14th July to 18th August, 2009 on-board TDV Sagar Nidhi for conducting CTCZ experiments.

11.4 Buoy Tender Vessel (BTV) Sagar Manjusha

Ocean Research cum Buoy Tender Vessel (BTV) Sagar Manjusha was mostly deployed for 'transportation of heavy machinery and equipment for establishment and commissioning of desalination plants to generate fresh water' at the Agathi, the Minicoy and the Androth Islands during the period. It was also deployed for "Supra Project" undertaken by NIO, Goa, which involved ADCP mooring and retrieval for data collection and servicing.

11.5 Coastal Research Vessels (CRV) Sagar Purvi and CRV Sagar Paschimi

Coastal Research Vessel (CRV) Sagar Purvi and CRV Sagar Paschimi 16 and 14 scientific cruises respectively, during the period April 2009 to December 2009.

- CRVs were deployed for COMAPS programme in the East and West Coast of India. (CAS –Annamalai; NIO RC, Visakhapatnam; IMM, Bhubaneswar; CESS, Thiruvananthapuram; NIO-Goa and NIO Mumbai regional centre).

- Sagar Paschimi was dry-docked at Visakhapatnam fishing harbour dry-dock facility and completed all annual surveys by CLASS and statutory body.
- Sagar Paschimi was deployed for Ph. D students of Anna University, Geology department to study the shallow continental shelf in the East coast of Tamil Nadu.
- Sagar Paschimi was deployed on satellite data validation study.
- Sagar Purvi was deployed for NIO-Goa for Poly-oceanography of Northern Indian Ocean.
- Sagar Purvi was deployed for NIO-Goa for surface water Isotope finger printing of waters in 20 m water depth and investigating all parameters between Pamban to Goa.

12 International Cooperation

12.1 Participation in International/UN Organisations

- Vice Chair, Council of Managers of National Antarctic Programme (COMNAP)
- Vice President, Scientific Committee on Antarctic Research (SCAR)
- Founder member of Asian Forum for Polar Science (AFOPS) that has China, Korea, Japan, and Malaysia as other partners
- Member-Legal and Technical Commission,
- Member-United Nations Convention on Law of the Sea
- Member-Finance Committee, International Seabed Authority (ISBA)
- Member-Commission on the Limits of Continental Shelf (CLCS)
- Chairman-Sub-commission, examine the submissions by Barbados
- Member, Executive Council, Intergovernmental Oceanographic Commission (IOC) and continued to be a Member of the Executive Council
- Chair, Indian Ocean Global Ocean observing system (IOGOOS)
- Member, Partnership for Observation of Global Ocean (POGO)
- IBSA-Ocean is an emerging trilateral cooperation among India, Brazil and South Africa in the field of ocean science and technology.

12.2 SAARC-Activities

- SAARC Disaster Management Centre (SDMC) has been established at National Institute of

Disaster Management (NIDM), New Delhi, under Ministry of Home Affairs. IMD has close cooperation with the centre. IMD organised a workshop on “Use of Satellite Products in day to day Weather Forecasting Techniques” from 1st to 14th March, 2008.

- Under International Programme Committee (IPC) of SAARC, India has offered installation of observing centres.

Bangladesh: 25 AWS, 1 GPS receiver

Bhutan: 10 AWS, 1 GPS receiver

Nepal: 15 WS, 1 GPS receiver and 1 DWR

Maldives: INSAT Digital meteorological Dissemination

Nepal: INSAT Digital Meteorological Dissemination

Sri Lanka: INSAT Digital Meteorological Dissemination

12.3 Bilateral Cooperation

- **Indo-Russian Cooperation Programme:** Earth Sciences and Oceanology and Gas hydrates’ under Integrated Long-Term Programmes (ILTP)
- **Cooperation with NOAA, USA:** Weather and climate science
- **Cooperation with UKMO, UK:** Unified model for weather and climate
- **Cooperation with NERC (Natural Environmental Regional Council):** Water cycle
- **Cooperation with University centre in Svalbard:** Polar Science

13 Administrative Support

The sanctioned strength of the Ministry of Earth Sciences including attached offices is 297 during the year 2009-10. The detailed break up may be seen at Ministry's website which includes 121 Scientific/ Technical and 176 Non-Technical posts. Four autonomous institutes Viz. IITM-Pune, NCAOR-Goa, NIOT-Chennai, INCOIS-Hyderabad under administrative control of MoES have sanctioned strength of 351, 63, 139 & 53 respectively. Similarly, IMD, a subordinate office under this Ministry, has a sanctioned strength of 6737. Details are available at their respective websites.

13.1 Implementation of the 15-Point Programme on Minority Welfare

Due care has been taken for proper implementation of the 15-point programme on minority welfare including, inter alia, ensuring adequate representation of minority communities while making recruitment or forming Selection Committee set up for filling up of vacancies in Group A, B, C, and D.

13.2 Grievances of Public and Staff and their Redressal

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

The Ministry is implementing 3% reservation in Government jobs for handicapped and disabled persons.

13.3 Gender Budget

Most of the activities undertaken by the Ministry in the "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 marine culture to improve the livelihood of fishers where the women folk also participate. NIOT also imparts training to the fishermen/women.

13.4 Right to Information Act

Information about the activities of the Ministry and staff have been put on website. Public Information Officer and Assistant Public Information Officer have been nominated in respect of the Ministry proper and its attached/subordinate offices and autonomous institutes. Between April 2009 and December 2009, 53 requests under the Right to Information Act, 2005 were received in the Ministry of Earth Sciences and replies were given.

13.5 Vigilance Activities and Achievements

Shri D. P. Singh, 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 Ministry is continuing with preventive as well as punitive vigilance monitoring rigorously through the Central Vigilance Commission and other Vigilance Officers.

13.6 Training for the Human Resource Development

During the year **17** officers/staff of this Ministry (from the Headquarters) were sent for different training/workshop/seminar programmes to update their knowledge and skills.

13.7 Implementation of the Judgements/Orders of the CAT

All the judgements/directions/orders of Hon'ble CAT's or any other courts have been implemented or contested in proper fora within the stipulated period of time.

14 Use and Promotion of Hindi

The Ministry is constantly working for promotion and propagation of the Official Language. During 2009-10 also, efforts were made to promote the progressive use of Hindi in the Ministry.

As per the directives and guidelines on Official Language policy all official works like 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 bilingual. The Ministry also organised Hindi fortnight from 1st to 14th September, 2009. During the period, various competitions including Hindi essay writing, noting, drafting, debate and recitation were held. This was followed by a Hindi Kavi Goshthi, wherein poets of repute enthralled the audience. The Ministry organised

18th National Scientific Hindi Seminar on the topic "Jalvayu Parivartan ka Samaj Par Prabhav" on 8th February 2010 at New Delhi. Shri Shyam Saran, Special Envoy to the Prime Minister, was the Chief Guest. On this occasion, the Ministry released a Hindi book titled "Jalvayu Parivartan",

Under the Prithvi Vigyan Mantralaya Maulik Pustak Lekhan Yojana-2009, the Ministry awarded first, second and third prizes to the books titled (i) "Hind Mahasagar ki Samudri Khanij Sampada by Premchand Srivastava; (ii) Hind Mahasagar avam Salagn Rashtra-Ek Bhū-Arthik avam Bhū-Samarik Adhyayan by Dr. Tara Devi Singh; and (iii) Sagar Sampada-Mahatva avam Prabandhan by Professor Madhu Sudan Tripathi. Prize worth Rs. 50,000/-, Rs. 40,000/- and Rs. 30,000/- respectively were given as prize money.

15 Parliament Work

The Parliamentary Standing Committee on Science and Technology, Environment and Forests did not meet during the calendar year 2009-10 owing to the General Elections, 2009.

Between April and December 2009, the Ministry replied to Parliament Questions in Lok Sabha and Rajya Sabha as listed:

| S.No. | Parliament Questions | Number |
|-------|---------------------------------|--------|
| 1. | Lok Sabha Starred Questions | 05 |
| 2. | Lok Sabha Unstarred Questions | 24 |
| 3. | Rajya Sabha Starred Questions | 01 |
| 4. | Rajya Sabha Unstarred Questions | 27 |

The total budget allocation for the Ministry of Earth Sciences for the year 2009-10 was Rs. 1213.35 crore, which includes Rs. 900.00 crore for Plan Schemes and Rs. 313.35 crore for Non-Plan Schemes. The revised estimates for the Ministry of Earth Sciences have been fixed at Rs. 1137.35 crore (Rs. 793.00 crore for Plan and Rs. 344.35 crore for Non-Plan activities). The budget estimates for 2010-11 for Plan Schemes are Rs. 1000.00 crore and for Non-Plan Scheme is Rs. 305.35 crore. The details of budget estimates for 2010-2011 and actual expenditure for the year 2008-09 are given in the following table:

Table 16.1: Details of Budget Expenditure and Actual Expenditure for the year 2008-09

| Rupees in crore | | | | | | | | | | | | | | | |
|------------------------|---|------------|----------------|---------------|----------------|-------------------|---------------|----------------|----------------|---------------|----------------|-----------------|---------------|---------------|---------------|
| S. No. | Scheme name | Major head | 2009-10 Budget | | | 2009-2010 Revised | | | 2010-11 Budget | | | 2008-09 Actuals | | | |
| | | | Plan | Non-Plan | Total | Plan | Non-Plan | Total | Plan | Non-Plan | Total | Plan | Non-Plan | Total | |
| REVENUE SECTION | | | | | | | | | | | | | | | |
| 1 | Secretariat-Economic Services | 3451 | 0.00 | 19.00 | 19.00 | 0.00 | 19.25 | 19.25 | 0.00 | 22.99 | 22.99 | 0.00 | 12.31 | 12.31 | 12.31 |
| 2 | Oceanographic Research | 3403 | 481.62 | 38.25 | 519.87 | 457.12 | 40.30 | 497.42 | 564.78 | 39.88 | 604.66 | 260.85 | 37.44 | 298.29 | 298.29 |
| 3 | Other Scientific Research | 3425 | 72.00 | 16.65 | 88.65 | 70.00 | 19.54 | 89.54 | 67.45 | 21.12 | 88.57 | 36.71 | 14.59 | 51.30 | 51.30 |
| 4 | Meteorology | 3455 | 58.50 | 236.95 | 295.45 | 51.30 | 262.88 | 314.18 | 85.98 | 218.86 | 304.84 | 33.94 | 198.10 | 232.04 | 232.04 |
| CAPITAL SECTION | | | | | | | | | | | | | | | |
| 5 | Capital Outlay on Oceanographic Research | 5403 | 28.00 | 0.00 | 28.00 | 29.50 | 0.00 | 29.50 | 32.77 | 0.00 | 32.77 | 1.12 | 0.00 | 1.12 | 1.12 |
| 6 | Capital Outlay on Other Scientific and Environment Research | 5425 | 8.00 | 0.00 | 8.00 | 0.00 | 0.00 | 0.00 | 14.00 | 0.00 | 14.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 7 | Capital Outlay on Meteorology | 5455 | 251.88 | 2.50 | 254.38 | 185.08 | 2.38 | 187.46 | 235.02 | 2.50 | 237.52 | 156.43 | 0.17 | 156.60 | 156.60 |
| | Grand Total | | 900.00 | 313.35 | 1213.35 | 793.00 | 344.35 | 1137.35 | 1000.00 | 305.35 | 1305.35 | 489.05 | 262.61 | 751.66 | 751.66 |

17 Report of the Comptroller and Auditor General of India for the Year Ended March 2008

17.1 Construction of Residential Quarters and Hostel Units without Demand

Despite incurring Rs. 9.32 crore on construction of residential quarters and hostels, the National Centre for Medium Range Weather Forecasting could not allot these quarters as there was no demand for them.

17.2 Avoidable Expenditure due to Contracting of Higher Load

Delayed decision of the Regional Meteorological Centre, Kolkata to revise the agreemental

load from 285KW to 150KW for electricity consumption resulted in avoidable expenditure of Rs. 51.76 lakh between August 2004 and March 2007.

17.3 Status of Action Taken Notes (ATNs) Pending from C&AG Reports

The number of Action Taken Notes (ATNs) pending from various C&AG reports are given in the following table:

Number of ATNs Pending from various C&AG Reports

| S. No. | Year | No. of paras/PAC reports on which ATNs have been submitted to PAC after vetting by Audit | Details of the paras/PAC reports on which ATNs are pending | | | |
|--------|------|--|--|---|--|------------------------|
| | | | No. of ATNs not sent by the Ministry even for the first time | No. of ATNs sent but returned with observations and Audit is awaiting their re-submission by the Ministry | No. of ATNs which have been finally vetted by Audit but have not been submitted by the Ministry to PAC | No. of ATNs with Audit |
| 1 | 2006 | 1 | | | | |
| 2 | 2007 | | | 2 | | |
| 3 | 2008 | | 3 | | | 2 |
| 4 | 1997 | 1 | | | | |

Table 18.1: Representation of SCs/STs/OBCs in Ministry including CMLRE and ICMAM (attached offices) and IMD (a subordinate office).

| Groups | Number of Employees | | | | Number of appointments made during the previous calendar year (2009) | | | | | | | | | | |
|---|---------------------|-------------|------------|------------|--|-----------|-----------|-----------|------------|--------------|-----------|------------------|----------|----------|-----|
| | Total | SCs | STs | OBCs | By Direct Recruitment | | SCs | STs | OBCs | By Promotion | | By Other Methods | | SCs | STs |
| | | | | | Total | SCs | | | | Total | SCs | Total | SCs | | |
| I | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| Group A | 310 | 43 | 17 | 30 | 03 | - | - | - | 67 | 11 | 07 | - | - | - | |
| Group B | 3235 | 543 | 150 | 232 | - | - | - | - | 703 | 124 | 30 | - | - | - | |
| Group C | 2369 | 870 | 184 | 225 | 15 | 03 | 01 | 02 | 70 | 17 | 09 | - | - | - | |
| Group D (Excluding Safai Karamcharis) | 28 | 11 | 01 | 05 | - | - | - | - | 02 | 02 | - | - | - | - | |
| Group D (Safai Karamcharis) | 02 | 02 | - | - | - | - | - | - | - | - | - | - | - | - | |
| Total | 5944 | 1469 | 352 | 492 | 18 | 03 | 01 | 02 | 840 | 154 | 46 | - | - | - | |

Table 18.2: Representation of SCs/STs/OBCs in Autonomous Institutes/Centres of MoES: NIOT/IITM/NCAOR/INCOIS

| Groups | Number of employees | | | | | | Number of appointments made during the previous calendar year (2009) | | | | | | | | | | | | | | | | | | | |
|---------------------------------------|---------------------|-----------|-----------|-----------|-----------|-----------|--|-----------|-----------|-----------|-----------|-----------|----------|----------|--------------|--|-------|--|-------|--|------------------|--|-------|--|-------|--|
| | SCs | | STs | | OBCs | | By direct recruitment | | SCs | | STs | | OBCs | | By promotion | | SCs | | STs | | By other methods | | SCs | | STs | |
| | Total | | Total | | Total | | Total | | Total | | Total | | Total | | Total | | Total | | Total | | Total | | Total | | Total | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | | | | | | | | | | | | |
| Group A | 222 | 23 | 07 | 31 | 19 | 03 | - | 04 | 28 | 04 | 01 | 01 | - | - | | | | | | | | | | | | |
| Group B | 105 | 21 | 07 | 32 | 12 | 02 | - | 03 | 09 | 03 | 03 | - | - | - | | | | | | | | | | | | |
| Group C | 75 | 12 | 03 | 18 | 24 | 02 | - | 09 | - | - | - | - | - | - | | | | | | | | | | | | |
| Group D (Excluding Safai Karamcharis) | 33 | 06 | 03 | 03 | - | - | - | - | - | - | - | - | - | - | | | | | | | | | | | | |
| Group D (Safai Karamcharis) | 08 | 08 | - | - | - | - | - | - | - | - | - | - | - | - | | | | | | | | | | | | |
| Total | 443 | 70 | 20 | 84 | 55 | 07 | - | 16 | 37 | 07 | 04 | 01 | - | - | | | | | | | | | | | | |

Table 19.1: Representation of PWDs in Ministry including CMLRE and ICMAM (attached offices) and IMD (a subordinate office)

| Groups | Number of employees | | | | | Direct recruitment | | | | | | Promotion | | | | | | | | |
|--------------|---------------------|----|----|----|----|---------------------------|----|-------|----|----|----|-----------|---------------------------|----|-------|----|----|----|----|----|
| | 2 | 3 | 4 | 5 | 6 | No. of vacancies reserved | 7 | 8 | 9 | 10 | 11 | 12 | No. of vacancies reserved | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| | Total | VH | HH | OH | VH | HH | OH | Total | VH | HH | OH | VH | HH | OH | Total | VH | HH | OH | OH | |
| 1 | 310 | - | 03 | - | - | 03 | 03 | 06 | - | - | - | - | - | - | - | - | - | - | - | - |
| Group A | 3235 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Group B | 2369 | - | 02 | 11 | - | - | - | 13 | - | - | 01 | - | - | - | - | - | - | - | - | - |
| Group C | 30 | - | - | 01 | - | - | 01 | 01 | - | - | 01 | - | - | - | - | - | - | - | - | - |
| Group D | 5944 | - | 05 | 12 | - | 03 | 04 | 20 | - | - | 02 | - | - | - | - | - | - | - | - | - |
| Total | | | | | | | | | | | | | | | | | | | | |

Table 19.2: Representation of PWDs in Autonomous Institutes/Centres of MoES: NIOT, IITM, NCAOR and INCOIS

| Groups | Number of employees | | | | Direct recruitment | | | | | | Promotion | | | | | | | | | |
|--------------|---------------------|----|----|----|---------------------------|--------------------------|----|-------|----|----|-----------|----|---------------------------|----|----|----|--------------------------|----|----|----|
| | 2 | 3 | 4 | 5 | No. of vacancies reserved | No. of appointments made | 7 | 8 | 9 | 10 | 11 | 12 | No. of vacancies reserved | 13 | 14 | 15 | No. of appointments made | 17 | 18 | 19 |
| | Total | VH | HH | OH | VH | HH | OH | Total | VH | HH | OH | VH | HH | OH | HH | OH | Total | VH | HH | OH |
| 1 | 222 | - | 01 | 02 | 01 | - | - | 01 | - | - | - | 01 | - | - | - | - | - | - | - | - |
| Group A | 105 | - | - | - | 01 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Group B | 75 | - | 01 | 01 | - | - | 01 | 02 | - | 01 | - | - | - | - | - | - | - | - | - | - |
| Group C | 41 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Group D | 443 | - | 02 | 03 | 02 | - | 01 | 03 | - | 01 | 02 | 02 | - | - | - | - | - | - | - | - |
| Total | | | | | | | | | | | | | | | | | | | | |

The Citizens' Charter in its present form is available at the website on the Ministry. However, the vision and mission of the Ministry is as follows:

Vision

- The vision of MoES is to emerge as a knowledge and information technology enterprise for the Earth System Science (atmosphere, hydrosphere, cryosphere and geosphere) realm for the Indian subcontinent and ocean.

Mission

- To cover wide range of activities contributing to various social benefits in the areas of weather (general), weather advisories specific to agriculture, aviation, shipping, sports etc., monsoon, disasters (cyclone, earthquake, tsunami, sea level rise), living and non-living resources (fishery advisories, poly-metallic nodules, gas hydrates etc.), coastal and marine ecosystems, climate change and providing drinking water to the population in the islands of Lakshadweep (UT), through use of ocean science and technology. The frontline areas of MoES with immense potential for the benefit of the humankind and promotion of marine industry are:
 - To provide services in the areas of research, infrastructure and generation of human resources, popularisation of Earth System Science (atmosphere, hydrosphere, cryosphere and geosphere) mission to establish as information network for the scientific community.
 - To encourage dissemination of information in Ocean sector regarding work being performed by the department and its autonomous bodies, to stakeholders and promote establishment of an ocean related information system.
 - To bring about desired level of transparency in the management of funds received by the autonomous bodies by way of grants and also to make public the work done by the bodies out of such grants.
 - To tune the system with a view to encourage formulation of research and development schemes in the Ocean sector in a transparent manner, promote capacity building and human resource development by encouraging research.
 - To process research proposals for schemes on basic research, application areas and manpower development programmes for Ocean Sciences in a transparent and time-bound manner.
 - To extend support for seminars, symposia, conferences etc. and process application for grants to organise seminar/symposium/conference in a transparent and time-bound manner.
 - To create awareness about Ocean sector by participation in educational programmes, exhibitions and trade fairs and through partnership with NGOs, in order to appreciate the role of the Ocean system both as a provider of living and non-living resources, and as major contributor to earth's climate and ecological balance.

21 List of Publications 2009-10

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22 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 |
| COMAPS | Coastal Ocean Monitoring and Prediction System |
| COMNAP | Council of Managers of National Antarctic Programmes |
| CRS | Central Receiving Station |
| CSIR | Council of Scientific and Industrial Research |
| CVC | Central Vigilance Commission |
| DGS&D | Directorate General of Supplies and Disposals |
| DOS | Department of Space |
| DST | Department of Science and Technology |
| ECMRWF | European Centre for Medium Range Weather Forecast |
| EDB | Electronic Display Board |
| EEZ | Exclusive Economic Zone |
| EEIO | Eastern Equatorial Indian Ocean |
| ENSO | Elnino 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 |
| GRCC | Global and Regional Climate Change |
| 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 Organisation |
| IRS | Indian Remote Sensing Satellite |
| ITWC | Interim Tsunami Warning Centre |
| KPP | K-Profile Parameterisation |
| LTTD | Low Thermal Temperature Desalination |
| MDT | Mean Dynamic Topography |
| MLD | Mixed Layer Depth |
| MODIS | Moderate Resolution Imaging Spectroradiometer |
| 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 |
| OOIS | Ocean Observations and Information System |
| PBL | Planetary Boundary Layer |
| PFZ | Potential Fishing Zone |
| PO | Pacific Ocean |
| POGO | Partnership for Observation of Global Ocean |
| POM | Princeton Ocean Model |
| PWD | Persons with Disabilities |
| 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 |
| NPL | National Physical Laboratory, New Delhi |
| IIG | Indian Institute of Geomagnetism, Mumbai |
| GSI | Geological Survey of India |
| NGRI | National Geophysical Research Institute, Hyderabad |
| 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 |
| SCALOP | Standing Committee on Antarctic Logistics and Operations |

