Annual Report 2010-2011

Ministry of Earth Sciences Government of India



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1.1 Introduction

Earth System Science Organization (ESO), Ministry of Earth Sciences (MoES) addresses holistically various aspects relating to ocean, atmosphere, cryo-sphere, geosphere and bio-sphere processes for understanding the variability of earth processes for improving forecast of the weather, climate and hazards. ESO is responsible for development of technology towards the exploration and exploitation of earth resources in a sustainable way. The area of competence covers a gamut of policies and programmes that contribute to weather forecasting, weather advisories specific to agriculture, aviation, shipping amd sports, monsoon, disasters (cyclone, earthquake, tsunami, sea level rise), polar sciences, living and non-living resources (fishery advisory, poly-metallic nodules, gas hydrates, freshwater, etc), coastal and marine ecosystems and climate change. The satellite-based, airborne, in-situ atmospheric, ocean and

lithosphere observing systems, acts as backbone for accomplishment of the above-mentioned objectives.

The Earth System Science Organization(ESO) comprises India Meteorological Department (IMD), National Centre for Medium Range Weather Forecasting (NCMRWF), Indian Institute of Tropical Meteorology (IITM), National Centre for Antarctica and Ocean Research (NCAOR), National Institute of Ocean Technology (NIOT), Indian National Centre for Ocean Information Services (INCOIS), Centre for Marine Living Resources (CMLRE) and Integrated Coastal and Marine Area Management (ICMAM). The progress of the Projects and Programmes of ESO are monitored every six months viz., April and October by the ESO Council set up by the Earth Commission, besides being assessed by the respective monitoring/ steering committees.

The organization chart of the Ministry is given below:



1.2. Significant Achievements

Number of significant milestones slated for 11th Five Year plan were accomplished. They are detailed below.

1.2.1 Atmospheric Science and Services

- A location specific weather and air quality forecast 24 hours in advance was provided successfully for the Commonwealth Games 2010 in National Capital Region, Delhi. Location specific forecast was a first in this country.
- (ii) The monsoon prediction for the year 2010, using a suite of dynamical and statistical models, turned out to be correct forecast at 102% (of normal).
- (iii) The up-gradation of computing power and acquisition of real-time meteorological data through deployment of over 800 autonomous atmospheric observing systems has improved forecasting capability. The combined strength of High Performance Computing (HPC) in the country for weather forecast is about 75 TF, which has significantly improved both atmospheric and ocean modeling capability. An end to end forecasting system has been accomplished for data archival, processing and developing products and visualization.
- (iv) The Quantitative District-level agrometeorological advisory services 5 days in advance, covering 549 districts, has been made operational for farmers in partnership with a number of Central Government Ministries and organizations, state level institutions, private agencies, NGOs, farmers and media. Currently over 12 lakh farmers have subscribed for reception of this information through mobile phones.
- (v) For the first time in India, an experimental monthly prediction of monsoon rainfall has been done using fully coupled Ocean-Atmosphere General Circulation model (OGCM) based on NCEP Coupled Forecast System (CFS).
- (vi) Cloud Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX), has been conducted successfully in the monsoon seasons of 2009 and 2010, respectively.
- (vii) Towards human resource development in the field of earth science, Advanced Training School was established at Pune.

1.2.2. Ocean Science, Technology and Services

 Integrated and prioritized PFZ advisories (High, Medium, Low) and operational advisories for Tuna fishing were provided for the first time. The facility for dissemination of PFZ information has been extended to Island territories.

- (ii) A unique service for the Indian Ocean region, was made operational. This Integrated Indian Ocean Forecast System (INDOFOS), provides a 5-day forecast of vital ocean parameters, sea surface temperature, currents, etc. useful for various marine sectors including defence.
- (iii) The ocean observational network was strengthened through deployment of Wave Rider Buoys, Moored Buoy Network (7), Argo floats (50), Drifters (15) Current Meter Arrays (7) etc.. All the research vessels have been equipped with Automated Weather Stations. HF Radars have been installed in selected locations along the Indian coast.
- (iv) An integrated in-situ database (Drifting buoy, Moored buoy, Automatic Weather Station, XBT, Wave rider buoy, Current Meter array, Tide gauge) has been developed for easy access of information and data through web-interface.
- (v) Ocean modeling capability has been substantially augmented with assimilation of data from Argo floats and satellite SST including incorporation of seasonal river runoff.

1.2.3 Disaster Support

- (i) The Tsunami Warning System with a capability to forewarn of impending disasters within 15 minutes of the occurrence of an earthquake has been recognized as a Regional Tsunami warning centre for the Indian Ocean countries.
- (ii) Cyclone warnings have been significantly improved due to implementation of highresolution models and augmentation of capability to acquire atmospheric and ocean data.

1.2.4 Polar Science

- (i) The First Scientific expedition was launched to the South Pole on in November 2010. The team collected atmospheric aerosol data and drilled short ice cores from pole and surrounding area in extreme climatic conditions. The South Pole expedition team reached a position of 90°S and 0°W on 21st November. The team covered a total distance of almost 2240 km during their traverse to the south pole.
- (ii) The planning, co-ordination and execution of all scientific and logistics tasks related to the XXX Indian Scientific Expedition to Antarctica including activities related to building Third



Station at the Larsemann Hills have been completed as per schedule.

(iii) India has been accorded the Chairmanship of the Larsemann Hills Management Group and that of the Asian Forum for Polar Science (AFoPS) for the next two years (2010-12).

1.2.5 Ocean Survey and Resources

- (i) As a part of Technology Development for harnessing the deep sea resources, the Remotely Operable Submersible (ROSUB) was successfully tested in the Central Indian Ocean Basin at a depth of 5289 m during April 2010. Besides, the deepsea Mining System was tested successfully in Angria Bank (off coast of Malvan) at 512 m depth after laying artificial nodules during September– October 2010.
- (ii) Minicoy and Agatti desalination plants are in advanced stage of commissioning and are likely to be completed during the current financial year.

1.2.6 Coastal Ecology

- (i) The Coastal Vulnerability mapping Index (CVI) for both Andaman & Nicobar and Lakshadweep islands have been completed. An integrated system has been set up for dissemination of Sea State Forecasting System Sea on waves, swell wave, wind, tide and surface currents for 12 Islands of UT of Lakshadweep.
- (ii) The fish potential in the Indian EEZ of 4.32 MTA, has been estimated for the first time in the Indian EEZ using satellite and insitu data.
- (iii) The Indian delegation led by Secretary, MoES presented India's submission for an extended continental shelf before the UN-Commission on the Limits of the Continental Shelf (CLCS).

1.2.7 International Cooperation

Two Memorandums of Understanding (MOUs) were signed. The agreement with Natural Environment Research Council (NERC), UK involved addressing seminal issue related to the changing Hydrological Cycle and its components in the specific geographical regions of south Asia and northern Europe. The activity forms part of its program on capacity building and research and development in Earth Science. The second one is with the Korean Meteorological Administration (KMA) of Republic of Korea following the first bilateral meeting for collaboration in the field of Earth Science and Services. Initial thrust is on the Aviation and Monsoon related services.

1.2.8 Results Framework Document

The Ministry had actively participated in various activities of Performance Monitoring and Evaluation System (PMES), viz., submission of Results Framework Document (RFD) 2009-10 and 2010-11, Developing of Strategy and Perspective Plan, launched by the Cabinet Secretariat. The Ministry has secured a composite score of 92.25% for Results Framework Document 2009-10.

1.2.9 Important Events

Recognizing the work of various centers and Scientists, a number of national and international awards have been received during the year. The project "Development of Marine Geophysical Database" has been selected for this year's CSI-Nihilent e-Governance Awards 2009-10 under Project - G2G Category (a Jury Appreciation Award).

Fig 1.1 Prof. M.S. Swaminathan delivering the Earth Sciences Foundation Day Lecture

In 2010, Earth Sciences Foundation day was celebrated on 27th July 2010 at New Delhi. Hon'ble Minister Shri Prithviraj Chavan presided over the function. Prof. M.S.



Swaminathan delivered foundation day lecture (fig 1.1). Prof. S. Krishnaswamy received the national Award for Ocean Science and Technology (fig 1.2). A high level delegation led by Shri Prithviraj Chavan, Hon'ble Minister; visited Ny-Ålesund, Svalbard in the Arctic on 6th June 2010 (fig 1.3).



1.3. Budget and Expenditure

The budget estimates for current year (2010-11) for plan and non-plan schemes have been pegged at $\overline{\mathbf{x}}$ 1000 and $\overline{\mathbf{x}}$ 302 crores, respectively. The thrust area during the year has been for the Atmospheric Science and Services primarily for implementation of phase-I of modernization of IMD and for Polar Science programme (fig 1.4).



There has been a quantum jump in the Ministry's budget for plan activities from ₹ 553 crores in 2006-07 to ₹1000 crores in 2010-11.

1.4. Publications

The scientific publications in the field of earth sciences, emerging from programmes/centers of the ESO are well recognized internationally and the number has been growing steadily. The impact factor has increased from 60 in 2003 to 275 in 2010. The numbers of research publications have increased from 48 in 2003 to 226 in the year 2010 (fig. 1.5).





Atmospheric Science and Services

2.1 Introduction

The Meteorological services have significant impact on every spheres of life. The demand for accurate prediction of weather and climate at short and long time scales is increasing due to the increased awareness of possible impacts of weather and climate. Improved and reliable forecast of weather and climate requires routine integrations of observations using very high resolution dynamical models with high complexity (e.g. coupled ocean - atmosphere - biosphere - cryosphere models). A combined approach involving land, ocean and atmospheric processes hold the key to improve the forecasts at various temporal and spatial ranges for providing a credible policy tool. Intensive monitoring of various weather systems through different platformbased observing systems including satellites provide not only the necessary information about weather systems but their assimilation in numerical models provides accurate forecasts.

2.2 Meteorological Services

2.2.1 Weather monitoring and Forecast

Weather forecasts as well as precautionary warnings for cyclonic storms, heavy rainfall, squall, etc. were provided to save human life, livelihood and property. The weather reports were disseminated to all relevant Government agencies and public through media as well as hoisted on the Web. The year 2010 did not witness any remarkable heat and cold wave or unexpectedly heavy rainfall except for a few cases of extreme weather which were successfully foreshadowed. The performance skill of the model in the medium range time scale in terms of rainfall and other characteristic features of the monsoon were assessed. The verification show that the forecasts have reasonably good capability to capture large scale rainfall features, such as heavy rainfall belt along the west coast, over the domain of monsoon trough and along the foot hills of the Himalayas. The forecasts is able to capture, daily ups and downs of rainfall spells over different parts of the country, except over northeast India, which shows over-estimation. Performance of the model along the west coast of India has been significantly good (spactial Correlation Coefficient more than 0.5) which is comparable with the other global leading centre forecasts. Genesis of monsoon low

pressure systems with a lead time of 3 to 7 days were predicted along with their movement and associated rainfall. Other features of the summer monsoon such as lower troposperic strong cross equatorial flow, monsoon trough at 850 hPa and position of ridge at the 200 hPa were also well predicted.

2.2.2 Monsoon monitoring and Prediction

Salient Features of Monsoon 2010 were that the Southwest monsoon current advanced over the Andaman Sea on 17th May; the monsoon was set over Kerala on 31st May, one day earlier than its normal date of 1st June and covered the entire country by 6th July (fig 2.1). The forecast for monsoon onset over Kerala has been correct for the sixth consecutive year. The withdrawal of monsoon was delayed and it commenced from west Rajasthan only on 27th September compared to its normal date of 1st September.

Though there were two intense systems, viz., the Severe Cyclonic Storm (LAILA, 16th–21st May) over the Bay of Bengal and the Very Severe Cyclonic Storm (PHET, 31st May–2nd June) over the Arabian Sea during the advancing phase of monsoon, the entire season was devoid of any depressions. Thus, 2010 has been the only year after 2002, to have no depressions during the entire season.

Table 2.1 gives the summary of the verification of the long range forecasts for southwest monsoon 2010. The all India forecast was very accurate. The regional forecast was reasonably accurate except for the NE region.



Region	Period	Date of Issue	Forecast (% of LPA)	Actual Rainfall (% of LPA)
All India	June to September	23 rd April	98 ± 5	102
All India	June to September		102 ± 4	102
Northwest India	June to September		102 ± 8	112
Central India	June to September	25 th June	99 ± 8	104
Northeast India	June to September		103 ± 8	82
South Peninsula	June to September		102 ± 8	118
All India	July		98 ± 9	103
All India	August		101 ± 9	106
All India	August to September	30 th July	107 ±7	109
All India	September	27 th August	115 ± 15	113

Table 2.1 Verification of Long Range Forecast of the South West Monsoon

Out of 597 meteorological districts for which data are available, 173 districts (29%) received excess, 240 districts (40%) received normal, 173 districts (29%) received deficient and the remaining 11 districts (2%) received scanty rainfall during the season.

The first meeting of the South Asian Climate Outlook Forum (SASCOF) was held during 13-15 April, 2010. This forum provided a platform for participation of all the member countries, viz. Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan and Sri Lanka along with members from major global Forecast Centres to share their experience and discuss on issues of long range forecast of monsoon over the South Asian region. The general consensus that rainfall over South-Asia be in the normal range proved true.

2.2.3 Agrometeorological Services

Agrometeorological Services comprises weekly/ biweekly Agro-met advisory bulletins at district, state and national levels to cater to the needs of farmers and decision makers from local to national level. The district level bulletins are issued for 540 districts of the country. These bulletins are jointly prepared by the State Meteorological Centre of IMD and Agrometeorological Field Units (AMFUs) located at the State Agriculture Universities and institutes of the Indian Council of Agricultural Research (ICAR). These bulletins are useful to fertilizer and pesticide industries, irrigation department, seed corporation, crop-specific advisories including field crops, horticultural crops and livestock, etc. apart from farmers. National Agromet Advisory Bulletins are prepared for the Ministry of Agriculture. These are used to take decisions in Crop Weather Watch Group (CWWG) meetings at the national level.

TV, radio, newspapers, SMS and Interactive Voice Response Technology (IVR) are used for dissemination of weather information for agriculture purpose to the farming community. Agro Advisory has been extended to 12,00,000 users through mobile phone services during the current year. Fifty Farmer's Awareness Programmes were organized in various AMFUs during the year with an objective to enable the farmers to effectively use weather information for enhanced agricultural production. The participation in krishi melas helped to demonstrate the role of weather forecast in increasing overall preparedness of farmers.

2.2.4 Aviation Services

Meteorological Services for aviation are provided 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 68 other aviation meteorological offices. The aviation meteorological offices provide airport specific current weather reports, various forecasts and warnings for safety, economy and efficiency of aircraft operations.

New transmissometers have been installed at Lucknow, Jaipur, Chennai, Bangalore, Hyderabad, Amritsar and Delhi airports for visibility and Runway Visual Range (RVR) measurements to meet the upgraded category of Instrument Landing Systems at these airports. Aircraft based data from Lufthansa Airlines are being received from 1st October 2010. This data is being assimilated in NWP models to give more realistic forecasts especially for the aviation purpose.

CAT-IIIB dense fog with almost zero visibility on 19th and 26th November and 25-27 December 2010 were well predicted. All RVR instruments at the runways worked uninterruptedly. The accuracy of CAT-III dense fog forecast have been 93% which include 29 hits, one under warning and with two false alarms. Eighteenhours fog forecast, trend forecast for two hours and RVR information have been disseminated to users/print/ TV/media/passengers through on line briefing service, website (www.imd.gov.in) and FAX/telephone/Email.

2.2.5. Mountain Meteorological Services

The Himalayan region has a complex terrain which interact with synoptic scale systems leading to modification of air flow and formation of meso-scale systems. So high resolution meso-scale models (~3 km resolution) requiring dense network of observatories over the entire region are necessary. Currently a network of 26 AWS and 3 upper-air stations was established in the Western Himalayan Region. A cloud burst that occurred over northwest India over Leh in Jammu & Kashmir on 6th August 2010 leading to flood and mud slides over the region was not predicted. However, forewarning of very heavy rainfall was provided 24 hours in advance.

2.2.6 Metropolitan Weather and Air Quality Service

A detailed weather and air quality information and forecast for Delhi has been initiated during the Commonwealth Games. The information including current and forecasted weather information as well as information on major gaseous pollutants namely ozone (O₂), oxides of Nitrogen (NOx), Carbon monoxide (CO), Benzene and other hydrocarbons, particulate matters of 2 different sizes, viz. PM10, PM2.5, and Black carbon is based on 11 air-quality stations and 34 weather stations. The air quality forecast was found to be reasonably accurate and was able to reproduce the diurnal pattern satisfactorily. Venue-specific nowcasts and forecasts for all the stadiums were also issued during the Commonwealth Games using Doppler Weather RADAR. The information was disseminated through LCD and LED displays and dynamic web page. Presently, the observing systems that were in the specific sports venues are being re-located at appropriate places covering the entire NCR region of Delhi.

2.2.7 Satellite- Meteorological services

Satellite Meteorological services involve receiving satellite meteorological data from satellites, its processing for generation of images in all channels and derivation of operational parameters for weather forecasting, e.g. cloud top temperature, vertical profiles of temperature, humidity, fog, sea surface temperature, atmospheric motion vectors, outgoing longwave radiation, etc. and their dissemination to the forecasters and various users of the country. At present meteorological data is received and processed from two satellites namely Kalpana-1 and INSAT-3A. Three ground receiving and processing systems for NOAA/ METOP and MODIS Polar orbiting satellites have been installed during the current year at New Delhi, Chennai and Guwahati.

The images of some of the products viz. sea surface temperature and NDVI are illustrated in fig. 2.2 and fig. 2.3.

2.2.8 Climate Monitoring and Information Services

The National Data Centre (NDC) at Pune has more than 100 millions records in its archive and every year



about 2.5 million records are added. NDC provides data for research and preparation of Climate Normal as per WMO guidelines and brings out the State Climate Summary. The latest Climate Normal prepared is based on 1971- 2000 period. An e-atlas of the cyclones and its track formed in the Indian Ocean was recently brought out. The National Climate Centre (NCC), Pune prepares and publishes monthly, seasonal and annual climate diagnostic bulletins for the Indian region regularly. NCC data products include high-resolution-daily-gridded (1deg X 1deg) rainfall and temperature data over Indian region, district-wise normal for various surface parameters, marine climate summaries for the Indian Ocean region, etc.

Monitoring of Agricultural drought conditions during Southwest and Northeast monsoons through Aridity Anomaly Maps is one of the important climate monitoring activities. The weather charts are now available at URL http://210.212.173.104.

2.2.9 Customized Services

The Numerical Weather Prediction (NWP) output from mesoscale model (WRF) was provided to the Bhaba Atomic Research Centre (BARC), Mumbai at 9km resolution for the four nuclear sites, namely, Trombay, Kalpakkam, Kaiga and Narora. BARC uses this input for the Indian Real time Online Decision Support System for Offsite Nuclear Emergency (IRODOS). This system is operational since 21st February 2010. The finer resolution NWP data is used in driving atmospheric contaminant dispersion model RIMPUFF (Riso Mesoscale Puff Model) to simulate the transportation and deposition of various radionuclides in case of an accident at nuclear power plant in a grid size of 1 km x 1 km with a time resolution of 1 hour upto a radial distance of 75 km from the reactor centre.

A regional version of the Unified Model (UM) having a horizontal resolution of 12 km with 38 levels in the vertical, a nested mesoscale version of the UM having a horizontal resolution of 4 km with70 levels in the vertical and a nested variable resolution version of the UM mesoscale model with an interior horizontal resolution of 1.5 km and 70 levels in the vertical have been successfully installed. The output from these models was used for the nowcast system during Commonwealth Games as well.

During satellite launches, daily forecast were issued to the SHAR center along with wind profile and meteogram based on numerical model.

Customized forecasts for mountaineering expeditions were issued with day-to-day direct interaction with expedition teams and coordination with their HQs. The forecast bulletin for mountain expeditions have been issued for Mt. Saser Kangri, Mt. Trishul, Mt. Nanda Devi and Mt. Baderpunch expeditions.

India's first ever South Pole Expedition had been supported by providing 7-day forecast of snowfall, wind speeds, maximum and minimum temperature during 12th November to 2nd December 2010.

2.3. Observation and Forecasting Infrastructure

A comprehensive upgradation of observation platforms, acquisition, integration and forecasting infrastructure is continuing under IMD's modernisation programme.

2.3.1 Observation platforms

The installation of automatic weather stations (AWS),

automatic rain gauges (ARGs), Doppler Weather Radars (DWR), upper air observations, etc. has been underway. The progress during this year is given in Table 2.2.

Table 2.2 Status of	Installation of	Observing	Platforms
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Observa- tion Type	Target (under Modern- ization)	Commis- sioned up to Decem- ber, 2010	Ex- isting	Total	Data report- ing
Automatic Weather Station	550	427	125	552	505
Automatic Rain Gauge	1350	356	-	356	222
GPS sonde	10	10	1	11	11*
Doppler Weather Radar	13	2	5	7	7

*GPS sondes are at present used in Delhi. Rest of places data are received from old instruments.

Neutral Air-Ion Spectrometer (NAIS) Laboratory has been established to study new particle formation in the atmosphere. The NAIS can measure ion mobility spectrum of both positive and negative polarities. This would be helpful in the study of the generation mechanism and particle formation of intermediate ions.

A Multi-Parameter Raman Lidar System of Raymetrics has been acquired, and successfully installed and commissioned, for the first time in India. This autonomous Lidar uses a pulsed Nd:YAG laser as transmitter and a 40-cm diameter Cassegrain telescope as receiver. The system provides high space-time resolution vertical profiles of aerosol/cloud backscattering/extinction at two elastic wavelengths (355 and 1064 nm), water vapour at vibrational Raman-shifted in-elastic wavelengths of 387 and 408 nm, and temperature at 376 nm.

An ultra-high space-time resolution, portable Doppler Wind LIDAR has been successfully installed and commissioned for the first time in the country occupying 25th place in the world. A 1.54 micron eye-safe LIDAR system can probe 3-dimensional wind field in all weather conditions (including rain, fog, snow, etc.) from surface to about 12 km using atmospheric aerosol particles and cloud droplets as tracers. This versatile compact (weighing about 65 kg) system provides simultaneous wind and aerosol backscatter profiles in clear-sky as well within the cloud at spatial resolution of 20-50 m and time resolution of 1 second from land, ocean and in complex terrains using suitable platforms.

2.3.2 Meteorological Telecommunication Network

The new Automatic Message Switching System 'TRANSMET' of RTH New Delhi was commissioned during the year. It is capable of exchanging 1 Tera Byte (1000 GB) of weather data and processed information every day. The system has easy browser based Graphical Interface for circuit configuration, circuit monitoring tool, data monitoring, audio-visual warning system for circuit failure and special message reception. The new RTH system has special features of data ingest and transmission through Email, SMS, Fax transmission, file switching for files of different formats like satellite, RADAR, model output, etc. data file to predefined users, media file, i.e. audio-visual files to RMC, MC, etc. through FTP, automatic conversion of the received SYNOP and Upper Air messages to BUFR and their transmission on GTS, message submission through web browser.

2.3.3 Integration and Forecasting

New forecasting workstations have been installed at 34 forecasting offices all over India. These have capabilities to visualize multiple layers of observation and forecast overlayed on each other thus providing to the forecaster the capability to assimilate terabytes of information before issuing weather forecast. A Public Weather Service System now operational in New Delhi enables the forecaster to generate required customized presentation for the automatic delivery of products to the newspaper, TV, farmers, shipping, etc.

A Central Information Processing System with a supercomputer at the back-end was commissioned in July 2010. Central Information and Processing System (CIPS) has given a paradigm shift from Observation Network Management towards integrated and connected Information Systems to provide effective services to the user community. It is equipped with hardware and software to handle, manage, store, process and archive all data and products used operationally. It consists of 7 sub-systems comprising data acquisition, data policy management, National Data Centre, Task Policy Management, Tasks Centre, Backup Policy Management and Backup. The Operating System at the CIPS Data centre provide flexibility to ingest any kind of Meteorological data like satellite, radar, etc. CIPS provide in house task development platform for the programmers as per the need of users like forecasters, researchers, etc. Two dedicated servers with modern development tools, scientific libraries, scripting languages and compilers are available for the development jobs. Various products like color composites, cropping, re-sampling, verifications, etc. for satellite, NWP Models, radars and observations are running in CIPS for fulfilling the needs of forecasters.

2.4 Numerical Weather Modeling

2.4.1 Global Forecast System

A new Global Forecast System (GFS) T382L64 with latest version of data assimilation scheme (GSI) has been implemented for operational weather forecasts. It has approximately 35 km horizontal resolution with a Gaussian grid of 1152 X 576 points.

Major changes in assimilation system include

- (1) incremental improvement due to additional data types such as METOP-IASI, GPSRO, NOAA-19 ATOVS, AMRE, AIRS and Precipitation rates, etc.
- (2) use of GSI, a unified 3DVAR assimilation system, which can be used for meso-scale models WRF-ARW and WRF-NMM and other regional models as well.
- (3) Variational quality control and additional background error covariance that further fine tune data input, and
- (4) use of latest version community radiative transfer model and coefficients for uniform thinning mesh for brightness temperature data.

2.4.2 Unified Model

The UKMO Unified Model (Version: UM7.4, N320L50) has been successfully implemented using the recently acquired High Performance Computing System. Experimental real time forecasts were made daily from 15 May, 2010 onwards, from the initial conditions provided by UKMO. The forecasts were evaluated for the monsoon season of 2010 (Fig. 2.4). The forecasts show under prediction of rainfall over the west coast of India.

2.4.3 The Multi Model Ensemble (MME) for Monsoon 2010

In order to take care of uncertainties in initial conditions, model dynamics and model physics, MME forecasting is continued. During 2010, MME system was executed on daily basis in real time. Rainfall forecast data from 4 global models, i.e. NCMRWF, NCEP, UKMO and JMA for monsoon 2007, 2008 and 2009 were used to train the MME algorithm coefficients. The bottom panel in the fig. 2.5 shows the seasonal mean rainfall (made from day-5 forecasts) for member models and the top panel shows the corresponding observed rainfall and the MME products like simple ensemble mean (EMN), bias corrected ensemble mean (BCE Mn) and weighted multi-model ensemble (MME) rainfall. The observed rainfall (Obs S+G) is a merged satellite gauge product.

inter comparison of T254L64 (~50 km resolution), T382L64(~35 km resolution) and UKMO (~40km resolution) models is regularly carried out. This provides useful insight into the relative model performance in the Monsoon region and also helps to understand and isolate the regional and local aspects of forecast errors.

Comprehensive Model Evaluation and Inter comparison: A comprehensive model evaluation and





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2.5 Research Activities

2.5.1 Aerosol and Climate Studies

Cloud – **Aerosol Interaction and Precipitation Enhancement Experiment (CAIPEEX):** Phase II of the program was carried out during 7th September 2010 to 7th November 2010 with two aircrafts and one C Band Doppler Radar, spanning over 200 hours of flying. Cloud seeding experiments were conducted using a cloud seeding aircraft in coordination with the C band Doppler radar at Solapur and a S band Doppler radar at Hyderabad. About 20 h of cloud seeding was carried out using salt and hygroscopic flares on suitable clouds, identified by the radars, over Hyderabad and Solapur regions. The results are being analysed.

Black Carbon and Chemical Characteristics of Aerosols: The concentrations of aerosols (PM10, PM2.5) and associated water-soluble inorganic species (WSIS) along with Black Carbon (BC), were determined in New Delhi (28.63°N, 77.18°E), typically representing the plains of Ganga basin in the northern part of India from January to December. The annual mean PM2.5/PM10 ratio clearly indicate the dominance of coarser particles during summer and finer particles during winter. The associated WSIS comprise ~40% and 60% of PM 10 and PM 2.5, respectively and were dominated by SO₄²⁻, Cl⁻ and NO₃ along with BC. Source apportionment study reveal that most of the fine particles and polluted chemical constituents originate from anthropogenic sources.

Aerosol characterization over Darjeeling: Aerosol and gas phase chemistry studies have been carried out to investigate the sources, transport and distribution of physico-chemical properties of aerosols over the Northeastern Himalayas. Biomass burning, vehicular emissions and dust particles were the major types of aerosol from local and continental regions whereas sea salt particles were the major types of aerosol from marine source regions.

Role of clouds on solar dimming over the Indian region: In contrast to most of the world where solar brightening has been predominant since late eighties, dimming continues unabated over the Indian region. While the rate of dimming by clouds is similar during summer and winter monsoon seasons, the increased contribution to dimming by clouds during summer seems to come from increasingly deeper clouds covering increasingly larger area. During winter, dimming in cloudy conditions appears to be due to indirect effect of aerosols.

2.5.2 Development of a System for Seasonal Prediction of Monsoon

Dynamical Seasonal Prediction System : CFS coupled model successfully simulates many major features of the climatology and inter-annual variability of the Asian summer monsoon including centers of heavy precipitation and atmospheric circulation system. For the first time in India, experimental seasonal prediction of monsoon rainfall have been done using fully coupled Ocean-Atmosphere General Circulation model (OGCM) based on NCEP Coupled Forecast System (CFS). The coupled dynamical model (based on March initial conditions) predicted near normal rainfall over India in summer monsoon of 2010 and also predicted moderate La Nina condition in Pacific and basin-wide warming in Indian Ocean (fig. 2.6).

Experimental long range forecast for the Indian Summer Monsoon 2010: The experimental long range forecasts of the Indian Summer Monsoon (ISM) 2010 is based on an empirical model which is used to construct a large ensemble of models to deliver useful probabilistic forecast of all India rainfall. The empirical model picks up predictors only from global Sea Surface Temperature (SST). Methodology of construction implicitly incorporates uncertainty arising from internal variability as well as from the decadal variability of the predictor/predictand relationship.

Experimental extended range forecast of active/ break spells of the Indian summer monsoon: Extended range prediction of active/break spells of the Indian summer monsoon is carried out on an experimental basis. The prediction is done for various regions like All India (ALL), North India (NIN), North-east India (NEI), Monsoon Zone India (MZI), South-east peninsula (SEP), South-west peninsula (SWP). Three regions – ALL, SWP and MZI show some good skill in the hindcast data (1999 - 2009) with week lead 1, 2 and 3. However, there is some interannual variability. Breaks are more predictable in all the lead forecasts. Actives have predictability only in one week lead forecast.



2.5.3 Urban Air pollution, Chemical Transport Modeling and Middle Atmosphere Dynamics

Global distribution of tropospheric ozone and its precursor: Using satellite measurements of tropospheric ozone and its precursors (CO and NOx) the distribution of the pollutant sources and long-range transport on a global scale has been studied. This study indicates,

- (i) high CO and O₃ levels over the Atlantic and Indian Ocean is mostly due to the transport from the surrounding biomass burning regions,
- Southward outflow from North America and Europe can impact ozone and CO amounts over the Mediterranean, North Africa and the Middle East, and
- (iii) the satellite measurements can capture the regional distribution of ozone (along with its precursors) pollution and long-range transport in both hemispheres.

Features of SAO in ozone and temperature over tropical stratosphere: Spatiotemporal variation of Semi-Annual Oscillation (SAO) in temperature and ozone over the tropical–subtropical belts (40°N–40°S) was studied using Microwave Limb Sounder data for the period 1992–1999. Cross-wavelet analysis shows an anti-phase relation between the amplitude of the temperature and ozone SAO in the upper stratospheric region, whereas an in-phase relation exists in the lower stratospheric region.

Solar cycle variability in middle atmospheric ozone over tropics: To investigate the effects of decadal solar variability in ozone, data obtained from the Halogen Occultation Experiment (HALOE) onboard Upper Atmospheric Research Satellite (UARS) during the period 1992–2004 have been analyzed using a multifunctional regression model. The solar effect on ozone is found to be significant in most of the stratosphere.The observed results are in reasonable agreement with model simulations. Results indicate a hemispheric symmetry in the tropics.

Atmospheric aerosol formation and its growth during the cold season in India: The effects of molecular diffusivity of H_2SO_4 and NH_3 vapours on nucleated particles of SO_4^{2-} and NO_3^{-} species are reported. The results indicate that the nucleation involving H_2SO_4 and acidic NH_3 diffusion on SO_4^{2-} and NO_3^{-} particles is the most relevant mechanism in this region.

Rain-induced soil NOx emission from India during the onset of the summer monsoon: A satellite perspective, rain-induced soil NOx emission in the rural regions in India has been investigated using satellite observations of daily tropospheric NO₂ columns from the Ozone Monitoring Instrument (OMI). Relating OMI tropospheric NO₂ columns to surface NOx emission, soil emission accounts for an average emission flux of ~23– 28 ng N m⁻¹ s⁻¹ during the pulsing event. Lightning is unlikely to account for the enhanced OMI tropospheric NO₂ columns over the study regions.

2.6. Positional Astronomy

The Positional Astronomy Centre publishes the following:

- (i) The Indian Astronomical Ephemeris
- (ii) Tables of Sunrise, Sunset, Moonrise-Moonset
- (iii) Rashtriya Panchang in 14 languages namely— English, Hindi, Urdu, Sanskrit, Assamese, Bengali, Gujrati, Kannada, Malayalam, Marathi, Oriya, Punjabi, Tamil and Telegu.

The centre also fixes up dates of all India festivals for all communities for declaration of holiday by Central &

State Govt. The centre also acts as national agency for attending all matters concerning calendars.

2.7 Weather information on web and telephone

Two websites with URL http://www.imd.gov.in/ and http://www.mausam.gov.in/ are in operation. Both the websites contain static and dynamic information. All observational data and products are uploaded. The new

GIS-based web site http://www.mausam.gov.in was commissioned on 1st September 2010.

For public weather information, Interactive Voice Response Systems (IVRSs), popularly known as 'Weather on Telephone' have been installed at 26 stations (mainly state capitals) through out the country. One can access current weather and forecasts for major Indian cities by dialing a toll free number 1800 180 1717.



Ocean Science and Services

3.1 Introduction

3

The Ocean Science and Services encompass wide range of advisories to various sectors like fisheries, shipping, ports, offshore industry, academia, coastal states and island development authorities. The generation of information services involves integration of real-time data acquired from a network of both insitu and remote sensing platforms, running a suite of global and regional ocean models using the state-of-the art computational facilities.

During the year, two new services in the field of ocean forecasting with "High Wave Alert" during cyclones and "Tide Prediction System" for the Indian subcontinent to provide information on predicted ocean tides were started. The Ocean State Forecast System was launched exclusively for the Andaman and Nicobar Islands and Lakshadweep Islands. This system provides wave forecasts 7 days in advance at 3-hourly intervals.

Implementation of Global Ocean Data Assimilation System (GODAS) adopted from NOAA/NCEP on HPC was another significant development during the year. The Indian ocean regional model developed in collaboration with NOAA/GFDL was also ported successfully on INCOIS HPC and experimentation is in progress. In an effort to test the ability of HYCOM model to capture the sea level variability with the Navy Operational Global Atmospheric Prediction System (NOPGAPS) forcing, it was setup to simulate the inter-annual variability during 2003-2010 and the model was able to reproduce sea surface height anomaly with an RMSE less than 7 cm when compared with the altimeter based sea level anomaly.

3.2 Ocean Services

3.2.1 Potential Fishing Zone Advisories

Eighty two integrated PFZ (IPFZ) advisories were generated for the sectors of east and west coast of India on every Monday, Wednesday and Friday. Thirty six tuna fishery forecasts were generated and disseminated by providing maps and text information on every Tuesday, Thursday and Saturday except during the ban period (Fig 3.1).



3.2.2 Ocean State Forecast

The operational forecast system of ocean circulation features and wind-waves were continued. The Indian navy validated the quality of predicted temperature profiles with their observations and stated that the forecasts are meeting their requirements.

High Wave Alert, a bulletin with information about risky waves for the coast of Gujarat was provided during the cyclone Phet to a wide spectrum of users through web, digital display boards and through emails in local languages. Later these alerts were improved further using real-time data from moored buoys, argo floats, tide gauges, wave rider buoys and satellite images.

Another important achievement during the year was the launch of the Tide Prediction System for the Indian subcontinent to provide information on predicted tides for five days at 178 coastal stations including India (136), Myanmar (12), Sri Lanka (11), Bangladesh (9), Chagos (5), Pakistan (4) and Maldives (1). The tidal information is routinely disseminated through website as time series plots and High and Low tide listings (www.incois.gov. in).

A high resolution ocean forecasting system exclusively for the Andaman and Nicobar and Lakshedweep Islands was developed. The system give an early warning about the high waves during the cyclone period, catastrophic swells and other ocean parameters, 5-7 days in advance at three hourly interval (Fig 3.2). A map as well as the digital data on sea waves, swell waves, winds, tides and surface currents are being disseminated through INCOIS website, FAX and EDBs.

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3.2.3 Dissemination and User Interactions

To enhance the reachability of PFZ and OSF advisories and tsunami warnings to a wider section of population along Indian coasts, forty two new generation Electronic Display Boards (EDB) in Andhra Pradesh, Tamil Nadu, Puducherry, Maharashtra and Andaman islands were installed.

User interaction workshops/training were also conducted in different states. A workshop on the use of PFZ and OSF advisories along the Gujarat coast was organized at the Vanakabara gram panchayat hall, on August 10, 2010. 90 small to medium level user interaction workshops have been organized all along the coastal districts.

User interaction meeting for the OSF users was conducted on 29 November 2010. Users representing NODPAC, ONGC, Coast Guard, NGOs, aspirant offshore industries, etc attended the meeting. The existing users shared their experience about the OSF information and suggested modifications based on their experience. NODPAC (Southern Naval command, Kochi) officials visited INCOIS on 30-Aug-2010 for discussions on the usage of INDOFOS services for Naval operations as well as the data exchanges between INCOIS and NODPAC.

3.3 Ocean Observation System

A comprehensive ocean observation network program has been launched for the understanding of structure and dynamics of ocean, to improve the predictability of ocean and climate, for the sustainable development of continuing coastal ecosystem and for the generation of ocean information and advisory services. The ocean observing systems, include (i) in-situ observation systems that capture the changes in time at specific locations or along the ship tracks, (ii) the satellite based remote sensing systems that capture the spatial and temporal variations, synoptically, as ramified at the surface and sub-surface. The details of deployment of ocean observations systems are in Table 3.1.

Table 3.1 Details of deployme	nt of ocean observations systems
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S.No.	Type of Platform	Target for XI Plan	Achieved till January, 2011 since April 01, 2007
1.	Argo Float	200	131
2.	Drifters	50	49
3.	Moored Buoys	40	16
4.	XBT/ XCTD	1000	953
5.	Tide Gauges	45	25
6.	HF Radars	10	10
7.	Current Meter Array	3	7
8.	ADCP	12	12
9.	Tsunami Buoys	12	07
10.	Wave Rider Buoy	8	03
11.	Directional wave rider buoy	2	01
12.	Remote wave height meter	1	01
13.	Sediment trap	1	01

Large number of cruises were undertaken to deploy moored buoys to make data buoy Network operational (fig. 3.3). The data from all buoys are received in near real time and used in weather forecasting and ocean modeling.



As part of widening observational networks, the installation of Automated Weather Stations (AWS) on board MoES ships has been completed. The AWS are equipped with sensors to measure wind speed, wind direction, long-wave and shortwave radiations, air temperature, humidity, surface pressure, rainfall and sea surface temperature.

The surface moored buoy which was deployed in May 2008 in collaboration with Space Applications Centre, ISRO, Ahmedabad for the calibration and validation of remote sensing data was retrieved after two years. The surface met parameters were obtained for two years.

A network of 10 HF Radar stations along the Indian coast in May 2010 was established. The response in ocean circulation and waves associated with the passage of various clyclones are captured by the HF Radar stations along the east coast of India (fig. 3.4). A workshop was conducted on HR Radar data processing, analysis and applications on 13th May 2010. A total of 45 participants from various research organizations and two experts from CODAR, USA participated in the workshop.



3.4 Ocean Modelling

3.4.1 GODAS Assimilation System

Global Ocean Data Assimilation System (GODAS) obtained from NOAA/NCEP has been successfully ported on HPC. The model domain extends from 75° S to 65° N and has 40 levels with a 10 meter resolution in the upper 200 meters. Presently temperature and salinity profiles from all in-situ observations (Argo profiling floats, moorings (RAMA, TAO and PIRATA) and XBT) over global ocean have been assimilated to produce best analysis products. The model is being tested with NCEP and QuikSCAT winds. Taylor plots were used to compare the ability both QuikSCAT and NCEP forced models to capture variability of D20 in the equatorial Indian Ocean in terms of magnitude and phase. The model D20 and an "observed" reference composite with the standard deviation and its associated root mean square difference (RMSD) plotted in relation to the pattern of correlation were composed. In summary, the analysis clearly shows that GODAS-MOM simulation forced with NCEP and QuikSCAT winds are reasonably well simulating the thermocline (fig. 3.5).



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3.4.2 Colorado University Princeton Ocean Model (CUPOM)

A high resolution $(1/16 \times 1/16 \text{ degree})$ three-dimensional, baroclinic circulation data assimilative model, CUPOM was used to simulate and forecast SST for the application of PFZ identification. This model is expected to provide forecasts of high resolution SST (fig. 3.6).

10°N

0°

10°S └─ 45°E

55°E

65°E

HYBRID COORDINATE OCEAN MODEL (Hycom) Hycom 2.2.18 has been used to simulate sea level in the Indian Ocean on inter-annual timescales using NOGAPS winds for the period of 2003 to 2010. The model could simulate the sea level with an RMS less than 7 cm over most of the region (fig. 3.7 and fig. 3.8).





0

0

2.1

1.4

0.7

3.5 Research

3.5.1 Intra-seasonal variability in Barrier Layer

The Barrier Layer Thickness (BLT) was found to have large intra-seasonal variability mainly controlled by the vertical movement of isothermal layer depth (ILD) in the presence of a shallow mixed layer. Both ILD and BLT are modulated by the vertical stretching of upper water column associated with the westward propagating intra-seasonal down-welling/upwelling Rossby waves in the Southern Bay. The intra-seasonal variability of BLT significantly influences the formation of thermal inversions (TI) and mixed layer heat budget in the Southern Bay during winter (fig. 3.9).



3.5.2 Satellite Coastal and Oceanographic Research (SATCORE)

While continuing the time-series measurements initiated along nine transects in the Indian coastal waters, one more transect in the Gulf of Mannar was added to the network. During the year a revision was carried out for the sampling frequency along with protocols for calibration of spectrophotometer and fluorometer using standard chlorophyll-a solution.

The Automatic Data Processing Chain (ADPC) was further enhanced by incorporating the ability for domain scaling, spatial resolution scaling and addition of new satellite sensor supported by SeaWiFS Data Analysis System (SeaDAS) software. OCM-2 processing was also added in ADPC along with MODIS-Aqua. Three new standard products, namely Quasi True Colour Composite (QTCC), CDOM index and Aerosol Optical Thickness (AOT), were added in ADPC. 3-day, 7-day, 30-day standard rolled products as well as 30-days rolled anomaly products of chlorophyll and sea surface temperature (SST) were also added in ADPC. Two value added products – total suspended matter (TSM) and Bloom Indices (BI) were also incorporated in ADPC.

A conceptual frame work was designed, using outputs from ADPC, for detection and monitoring of Harmful Algal Blooms (HABs). The proposed methodology integrates the three bloom indicators: Rolling Chlorophyll Anomaly (RCA) and SST anomaly and it is being implemented as a pilot project for six areas: Mangalore, Kochi, Nagapattinam, Gulf of Mannar, Kakinada and Visakhapatnam.

The ADPC continued to supplement the global initiative Chlorophyll Global Integration Network (ChloroGIN). The ocean colour data was generated daily from MODIS-Aqua and disseminated at near real time to Indian ocean rim countries: Sri Lanka, Iran, Kenya, Maldives, Oman, Tanzania and Thailand. An agreement was also signed with European Space Agency (ESA) for coast colour project. The major objective of the coast colour project is to develop, demonstrate, validate and inter-compare different case 2 algorithms over a global range of coastal water types.

3.5.3. Indian Ocean Modelling

Some of the major accomplishments under the schemes being implemented through a network of pioneer research institutes in the field of ocean atmospheric modeling during the year are as follows;

- Improvement in initial values and position of the tropical cyclone utilizing state-of-the-art 3DVAR data assimilation system of conventional and nonconventional data sets over data sparse oceanic region, vortex re-location and initialization, simulation of track and intensity of tropical cyclones through multi-mesoscale model super ensemble forecasting system.
- Understanding the links between the variation of the Indian monsoon and the variation of the atmospheric convection over the equatorial Indian Ocean with analysis of observations.

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In the first three weeks of June 2009, there were no northward propagations across the Bay. Also, no low pressure systems were generated over the head Bay and naturally, the westward propagation of such systems across the Indian monsoon zone, which is characteristic of the onset phase of the monsoon, did not occur. Consequently, there was a deficit in the all India rainfall in June 2009. The El Nino induced Indian Ocean winter warming is significant in the following winter and spring and persists for the summer as well. The basin scale deep warming in the west is associated with the local IOD forcing rather than the remote El Nino forcing. Indian Ocean warming induce anomalous climatic effects in Asia, Africa and NW Pacific.

3.5.4. Eco-morphological Zonation of Coral Reef and Health monitoring

The mapping and database creation of coral ecomorphology for the Andaman and Nicobar, the Gulf of Kachchk, the Gulf of Mannar and the Malvan Coast has been completed. The atlas of the coral eco-morphology comprising 156 maps was prepared.

3.6 Ocean data management and dissemination

Ocean Data and Information System (ODIS) is further strengthened by integrating HF Radar data in real-time and connectivity to receive the surface meteorological and oceanographic data from the RAMA moorings in real-time. Live Access Server (LAS) was enhanced with the addition of weekly OCM Chl-a climatology, MLD climatology from Argo, daily pass of Chl-a from MODIS and daily pass of MCSST from NOAA AVHRR. The Fog product from AVHRR and MODIS was also developed. More than 40,000 users were using various products on the website.

3.7 Indian Ocean GOOS (IOGOOS)

The IOGOOS secretariat has been functioning at INCOIS since its inception in 2002. The IOGOOS membership has grown from 19 to 26 institutions representing 14 countries. The functioning of IOGOOS secretariat at INCOIS was extended upto 2013. IOGOOS 7th annual meeting was held at Perth, Western Australia. IOGOOS elected Indian representation to one of its officers position and IRF forum has elected Dr. Shailesh Nayak as the founder chairman.

Polar Science

4.1 Introduction

Annual scientific research expeditions have been launched to Antarctica to utilise its singular environment as a great natural laboratory for scientific investigations, since 1981. To carry out its scientific programmes India established its first station at Dakshin Gangotri (at 70° 05' South long, 12° 00' East) in 1983. The second permanent station Maitri was established at Schimacher ranges (at 70° 46' South long, 11° 50' East) in 1989. Dakshin Gangotri 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 multiinstitutional in character. Scientific investigations and researches are undertaken to understand the various phenomenon and processes in Antarctica to understand global climate and weather. A third station 'Bharti' is being established at the Larsemann Hills area of East Antarctica. Polar Science research was expanded to the Arctic, in 2007. A station 'Himadri' at Svelbard, Norwy was established in July 2008.

4.2 Indian Antarctic Programme

4.2.1 Indian Scientific Expedition to the South Pole

The year 2010-11 marks the centenary of landing of man at the South Pole. To commemorate Amundsen's historical expedition to the South Pole and to mark thirty years of Indian presence in the Antarctica, a scientific expedition to the South Pole from the Indian Station, Maitri, was launched. After traversing a 11-day journey over ice, the team reached the South Pole at 1600 h (IST) on Nov.22, 2010 (fig. 4.1). The scientific studies carried out by the team enroute as well as on the South Pole comprised:

- Raising cores at regular spacing along the Maitri-South Pole (Amundsen-Scot station) traverse to study variability of snow chemistry, particulate matter, etc.
- b) GPR sections along traverse to understand bed rock topography and Sub surface-Ice structure.
- c) Study of glacial- geomorpholoical landforms along the plateau,
- d) Collection of meteorological and geophysical parameter along the 2000 km long traverse.



On completion of the studies, the team started its return journey from the Pole on the 23rd November 2010 and reached Maitri on the 1st December 2010.

4.2.2 Constructon of 'Bharti' Station at the Larsemann Hills

The Phase I construction activities of the Indian Research Base at the Larsemann Hills commenced during the austral summer of 2010. The following tasks were accomplished.

- Piling for the foundation for the main station building and erection of garage sump and walls.
- Construction of helipad using pre-cast concrete elements.
- Construction of foundation of fuel farm using precast concrete elements.
- Construction of fuel farm using thirteen 20-feet tank-containers and one service container.
- Laying of pipeline for fuel, fresh and waste water.
- Site survey and foundation piling for the planned satellite ground station.
- Preparation of approach roads from landing site to station building and to the satellite ground station.

4.2.3 XXX Indian Scientific Expedition to Antarctica

The discipline-wise breakup of the scientific projects being undertaken during the Expedition is detailed in Table 4.1.

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Table 4.1 Scientific Projects in Antartica

Discipline	No. of Projects
Atmospheric Sciences, Meteorology & Climate Change	4
Biology & Environmental Sciences	1
Earth Science & Glaciology & Paleoclimatology	6
Others	1

To cater to the enhanced requirements at the Larsemann Hills & Maitri, two ships – an Ice Breaker Vladimir Ignatjuk and a multipurpose cargo vessel MV Ivan Papanin- have been chartered for 50+/-10 and 140+/-30 days, respectively, for the XXX Expedition. Similarly, the services of two helicopters Kamov 32A (LG Helicopters, Korea) and Aerospatial 350B2 have been requisitioned for the 2010-11 season. The Expediton team proceeded to the Antarctica in different groups, through the ALCI flights from Cape Town and on board the Expedition Vessel.

4.3 Indian Scientific Endeavors in the Arctic

The year 2010-2011 was marked by a gamut of research initiatives by Indian researchers from the research base, HIMADRI at Ny-Alesund. A brief account of these research activities is given below:-

4.3.1 Marine Sciences

As a prelude to the monitoring of the Kongsfjorden system at Ny-Alesund on the Svalbard archipelago in the Arctic, systematic CTD casts and surface sediment sampling were carried out during May- June and JulyAugust 2010. Twenty locations (between latitudes 78° 54' 35" N-79° 02' 58" N and between longitudes 11° 19' 46" E-12° 26'17" E) extending from the mouth to the head of the fjord were chosen for the data collection. The surface water of the fjord was saline, with salinity ranging between 30.9 to 33.3 psu. All the CTD casts showed a persistent increase in salinity with depth. A distinct decrease in the salinity of the water column from the mouth to the head of the fjord was also observed. The SST during the period of study ranged between 1.5 to 7.5° C.

4.3.2 Atmospheric Sciences

Investigations of atmospheric aerosols over the Ny Alesund region and their characterization were carried out. This long-term project envisages quantification of the physical and optical properties of the aerosols and associated processes during the summer season and estimating the aerosol radiative forcing over that region. Characterization of aerosols and pre-cursor gases in terms of their optical, physico-chemical and radiative properties were undertaken by means of multi-spectral solar radiometers. Comparison of measured parameters with in-situ and satellite data and modeling efforts would help in better understanding of the regional climate processes.

Results from the variations in black carbon (BC) during the period of study indicated a high loading of BC of about 90 ng/m3 in the atmosphere, with a mean value of BC-0.023 μ g/m3 during the afternoon period from 12:00 to 16:00 h (local time). It was also observed that the day-time BC at Ny Ålesund is 2.4 times higher than during the night.

No.	Subject/Proposal	Institution
1	In-situ Measurement of Biooptical properties of the Southern Ocean	CIFT, Kochi
2	Studies on Biogeochemistry and Hydrodynamics of the Indian Ocean sector of the Southern Ocean.	NCAOR, Goa
3	Relationship between oceanographic parameters and deep sea megafauna and marine mammals of the Southern Ocean	CMFRI, Kochi
4	Isolation and molecular characterization of novel micro-algal species from the Southern Ocean towards exploring their metabolic potential and biological variability.	Birla Institute of Technology (BIT), Mesra
5	Suspended particulate matter and its selected elemental chemistry in the Southern and Indian Ocean – approach to understand source and processes	Goa University
6	Investigation of ocean-atmosphere interaction, atmospheric vertical structure and aerosol characteristics.	NCAOR, Goa
7	Routine monitoring of upper ocean thermal fields in the Indian Ocean.	NIO, Goa
8	ACC fronts Interactions around Crozet Plateau regulating Phytoplankton assemblage (ACC-PHYTO)	Federal University of Rio Grande [FURG], Brazil

Table 4.2 Scientific Projects in the Southern Ocean

4.4 Fifth Indian Scientific Expedition to the Southern Ocean

The fifth multi-institutional expedition to the Southern Ocean was launched during the second week of January 2011. The projects undertaken during this Expedition, are listed in Table 4.2.

4.5 Research & Development Activities

4.5.1 Polar Science & Cryospheric Studies

Glacio-chemical studies on surface snow and shallow ice cores from the coastal and inland region of the East Antarctica were undertaken. Microbiological studies in fresh snow deposits in the coastal Antarctica reveal the crucial role of bacteria in the air-snow biogeochemical cycling within the coastal Antarctica. A first report on the isolation of Cellulosimicrobium cellulans bacteria in the snow deposits of the Larsemann Hills with physiological traits that were markedly different from that of the mesophilic C. cellulans type strain reveal that this genus could be more cosmopolitan than hitherto thought of and is capable of living in extreme cold environments. Carbon utilization studies demonstrated that C. cellulans preferred complex carbon substrates over simple ones, suggesting that it could play a potential role in carbon uptake in snow.

Biogeochemical and microbiological study of snow from the coastal Larsemann Hills (East Antarctica) reveal that elevated nutrient concentrations in ice cap snow seems to enhance the growth of microalgae in snow and the subsequent production of bromo-carbons leading to high bromide concentration in snow. The activated Br in the Antarctic atmosphere would react with ozone leading to BrO enhancement with subsequent DMS oxidation and production of sulphur aerosols. Since BrO based DMS oxidation is much faster than OH/NO₃ pathway, elevated bromide in the Antarctica could contribute more towards the formation of cloud condensation nuclei (CCN) at the expense of ozone (fig. 4.2).

Glaciochemical analysis of snow deposits from the Ingrid Christensen Coast reveal that the sea spray contribution dominated the supply of Na+, Cl-, K+ and Mg2+, whereas the estimated enrichment factors suggest that crustal input was the primary source for Ca2+. The distribution pattern of sea spray constituents was influenced by the distance from the sea as well as the altitude. Secondary sulphur species (nssSO₄²⁻ and MSA) within the snow samples suggest that both vary independent of each other, possibly influenced



by the local biological activities. The $nssSO_4^{2-}$ data revealed that several summer snow deposits in the study region are significantly fractionated, suggesting that serious underestimation can arise in the assessment of summer atmospheric sulphate budget within the coastal Antarctica (fig. 4.3).



Analysis of temporal isotopic variability of the Antarctic ice cores as high-resolution quantitative proxy record of air temperatures using an ultra-high-resolution (>12 samples per year) ice core record reveal its reliability visà-vis the instrumental records from the Novlazarevskaya station. The study indicates a fundamental relationship between the snow accumulation and temperature with the climatic modes like the Southern Annular Mode (SAM) and El Niño Southern Oscillation (ENSO). Snow accumulation rates in this region illustrate a decreasing trend with opposite relationships with $\delta^{18}O$ data and surface air temperature prior and subsequent to the year 1997. A reorganization of the local water cycle is further indicated by the deuterium excess data showing a shift around 1997, consistent with a change in evaporation conditions.

4.5.2 Polar Biological Studies

Study of bacterial diversity and adaptability in snow and ice from the Larsemann Hill and the Schirmacher Oasis, Antarctica were processed for evaluating the culturable heterotrophic bacterial diversity. Aliquots of the samples were spread plated on to dilute Nutrient agar and Zobell's Marine Agar plates and were kept for incubation at RT until visible colonies appeared. About 105 discrete bacterial colonies were isolated and purified.

To understand the adaptability to cold environment the isolates were subjected to growth at 40°C. Twenty six isolates from the Schirmacher Oasis and 50 isolates from the Larsemann Hills area showed growth at 40°C. The protein profiling of the isolates were carried out in the range of 14.4 Kda to 97.4 Kda. Based on the similarity of the protein profile 55 isolates were short-listed and were subjected to 16 S rDNA analysis. The isolates were predominated by *Bacillus flexus*, *B. thuringiensis*, *B. cereus* and *B. aryabhattai*.

4.5.3 Polar Environmental Studies

Draft Comprehensive Environmental Evaluation (CEE) of the New Indian Research Station at the Larsemann Hills, Antarctica was presented at the XXX ATCM (2007), New Delhi. Based on the inputs and suggestions received from many member countries, a Cumulative Impact Assessment study was carried out, employing prediction models, i.e Industrial Source Complex-Short Term (ISCST3) for air quality, Noise Prediction Model (Predictor 7810) for noise environment and CORMIX 6, model for dilution and dispersion study of wastewater discharge into sea. Additional data and important





information on station design and initial environmental reference have been incorporated in final CEE report including discussions on baseline data.

4.5.4 Polar Remote Sensing

An enhanced digital elevation model (DEM) of the Larsemann Hills region, (on the eastern boundary of Antarctica) was generated synergistically by using highly accurate ground-based GPS measurements, satellite-derived laser altimetry (GLAS/ ICESat) and Radarsat Antarctic Mapping Project (RAMP) DEM-based point elevation data (Fig. 4.4). A DEM is essential to model the ice elevation change and address the ice mass balance.

The link between the Tropical Indian Ocean Processes, Indian Ocean Dipole (IOD) and Sea-ice was studied at the Lamont Doherty Earth Observatory, Columbia in Feb to April 2010 under the SCAR Fellowship scheme.

The Indian Ocean Dipole (IOD) one of the most studied phenomenona in the Indian Ocean. Most remarkable correlations were obtained when the ice concentration anomalies lags Dipole mode index (DMI) by 2 years and when the ice concentration anomalies leads the DMI by one year. The reasons for these correlations are being investigated (fig. 4.5).

Ocean Survey and Resources

5.1 Introduction

Oceans have always influenced the life and history of man. Because of its vastness and interplay of processes, oceans control the atmosphere and global climate besides being a vast storehouse of resources necessary for sustenance of life on earth. The greatest unexploited mineral resources on earth are in 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. The survey of Exclusive Economic Zone (EEZ), study of continental shelf, gas hydrates, assessment of mineral resource potential of polymetallic nodules, cobalt crusts and hydrothermal sulphides in the Indian Ocean are the major objectives of this programme.

5.2 Comprehensive Topographic Survey of Exclusive Economic Zone of India

India, a traditionally maritime country with rich maritime heritage, has an Exclusive Economic Zone (EEZ) of about 2.00 million sq km wherein India has exclusive legal rights to utilize all living and non-living resources. The project mainly focuses on mapping the entire EEZ of India using survey technologies of multibeam survey apart from systematic sediment sampling and its analysis. The entire EEZ has been divided into two areas, viz. deep water areas (> 500 m water depth) and shallow water areas (< 500 m water depth). The status of survey is given in Table 5.1. Some of the major research findings in deep waters are highlighted below:

i) The three-dimensional geomorphic view of the Wadia guyot and Panikkar seamount in the Laxmi Basin area shows a number of elongated features with numerous individual peaks oriented towards north-south direction, whereas changes in trends have been noticed in its southern part (Fig. 5.1).



- The satellite altimeter derived gravity from Geosat (US Navy), ERS-1 (ESA) and Topex/Poseidon (NASA & CNES) revealed bathymetry and helped to identify two seamounts in the Arabian Sea.
- iii) Canyons at off Cheyyur/ Marakkanam and Cuddalore were identified (Fig.5.2). Two features at 107 m contour at 80°44'36.18" E & 12° 57' 49.14" N and 52 m contour at 80°43'49" E & 12° 57' 45" N were found off Chennai.



Organisation	Deep water beyond 500 m Total Area about 1.5 million sq.km	Shallow water Upto 500m. Total Area about 0.5 million sq.km	Area Covered
NCAOR	5.26 lakh sq.km area surveyed	-	Arabian Sea
NIO	-	About 4000 sq.km area surveyed	off Marmagoa, off Bombay High and Karnataka coasts
NIOT	-	10300 sq.km area surveyed	off Chennai, Cheyyur, Marakkanam, Cuddalore

Tabel 5.1 Status of EEZ Survey

(iv) Morphology of the "Carbonate Platform" features in the western margin of India has been studied to understand the role of neo-tectonic activity and sea-level changes in the formation of carbonate deposits, off the Mumbai High and Ratnagiri area.

5.3 Delineation of outer limits of continental shelf

The programme aims at gathering, analyzing and documenting the requisite scientific and technical information that would help define the outer limits of India's continental shelf beyond 200 nautical miles as per the provisions of the United Nations Convention on the Law of the Sea (UNCLOS) and prepare the Indian claims based on scientific and technical data. India made its first partial submission for an extended continental shelf to the Commission on the Limits of the Continental Shelf on the 16 August 2010. A six-member delegation led by Dr. Shailesh Nayak, Secretary, MoES made a formal presentation of India's submission before the Commission on the Limits of the Continental Shelf at the UN Headquarters, New York.

The marine geophysical database developed by NCAOR won the 2010 Computer Society of India-Nihilent e-Governance Award under Project - G2G Category.

5.4 Indian Ocean Deep-Drilling Program

The scientific proposal "Deep sea drilling in the Arabian Sea : Discovering the tectono-climatic unknowns" has been submitted to the IODP primarily aims at recovering deep sea cores from five different sites from the Arabian Sea to :

- i) Obtain high-resolution climate records from regions of high pelagic sedimentation in the Arabian Sea (vs. records of Himalayan erosion in the Indus Fan).
- Reconstruct the erosion response of the western Himalaya to proposed monsoon strengthening at 8 Ma.
- iii) Recover Paleogene sediments from Arabian Sea to understand significant issues pertaining to the evolutionary history of this region such as offshore extension of Deccan Traps and the Mesozoic sediments beneath them and the nature of crust in the Laxmi basin area of the Arabian Sea.

5.5 Gas Hydrates Exploration

Good prospects of gas hydrates as apparent from the Gas Hydrate Stability Thickness (meters) Map along the Indian continental margins in the Krishna-Godavari (KG), the Mahanadi (Mn), the Andaman (Am), the Kerala-Konkan (KK) and the Saurashtra (S) offshore basins have been located (Fig.5.3). Detailed investigation shows widespread occurrences of Bottom Simulating Reflectors in both the blocks.



The coring and drilling has established gas-hydrates in fractured shale in the Krishna-Godavari (KG) basin. The gas hydrate morphology varies from complex vein structures (grain-displacing) to invisible pore-filling. It has estimated the saturation of gas-hydrates, for the first time. The average saturation of gas-hydrates is estimated as 33-41% of total porosity between 60 to 140 meters below the sea floor (Fig.5.4).



5.6 PolyMetallic Nodules (PMN):

India, has 75,000 sq.km in the Central Indian Ocean Basin(CIOB) for harnessing the polymetallic nodules lying on the seabed at 4000 m to 6000 m water depth. These potato shaped nodules contain Copper, Nickel and Cobalt which are strategically important elements.

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The Polymetallic Nodules Programme consisting of four components viz. Survey and Exploration, Environmental Impact Assessment (EIA) Study, Technology Development (Mining) and Technology Development (Extractive Metallurgy).

5.6.1 Survey & Exploration

The major objective is to carry out comprehensive resource evaluation of the area and identification of the First Generation Minesite (FGM). Bathymetry data was acquired with high resolution multibeam system for the FGM with hydrosweep system with close grid sampling in selected marginal blocks and insitu soil bearing strength testing. A total area of 7858.59 sq. km contains 42 blocks of 0.125° x 0.125° was identified for potential mine site based on detailed chemical analysis, interpretation of the collected samples.

5.6.2 Environmental Impact Assessment Studies (EIA)

The environmental impact assessment was aimed at evaluating the inter-seasonal as well inter-annual variability of environmental parameters in and around the proposed FGM site in the CIOB. The studies on sedimentological, geotechnical, geochemical, microbial and biochemical parameters have shown that environmental conditions vary over different time scales (seasonal and annual) on a wide range and that these variations could probably well encompass the changes in conditions created by other activities such as deep seabed mining. A 3-Dimensional hydrodynamic sediment plume model has been developed for its application to the Central Indian Ocean Basin (CIOB) in the PMN area.



5.6.3 Technology Development (Mining):

The details are described in the section 6.2.4.

5.6.4 Technology Development (Extractive Metallurgy):

Various research endeavours were carried out at the National Metallurgical Laboratory (NML), Jamshedpur and the Institute of Minerals and Materials Technology, (IMMT) Bhubaneswar for optimizing the process routes for extraction of Cu, Ni, Co and Mn from the polymetallic nodules.

Towards improvement of reduction roast - ammonia leach process of NML for recovering valuable metals from polymetallic sea nodules, reduction roasting parameters were optimized with Talcher coal and the optimum roasting conditions were established. Subsequently, lock-cycle mode leaching scheme was developed and optimized on 1 kg scale for extraction of Copper, Nickel and Cobalt.

5.7 Studies on Cobalt Crusts Exploration:

The primary objective of the project is to identify areas of occurrence of cobalt-enriched ferromanganese crusts, assessment of resource potential of Co-rich deposits on Afanasiy-Nikitin Seamount region. The reconnaissance sampling has yielded few crust samples containing up to 0.5 % Cobalt in northern region. The ⁸⁷Sr/⁸⁶Sr and \in Nd varied ~0.7 and -6.5 respectively indicating the signatures of mixing of lithogenous material both from Himalayan weathering and younger volcanism. Ce content in these crusts varied from 0.1 to 0.15 % and Cobalt from 0.5 to 0.65 %.

5.8 Studies on Hydrothermal Sulphides

The program envisages the discovery of active hydrothermal vent fields in the northern Indian Ocean. Extensive exploration efforts resulted in the identification of a significant hydrothermal plume over the slow spreading Carlsberg Ridge (CR). The observed prominent plume suggests that an active vent source is close by.

5.9 Vessel Management

The Ministry of Earth Sciences (MoES) owns a fleet of six research vessels for conducting Oceanographic Research Programme/ projects of the country. The following Vessels are under operation (Table 5.2).

- Oceanographic Research Veesel Sagar Kanya.
- Fisheries Oceanographic Research Vessels Sagar Sampada.
- Technology Demonstration Vessel Sagar Nidhi.
- Bouy Tender Vessel Sagar Manjusha.
- Coastal Research vessel Sagar Purvi and Sagar Paschimi.

ORV Sagar Kanya is undertaking scientific programmes in the survey and exploration of non-living ocean resources and FORV Sagar Sampada undertake research on marine living resources. Both the vessels undertake scientific activities on the vast area of Arabian Sea, Bay of Bengal and the Indian Ocean.

The TDV Sagar Nidhi is catering to the on-going and several programmes such as; deep sea mining Programme, demonstration of remotely operable Vehicle (ROV), Autonomous Underwater Vehicle (AUV) etc.

Sagar Nidhi; became the First Indian Flag Vessel; to successfully cross Antarctic Circle 66° 30' S along 58° 39' E on feb 16, 2010 at 1145 h.

The BTV Sagar Manjusha actively involved in logistic for timely execution of desalination projects at island and also the National Data Buoy programmes. The two Coastal Research Vessel CRV Sagar Purvi and Sagar Paschimi are being used for implementation of Coastal Ocean Monitoring and Prediction System (COMPAS) and Integrated Coastal and Marine Area Management (ICMAM) progemmes. These Vessels are also providing services to many other agencies involved in the Marine Research work in the country for Oceanographic survey and for Marine scientific data collection.

Name of the Vessal	Days at Sea / Utilization	Maintenance / Inspection / Scientific Logistics / Cruise Preparation	No. of Cruise	No. of Port Cells / Port Stay
ORV Sagar Kanya	248	56	13	61
FORV Sagar Sampada	220	68	22	77
TDV Sagar Nidhi	319	30	14	16
BTV Sagar Manjusha	231	84	20	50
CRV Sagar Paschimi	282	51	26	32
CRV Sagar Purvi	206	94	20	65

Table 5.2 Utilisation of Research Vessels in 2010-11

Ocean Technology

6.1 Introduction

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Oceans are endowed with resources such as polymetallic nodules rich in Manganese, Copper, Nickel, Cobalt, and Gas Hydrates, a potential energy source of the future. The development of technology is critical to harness these resources from oceans in sustainable manner. Major and significant technology developments pursued are enumerated below.

6.2 Deep Sea Technology and Ocean Mining

The challenging tasks that daunt the exploitation of the resources are primarily the depth and very high pressure.

6.2.1 Remotely Operable Submersible – ROSUB-6000

ROSUB - 6000 is a heavy work class remotely operable underwater vehicle with a 6000 m depth rating and is equipped with cameras and mechanical devices such as movable arms is normally used for researching the for their envisaged functionality at depths of 1250, 1810, 5256 and 5289 meters (fig. 6.1). Scientific payload of ROSUB 6000 such as forward and bottom looking sonar and sensors for oxygen, conductivity, salinity, temperature, sound, velocity were tested satisfactorily and continuous data (at 1 Hz) was obtained throughout the trial. Using the navigational joysticks, ROSUB-6000 was piloted as planned, in forward, reverse and lateral direction with fixed heading position. The depth sensor data was collected and testing of depth control algorithm from the altitude obtained from Doppler Velocity Log (DVL) was carried out (fig. 6.2). Two samples of polymetallic nodules were collected in the short corer during trials (fig. 6.3).

6.2.2 Remotely Operable In-situ Soil Tester

The optimum design of an integrated deep sea mining system is mainly dictated by the bearing and shear strength of the soil, which are required to be measured accurately in situ. This is important to avoid sinking of crawler in soft soil during locomotion, which affects 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. The qualification trial of ROSUB 6000 was successfully completed at a depth of 5289 m during April 2010. During the course of trial, integrated sub systems along with interfaced sensors were tested and qualified maneuverability of the crawler during mining operation. A remotely operable in-situ soil testing equipment has been modified to reduce weight for operational purpose. Parallel validation trials of the modified electrical soil tester were done in test pond and off the Ennore harbour (fig. 6.4).



6.2.3 Autonomous Coring System (ACS)

Autonomous Coring System (ACS) developed to collect long cores from ocean basins up to a maximum water depth of 3000 m by employing wire-line drilling technology. This would be useful for ground truth validation of gas hydrate occurrence in the Indian continental margins. Autonomous Coring System was delivered during March/April 2010. The ACS components were assembled, integrated and tested for its envisaged functionality. The first shallow water trial was conducted using Technology Demonstration Vessel (TDV) SAGAR NIDHI off the Chennai coast in the Bay of Bengal during June 2010 at 110m water depth and drilled up-to 35m length (fig. 6.5).



6.2.4 Deep Sea Mining System

Deep sea mining of polymetallic nodules from soft ocean floor at 5000 to 6000 m depth is a major technological challenge. A mining concept where a crawler based mining machine collects, crushes and pumps nodules to the mother ship has been developed. Development of this complex technology is being attempted in a phased manner with all R&D work being done at 500 m depth before venturing into deep waters. Accordingly, remotely-operable artificial-nodule system has been developed and tested. The development of underwater crushing and collection systems has been completed.

The testing and qualification of underwater mining system with collector and crushing systems was done in the Angria Bank (off coast of Malvan) at 512 m depth successfully after laying artificial nodules during September–October 2010 (fig. 6.6). Crawler sub-systems (Pick-up device, collector crusher and slurry pump) were operated and artificial nodules were collected, crushed and pumped to ship. The maximum concentration achieved was about 15% by volume intermittently.



6.3 Low Temperature Thermal Desalination (LTTD)

A Desalination Plant at Kavaratti was set up in May, 2005, using Low Temperature Thermal Desalination Technology. The plant has continuously been generating freshwater which is distributed to the people of Kavaratti. Two plants, in islands of Agatti and Minicoy are being set up currently; all plant equipments have been installed (fig. 6.7 and 6.8) and the plants are expected to be commissioned by May 2011.



6.4 Development of Suction Pile

Suction Piles are widely used in mooring applications for floating production units and find widespread applications in offshore oil industry. The objective of the project is to demonstrate suction pile for offshore applications. The procurement and fabrication of the components of suction pile such as suction pile, pump skid, emergency release mechanism, etc are completed. Model tests with varied pile sizes have been conducted and integration of electronics is in progress. Sea trials of the suction pile are planned in the beginning of year 2011.

6.5 Coastal and Environmental Engineering

6.5.1 Demonstration of Shore Protection Measures

The current program aims at developing environmentally friendly solutions and demonstrating it through pilot projects so that it can be replicated in other areas. Studies have been initiated at two sites that have been potentially undergoing erosion and siltation. The first site is the Pondicherry coast at Mudaliarchavadi, which is undergoing severe erosion. The second one is Pulicat Inlet that is experiencing siltation, causing concern to ecosystem and livelihood of fisherman. Shoreline changes analysis using secondary and remote sensing data is completed and observations are being planned in beginning of year 2011. The demonstration of soft solution using geotextiles is being planned after completion of oceanographic observations.

6.5.2 Engineering Investigations for the 'Kalpasar' Project

The project aims at construction of a dam across the Gulf of Khambat to impound the water of the Narmada river which otherwise drains into the Arabian sea. Engineering investigations and modeling requirements of the project have been taken up.

6.5.3 Feasibility study of Marine Terminal off Cheyyur

Oceanographic observations were completed for two seasons. The bathymetric survey was completed and the Port layout has been finalized. Hydrodynamic modeling and wave tranquility studies were also completed. The data analysis and report preparation are in progress.

6.5.4 Environmental Impact Assessment (EIA)

Rapid EIA studies for construction of storage godown at Baratang, VHF repeater at Jirkantang, Check Dam at the Vasunthara Nallah and lighthouse at the Treis Island have been completed for A&N Administration.

6.6 Ocean Acoustics

Acoustics offers the most effective means of exploring the ocean and judging the underwater environment. The key to successful interpretation of sound in the ocean lies in research efforts that are both scientific and technologydevelopment oriented. Thus, part of the research concerns improving the fundamental understanding of underwater acoustic phenomena, while the other focus is on the development of measurement systems and techniques with which to test and apply our understanding.

6.6.1 Measurement and characterization of ocean ambient noise in shallow waters

This project envisages deployment of automated ambient noise recording systems with a vertical linear array of hydrophones, developed indigenously at four locations spanning the east and west coast of India for time series measurements. The first system had been deployed off Cuddalore and 3 months of time series measurements of noise, wind and rain have been successfully obtained (fig. 6.9). The system proved to be highly stable even in rough seas and was capable of collecting noise during JAL cyclone crossing. Wind, shipping and biological noise off Cuddalore had been studied from the measurements.



6.6.2 Tsunami Systems

Indigenous development of a data acquisition/processing unit for bottom pressure recorder has been initiated. The system captured the signal during the earthquake event on 12th June 2010 and 25th October 2010. Indigenization of deep Ocean pressure recorder for tsunami detection along with surface buoy has been completed and the sea trials have been conducted successfully in July 2010.

6.7 Marine Biotechnology

6.7.1 Open Sea Cage Culture

Site selection survey was carried out in Tamil Nadu, Andhra Pradesh, Pondicherry and South Andaman and three sites, viz., Olaikuda (Tamil Nadu), Minnie Bay (Andaman) and Kothachathram (Andhra Pradesh) were selected. Two experimental HDPE square open sea cages were fabricated and deployed at Olaikuda. Juvenile (250-300 g) parrot fishes *(Scarus ghobban)* were cultured and average growth rate of 0.96 g/day was achieved. A total of 48.6 kg of live *Scarus ghobban* was harvested and sold at the rate of Rs.150/kg by the beneficiaries.

6.7.2 Marine Micro Algal Biotechnology

Sixteen strains isolated from the Andaman Sea and the Bay of Bengal were screened for production of lutein under phototrophic and heterotrophic conditions.

6.7.3 Marine Microbial Biotechnology

Halotolerant pigment producing bacteria *Serratia sp.* was isolated and the pigment was purified and characterized. The FTIR and GC-MS analysis confirms the pigment as prodigiosin. Two endophytic marine fungi were isolated from the roots of *Rhizophora mucronata* from the Andaman Island in addition an entophytic biopolymer producing bacteria from sea anemone.

6.7.4 Materials for Marine Applications and Antifouling Measures

Fifty eight microbial strains including 28 deep sea strains were screened for synthesis of metal nanoparticles. Completed screening of 20 crude extracts from marine seaweeds against biofilm forming bacterial strains. The crude extracts from two seaweeds (*Stoechospermum marginatum, Turnbinaria conoides*) have shown positive antimicrobial activity, and further purification of active compound is in progress.

6.7.5 Development and deployment of Fish Aggregation Device (FAD) and Artificial Reef

MoUs were signed with the Andaman & Nicobar and Lakshadweep Administration for deployment and redeployment of 10 Nos. of FADs, respectively.



As a part of UNDP sponsored project of the Department of Fisheries, Government of Orissa, construction of 750 numbers of artificial reef structure (fig. 6.10) has been completed.

6.7.6 Training programme

SCUBA Diving training programme was conducted in the Andaman and Lakshadweep Island and 12 members of staff of NIOT were trained and certified up to Advance Open Water level. **Coastal and Marine Ecology**

7.1 Introduction

India has 7500 km long coastline. Coastal ecosystems tend to have very high biological productivity. The reproduction and nursery grounds of most fish and shellfish species of economic value are in the coastal fragile strips. The ecology of these areas is raising major concerns.

7.2 Coastal and Marine Area

7.2.1 Development of Shoreline Management Plans (SMPs)

Manmade structures established along the coastline have caused alteration in coastal processes, resulting in coastal erosion/accretion, bar formation, etc. Aspects such as near-shore bathymetry, currents, waves, sediment transport, shoreline mapping, coastal morphology, beach profiles, etc. are studied for different seasons to analyse the cause of erosion/accretion and to recommend the best possible interventions in the form of Shoreline Management Plans (SMPs) to manage the coast.

Along the Kerala coast, SMP studies were taken up at selected highly eroding sectors such as Muthalapozhi, Vadanappally and Kozhikode. The impact of mud banks on shoreline stability is also studied for the Vadanappally sector during the year 2010-11. Suitable engineering measures have been suggested.

Four sites along the Karnataka coast (Devbhag: Karwar, Pavinkurve: Honnavar Kundapur Kodi: Kundapur, Uliargoli Padukere: Malpe) have been selected to develop SMPs. The analysis shows the long term changes are moderate (~200m) and are confined in the vicinity of the river mouth.

Erosion along the Gopalpur coastline is attributed to very high rate of longshore sediment transport mostly towards north. The seasonal and interannual variation in beach profile, beach width and beach volume on the north and south of the Gopalpur port as well as on the tourist beach were studied (fig. 7.1). The results clearly indicate the impacts of the groins in causing erosion on the north of the port and deposition on the south of the port. Hence, it is suggested that in order to arrest the erosion on the north of the port, beach fill and periodic beach nourishment should be favored, instead of the proposed groin field (seven groins) to the north as there is availability of huge sand as dredged materials and those accreted on the south side.



7.2.2 Ecosystem Modelling

Ecosystem Modelling for Chilika lake: In order to understand hydrodynamics and biogeochemical changes that are prevalent in the ecosystem and resultant changes on productivity, the present project has been taken up. To understand seasonal variability of the lake volume and its influences on salinity to different sectors of the lagoon, studies on hydrodynamics and monitoring of mouth cross-section were carried out.

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Nutrients biogeochemistry is defined as the dynamic reactions in biological, physical, chemical and geological processes of nutrients. To understand these in a dynamic system like the Chilka lagoon, data on nutrient parameters like NO_3 , NO_2 , NH_4 , DIN, TN, PO_4 were collected (36 stations inside the lagoon and 10 rivers that empty at lagoon). Lagoon is serving as net sink for most nutrients and its magnitude is several fold higher during monsoon. Whole system, except during monsoon, indicate that the lagoon acts as N-fixing zone, whereas monsoon shows strong denitrifying activity. The net lagoon system is moderately autotropic.

The Chilka Lake Ecosystem is characterized by heterotrophic activity and highly contributed to emission of CO_2 fluxes. Large flux of trapped organic carbon from rivers is biologically respired in the lake and converted CO_2 is pumped out to the atmosphere instead of exporting to the sea. The bacterial respiration is very high along the northern sector and at least at outer channel.

Various isotopic tracer experiments for nutrient uptake by nitrogen tracers experiment and primary production by 14C methods were conducted. The 1st phase of experiment was conducted during April- June 2010 for determining coefficients. The experimental results are in Table 7.1.

S1.	Name of the MODELING coefficient	Value
1	BOD processes : 1st order decay rate at 200C	0.46 Per day
2	Ratio of ammonium released by BOD decay	0.22 g NH4/g BOD
3	Phosphorus content in dissolved BOD	0.06 g P/g BOD
4	Maximum oxygen production at noon	6.49 mg/l per day
5	Primary production at Stn.15 (14C method)	3.15mgC/m3/day

Table 7.1 Ecosystem Parameters and Modelling Coefficients

Ecosystem modelling of the Kochi backwaters

Under the project, the tasks to be undertaken during the current year include collection of field data on tides, currents and water quality at least for two seasons to develop hydrodynamic and water quality modeling, and field and laboratory experiments to determine the coefficients on growth and grazing rates of phytoplankton.

7.2.3 Marine Ecotoxicology

Toxicity studies (acute/chronic) are carried out for different marine organisms to prescribe seawater quality criteria for protection of marine organisms from the harmful effects of various heavy metals. Derivation of the draft Seawater Quality Criteria (SWQC) for Cadmium, Copper and Mercury for the Ennore creek and adjacent coastal waters of Chennai was completed. Acute and chronic toxicity experiments for zinc and lead have been completed and data obtained are being evaluated for determination of seawater quality criteria.

7.2.4 Coastal Ocean Monitoring and Prediction System (COMAPS)

Monitoring the health of coastal seas is highly essential to find suitability for fisheries and other human related uses. Data on 25 environmental parameters including physical, chemical, biological and microbiological characteristics of water and 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 achievements made during 2010-11 pertaining to water quality monitoring are as given below:

Gujarat : Along Gujarat coast, monitoring was carried out at Veraval, Tapi and Vadinar. Water quality of the Veraval harbor continued to be considerably degraded. However, water quality off Veraval Coast was healthy (DO: 3-6 mg/l; NH4: 1-6 µmol/l; PO4: 0.5-3 µmol/l), indicating flushing of contaminated harbor water. Water quality of Vadinar is observed to be good with normal values of DO and nutrients. Water quality of the lower and upper Tapi Estuary shows build up of nutrients. Though the lower estuary sustain DO generally >2.0 mg/l, in the upper estuarine region DO goes <0.2 mg/l, especially during ebb. Overall observation indicated that the estuary is in stress condition.

Maharashtra : The monitoring of water quality was carried out at Mumbai and Tarapur. Levels of nutrients were observed to be high in the Thane creek, indicating organic load is being discharged into the creek. Water quality at the Tarapur creek was observed to be poor due to tidal flushing and industrial effluents.

Karnataka: Near Mangalore, levels of nutrients were observed to be high in nearshore waters. An increase in the bacterial population especially coliform bacteria was observed.

Kerala: At Veli, moderate increase in DO and total viable bacteria indicate an improvement in water quality. At Kochi, high presence of nutrients such as nitrate, phosphate and significant increase in pathogenic bacteria indicate influence of domestic wastes.

West Bengal: Coastal waters of the Sandheads and the Haldia Port indicate good water quality. However, high levels of total nitrogen were observed.

Orissa: Coastal waters of the Mahanadi, Paradip and Puri are characterized by continued high DO values. However, an increase in levels of pathogenic bacteria has been observed indicating contamination due to domestic sewage.

Andhra Pradesh: High levels of nutrients in the Visakhapatnam harbor channels and the Kakinada Bay show the impact of industrial waste discharges, domestic sewage and agricultural run off. Levels of nutrients in nearshore waters off the Visakhapatnam and Kakinada Coast were observed to be within ambient levels of coastal environment indicating fairly good water quality.

Tamil Nadu and Puducherry: Along Coastal waters of Ennore, Chennai harbor, Cooum, Muthukadu, Puducherry, Cuddalore, Karaikal, Nagapattinam, Tuticorin, Arumuganeri, Kudankulam and Kanyakumari, high levels of pathogenic bacteria are observed indicating contamination due to domestic sewage.

Andaman & Nicobar Islands: Coastal water quality of Port Blair and Wandoor is observed to be good.

Database: Data collected under COMAPS programme over the years have been compiled and is being organized into database. Database for Ennore, Pondicherry, Tuticorin, Kakinada, Visakhapatnam and Mumbai was finalized. GIS-based database on marine pollution was completed for Kayankulam and Paravur.

7.2.5 Oil Spill Modeling

Hydrodynamic models were developed for the Chennai, Mumbai, Vishakhapatnam and Cochin coasts for different environmental conditions. A indigenous software 'Hydrodyn-OILSOFT' is developed and customized for the Goa waters to predict the oil spill transport under various tidal and meteorological conditions.

The Oil Spill Modelling and trajectory prediction System was used for the prediction of movement of spilled oil,

its spreading, direction for the recent Mumbai oil Spill which occurred on 7th August 2010. The oil trajectory simulation was carried out for 6 days, however, the spill oil was washed to shore at end of 4 days. Fate analysis suggested that oil reached at various locations and the maximum area covered by spilled oil was about 52 sq. km at 0300 h on 10 August. Out of total release, about 67.1% oil reached on the coast, 11.4% evaporated and only 21.5% oil was remaining on sea surface, by 0300 hrs on 10 August, and less than 1% oil only remained on sea surface by 1800 h of 10th August 2010.

7.3 Drugs from sea

In order to harness the bioactive compounds from the marine organisms for human therapeutic purposes, a national coordinated research programme on "Development of drugs from ocean (Drugs from sea)" is being implemented. There are 14 different R& D Labs including Academia actively participating under the Coordination of CDRI, Lucknow. So far, around 14,000 extracts of marine samples have been screened for wide spectrum bioactivity including anti-diabetic, antihyperlipidemic, anti-malarial, anti-HIV, anti-cancer, anti-osteoporosis properties. At present 185 hits have been identified out of which 18 leads found potential and being optimized for various diseases. Further, four compounds for the clinical usage are in the different stages of product development. The Phase-I Clinical Trial of CDR-134-D123 for anti-diabetic property has been completed successfully and the drug was well tolerated without side effect. The CDRI has licensed this compound to a private company so as to develop the drug on herbal mode through AYUSH for faster track marketing. Commencement of Phase-II Clinical Trial of Antidiabetic compound, CDR-134-D123 is pending for want of approval of Drugs Controller General of India (DCGI).

Genotoxicity study of CDR-134-F194 antihyperglycemic-cum-anti-dyslipidemic fraction of an earlier identified active marine sample has been completed and no adverse effects were observed. Permission for conducting Phase I Clinical trial of CDR-134-F194 is under consideration by DCGI. Single dose and sub-acute toxicity study of anti-dyslipidemic agent CDR-267-F018 has also been completed in rodents and it was found safe even at the maximum dose (500mg/kg). Regulatory toxicity studies of anti-dyslipidaemic agent CDR-267-F018 in monkeys for product development have been initiated. Commercialization of products, CDR-134-D-123 and CDR-134-F-194 are in pipe line.

7.4 Aquaculture and Mari culture

7.4.1 Ornamental fish culture

A full fledged hatchery unit for the breeding and rearing of ornamental fishes was established at Agatti, Lahshadweep islands. Technology for the commercial production of 2 species of clown fishes, *Amphiprion nigripes* and *A. clarkii* have been perfected (fig. 7.2). The spawning and rearing of other species of clown fishes viz; *A. sebae, A. ocellaris, A. percula* and *Premnas biaculeatus* and 5 species of damsels such as *Dascyllus aruanus, D. trimaculatus, D. carneus, Chromis viridis* and *Chrysiptera unimaculata* was successful. Islanders from Agatti have been identified for providing 3 months hands-on– training on ornamental fish culture.



7.4.2 Hatchery production and Sea- ranching of Marine gastropods

Technology for hatchery production of several species of gastropods, viz. *Babylonia spirata, B. zeylanica, Chicoreus ramosus, C. virgineus, Hemifusus pugilinus* and *Rapana rapiformis* were developed. In order to ensure the gastropod diversity and rejuvenate the stock size, ten thousand reared juveniles of the above species were sea ranched near the Kariyashuli Island of the Gulf of Mannar, Tuticorin.

7.4.3 Pearl production

Hatchery technology for spat development of *Pinctada margaritifera* (Black- lip pearl oyster) have been perfected at the hatchery unit in the Andamans Islands. About 1.02 lakh spat is now available with the hatchery.

7.5 Harmful Algal Blooms (HABs)

Trichodesmium erythraeum bloom with straw yellow discolouration of the surface water spread over an

area of 25sq. km was observed off Goa (May 2010) during the spring inter-monsoon period (fig. 7.3). Surface chlorophyll a concentration and cell density of the bloom area was 12 mg m-3 and 2.93x106 filaments L-1 respectively. The occurrence of the nutrient depleted Arabian Sea High Saline Water (ASHSW) is expected to be the causative factor for the blooming of *Trichodesmium* species. It is well known that *Trichodesmium* can fix atmospheric nitrogen and hence occurrence of *Trichodesmium* blooms along the southwest coast during spring inter monsoon can be an adaptation to recycle nitrates to the ocean.

Asterionella japonica bloom was observed off Kochi during summer monsoon period (June, 2010) with cell density 5.5x 106 cells L-1 (fig. 7.4). Greenish surface water discolouration was observed in the bloom area. The depletion of nitrate and increased concentration of phosphate is expected to favour the bloom of this pennate diatom.



Thalassiosira partheneia bloom was observed off Trivandrum during the summer monsoon period (June, 2010) with cell density 6x105 cells L-1. Chlorophyll a concentration of the bloom area was 11.2 mg m-3. The cells were disc shaped 4-10 μ in diameter, embedded densely in formless gelatinous masses (fig. 7.5).

Preponderance of *Noctiluca scintillans* was observed along with a multi species diatom bloom off Kochi during the summer monsoon period of 2010 (Aug, 2010) with tomato soup like consistency of the surface waters (fig. 7.6). *Noctiluca* cell density of the bloom area was 6.27 x 106 cells L-1, whereas the diatom cell density was 3.4x 106 cells L-1. Diatoms were represented by *Asterionella sp., Chaetoceros app., Eucampia sp., Skeletonema sp.* and *Thalassiosira sp. Noctiluca* cells were devoid of the green endosymbiont Pedinomonas noctilucae, hence it is red Noctiluca. Noctiluca cells contained number of food vacuoles with diatom cells.



In addition, four algal blooms were observed in the inshore and estuarine waters off the Goa coast. During April 2010 two algal blooms were observed, one by *Rhizosolenia setigera* and the other by potentially toxic diatom *Pseudonitzschia seriata*. Two algal blooms were also observed during the southwest monsoon period, one by *Skeletonema costatum* and the other by a multi species bloom dominated by toxic cyanobacteria *Microcystis sp.*

7.6 Marine Living Resource Programme [MLRP]

Marine Living Resource Programme is multi-disciplinary and multi-institutional in nature with focus on studying the marine ecosystems and correlating the living resources with their physical environment with a view to develop predictive capabilities. Accomplishments of MLRP during 2010-2011 are:

Assessment of Environment and Productivity Patterns of Indian EEZ: An 'Atlas on Environment and Productivity Patterns of Indian EEZ' was prepared. This atlas provides comprehensive information on the physical, chemical and biological features of the Indian EEZ covering the various seasons of a year.

Estimation of fishery potential of Indian EEZ: Satellitederived Chlorophyll a data is used in conjunction with in situ data on chl-a, primary productivity, secondary productivity and benthic productivity to generate the fishery potential of the Indian EEZ. The estimated figure of 4.32 million tons of fish is more robust and reliable as the estimates are made separately for each ecosystem in the Indian EEZ and covering the various seasons of a year. Reliable transfer efficiencies ranging from 5 to 32% have been used in the model.

Spawning grounds of Oil Sardines: Major spawning grounds and spawning season of the oil sardine, *Sardinella longiceps* along the south-west coast of India have been identified on the basis of extensive field surveys. The studies indicate that peak spawning of the species occurs during May-June in the near shore waters north off Kochi (Valappad) from where 40575 larvae per 10m3 water were obtained. As the upwelling season advances, spawning grounds shift northwards, to Kannur and Mangalore but with comparatively less spawning intensities.

Monograph on Bothid Larvae: A monograph on distribution and abundance of Bothid eggs and larvae in the Indian Ocean have been prepared. This monograph provides comprehensive and authentic information on the eggs and larvae of bothids and can be an excellent reference material.

Indian Ocean Biogeographic Information System (IndOBIS): The IOC have recognized CMLRE as the OBIS node for Indian Ocean. OBIS is an International system dedicated to the representation of the species diversity and abundance in world oceans in a $5^{\circ} \times 5^{\circ}$ grid resolution. IndOBIS have at present 48422 record holdings.

Climate Change Research

8.1 Introduction

8

The Centre for Climate Change Research (CCCR) was formally established in January 2009. The primary focus and goal of CCCR is to build a high resolution Earth System Model (ESM), which is a fully coupled atmosphere-ocean-land-biosphere-cryosphere dynamical model, required to address issues on attribution and projection of regional climate change; and provide reliable inputs for various multi-sector impact assessments studies. CCCR addresses the critical issues of science of regional climate change with particular emphasis on the variability of the South Asian monsoon system in the global warming environment.

Twenty five scientists have been working on various aspects of development of earth system model, uncertainty of the South Asian monsoon, radiative forcing due to green house gases and aerosols, cloud aerosol interactions, and past changes in monsoon climate. A HPC system with 20 Terra Flops (TF) speed has been established and is being upgraded to 70 TF. This would be the second fastest computer system in the country and ranks 94th in the world after the upgradation.

With the CFS coupled model as the basic climate modelling framework, efforts has been initiated to validate and include (a) Marine Biogeochemistry Module; (b) Aerosol Transport Module; (c) Sea-ice Module.

8.2 State-of-Art Ultra-high Resolution Monsoon Projections using Global Climate Model

Ultra-high resolution simulations of monsoon climate for the present-day and the future scenario projections have been initiated.

Preliminary simulations indicate that the summer monsoon rainfall along the narrow Western Ghat mountains and the mountain slopes near Burma and the Northern Bay are well captured by the model. A realistic simulation of the Monsoon Trough is also noted in the ultra-high resolution model simulations. Distribution of spatial seasonal rainfall departure of monsoon rainfall for June-September 2010 as generated based on the conditions of March 2010 is presented in Figure 8.1. It is seen that most of the zones of observed rainfall variability (excess/deficit) are captured by the coupled ocean-atmospheric model, implemented for the first time in India.



8.3 Environmental Monitoring

8.3.1 Aerosols

Aerosols using Sky-radiometer (POM-I) operating at wavelengths 315, 340, 400, 500, 670, 1020 nm are being monitored for the last 4 years and has found that Aerosol Optical Depth (AOD) remains lowest at all wavelengths during the Monsoon season while high values of Single Scattering Albedo (SSA) and Alpha (α) represent the presence of small aerosols and washout effect of large aerosols by rains. In Pre-monsoon season, AOD was found as second minimum with SSA and AOD lower than Monsoon season. However, AOD was lower in the winter season as compared to the Post-monsoon season because of movement of westerly systems. Measurements have also shown that AOD values were higher at shorter wavelengths in comparison to the values at longer wavelengths for all four seasons of the year. The aerosol monitoring network is being augmented with advanced Sky-radiometer at 14 stations over the country in different representative geographical regions during current year.

A network of 10 Global Atmosphere Watch stations (GAW, formerly Background Air Pollution Monitoring

Network or BAPMoN) consisting of Allahabad, Jodhpur, Kodaikanal, Minicoy, Mohanbari, Port Blair, Pune, Nagpur, Srinagar and Vishakhapatnam, is maintained as per WMO protocols and standards since 1974 to generate data/ information on the exchange of trace materials between the atmosphere and the earth's surface, making atmospheric turbidity and air quality measurements to quantify trends and acid rain threats. Important findings are summarized as under:

- Total Suspended Particulate Matter (TSPM) values at Jodhpur exhibited significant positive correlation with pH indicating its alkaline behavior. The soil-derived aerosols have pronounced effect on the precipitation acidity at a place.
- Principal Component analysis of rain water constituents indicates that marine and coastal aerosols predominantly govern the acidity of rainwater.
- The observed atmospheric turbidity values at all the Indian GAW stations showed systematic seasonal as well as long-term variation apart from random fluctuations. However, the nature of variation is station dependent. Annual mean values of the turbidity coefficients showed a general increase of turbidity at all stations except Kodaikanal. The increasing trend of the turbidity at short wavelength (500 nm) indicates that it is caused more by fine size range aerosol, which are the product of primary and secondary production processes associated with anthropogenic activities. On an annual basis, the lowest turbidity was observed at Kodaikanal and Srinagar and highest in the north and central India.
 - A sharp decline in aerosol optical depth was observed at all the stations during post-monsoon season in 2010 when compared with 2009 data, for example; AOD 500 nm at Jodhpur during 2009 was 0.499 and during 2010 0.43. At Pune during 2009 postmonsoon, AOD was 0.735 and during 2010 it was 0.632. Other season the AOD values are comparable with 2009 values (no significant difference). The strong post-monsoon decline in AOD may be due to washout by the good rainfall during 2010.

8.3.2 Radiation Network

Global solar irradiation:	43 stations
Diffuse solar irradiation:	24 stations
Net terrestrial radiant energy:	12 stations
Net total radiant energy:	06 stations
Linke turbidity factor T:	22 stations
Ångström turbidity coefficient β:	14 stations
New Initiative: UV-A measurement:	45 stations
Athalometer for Black Carbon	
Measurement:	04 stations

8.3.3 Ozone Monitoring Network

Total Ozone:	06 stations
Vertical Profile using Umkehr method:	06 stations
Columnar SO2 and NO2	06 stations
Ozone sonde:	05 stations
Surface Ozone:	06 stations
Surface Ozone Measurement using	
UV-Absorption Photometer	10 stations

8.3.4 Precipitation Chemistry

The trends of pH were monitored in rain water samples during the year at 11 GAW stations. During 2010 (till November 2010), no rainfall samples from Pune, Minicoy, Portblair, Srinagar, Allahabad, Ranichauri were found to be acidic in nature (No instance of acid rain). At Kodaikanal only ten samples out of 120 were slightly acidic (pH range varies from 4.92-7.06). Mohanbari also shows slightly acidic samples (pH range 4.76 - 7.06). Around both the stations, the soil is acidic and very low alkali components in rainwater make it slightly acidic. Some rainwater samples from Nagpur also found to be acidic (pH range 4.6-7.41). Nagpur samples seem to be contaminated by large construction activity going on near the airport.

Disaster Support

9.1 Introduction

9

24×7 monitoring and early warning services in respect of tropical cyclones, heavy rainfall scenarios over the river basins, tsunami and storm surges and earthquakes is carried out. Continuous R & D efforts followed by exhaustive performance evaluation to improve the prediction systems is an on-going exercise carried out in association with research institutions.

9.2 Cyclonic disturbances during 2010

The north Indian Ocean witnessed the formation of eight cyclonic disturbances during 2010. Out of eight disturbances six cyclonic disturbances formed over the Bay of Bengal and two over the Arabian Sea. Out of the six cyclonic disturbances over the Bay of Bengal, one intensified up to the stage of very severe cyclonic storm (GIRI), two up to the stage of severe cyclonic storm (LAILA & JAL) and one up to the stage of deep depression. Out of two cyclonic disturbances formed over the Arabian Sea, one intensified up to the stage of very severe cyclonic storm (PHET) and the other (BANDU) up to the stage of cyclonic storm.

9.2.1 Analysis and prediction of Cyclone

The tropical cyclone analysis, prediction and decisionmaking process are based on conceptual models, dvnamical and statistical models, meteorological datasets. technology and expertise. Conventional observational network, automatic weather stations (AWS), buoy & ship observations, cyclone detection radars and satellites were used for this purpose. The Multi-Model Ensemble (MME) Prediction Scheme for cyclone track prediction has been introduced experimentally. This MME is based on five global and regional models. The forecast of maximum wind in four quadrants of a cyclone was commenced with effect from cyclone, GIRI during October 2010. In this forecast, the radius of 34, 50 and 64 knot winds are given for various forecast periods like +06, +12, +18, +24, +36, +48, +60 and +72h. The high resolution storm surge model for different member countries was made operational during 2010. The cyclone track error has been improved over the past few years due to the continuous efforts (fig.9.1).



The 12 and 24 hour track forecast error is 67 km and 131 km, respectively. Details of the track forecast errors are presented in Table 9.1

Table 9.1:	Cyclone	track	forecast	error	(km))
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System			Lead Ti	me (h)		
	12	24	36	48	60	72
LAILA	84	153	228	254	372	210
BANDU	39	78	78	-	-	-
PHET	82	162	215	311	410	545
GIRI	45	73	68	117	-	-
JAL	41	78	56	83	54	54
MEAN	66	131	167	249	330	465

The percentage improvement for 12h and 24h cyclone forecasts with respect to climatology and persistence forecast (CLIPER) achieved during 2010 is found to be 18.1% and 24.1%, respectively.

9.2.2 Cyclone early warning and advisory services 3 hourly warning/advisory bulletins were issued to various national and international disaster management agencies including National Disaster Management (NDM) Division of the Ministry of Home Affairs (MHA), concerned State Governments and World Meteorological Organisation (WMO)/Economic and Social Cooperation for Asia and the Pacific (ESCAP) Panel member countries including Bangladesh, Myanmar, Thailand, Pakistan, Oman, Srilanka and Maldives during cyclone period. As tropical cyclone advisory centre (TCAC),

it also issued tropical cyclone advisories with effect from the stage of cyclone for international civil aviation purpose as per the requirement of international civil aviation organization (ICAO).

A new Public Weather System (PWS) has been set up for automatic production of cyclone warning bulletins, graphical display of warnings and automatic warning dissemination to various users through different telecommunication channels (fig. 9.2).



Six hourly best track data and figures of cyclones over north Indian Ocean since 1990-2010 in digital form are available and are made accessible through web access.

9.2.3 International cooperation

Six hourly best track data of cyclones over the north Indian Ocean during 1990-2009 has been provided for the development of international best track archives of tropical cyclones to the World Climate Data Centre (WCDC), located at the National Climate Data Centre (NCDC), National Ocean and Atmospheric Administration (NOAA), Asheville, USA. The cyclone products generated for the north Indian Ocean are also provided to WMO's Aviation Disaster Risk Reduction (ADRR), Hong Kong.

Tropical cyclone advisories are also provided to Middle-East Asian countries. For this purpose, a significant meteorological (SIGMET) forecast test was successfully conducted by International Civil Aviation Organization (ICAO) on 10th November 2010.

9.3 Flood Meteorological Services

Quantitative Precipitation Forecast (QPF) was provided to the Central Water Commission (CWC) which in turn generates flood warnings for monitoring/predicting river water levels, for the State Government Authorities. Following inputs was provided to CWC through 10 Flood meteorological Offices (FMOs) established in different parts of India.

- Quantitative Precipitation Forecast (QPF) for next 24h.
- Rainfall occurred in catchments in last 24h.
- Prevailing Synoptic Situation
- Significant station-wise rainfall
- Heavy Rainfall Warnings over the catchment for next 48 hours

In all, during the flood phases of 2010, 15372 QPFs were issued by Flood Meteorological Offices (FMO) and supplied to CWC for generating flood forecasting scenarios. From this year lead time of QPF is enhanced and now it is issued at 0930 IST instead of 1200 IST earlier. In addition Numerical Weather Prediction model output at 9km \times 9km grid scale and MME Forecast is also operationally provided for the Mahanadi basin.

9.4 Seismological Research

9.4.1. Earthquake monitoring

A national network of 55 Seismological observatories, 16-station V-SAT based digital seismic telemetry system around National Capital Territory (NCT) of Delhi is operational. The earthquake source parameters are estimated immediately on occurrence of an earthquake and information is disseminated to all the user agencies including the concerned State and Central Government agencies. During the period January-November, 2010 a total of 3524 earthquake events have been detected and located by the network. Following are the few significant achievements made during the year 2010-11:

- Earthquake data and seismicity reports specific regions were supplied to insurance companies, industrial units, power houses, river valley projects etc.
- Monthly Seismological Bulletins containing the phase data and the processed information on source parameters of all earthquakes was prepared and supplied to International Seismological Centre (ISC), UK for incorporation in the ISC's Monthly Seismological Bulletins.

9.4.2 Seismicity and Earthquake precursors

The aim of the programme is to generate long-term, comprehensive multi-parametric geophysical database in seismically active areas to establish possible correlation between various earthquake precursors and the earthquake occurrence as well as to understand the source processes. The salient achievements made during FY 2010-11 are listed below:

- Analysis of 710 events recorded in the Garhwal-Kumaun region of Himalaya shows that most of the events are of shallow depth (<25 Kms). The epicentral location map indicates that Munsiari thrust, located south of MCT is more active.
- A first estimate of the amplification of seismic waves in the Indo-Gangetic region has been made. Standard spectral ratios (SSRs) were computed at sites near the Himalayan foothills, where the sediment thickness is ~4 km, reveal a broadband amplification with a fundamental frequency of 0.13 Hz. The fundamental frequency increases to the south as the thickness of the sediments decreases, becoming ~0.8 Hz at the southernmost site.
- Radon anomalies observed in soil, gas and ground water in the NW Himalayas have been correlated with the seismic events in the magnitude range 2.2 to 5.0. Based on high concentration of radon/ helium recorded in the study area, an indication has been given towards the presence of a buried

fault/ fault zone running parallel to the Himalayan Frontal Fault.

- Joint modelling of gravity and magnetic data along the Ganganagar-Chandigarh profile shows large variation in the basement depth depicting significant upwarps and depressions. Basement is heterogeneous in nature suggesting extension of major litho-tectonic units beneath the Ganga basin.
- On the basis of observed surface deformation of 1.4 to 2.5 mm/yr as obtained from GPS sites along the fault trace in the Ladakh Himalayas, a dextral slip of 3mm/yr has been modelled.
- The post-seismic deformation in the Bhuj earthquake zone is found negligible. The study of high resolution satellite imagery data helped to find out the extension of the Kachchh Mainland Fault for a total length of over 140 km from northeast of Lakhpat to near Bhachau.

9.5 Monitoring and Early Warning of Indian Ocean Tsunamis

9.5.1 Tsunami Advisories

The tsunami early warning centre is operated on 24x7 basis and reported 163 earthquakes of magnitude > 6.0 during January 01 - November 30, 2010 (fig. 9.3).



The centre issued tsunami advisories for 7 earthquakes which occurred in the Indian Ocean; the details are given in Table 9.2.

Sl. No.	Magnitude	Region	Date	Time	First Bulletin after lapse of time	Second Advisory and time	Third Advisory and time	Fourth Advisory and time
1.	6.9 Mw	Andaman Islands	30.03.10	22:24:50	22:37:00	22:55:00 Watch for A&N Island	23:45:00 Watch Cancelled	_
2.	7.7Mw	Northern Sumatra	07.04.10	03:45:01	03:52:01	04"21:00 No tsunami threat to India	-	_
3.	7.4Mw	Northern Sumatra	09.05.10	11:29:44	11:35:00	11:45:00 No tsunami threat to India	-	_
4.	6.5CMT	Andaman Islands	01.06.10	01:21:48	01:27:00	01:57:00 No tsunami threat to India	_	_
5.	7.5Mw	Nicobar Islands	13.06.10	00:56:47	01:07:00	01:37:00 Watch for Nicobar Islands	01:58:00 Watch for Nicobar Isands	02:34 Watch Cancelled
6.	7.4Mw	Irian.Jaya Indonesia	16.06.10	08:46:48	08:55:00	09:00:00 No tsunami threat to India	_	_
7.	7.5Mw	Sourthern Sumatra	25.10.10	20:12:20	20:17:00	20:28:00 No tsunami threat to India	_	_

Table 9.2: Summary of Tsunami Advisories

9.5.2 Observational Networks

- Seismic Network: The warning centre received continuous data from 377 broadband seismic stations (17 national & 360 international) through VSAT communication and internet.
- Bottom Pressure recorder Network: Data from 5 Indian Tsunami Buoys in the Indian Ocean and 3 international buoys received (fig. 9.4).



(iii) Tide gauge network: Continuous data from 21 tidal stations on the Indian Coast and 68 international tide gauges located along the coasts of the Indian Ocean received in near real-time (fig. 9.5).



(iv) HF Radar network: 10 HF radars are installed at Machilipatnam, S. Yanam, Kalpakkam, Cuddalore, Puri, Gopalpur, Jegri, Wasi, Hut Bay and Port Blair for estimation of the direction and strength of currents and continuous data is being received.

9.5.3 Tsunami Modelling

Presently the centre consists of a database of prerun scenarios for 5000 unit sources covering all the tsunamigenic sources in the Indian Ocean region. Creation of more scenarios for the tsunamigenic source regions of the Indian Ocean for faster evaluation of the threat to the coastal regions is under progress.

9.6 Coastal Vulnerability

9.6.1 Coastal Vulnerability Indices

Coastal Vulnerability Indices (CVI) estimation is an established technique and several such studies were carried out worldwide. CVI for the entire India using the seven basic parameters, viz. Shoreline Change, Geomorphology, Coastal Regional Elevations, Coastal Slope, Sea-level Change Rate, Mean Significant Wave Height and Tidal Range., have been generated. The CVI atlas on 1:100000 scales has been prepared for entire India for 9 coastal states and Islands comprising 157 maps.

9.6.2 Multi-hazard Vulnerability Mapping

The pilot studies in the Nellore and Cuddalore regions, focused on development of a comprehensive coastal vulnerability index (CVI) and vulnerability mapping on 1:25000 scale due to multiple hazards (called MHVM). These maps are intuitive and critical information input to coastal managers (fig. 9.6).



9.6.3 3D GIS Mapping

3D GIS mapping is a geo-spatial technology transferring the human settlements utilities and socioeconomic details on to the desktop. A pilot project for Nagapattinam coast using 3D GIS covering 100 sq. km has been carried out and found extremely useful for the disaster management. Since the generation of 3D GIS models is expensive and time consuming, it will be prioritized based on the risk potential of coastal areas.

10 Extramural and Sponsored Research

10.1 Introduction

Research activities have focused towards improving the various services of the country in earth, ocean and atmospheric sciences for the societal benefit. A programme on R & D in Earth System Sciences has been launched for granting extra-mural funding to various academic/research organizations and universities under 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

10.2 Focussed Research Project

The following research projects in focussed research areas were funded in 2010-11:

- (i) Marine Resource & Technology: "To develop a long term multidisciplinary programme in the Area of Marine Resource Development and Management (MRDM)" to be implemented by IIT, Kharagpur. The proposal involves the exploration and exploitation of the natural oceanic resources and corresponding technology development.
- (ii) Economic Benefits of Weather and Hazard Services: Impact Assessment and Economic Benefits of Weather and Marine Services" was carried out by the National Council for Applied Economic Research (NCAER), Delhi. NCAER has carried out the socio-economic benefits of the (a) Agromet Advisory Services (b) Fishery Service (c) Public Weather Forecast (d) Disaster Warning Service. The study has concluded that the weather and fishery services have made large impact on income generation of farmers and fishermen.
- (iii) **Monsoon Research:** Continental Tropical Convergence Zone (CTCZ) under the Indian Climate Research Programme (ICRP) involving multi-institutes is a National coordinated program

focussed on understanding the variability of convection/rainfall over the Indian monsoon region through various field observations and modeling studies.

Design and Development of a Unified Modelling System for Seamless Weather and Climate Predictions of Monsoons to be implemented by IIT Delhi aims to formulate and design a new forecasting system on icosahedral-hexagonal grid for seamless predictions and develop efficient code for exploiting GPU computing potential for a unified model designed on these grids.

(iv) Climate Change: Collaborative Programme to Study the Impacts of Climate Change on Human, Natural and Spatial Environments to be implemented by the CEPT University, Ahmedabad, the Indian Centre for Climate and Societal Impacts Research (ICCSIR), and the Indian Society for Community Education (ISCE) will carry out research, education, applications and outreach activities in natural, climate variability and human induced climate changes, including global warming, and their impacts on urban and regional and natural environments.

> Fine Particles over an Ecologically Sensitive Zone Source Apportionment, Visibility and Climate Effects to IISER Bhopal: The project aims to significantly enhance the understanding of the sources of visibility reduction over ecologically sensitive locations in Central India, quantify the radiative forcing (climate effects) of such sources, and thereby provide background information for future source.

(v) Atmospheric Research: Physicochemical characterization of aerosol and source apportionment in the mid-Brahmaputra plain in Assam: a modeling approach to Tezpur University, Assam. The study proposes to carry out aerosol characterization in terms of morphology and physicochemical characterization, modeling for source apportionment and study the spatial and seasonal variability of aerosol characteristics and effect of biomass burning and monsoon on aerosol properties.

10.3 Research projects through Ocean and Atmospheric Science and Technology Cells (OASTCs)

In order to create adequate expertise in various disciplines of ocean and atmospheric science & technology for the benefit of the society for enhanced awareness about the phenomenon and processes of earth systems, following nine OASTCs in universities and IIT-Kharagpur have been set up with following objectives:

- Encourage universities, colleges and institutes to perform front-ranking research in earth system science.
- Evolving technology for harnessing of resources including energy to meet the present and future needs for scholastic pursuits and industry.
- To maximize the benefits that our country could realize from her vast ocean regime.
- To promote scientific temper and awareness among the public and school children about climate change and its variability, ocean and its resources,

usefulness, management and development.

 Promotion of proven/viable technologies for harnessing of resources for the benefit of the local communities in the areas of aquaculture, seaweeds, etc.

Name of the universities/institutes where OASTCs are located

- Annamalai University on marine biology
- Goa University on marine microbiology
- Berhampur University on marine coastal ecology
- Bhavnagar University on marine coastal ecology
- Tamil University on Beach Placers
- Mangalore University on marine geology and geophysics
- Andhra University on coastal marine culture systems
- Cochin University of Science and Technology on Marine benthos
- IIT, Kharagpur on Ocean engineering and underwater robotics

Following new projects were funded during the year through OASTCs:

SI. NO.	Project Title	Grantee Institute	Principal Investigator
1	Study on white spot syndrome virus (WSSV) prevalence and diversity of disease resistant population among wild giant black tiger shrimp (penaeus mondon) of the entire coastal area of India	Bose Institute, Kolkata	Dr. N. Mondal
2	Coastal processes and Hazards in the Coastal Zone of Dakshina Kannada and Udupi Districts-An Integrated approach through Field Measurements, Remote sensing and GIS Techniques	Manglore University	Dr. K.S. Jayappa
3	Modeling of coastal and near shore dynamics around Dhanuskodi using field data and MIKE21	Anna University	Dr. Usha Nateshan
4	Natural gums of forest plants of Andhra Pradesh as Pharmaceutical Excipients	Andhra University	Dr. K.V. Ramana Murthy
5	Anticancer compounds from <i>pimpinella tirupatiensis</i> and <i>Cycas beddomi</i> lead discovey and development	Sri Venkatesh- wara University	Prof C. Venkata Rao
6	Potential of marine bacterial isolates in arsenic bioremediation	Sardar patel University	Dr. Mrs Kiran Kalia
7	Facilitation through hydrological coastal habitat modifications in Gulf of Khambhat (Cambay): An exhaustive inventory for native plant diversity and soil dynamics	Gujarat University	Dr. Yogesh T.Jasrai
8	Monitoring nesting of marine turtles and assessments of their population near Piram island in the Gulf of Khambhat	Bhavnagar University	Dr I R Gadhvi
9	Survey of immune organs (spleen and Kidney) in marine catfish of Parangipettai in Tamilnadu	Annamalai university	Dr. B. Deivasigamani

10	Investigations on biology, population dynamics, stock assessment and fishery modeling of lizard fishes and preparation of value added products (frozen and curd)	Annamalai University	Dr. P.S. lyla
11	Evalution of putative probionts from shrimp gut micro flora and bioactive phytocomponents against vibrio-infected, penaeus mondon.	E.V.R College (Autonomous), Tiruchipapalli	Dr. George John
12	Study of Si fluxes and nutrient inputs across the Tambraparani River basin in the east Coast of India and assessment of their impacts on coastal resources- A Geo- Biochemical Approach (SINUINAIC)	Annamalai University	Dr. S. Rajendran
13	Immunostimulative secondary metabolites from marine sponges in Gulf of Mannar Marine realm	Sri Parmakalyani College, Al- warkurichi (TN)	Dr. A.J.Ranjit Singh
14	Hydrogen production using micro-organisms from mangrove sediments in anaerobic hybrid reactor(AHR)	Annamalai University	Dr. P. Mullai
15	Genotoxicity Studies on field propulations of commercially important Fin fishes and shellfishes of central west coast of India	Goa University	Dr. S. K. Shyama
16	Biological Synthesis of metal sulfide and metallic nano-particles using Halophilic Archaeobacteria	BITS Pilani,	Dr. Meenal Kowshik
17	Studies of the surface and upper ocean mesoscale features of the north Indian Ocean	IIT,Kharagpur	Dr. M. K. Dash
18	Development of Robust signal processing Techniques for detection of Underwater Impact	IIT,Kharagpur	Prof. A.R. Mohanty
19	Development of cage for Mari culture through numerical and physical modeling	IIT,Kharagpur	Prof.C K Mukherjee
20	Coastal protection in the Mahakalpara area of Kendrapara district,Orissa	IIT,Kharagpur	Prof. Nisith R Mondal
21	High resolution mesoscale prediction of Land-filling Bay of Bengal cyclones for coastal disaster preparedness	IIT,Kharagpur	Dr. M Mandal
22	Studies on sustainable Development of India's Coastal and Island Ecosystems	Centre for Ocean and Environment Studies, Delhi	Dr. S.Z. Qasim

Evaluation of OASTCS:

A 6-member evaluation committee under the chairmanship of Dr.A.E.Muthunayagam, Ex-Secretary, Department of Ocean Development was constituted to evaluate the performance of the OASTCs since inception. The committee has submitted its report containing suggestions for expanding the scope of the programme and improving the productivity and output of the centres. It is also proposed to open new OASTCs.

10.4 Setting up specialized Labs as National facility for use by various researchers and Institutes

The Ministry has supported setting up a Laser Diamond Anvil Cell as a National Facility at IISER Kolkata. This facility will be a useful to generate and maintain states of matter at high pressures (ranging above 150 GPa) and temperatures (more than 50000K) to enable measurements of material properties at these extreme conditions and therefore can be used by researchers to simulate conditions of the core and lower mantle of the Earth.

10.5 Building indigenous capability through Joint Developmental Projects with joint Funding

The Ministry of Earth Sciences and CSIR (NMITLI) are working jointly in the field of Meteorological and Oceanic Sciences and Technology and supporting specific projects through joint funding. Projects "Mesoscale modelling for monsoon related weather predictions" and "Biofuel from Marine Microalagae" have been funded.

10.6 Human Resource Development & Capacity Building

MoU with IIT Delhi: Under the existing MoU for sponsored M Tech and PhD programmes in the field of Earth & Atmospheric Sciences, the first batch of MTech students graduated in May 2010. Dr. Sagnik Dey has joined IIT Delhi as the 1st recipient of Sudhansu Kumar Banerji MoES Outstanding Faculty Fellow. The lectures by Sir Gilbert Walker MoES Chair Prof T.N.Krishnamurti, have been adopted as one credit course in the IIT curriculum as "Special Module in Numerical Weather Prediction (ASV 887)". A total of 39 MTech and B Tech students have registered for the course.

IIT, Roorkee: To encourage research in Earth Sciences and also to augment capacity building in the field of Earth Sciences, a project proposal entitled "Text-Book Series for the Graduate Students in Earth Science" to IIT Roorkee has been funded. The proposal aims to fill in the gaps in knowledge for the Earth Science Graduate Students by providing a set of 14 affordable and illustrative text books with examples that are Indiacentric. Subsequently these books will be published by the Geological Society of India (GSI) to be used by the Earth Science Graduate students.

IIT, Kanpur: "D.N.Wadia MoES Chair" will be established at IIT Kanpur through an MoU between MoES and IIT Kanpur. The Chair will help to promote excellence and leadership in teaching, research and development in Earth System Science and Climate Change at IIT Kanpur.

10.7 Progress of ongoing projects

(i) River dynamics and Flood Risk evaluation of the Kosi River, North Bihar plains: an integrated approach" being implemented by 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. The avulsion threshold of the Kosi river was computed. Dynamic Geomorphic mapping for the Kusaha and Raghopur areas has been done. To analyze the channel processes in the Kosi river a stream power distribution map has been prepared.

- (ii) "Research, Education & Manpower Development in the Discipline of Earth Processes" being implemented at Centre for Earth Atmospheric Sciences, IISc, Bangalore. The aim of the proposal is to strengthen the infrastructural facilities for earth science research and training at CEaS. An undergraduate programme to be launched by IISc in 2011 will be using lab facilities created under this project. Some advanced research activities that include study of the 2004 Sumatra Earthquake, short and long term climate change and reconstruction of Indian Monsoon using stable isotopic technique are being carried out.
- Research for Seasonal Prediction of the Indian (iii) Monsoon (RESPIM) being implemented by IISc Bangalore basically aims at improving the accuracy in simulating the interannual variation of the Indian summer monsoon rainfall by assessing several state-of-the art Atmospheric General Circulation Models (AGCM) and Coupled General Circulation models (CGCM) by analysis of the available long runs. In order to see the model performance of extreme seasons; detailed analysis of the 2009 monsoon failure was conducted. The forecasts of various operational centres were analysed. It was found that almost all the models failed to predict the failure of 2009 monsoons. Analysis of the Climate Forecast System (CFS) for interannual variations was done and it has been found that CFS can simulate the Elnino-Southern Oscillation(EnSO) monsoon link quite realistically but has a tendency to over-predict a positive Equatorial Indian Ocean Oscillation (EQUINOO). This can have significant impact on the ability of CFS to predict the interannual variability of the monsoon.

10.8 Open Access Repository of research outputs on Earth, Ocean and Atmospheric Science

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

10.9 Providing access to electronic journals (Science Direct) and abstracting and indexing database (SCOPUS)

To provide access to scholarly information at ESO, two global databases — Science Direct and Scopus were subscribed which will help scientists to remain in touch with latest international developments in scientific research in earth system sciences. Scholarly articles from 117 full text journals on earth system sciences and technologies will be accessible through Science Direct database. The scientists based in Indian station at Antarctica will also be able to access these resources for research.

SCOPUS database provides information on more than 18000 titles published by over 5000 international publishers including around 300 Indian journals having 42.5 million records in all. To avail discounts and gaining access to greater number of journals by all member institutions, 'Consortium' model was preferred over subscriptions by individual institutions.

Awareness and Outreach Programmes

11.1 Introduction

With a view to propagate and bring awareness about the programmes and achievement among the public, students and user communities, the Ministry participated in major National and International exhibitions held in India and abroad, supporting Melas, Seminars, Symposia, Workshops and used the electronic and print media and also exhibitions through various National Science Centres. The Earth Day was elebrated with participation of school children, college and University students. Seminar and Symposia were supported to create a platform between scientist, engineers, social scientists and user community to exchange information and knowledge.

11.2 Exhibitions

The Ministry has been taking active participation in various kind of exhibitions in India and abroad highlighting the research & development programmes and the achievement of the Ministry. The Ministry participated in fifteen exhibitions.

11.2.1 International Exhibitions

The Ministry participated in the India International Trade Fair 2010 (IITF 2010) at Pragati Madam New Delhi, 2nd Bengaluru Space Expo 2010 at BIEC, Bengaluru, Karnataka; Science & Technology Contribution of India Scientific Institutions at National Science Centre, Bhairon Marg, Pragati Maidan, New Delhi; North India International Trade Fair 2010 at Kanpur, Indian Trade and Industry in Budapest International Fair Budapest (Hungary) at ITPO, New Delhi; "XXX INCA International Congress" at Indian National Cartographic Association (INCA), Survey of India, Surveyor General's Office, Dehradun-248001 (UK); Bangalore IT biz 2010 at Department of IT and BT, Govt. of Karnataka and STPI, Vasanthnagar, Bangalore. The Ministry participated in MAP - Asia 2010, Kaula Lampur, Malaysia.

11.2.2 Exhibitions in India

The Ministry participated in 8th Infra-educa 2010 at Pragati Maidan, New Delh, Patna, Bangalore (fig. 11.1),



Bihar, Ranchi, Jharkhand; 14th National Science Exhibition at Central Calcutta Science & Culture Organisation for Youth, Kolkata; Exhibition "Science & Technology Contribution of India Scientific Institutions" at National Science Centre, New Delhi (fig. 11.2).



11.2.3 Rural Exhibitions in India

Agro-met services and weather forecasting are crucial to farmers therefore the Ministry participated in the Rural Exhibitions and inform / showcase these activities to the farmers. This year the Ministry participated in "KUMAON SRAJAN 2010" at Mansiyari, Uttarakhand, "Science & Technology Expo-2010" at National Exhibition and Business Summit at GIC, Tallital, Nainital, Uttarakhand.

11.3 Earth Day Celebration

Earth Day is the largest, most widely celebrated international event. It provide a chance to remember what an amazing planet we live on. It is the only planet in our solar system which is teeming with incredible biodiversity. Learning about earth, which include ocean, atmosphere, cryosphere, geosphere and protecting the biodiversity, is what Earth Day is all about. People all over the world celebrate and make efforts to protect plants and animals and to clean up the earth we live in. "Earth Day" was celebrated across the country on 22nd April 2010 and the event was organized in 200 schools, colleges, and Universities. The theme of the year 2010 was "Save Earth".

11.4 Participation in International Earth Science Olympiad

The top 20 ranked students (X and XI standard) among 862 were selected through entrance test and were invited to attend a Training Camp followed by the Indian National Earth Science Olympiad. The top four participants (Mr. Shreyas Srivastava, Varanasi; Mr.S Varun Rajgopal, Chennai; Mr. Nikhil Suhas Deodhar, Goa and Mr. Aneesh Pasricha, New Delhi) were recognized through Merit Awards (including a cash prize of Rs.5,000/-) and they constituted the Indian contingent at the International Earth Science Olympiad.

The International Earth Science Olympiad was organized by the Gadjah Mada University, Yogyakarta, Indonesia, during September 19-28, 2010. The Indian team won one Silver Medal and three Bronze medals at the Olympiad.

11.5 Seminar, Symposia, Conference & Workshop

To exchange information in area of Earth System Science among scientist, engineers, technologists, experts, social scientists and user communities about 157 events were supported. The beneficiaries are Indian Institute of Technology/Indian Institute of Managements, CSIR Universities, Non-Governmental Labs. Organizations, Government bodies and other Research organization, etc. Major areas supported were climate change and impact on health; weather modification technology, disaster management; global warming and its mitigation; coastal and marine ecosystem; earth system; environmental pollution and its effects on agriculture and human health; agro-meteorological service; space technology and applications; geological science; current science and technology; snow and avalanche processes, etc.

2 International Cooperation

12.1 Cooperation with NOAA, USA

Consequent upon signing of MoES-NOAA MoU in 2008, and subsequent signing the four Implementing Arrangements the three Joint Executive Meetings (JEM) have been held to review the progress of these projects. Good progress is seen in these projects.

South Asian Regional Reanalysis(SARR)

Sensitivity experiments with data and physics options (convection, PBL and land surface) have been carried out. It is seen that just downscaling of coarse resolution global reanalysis is not sufficient for accurate representation of the Indian monsoon hydroclimate which is possible with regional high-resolution assimilations. Additional SARR analysis runs are being carried out using ISRO derived vegetation data instead of USGS climatological vegetation which further improves hydroclimate representation over India. With NCEP archived data complete annual cycle reanalysis shall be carried out along with physical initialization and rainfall assimilation experiments

The Research Moored Array for African–Asian– Australian Monsoon Analysis and Prediction (RAMA)

A new moored buoy array in the historically datasparse Indian Ocean provides measurements to advance monsoon research and forecasting has been deployed. It is designed specifically for studying large-scale ocean-atmosphere interactions, mixed-layer dynamics, and ocean circulation related to the monsoons on intraseasonal to decadal time scales. The planned array consists mainly of 38 surface moorings and 8 subsurface moorings. Presently, 21 surface moorings 8 sub subsurface moorings have been deployed in the Indian Ocean by collaborative effort by many countries. Out of total 47 moorings, India has deployed 3 subsurface moorings and 20 out of 28 surface moorings. These data are being used for operational and research purposes which are relevant to Monsoon.

Climate Modeling and Ocean Data Assimilation Analysis

This involves work on statistical downscaling using

GFDL coupled model analysis in predicting seasonal precipitation over India towards development of prediction of monthly rainfall for the Indian region using different GFDL model outputs. It is seen simple regression model as rainfall is not linearly related to a single predictor, a multiple regression model to forecast monthly rainfall is more useful. Impact of other parameters like 200 hPa height, sea level pressure or 850 hPa relative humidity are being carried out. Future work will include nonlinear technique like neural network in order to improve the performance of the forecast.

Climate Monitoring and Prediction System for South Asian Region

A set of tools are being developed to monitor real-time current state of climate over the South Asian Region using observational datasets based on the global data assimilation system and renalysis; outgoing longwave radiation; sea surface temperatures, estimate of soil moisture, surface temperature, rainfall, etc.

During the 3rd Joint Executive Meeting during October 2010 three more IAs were signed on Tropical Cyclone Research, INSAT 3D and on Tsunami Science, Detection, Analysis, Modeling & Forecasting. During the recent visit the President Barack Obama in November 2010, an Implementing agreement was signed on 'Dynamical Seasonal Prediction of Indian Summer Monsoon Rainfall' under which Indian and US scientists will jointly work for improved monsoon prediction starting from monsoon 2011. To accomplish the same a "monsoon desk" is being established. This was highlighted as one of the important areas of cooperation between the two countries during recent visit of the US President.

12.2 Cooperation with UKMO, UK

MoU was signed between MoES and UKMO in July 2008 on the Unified Model initially has been extended for a period of five years now. Work is in progress as per the mutually agreed science plan for joint research with the unified model. As a part of the forecast verification, model evaluation and inter comparison that provide reality check for the skill and performance of the state of the art numerical models, performance

have been assessed during the monsoon 2010 against observations. A regional version of unified model over the Indian domain has been implemented successfully that was utilised for nowcasting during the recently concluded Commonwealth Games. The science plan is being augmented to include coupled modelling for the purpose of providing two week forecast.

12.3 Cooperation with NERC (Natural Environmental Regional Council)

Ministry of Earth Sciences and the Natural Environmental Research Council of UK, entered into an MoU with the objective of articulating a set of high priority research initiatives towards addressing the seminal issues raised by the changing Hydrological Cycle. This joint initiative is aimed at refining the knowledge of the structure and processes of the various water cycle components in the specific geographical regions of south Asia and northern Europe, set in their global perspective. It is expected to accomplish this through a set of jointly formulated research programmes focusing on the design of potentially insightful theoretical and experimental approaches that may result in i) the minimization of data and model uncertainties, ii) generation of incisive ideas for information processing and its interpretation, iii) prognostication of possible impacts on the sustainability of natural resources, and iv)design of adaptive strategies. In this endeavour, the ongoing scientific endeavours in India would be enriched by modelling frameworks developed by UK institutions whilst the models themselves get more widely validated by being applied and modified over much longer scales of the Indian hydrological systems. Joint projects with specific objectives are in the final stage of evaluation for subsequent funding.

12.4 Cooperation with Korea Meteorological Administration

Ministry of Earth Sciences and Korea Meteorological Administration, Republic of Korea signed an Agreement of Cooperation (MOU) on 29th September 2010 in the field of Earth Sciences and Services following the first bilateral meeting for collaboration in the field of Earth Science & Services. The main objective of the Agreement of Cooperation is to enable in-depth understanding and joint development of skilful forecasting capabilities of various weather and climate related phenomenon. Under this MoU, specific projects have been mutually identified that have their own Implementation strategy with identified PIs from India and Republic of Korea with well defined objectives, deliverables, individual as well as joint roles. Some of the prioritized areas of cooperation include aviation meteorological services, numerical weather prediction in various ranges and Asian monsoon.

12.5 Cooperation Agreement for joining Regional Integrated Multi-Hazard Early Warning System(RIMES)

A cooperation Agreement for Afro-Asian Region was approved by the Cabinet on 7th Dec., 2010 for the Establishment of Multi-Hazard Early Warning Systems at the regional level for the 26 countries of Afro-Asian region which shall provide India to lead the initiatives in the following major areas:

- Promote the development of multi-hazard (cyclones; floods; Tsunami and various coastal hazards etc.) early warning systems to cater the specific and different needs and demands of Member States,
- Build technical capacity building programmes to Member States in respect of rendering country specific early warning services for enhanced hazard preparedness with emergency response and risk reduction mechanisms,
- iii) Design, support and facilitate establishment/ expansion and maintenance of core regional observational and monitoring networks for building a effective regional multi-hazard monitoring systems,
- iv) To provide Regional Tsunami Watches within the framework of UNESCO's IOC and multi-hazard watches within the framework of WMO,
- v) To Provide Research and Development support to various Meteorological, Oceanographic, Hydrological and Seismological Services of the Member States, and
- vi) To provide portfolio of options for Member States to avail from/contribute to various emerging needs and demands from time to time.

India is currently serving as the Chair of the RIMES Executive Board.

12.6 An MOU For Building Long-Term Cooperation on Weather, Climate and Geophysics Services, and Early Warning of Coastal Hazards

An MOU between the Ministry of Earth Sciences

(MoES), and the Agency for Meteorology, Climatology and Geophysics (BKMG) of the Republic of Indonesia was signed on 25th January, 2011. It provides India an opportunity to lead the initiatives in the following major areas:

- i) Agro-meteorological Advisory Services
- ii) Fishery Services
- iii) Observing Systems

- iv) Climate Variability and Change
- v) Tsunami Operations

The MOU is to facilitate arrangements for improving weather and climate services, early warning of coastal hazards and technology for observing systems.

3 Official Language Implementation

The Ministry is constantly working for promotion and propagation of the official Language. During 2010-11 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 work 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 bilingually.

The Ministry also organized Hindi fortnight from 6th to 20th September, 2010. During the period, various competitions including Hindi essay, writing, Noting, Drafting, debate, typing, quiz and recitation were held. This was followed by a Hindi Kavi Goshthi, wherein poets of repute enthralled the audience.

The Ministry organized 19th National Scientific Hindi Seminar on the topic "Mausam aur Jalvayu ka Krishi par Prabhav" on 10th December, 2010 at New Delhi. Shri Prabir Kumar Basu, Secretary, Ministry of Agriculture was the chief Guest. On this occasion, the Ministry released a Hindi book titled "Jalvayu Parivartan aur Samaj"

Under the Prithvi Vigyan Mantralya Maulik Pustak Lekhan Yojana-2010, first and second prizes were awarded to the books titled (1) Sagar Ki Khanij Sampda by G.S Roonwal and Shyam Sunder Sharma; (2) Dharti Bachao Saur Urja Apnao by Dr. C.L. Garg. Prizes worth ₹ 50,000 and ₹ 40,000, respectively, were given.

	Repres OBCs	sentatior (as on 1	1 of SCs .1.2010	/STs/	Numbe	er of A	ppoint	ments m	ade duri	ng the	calend	ar year (2010)			
Groups					By I	Direct F	Recruit	ment		By Pro	motion			By De	sputation	
	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs	Total	SCs	STs	OBCs
	0	σ	4	S	6	Ъ	~	6	10	Ξ	12	13	14	15	16	17
Group A	27	90	01	ı	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	liN	liN	Nil
Group B	34	08	02	I	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	liN	Nil	Nil
Group C inluding MTS	50	13	02	07	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Total	111	27	05	07	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil

Representation of Persons with Disabilities

in Government Services

	ß	15	НО	Nil	Nil	Nil	Nil
	ointment ide	14	HH	Nil	Nil	Nil	Nil
ų	lo. of app me	13	НЛ	Nil	Nil	Nil	Nil
Promotio	2	12	Total	Nil	Nil	Nil	Nil
	vies	11	НО	Nil	Nil	Nil	Nil
	of vacand reserved	10	HH	Nil	Nil	Nil	Nil
	No.	6	НЛ	Nil	Nil	Nil	Nil
		∞	НО	Nil	Nil	Nil	Nil
	ointments de	7	HH	Nil	Nil	Nil	Nil
ment	o. of app ma	9	НЛ	Nil	Nil	Nil	Nil
t Recruit	Ž	5	Total	Nil	Nil	Nil	Nil
Direc	ies	4	НО	Nil	Nil	Nil	Nil
	of vacand reserved	3	НН	Nil	Nil	Nil	Nil
	No.	7	НЛ	Nil	Nil	Nil	Nil
	Groups	1		Group A	Group B	Group C including MTS	Total

Note:

VH stands for visually Handicapped (Persons suffering from blindness or low vision)

- HH stands for Hearing Handicapped (Persons suffering from hearing impairment)
- OH stands for Orthopedically Handicapped (persons suffering from locomotor disabilities or cerebral palsy) ĒĒ

6 Citizens' Charter

This charter is a declaration of vision, mission, values, and standards and commitment to act in manner to achieve excellence for improving forecast for weather, climate and hazards as well as the exploration and exploitation of vast marine resource for the socio-economic benefit of the society. All the units of ESO have been directed to adopt the Citizen Charter in toto.

Vision

The vision is to emerge as a knowledge and information technology enterprise for the Earth System Science (atmosphere, hydrosphere, cryosphere and Geosphere) realm.

Mission

Provide Scientific and technical support for conducting front ranking research both academic and applied aspects in Earth System sciences as a whole comprising the atmosphere, hydrosphere, cryosphere and the geosphere with particular reference to the Indian sub-continent and the surrounding oceans as well as the Polar Regions.

Provide the Nation with the best possible services in forecasting the monsoons and other weather/climate parameters, ocean state including early warnings to natural disasters like storm surge, earthquakes, tsunamis and other phenomena through well integrated programmes.

Support science and technology development for exploration and exploitation of ocean resources (living and non-living in a sustainable way).

The front line areas with immense potential for the benefit of human kind are:

- To provide services in the areas of research infrastructure and generation of human resources, popularization of Earth System Sciences (atmosphere, hydrosphere, Cryosphere and Geosphere) mission to establish as information network for the scientific community.
- To encourage dissemination of information in atmospheric, ocean and polar ocean sciences to stakeholders and promote establishment of an earth system 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 system with a view to encourage formulation of research and development schemes in the earth system science sector in a transparent manner, create capacity building and promote human resource development by encouraging research.
- To encourage basic research, application areas and manpower development programmes for earth system science in a transparent and time-bound manner.
- To extend support to seminars, symposia, conferences etc. and process application for grants to organize seminars / symposium / conference in a transparent and time-bound manner.
- To create awareness about earth system science sector by participation in educational programmes, exhibitions and trade fairs and through partnership with NGOs.

The total budget allocation for the Ministry of Earth Sciences for the year 2010-11 was $\mathbf{\overline{z}}1302.00$ crore, which includes $\mathbf{\overline{z}}1000.00$ crore for Plan Schemes and $\mathbf{\overline{z}}302.00$ crore for Non-Plan Schemes. The budget estimates for 2011-12 for the Ministry of Earth

Sciences have been fixed at ₹1567.00 (₹1220.00 crore for Plan and ₹347.00 crore for Non-Plan activities). The details of budget estimates actual expenditure are given in the following table.

17

S. No.	Scheme name	200	3-09 Actu	al	20	09-10 Act	ual	201	0-11 Bud	get	20	₹ in crore	ss dget
	Revenue Section	Plan	Non Plan	Total	Plan	Non Plan	Total	Plan	Non Plan	Total	Plan	Non Plan	Total
	Oceanographic Research	260.85	37.44	298.29	454.14	36.31	490.45	563.78	39.88	603.66	799.00	39.88	838.88
7	Other scientific Research	36.71	14.59	51.30	66.97	19.02	85.99	68.45	21.12	89.57	49.10	26.28	75.38
3	Secretariat Expenditure	0.00	12.31	12.31	0.00	17.35	17.35	0.00	22.99	22.99	0.00	24.00	24.00
4	Meteorology	33.94	198.10	232.04	36.30	251.81	288.10	85.98	215.51	301.49	88.80	255.74	344.54
	Capital Section												
1	Capital outlay on Oceanographic Research	1.12	0.00	1.12	26.53	0.00	26.53	32.77	0.00	32.77	16.50	0.00	16.50
2	Capital outlay on other scientific & environmental Research	0.00	0.00	0.00	0.00	0.00	0.00	14.00	0.00	14.00	3.40	0.00	3.40
3	Capital outlay on Meteorology	156.43	0.17	156.60	170.43	0.98	171.40	235.02	2.50	237.52	263.20	1.10	264.30
	Grand Total	489.05	262.61	751.66	754.37	325.46	1079.83	1000.00	302.00	1302.00	1220	347	1567

Budget and Accounts

The number of Action Taken Notes (ATN's) pending for Ministry of Earth Science taken from various C&AG reports are given in the following table :-

18

Year		No. of Paras/ PAC reports on which ATNs have been submitted to Monitoring Cell after vetting by Audit	Details of the C&A are pending	G paras/PAC report	is on which ATNs	No. of ATNs with Audit
			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 resubmission by the Ministry	No. of ATNs which have been finally vetted by Audit but have not been submitted by the Ministry to PAC	
2002						Para 6.2 CA 5 of 2002 "Avoidable Expenditure of Water Charges"
2007					1	Para 5.1 Report no. 2 of 2007 "Wasteful Expenditure"
2008						Para 7.1 Report no, CA 3 of 2008 "Non-achievement of the objectives of Modernizing the Accounting & Personnel Management Functions"
2008						Para 7.3 Report no. CA 3 of 2008 "Unfruitful Expenditure on in -house projects in NIOT"
2008 A	r. ∕	Para 7.2 CA - 3 Of 2008 " vvoidable Expnditure on nterest"				
2008-09					_	Para 7.1 Report no. CA 16 of 2008-09 "Construction of Residential Quarters and Hostel Units without demand"
2008-09 t		Para 7.2 CA-16 of 2008-09 'Aviodable Expenditure due o Contracting of Higher load ·RMC Kolkata"				

Report of the Comptroller and Auditor General of India

Administrative Support

19.1 Implementation of the 15 - Point Programme on Minority Welfare

The 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 has been ensured.

19.2 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. 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. Details are given on website (www.moes. gov.in) of the Ministry.

The Ministry of Public Grievances and Administrative Reforms has launched an online public Grievances website www.pgportal.gov.in where grievances can be lodged online.

19.3 Capacity Building & Human Resource Development

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

A capacity-building programme has been taken up in the Ministry, its Units and faculty members of the IMD training institutions in collaboration with the Training Division, Department of Personnel & Training (DoPT). In this regard, 18 national-level training courses (fig. 19.1) have been conducted. The total number of participants in these courses was 260.



19.4 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.

19.5 Right to Information Act 2005

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 and its attached/ subordinate offices and autonomous institutes. Between April 2010 and December 2010, 80 requests under the Right to Information Act, 2005 were received in the Ministry of Earth Sciences and replies were given to all the cases. There is no case lying with Central Information Commission in appeal.

In the year 2010 a Transparency Officer has also been appointed to over-see and expedite the information to the applicants in time.

19.6 Parliamentary Matters

The Parliamentary Standing Committee meeting on Science and Technology, Environment and Forests was held on 30th March, 2010.

Between April and December 2010, the Ministry replied to Parliament Question in Lok Sabha and Rajya Sabha as listed in Table 19.1.

Table 19.1	Status	of Parliament	Questions
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S.No.	Parliament Questions	Number
1.	Lok Sabha Starred Questions	07
2.	Lok Sabha Unstarred Questions	33
3.	Rajya Sabha Starred Questions	04
4.	Rajya Sabha Unstarred Questions	16

19.7 Vigilance Activities and Achievements

Joint Secretary (ES) has been declared as Chief Vigilance Officer in consultation with the Central Vigilance Commission. Senior level Officers have been appointed as Vigilance Officers 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 Chief Vigilance Officers and Vigilance Officers.

Staff Strength

TOTAL	(12)	206	4693	3794	9394
IITM	(11)	141	74	136	351
INCOIS	(10)	37	26	-	63
NCAOR	(6)	87	51	26	164
NIOT	(8)	36	13	23	72
IMD	(2)	460	4452	3501	8413
ICMAM	(9)	=	05	06	22
CMLRE	(5)	10	04	15	29
NCMRWF	(4)	46	21	23	06
MoES	(3)	79	47	64	190
Groups of Post	(2)	Group A	Group B	Group C (Including MTS)	Total
S.No.	(1)		2.	3.	

Strength of all groups of Ministry of Earth Science including all the constituents of Earth System Organization is as below:

20

Ministry of Earth Sciences : Annual Report 2010-2011

1 List of Publications

- Ahmed,G.J., Suman Kumar, Neeraj Kumar and Pal,R.K. "Estimation of evapotranspiration in a mollisol of Tarai region of Uttrakhand from chickpea (Cicer arietinum I.)", MAUSAM, 61, 3, 407-410.
- Alagarsamy, R., You. C.F., Nath, B.N., Sijin Kumar, A.V. (2010) Determination of rare earth, major and trace elements in authigenic fraction of Andaman Sea (Northeastern Indian Ocean) sediments by Inductively Coupled Plasma-Mass Spectrometry. Microchemical Journal 94; 90–97.
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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
СМАР	CPC (Climate Prediction Centre) Merged Analysis of Precipitation
C-MMACS	Centre for Mathematical Modelling and Computer Simulation
COMAP	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
НС	Heat Content

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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
ΙΟ	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
РО	Pacific Ocean
POGO	Partnership for Observation of Global Ocean
РОМ	Princeton Ocean Model
PWD	Persons with Disabilities
RDBMS	Relational Data Base Management System
ROM	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